



Review Article

Global Research Trends in the Cytotoxicity and Biocompatibility of Biosynthesized Silver Nanoparticles: A Bibliometric Analysis

Muhammad Fauzan Lubis^{1*}, Ana Yulyana², Sumaiyah Sumaiyah³, Khairani Fitri⁴, Rezza Fikrih Utama⁵, Vera Estefania Kaban⁶, Hafid Syahputra⁷, Ririn Astyka¹, Raudhy Auliya⁸

1. Department of Pharmaceutical Biology, Faculty of Pharmacy, Universitas Sumatera Utara, Medan 20155, Indonesia.
2. Department of Pharmacy, Faculty of Pharmacy, Universitas Pancasila, Jl. Srengseng Sawah, Jakarta Selatan, 12640, Indonesia.
3. Department of Pharmaceutical Technology, Faculty of Pharmacy, Universitas Sumatera Utara, Medan 20155, Indonesia.
4. Department of Pharmacy, Faculty of Pharmacy and Medicine, Institut Kesehatan Helvetia, Medan, Indonesia.
5. Department of Pharmacy, Faculty of Pharmacy and Medicine, Universitas Sari Mutiara, Medan, Indonesia.
6. Department of Clinical Pharmacy, Faculty of Medicine, Dentistry, and Health Science, Universitas Prima Indonesia, Medan, Indonesia.
7. Department of Pharmacy, Faculty of Mathematics and Natural Sciences, Universitas Sriwijaya, South Sumatra, Indralaya, 30662, Indonesia.
8. Faculty of Pharmacy, Universitas Sumatera Utara, Medan, 20155, Indonesia.

Citation Lubis MF, Yulyana A, Sumaiyah S, Fitri K, Utama RF, Kaban VE, Syahputra H, et al. Global Research Trends in the Cytotoxicity and Biocompatibility of Biosynthesized Silver Nanoparticles: A Bibliometric Analysis. *International Journal of Medical Toxicology and Forensic Medicine*. 2026; 16:E53458.

doi <https://doi.org/10.22037/ijmtfm.v16.53458>

ABSTRACT

Article info:

Received: 14 September, 2026

Accepted: 25 September, 2026

Published: 02 October, 2026

Keywords:

Silver nanoparticles, Green synthesis, Cytotoxicity, Biocompatibility, Bibliometric analysis

Background: Biosynthesis is widely used to reduce the chemical burden of silver nanoparticle production, but a biological synthesis route alone does not establish cellular safety. This study mapped global research on the cytotoxicity and biocompatibility of biosynthesized silver nanoparticles (AgNPs).

Methods: We searched Scopus without a year restriction for English-language final-stage journal articles and reviews. Single-reviewer screening retained 461 of 598 records; 46 were excluded, and 91 were classified as uncertain. Endpoint analysis included 457 original articles, while sensitivity analysis included all uncertain records (n = 552). Analyses were performed using Python.

Results: Publications increased from six in 2012 to 69 in 2025; 2026 and 2027 data were incomplete. India led in country-associated production, followed by Egypt and Saudi Arabia, while international co-authorship was present in 34.3% of articles. The International Journal of Nanomedicine was the most productive source. Keyword mapping identified 30 normalized terms and 99 links across five clusters, with silver nanoparticles, green synthesis, and cytotoxicity occupying central positions. Cytotoxicity- or cell-viability-related terminology dominated the indexed metadata, whereas genotoxicity and hemocompatibility-related terminology was less visible. Many studies combined safety measurements with antibacterial, anticancer, antioxidant, or wound-healing claims.

Conclusion: The literature shows rapid growth in the development of biological AgNPs, but metadata patterns indicate that biocompatibility is often assessed using short-term cellular endpoints.

* Corresponding Authors:

Muhammad Fauzan Lubis, PhD

Department of Pharmaceutical Biology, Faculty of Pharmacy, Universitas Sumatera Utara, Medan 20155, Indonesia.

E-mail: fauzan.lubis@usu.ac.id



Copyright © 2026 The Author(s).

This is an open access article distributed under the terms of the Creative Commons Attribution License (CC-BY-NC: <https://creativecommons.org/licenses/by-nc/4.0/legalcode.en>), which permits use, distribution, and reproduction in any medium, provided the original work is properly cited and is not used for commercial purposes.

Introduction

Silver nanoparticles (AgNPs) are used in antimicrobial coatings, wound dressings, drug-delivery systems, food packaging, diagnostics, and environmental applications [1]. Their biological effects arise from interactions among particle size, morphology, surface chemistry, aggregation, and the release of Ag⁺ ions [2]. These properties can damage microbial and malignant cells, but the same mechanisms may also injure normal cells through oxidative stress, membrane disruption, mitochondrial dysfunction, DNA damage, and inflammatory signaling [3, 4]. Safety assessment must therefore accompany claims of biomedical performance. Biological synthesis uses plant extracts, fungi, bacteria, algae, or isolated biomolecules as reducing and stabilizing agents [5]. This approach may decrease the use of hazardous reagents and produce surface-bound biological compounds that can influence colloidal stability and cellular interactions [6]. Nevertheless, the term "green" refers to the production route rather than the toxicological profile. Biosynthesized AgNPs have demonstrated antibacterial and wound-healing activities in experimental models [1, 3]. Selective anticancer effects have also been reported, although their interpretation requires comparison with non-malignant cells [4, 5]. Other studies have evaluated compatibility with fibroblasts, erythrocytes, or related normal biological systems [6-8]. Differences in particle characterization, exposure media, cell models, and endpoint definitions make these findings difficult to compare. Previous reviews have summarized AgNP synthesis and biomedical applications, but publication growth alone does not reveal how safety evidence is distributed or whether biocompatibility receives the same attention as therapeutic cytotoxicity. A focused bibliometric assessment can identify influential contributors, conceptual clusters, emerging topics, and neglected endpoints. Previous reviews have summarized the synthesis, physicochemical properties, antimicrobial activity, anticancer applications, and general toxicity of green-synthesized AgNPs. However, these reviews have not quantitatively mapped publication growth, geographic and collaborative patterns, citation structure, keyword development, and the reporting visibility of safety endpoints in normal or non-malignant biological systems. The present bibliometric analysis was designed to address this gap. This study aimed to map the development, contributors, collaboration patterns, conceptual structure, and safety endpoints of Scopus-indexed research on biosynthesized AgNPs, with particular emphasis on the balance between therapeutic

cytotoxicity and biocompatibility evaluation in non-malignant biological systems.

Methods of Literature Search

Study design and data source

A descriptive bibliometric and science-mapping design was used. The study mapped bibliographic performance, collaboration patterns, conceptual structure, and reported safety endpoints rather than conducting a systematic or scoping review of intervention evidence. Scopus was selected as the sole bibliographic source because it provides consistently structured metadata for citations, affiliations, countries, authors, abstracts, and keywords, which are required for performance analysis and science mapping. Its multidisciplinary coverage was also relevant, as research on biosynthesized AgNPs spans biomedical sciences, nanotechnology, materials science, chemistry, biotechnology, and environmental science. Using a single database avoided inconsistencies in citation counts and metadata fields that would have arisen from the retrospective merging of Scopus, PubMed, and Web of Science records. The Scopus search and bibliographic export were conducted on September 10, 2026. The search covered all indexed years available at the time of export and included English-language journal articles and reviews at the final stage of publication.

Search strategy

The search combined four concept groups: silver nanoparticles; biological or green synthesis; cytotoxicity or biocompatibility; and potential normal or non-malignant biological models. Concept groups were connected using AND, whereas terms within each group were connected using OR. The fourth group was designed as a sensitivity-oriented retrieval filter; because some cell-type terms were context-dependent, their relevance was confirmed during title and abstract screening. The complete search string and database restrictions are provided in Supplementary Table S1.

Eligibility and screening

Records were eligible when their titles or abstracts described biologically synthesized AgNPs and a safety endpoint relevant to a normal or non-malignant system. Cancer studies required a non-malignant comparator or directly interpretable safety endpoint. One reviewer screened titles and abstracts using predefined criteria for AgNP identity, biological synthesis, safety endpoints, and biological models. Screening was not independently duplicated; therefore, no disagreements

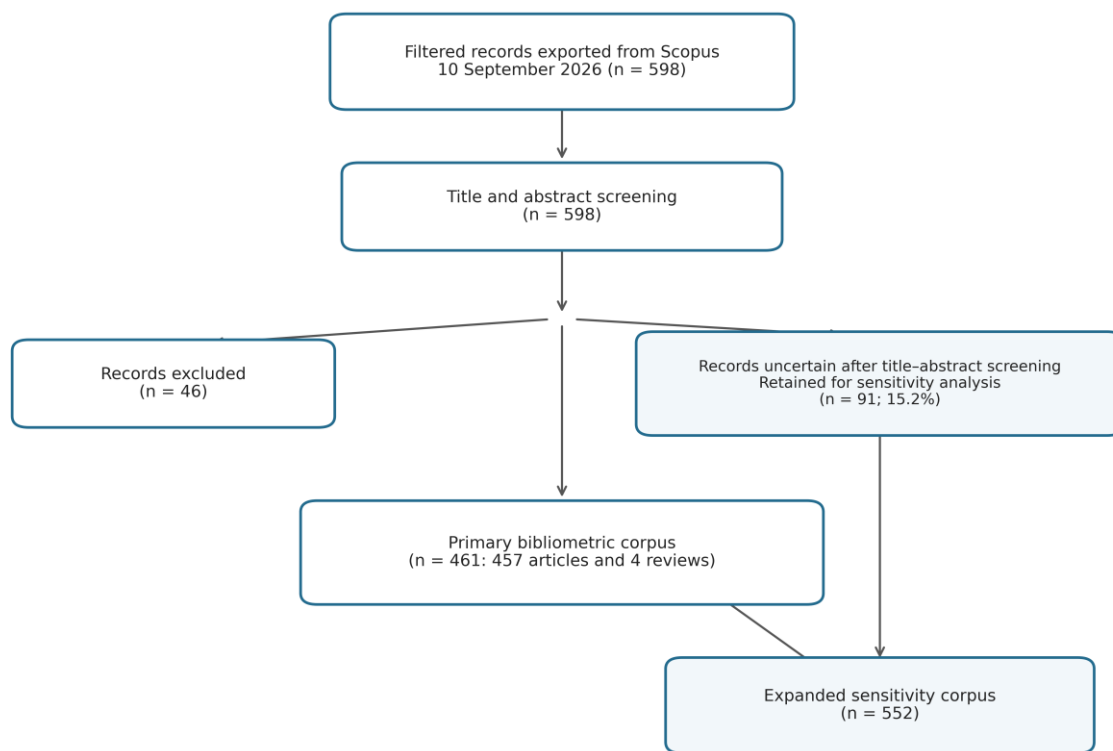
International Journal of
Medical Toxicology & Forensic Medicine

Figure 1. Selection of the primary bibliometric corpus and construction of the sensitivity-analysis corpus. Uncertain records were excluded only from the primary analysis and were retained for the conservative sensitivity analysis.

were resolved, and inter-rater agreement was not calculated. Records lacking the required concepts were excluded, while ambiguous records were retained as uncertain. Full-text adjudication was outside the scope of this metadata-based analysis; instead, all uncertain records were included in sensitivity analysis. Record-level decisions are provided in Supplementary Table S2.

Data processing and analysis

We normalized author keywords using a predefined thesaurus that consolidated lexical, abbreviated, singular–plural, and activity-related variants before calculating occurrences and co-occurrences. The 1,133 distinct keyword forms were reduced to 1,119 normalized terms; 30 terms occurring in at least five articles were retained, and links occurring in at least two articles were included. Spectral embedding generated a two-dimensional co-occurrence map. We compared K-means solutions with two to ten clusters using the mean silhouette coefficient; we retained five clusters because they produced the highest score (0.518). Clustering used a random seed of 18 and 20 initializations. We identified six non-exclusive safety-endpoint categories through rule-based searches of titles, abstracts, author keywords, and indexed keywords: cytotoxicity or cell viability; biocompatibility or biosafety; hemocompatibility;

genotoxicity; oxidative stress or related mechanisms; and *in vivo* systemic or histological evaluation. We manually validated the classifier on a stratified sample of 46 records (approximately 10%) using confusion matrices, precision, recall, accuracy, and F1 scores. The rules were subsequently refined and reapplied to the corpus. Reviews were retained for general bibliometric mapping but excluded from the endpoint-frequency analysis, which was restricted to 457 original research articles. Supplementary Tables S3–S5 and S14 provide the normalization rules, endpoint definitions, and validation results. Sensitivity analysis repeated the principal indicators after adding all 91 uncertain records. Analyses used Python 3.12 with pandas, NumPy, Matplotlib, and scikit-learn.

Results

Corpus selection and overall profile

The search identified 598 records, with no duplicate DOIs, EIDs, or normalized titles detected. Following title and abstract screening, 137 records (22.9%) were not carried into the primary corpus: 46 were excluded, and 91 were retained separately as uncertain. The primary corpus comprised 461 high-confidence records, including 457 original research articles (99.1%) and four reviews (0.9%) (Figure 1). Reviews

were included in general bibliometric mapping but excluded from endpoint-frequency analysis. The primary corpus covered 235 publication sources, 2,534 Scopus author-name entries, and 76 countries. It accumulated 17,677 citations, with a mean of 38.34, a median of 16, an IQR of 4–43, and a range of 0–544 citations per article, indicating a strongly right-skewed distribution (Table 1). The included records are listed in Supplementary Table S6. Adding all 91 uncertain records produced a sensitivity corpus of 552 records. The five leading countries remained unchanged;

Table 1. Main characteristics of the bibliometric corpus.

Indicator	Value
Publication period	2012–2027*
Records identified	598
Included articles	461
Publication sources	235
Author-name entries	2,534
Countries	76
Total citations	17,677
Mean citations per article	38.34
Median citations per article	16
Citation IQR	4–43
Citation range	0–544
International co-authorship	34.3%

International Journal of
Medical Toxicology & Forensic Medicine

*The 2026 and 2027 publication data were incomplete at the time of the Scopus search and should not be interpreted as complete annual output.

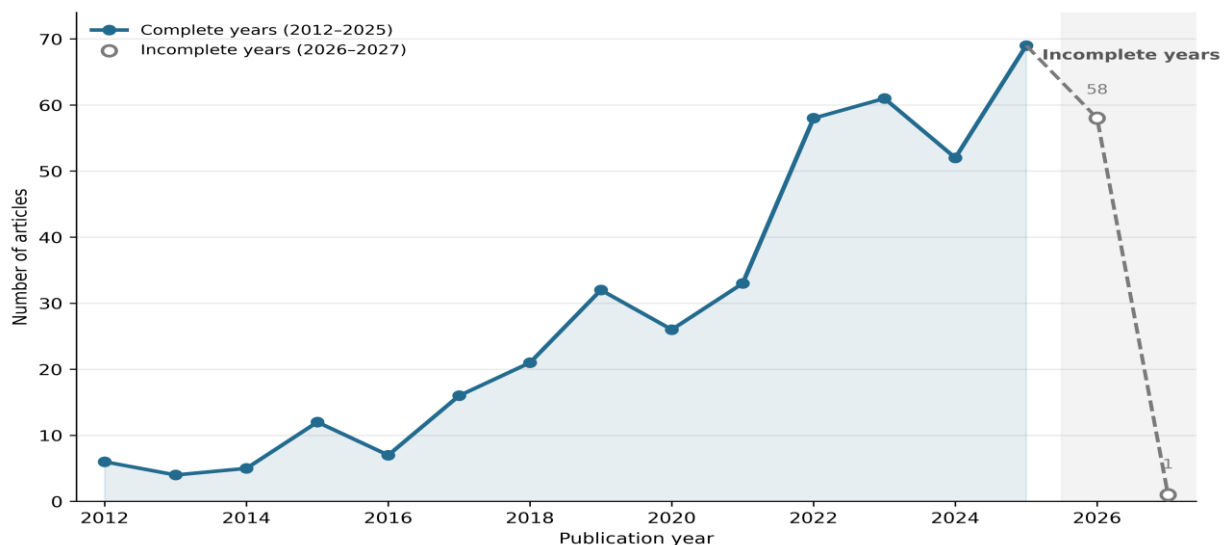
international co-authorship increased from 34.3% to 34.6%, and the 2022–2025 publication share decreased from 52.1% to 50.7%. The principal temporal, geographic, collaboration, and endpoint-reporting patterns remained stable.

Growth of scientific production

Annual output remained relatively low through 2018, then plateaued at 32 publications in 2019, 26 in 2020, and 33 in 2021, before increasing to 58 in 2022. Output remained high in 2023–2025, with 61, 52, and 69 publications, respectively. Publications from 2022–2025 accounted for 52.1% of the primary corpus. The 58 records assigned to 2026 and the single record assigned to 2027 represent incomplete publication years and were excluded from temporal-trend interpretation (Figure 2). The 2027 record reflected a Scopus-assigned future cover year for a final-stage publication available at the export date. The complete annual series is provided in Supplementary Table S15.

Productive sources, authors, and countries

The *International Journal of Nanomedicine* was the most productive source, with 19 articles, followed by *Scientific Reports* with 15. The *International Journal of Biological Macromolecules* and *BioNanoScience* each published 11 articles. After disambiguation using Scopus Author IDs, Sobhan Mortazavi-Derazkola was the most productive author with six publications. Aziz Eftekhari, Ayşe Baran, Mehmet Fırat Baran, Sudarshan Singh, Ozioma F. Nwabor, Supayang Piyawan



International Journal of
Medical Toxicology & Forensic Medicine

Figure 2. Annual publication output; Complete publication years through 2025 are shown using a solid line and filled markers. The incomplete 2026–2027 publication years are distinguished using a dashed line, open markers, and grey shading and should not be interpreted as a decline in research activity.

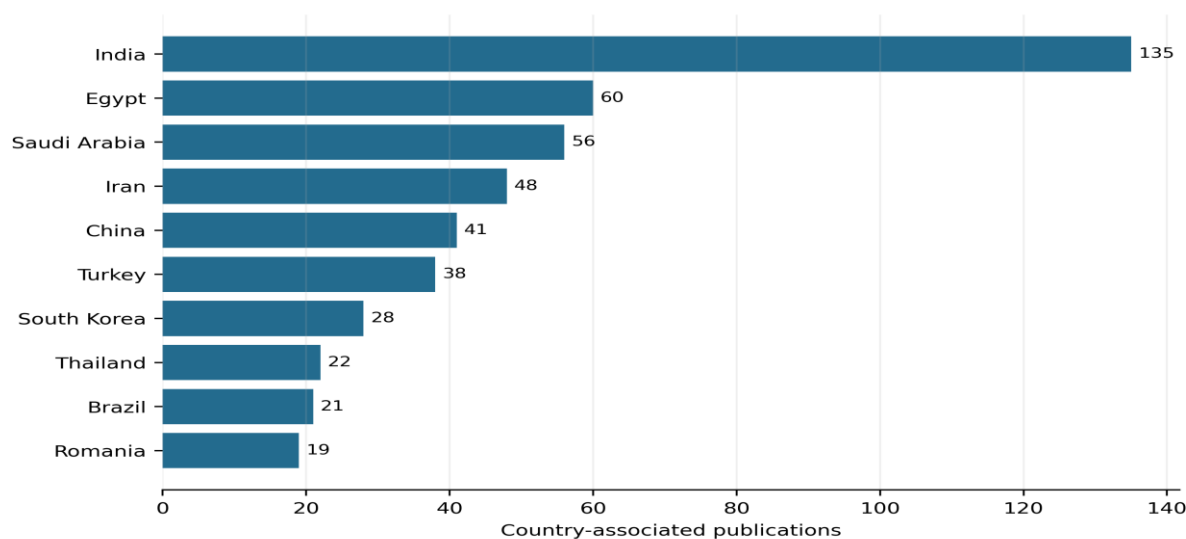
International Journal of
Medical Toxicology & Forensic Medicine

Figure 3. Ten leading countries by country-associated publication frequency.

Voravuthikunchai, Amedea-Barozzi Seabra, and Mahendra Rai each contributed five publications. Complete source and author rankings are provided in Supplementary Tables S7 and S8. India had the highest country-associated publication frequency with 135 articles, followed by Egypt (60), Saudi Arabia (56), Iran (48), and China (41). International co-authorship occurred in 158 articles, representing 34.3% of the corpus. Country counts exceeded the number of articles because internationally co-authored records were counted once for each represented country (Figure 3).

Citation profile

The most cited article, concerning the selective cytotoxicity of green-synthesized AgNPs against MCF-7 cells, accumulated 544 citations, followed by studies on theranostic biosynthesized AgNPs (498 citations) and green-tea-mediated AgNPs (483 citations). Because the 59 records assigned to incomplete publication years had limited time to accumulate citations, citation indicators were recalculated for the 402 records published during 2012–2025. This complete-publication-year subset accumulated 17,620 citations, with a mean of 43.83, median of 21, IQR of 8–50.75, and range of 0–544 citations per article, compared with a mean of 38.34 and median of 16 in the full corpus. Citation counts indicate scientific visibility and publication age rather than toxicological rigor. The complete ranking is provided in Supplementary Table S11.

Keyword structure and temporal development

After normalization, the author-keyword network comprised 30 terms and 99 retained links distributed

across five clusters (Figure 4). *Silver nanoparticles*, *green synthesis*, and *cytotoxicity* had the highest frequencies of occurrence. Other prominent terms included *antibacterial*, *antimicrobial*, *anticancer*, *antioxidant*, *wound healing*, *biosynthesis*, and *apoptosis*. The five-cluster solution produced the highest mean silhouette coefficient (0.518) among the candidate solutions and was therefore retained. The

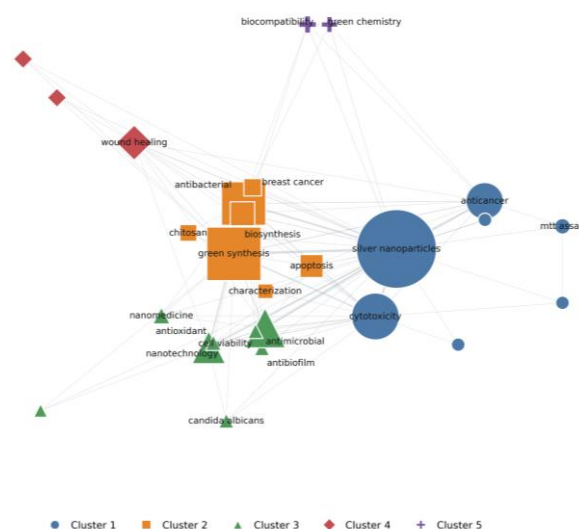
International Journal of
Medical Toxicology & Forensic Medicine

Figure 4. Author-keyword co-occurrence network after keyword normalization. Node size represents keyword occurrence, links indicate co-occurrence, and colors represent the five clusters selected using silhouette analysis. Only terms occurring in at least five records and links occurring in at least two records were retained. For readability, labels are displayed only for terms occurring in at least seven records.

resulting structure indicates substantial overlap between synthesis, biological activity, and safety evaluation rather than completely independent research themes. Keyword occurrences, mean publication years, and cluster assignments are provided in Supplementary Table S4.

The temporal overlay showed that green chemistry, cell viability, nanotechnology, and biosynthesis were more established terms, whereas *wound healing*, *nanomedicine*, *antibiofilm*, *characterization*, and *MTT assay* were more prominent in recent publications. The normalized temporal network is presented in Supplementary Figure S1.

Distribution of cytotoxicity and biocompatibility endpoints

Rule-based classification after validation and refinement was restricted to the 457 original research articles. Cytotoxicity- or cell-viability-related terminology was identified in 419 articles; biocompatibility or biosafety terminology in 284; oxidative-stress or related cellular-mechanism terminology in 122; *in vivo* systemic or histological terminology in 74; hemocompatibility terminology in 53; and genotoxicity terminology in 19 articles. Because the categories were non-exclusive, their combined total exceeded the number of primary

articles. Cytotoxicity- and cell-viability-related terminology dominated the indexed metadata, whereas genotoxicity- and hemocompatibility-related terminology was substantially less visible (Figure 5). These frequencies indicate metadata-based reporting visibility and do not confirm that the corresponding endpoints were experimentally tested.

Discussion

Research on the cytotoxicity and biocompatibility of biosynthesized AgNPs expanded substantially after 2021, and more than half of the included literature was published between 2022 and 2025. This expansion parallels the broad use of AgNPs in antimicrobial materials, cancer-oriented nanomedicine, wound care, and packaging. The concentration of country-associated production in India, Egypt, and Saudi Arabia indicates strong regional activity but also raises questions about the diversity of exposure settings, regulatory expectations, and biological models represented in the literature. The 34.3% international co-authorship rate shows meaningful cross-border collaboration, although multicountry investigations using harmonized nanoparticle preparation and safety protocols remain uncommon. The dominance of *in vitro* cytotoxicity and viability assays reflects the accessibility of assays such as the MTT assay and related colorimetric methods. These assays are useful

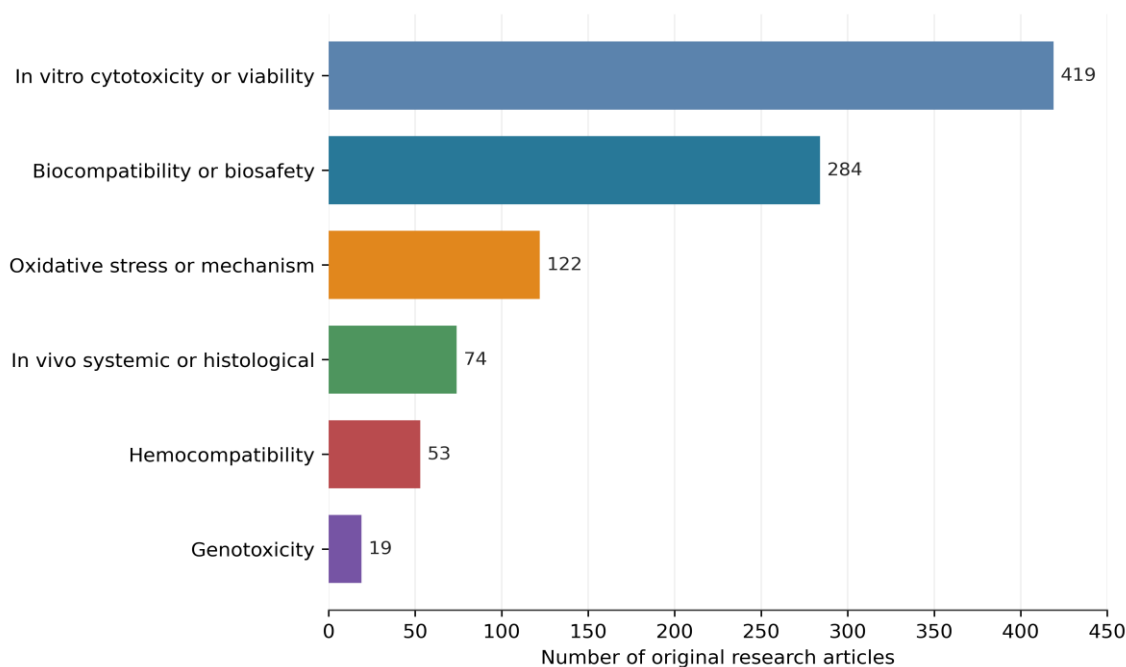


Figure 5. Metadata-based distribution of endpoint-related terminology among 457 original research articles. Counts represent primary articles containing relevant terminology in titles, abstracts, author keywords, or indexed keywords. Reviews were excluded, categories were non-exclusive, and the counts do not confirm that the corresponding endpoints were experimentally tested.

for early hazard screening, but nanoparticles may interfere with colorimetric readouts by absorbing or scattering light, adsorbing assay components, or sedimenting during exposure [9,10]. Apparent viability can therefore reflect assay interference in addition to biological injury. Studies that combine cancer-cell killing with a normal-cell comparator provide more interpretable evidence of selectivity [11-13], but differences in exposure time, serum content, particle dose, and reporting units limit cross-study comparisons. A low response in a single normal cell line should not be generalized to whole-organism biocompatibility. The keyword network confirms that cytotoxicity is closely connected to antibacterial, anticancer, antioxidant, and wound-healing research. This pattern aligns with experimental studies that evaluated antibacterial or anticancer performance alongside cytotoxicity, apoptosis, wound healing, or biocompatibility outcomes [11-14]. This structure is scientifically understandable because Ag^+ release, oxidative stress, membrane damage, mitochondrial dysfunction, and apoptosis contribute to both therapeutic activity and unintended toxicity. However, the same mechanism cannot be presented as desirable in target cells and ignored in non-target cells. Anticancer studies should report matched non-malignant comparators, calculate selectivity indices, and distinguish the effects of intact AgNPs from dissolved silver ions and residual plant or microbial extracts. Studies of antimicrobial materials should also examine the mammalian cells most likely to contact the material. Genotoxicity-related terminology appeared in 19 original articles, hemocompatibility-related terminology in 53, and *in vivo* systemic or histological terminology in 74 (16.2%). These metadata frequencies indicate reporting visibility rather than confirming that the corresponding endpoints were experimentally tested. Nevertheless, the substantially lower visibility of these terms compared with cytotoxicity or cell viability suggests that these safety dimensions receive less emphasis in titles, abstracts, and indexed keywords. Short-duration cellular assays cannot establish biodistribution, organ accumulation, immune effects, reproductive toxicity, delayed injury, or recovery. For wound dressings and injectable or implantable systems, hemolysis, coagulation, complement activation, inflammatory markers, and repeated-exposure designs are particularly important. For orally or environmentally relevant products, characterize dissolution, transformation, and exposure in realistic media. Comparative experiments should produce biologically and conventionally synthesized AgNPs with comparable primary size and morphology, characterize both materials in the relevant exposure medium, quantify Ag^+ release, and include extract-only and silver-salt controls. Without these controls, improved compatibility cannot be attributed specifically to the biosynthetic route. This

analysis applied explicit title–abstract criteria and retained record-level screening decisions. Screening was conducted by one reviewer; therefore, inter-rater reliability could not be assessed. Nevertheless, sensitivity analysis incorporating all 91 uncertain records showed that the principal geographic, collaboration, temporal, and endpoint patterns remained stable. Additional limitations include Scopus-only and English-language coverage, incomplete data for 2026–2027, reliance on indexed metadata, and potential author or affiliation ambiguity. Although Scopus provided consistent multidisciplinary metadata, records indexed exclusively in PubMed, Web of Science, or regional databases may have been missed. Keyword networks also depended on normalization and frequency thresholds. The endpoint classifier was validated in a stratified 10% sample and refined, but remained dependent on titles, abstracts, and keywords. Accordingly, the results represent patterns within Scopus-indexed literature and thematic coverage rather than a complete global census or evidence of study quality, methodological rigor, or toxic potency.

The following priorities are domain-informed recommendations based on established nanotoxicology principles and the cited literature; they should not be interpreted as direct empirical consequences of the metadata-based endpoint frequencies. Future studies should use interference-controlled viability assays, relevant normal-cell comparators, selectivity indices, blood-compatibility and DNA-damage testing, repeated-exposure designs, and characterization of Ag^+ release in biological media. Direct comparisons among biologically synthesized AgNPs, chemically synthesized AgNPs, silver salts, and biological extracts are needed to determine whether biosynthesis provides a measurable safety advantage.

Conclusion

Research on the cytotoxicity and biocompatibility of biosynthesized AgNPs expanded markedly between 2012 and 2025, but remained concentrated in a limited number of countries and journals. Cytotoxicity- and cell-viability-related terminology dominated the indexed metadata and was frequently associated with antibacterial, anticancer, antioxidant, and wound-healing applications. In contrast, genotoxicity-, hemocompatibility-, and systemic-safety-related terminology was less visible. Because these patterns reflect metadata-based reporting rather than confirmed assay performance, full-text evidence synthesis is needed to determine the actual extent and quality of safety testing. Nevertheless, biological synthesis should be regarded as a production method rather than

evidence of safety. Future studies should prioritize standardized physicochemical characterization in exposure media, appropriate normal-cell comparators, controls for assay interference and Ag⁺ release, blood-compatibility and DNA-damage testing, and fit-for-purpose repeated-exposure designs.

Acknowledgment

None.

Funding

This research did not receive any grant from funding agencies in the public, commercial, or non-profit sectors.

Conflicts of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this manuscript. All authors contributed to the manuscript and approved the final version.

Ethical Considerations

Not applicable.

References

- [1] Khorrami S, Zarrabi A, Khaleghi M, Danaei M, Mozafari MR. Selective cytotoxicity of green synthesized silver nanoparticles against the MCF-7 tumor cell line and their enhanced antioxidant and antimicrobial properties. *Int J Nanomedicine*. 2018;13:8013-24. [DOI: 10.2147/IJN.S189295]
- [2] Mukherjee S, Chowdhury D, Kotcherlakota R, Patra S, Vinothkumar B, Bhadra MP, et al. Potential theranostics application of bio-synthesized silver nanoparticles (4-in-1 system). *Theranostics*. 2014;4:316-35. [DOI: 10.7150/thno.7819]
- [3] Rolim WR, Pelegrino MT, de Araújo Lima B, Ferraz LS, Costa FN, Bernardes JS, et al. Green tea extract-mediated biogenic synthesis of silver nanoparticles: characterization, cytotoxicity evaluation and antibacterial activity. *Appl Surf Sci*. 2019;463:66-74. [DOI: 10.1016/j.apsusc.2018.08.203]
- [4] Patra S, Mukherjee S, Barui AK, Ganguly A, Sreedhar B, Patra CR. Green synthesis, characterization of gold and silver nanoparticles and their potential application for cancer therapeutics. *Mater Sci Eng C Mater Biol Appl*. 2015;53:298-309. [DOI: 10.1016/j.msec.2015.04.048]
- [5] Arumai Selvan D, Mahendiran D, Senthil Kumar R, Kalilur Rahiman A. Garlic, green tea and turmeric extracts-mediated green synthesis of silver nanoparticles: phytochemical, antioxidant and in vitro cytotoxicity studies. *J Photochem Photobiol B*. 2018;180:243-52. [DOI: 10.1016/j.jphotobiol.2018.02.014]
- [6] Saravanan M, Arokiyaraj S, Lakshmi T, Pugazhendhi A. Synthesis of silver nanoparticles from *Phenerochaete chrysosporium* (MTCC-787) and their antibacterial activity against human pathogenic bacteria. *Microb Pathog*. 2018;117:68-72. [DOI: 10.1016/j.micpath.2018.02.008]
- [7] Okafor F, Janen A, Kukhtareva T, Edwards V, Curley M. Green synthesis of silver nanoparticles, their characterization, application, and antibacterial activity. *Int J Environ Res Public Health*. 2013;10:5221-38. [DOI: 10.3390/ijerph10105221]
- [8] Parthiban E, Manivannan N, Ramanibai R, Mathivanan N. Green synthesis of silver nanoparticles from *Annona reticulata* leaves aqueous extract and its mosquito larvicidal and antimicrobial activity on human pathogens. *Biotechnol Rep (Amst)*. 2019;21:e00297. [DOI: 10.1016/j.btre.2018.e00297]
- [9] Zandi M, Malakootikhah J, Khosravy MS, Shohreh Shahmahmoudi AM, Bashar R, Pourhossein B, et al. Evaluation of the effectiveness of cerium nanoparticles as a potential adjuvant in veterinary rabies vaccine. *Microbial Pathogenesis*. 2026;213:108366. [DOI: 10.1016/j.micpath.2026.108366]
- [10] Guadagnini R, Halamoda K, Walker L, Pojana G, Magdolenova Z, Bilanicova D, et al. Toxicity screenings of nanomaterials: challenges due to interference with assay processes and components of classic in vitro tests. *Nanotoxicology*. 2015;9 Suppl 1:13-24. [DOI: 10.3109/17435390.2013.829590]
- [11] Jadhav K, Deore S, Dhamecha D, Hr R, Jagwani S, Jalalpure S, et al. Phytosynthesis of silver nanoparticles: characterization, biocompatibility studies, and anticancer activity.

- ACS Biomater Sci Eng. 2018;4:892-9. [DOI: 10.1021/acsbiomaterials.7b00707]
- [12] Ahn EY, Jin H, Park Y. Assessing the antioxidant, cytotoxic, apoptotic, and wound-healing properties of silver nanoparticles green-synthesized by plant extracts. Mater Sci Eng C Mater Biol Appl. 2019;101:204-16. [DOI: 10.1016/j.msec.2019.03.095]
- [13] Syed A, Saraswati S, Kundu GC, Ahmad A. Biological synthesis of silver nanoparticles using the fungus *Humicola* sp. and evaluation of their cytotoxicity using normal and cancer cell lines. Spectrochim Acta A Mol Biomol Spectrosc. 2013;114:144-7. [DOI: 10.1016/j.saa.2013.05.030]
- [14] Arokiyaraj S, Arasu MV, Vincent S, Prakash NU, Choium leaves and its antibacterial and et al. Rapid green synthesis of silver nanoparticles from *Chrysanthemum indicum* leaves and its antibacterial and cytotoxic effects: an in vitro study. Int J Nanomedicine. 2014;9:379-88. [DOI: 10.2147/IJN.S5354]