Review

Journal of the Brazilian Chemical Society

https://dx.doi.org/10.21577/0103-5053.20240167

J. Braz. Chem. Soc. **2025**, *36*, 3, e-20240167, 1-9

The Use of Silver Nanoparticles as Antimicrobial Agents between 2014 and 2023 in Brazil and Worldwide: A Bibliometric Review

Lauro S. Laurentino,[a] Lísia M. G. dos Santos,[,a] Cristiane B. Silva,[a] Ana L. R. de Barros,[a] Pamela C. L. Thomas[a] and Josino C. Moreira[a]*

[a]*Departamento de Química, Instituto Nacional de Controle de Qualidade e Saúde, Fundação Oswaldo Cruz, 21040-360 Rio de Janeiro-RJ, Brazil*

This study aimed to employ bibliometric methodologies to provide an overview of silver nanoparticles used as antimicrobial agents over the past decade. According to research conducted using the Scopus and Web of Science databases, a total of 2504 articles were published globally, of which 109 were from Brazilian institutions. Notably, approximately 70% of the leading article-producing countries are in Asia, with India emerging as the primary contributor with 1892 articles. Brazil ranked sixth in terms of publication volume, contributing 366 articles. Predominantly, the Southeastern region of Brazil exhibited the highest publication output, constituting 61% of the total, with the state of São Paulo playing a central role. Despite a gradual increase in the number of publications, most studies focused on synthesis methodologies, mainly producing aqueous silver nanoparticle solutions and their correlation with antimicrobial applications. The scarcity of publications addressing their efficacy in final commercialized products poses challenges for regulatory actions, quality control, and sanitary surveillance. Bibliometric studies are valuable tools for guiding future research efforts with significant potential impacts to foster a deeper understanding of this topic within the scientific community.

Keywords: silver nanoparticle, antimicrobial, bibliometric analysis

1. Introduction

Nanotechnology has evolved significantly, as evidenced by the recent increase in publications focusing on its applications, synthesis methodologies, characterization, and biological/environmental implications.[1] According to International Organization for Standardization (ISO) TS 80004-1:2015, nanotechnology is the "application of scientific knowledge to manipulate and control matter at the nanoscale to make use of size and structure-dependent properties and phenomena, as distinct from those associated with individual atoms or molecules or with bulk materials".[2] While the nanoscale is defined as the "size range of approximately 1 to 100 nm", nanomaterials are described as "material with any external dimension at the nanoscale or with an internal structure or surface structure at the nanoscale".[2]

The Nanotechnology Consumer Products Inventory (CPI), created in 2005 and revised in 2013, indicated that 1814 nanotechnology products were available on the market, originating from 622 companies across 32 countries. Notably, 37% of these products incorporate metallic nanoparticles, with silver nanoparticles (AgNPs) constituting 24% of this category.[3] These materials are employed in various products, including food packaging, medical devices, general and hospital disinfectants, deodorants, and masks.[4,5]

Silver nanoparticles is typically synthesized by physical, chemical, and biological methods. Among these, physical and chemical methods are the most conventional, each having its own advantages and disadvantages.[6] Physical methods are advantageous due to their speed, the use of radiation as a reducing agent, and the absence of hazardous chemicals.

However, they have drawbacks such as low yield, high-energy consumption, and lack of uniform distribution.[6-10] Chemical methods, on the other hand, involve water and organic solvents, which can be expensive and/or harmful to the environment. Generally, silver nanomaterials can be obtained by two approaches, classified as "top-down" and "bottom-up".[6,11,12]

*e-mail: lisia.gobbo@fiocruz.br
Editor handled this article: Célia M. Ronconi (Associate)

As the use of nanoparticles increases, studies have explored alternative synthesis methods, such as biological routes, which do not produce toxic waste and have minimal environmental impact.[13] Green synthesis methods use plant extracts to produce nanoparticles with well-defined size and morphology.[14,15] Electrochemical methods like electrodeposition form AgNPs with good stability, low polydispersity, and a high degree of purity.[11]

Despite the benefits of nanoparticles, AgNPs exhibit a distinct toxicity profile compared to their conventional forms. Research has demonstrated that AgNPs can have cytotoxic and genotoxic effects on human cells, impacting cell signaling and interfering with pathways such as c-Jun N-terminal Kinase (JNK), Epidermal Growth Factor (EGF), Phosphoinositide 3-Kinase (PI3K), and p38 Mitogen-Activated Protein Kinase (p38 MAPK).[16]

The biological activity of AgNPs depends on factors including surface chemistry, size, size distribution, shape, particle morphology, particle composition, coating/capping, agglomeration, dissolution rate, particle reactivity in solution, ion release efficiency, cell type, and the type of reducing agents used for their synthesis, which is crucial in determining cytotoxicity.

Additionally, the size of AgNPs significantly influences their toxicity: AgNPs with a diameter of 4 nm are notably more harmful to macrophages compared to those with a diameter of 20 nm.[17] AgNPs have been shown to cross the blood-brain barrier in animal studies, inducing neurotoxicity and neuronal death and accumulating in organs such as the liver, spleen, and kidneys.[16]

One of the primary challenges facing healthcare professionals is the emergence of microorganisms resistant to antibiotics and/or commercially available disinfectants, posing a significant threat to human health.[18] Consequently, research into alternative antimicrobial agents has gained prominence, with nanoparticles exhibiting antimicrobial properties emerging as one of the most promising alternatives.[19]

However, alongside the increased utilization of AgNPs as antimicrobial agents, concerns regarding their short- and long-term health and environmental impacts have also been raised. The widespread use of AgNPs in various products, coupled with their large-scale production and improper disposal, can lead to their accumulation in the environment, thereby increasing exposure levels for animals and humans alike. Metallic nanomaterials, being non-biodegradable, persist in the environment for extended periods.[20]

Consequently, nanomaterials have emerged as a focal point for public health and regulatory oversight. In this regard, the scientific community disseminates crucial insights through publications in high-impact scientific journals concerning the potential risks and impacts of nanomaterials on public health and the environment.[20]

Nevertheless, as noted by Aria *et al.*,[21] the growing volume of academic literature makes it progressively challenging for researchers and regulatory bodies to stay abreast of and comprehensively grasp all developments. However, mapping these studies facilitates the advancement of scientific knowledge by identifying emerging publication trends, identifying prolific authors, and pinpointing seminal works within specific topics.[22]

Bibliometrics involves the statistical analysis of written communication processes, applying quantitative methods to study the properties and behaviors of recorded information.[23] It is a scientific discipline that quantitatively examines bibliographic data such as titles, keywords, authors, and cited references.[24] Bibliometric studies have grown significantly in recent years and have proven invaluable in research endeavors aimed at mapping the development of specific knowledge domains, providing an overview, identifying gaps, assessing publication impact, and fostering new ideas and approaches on pertinent topics.[25]

The aim of this study is to perform a bibliometric analysis of publications from Brazil and around the world, focusing on the use of silver nanoparticles as antimicrobial agents. The data, spanning from 2014 to 2023, has been retrieved from the Scopus and Web of Science databases. This study aims to provide comprehensive insights into the total number of publications both nationally and internationally, trends in annual scientific output, distribution of publications by nationality, international collaborative networks, primary scientific sources, pivotal articles in the field, cumulative publications by domestic and foreign institutions, and the landscape of regional publications within the Brazilian context.

By examining these aspects, the study seeks to highlight the developments, collaborations, and trends in the research on silver nanoparticles, offering valuable insights for researchers, policymakers, and academic institutions.

2. Methodology

The study encompassed two bibliographic databases: Scopus, established by Elsevier in 2004, and Web of Science (WoS), renowned for its comprehensive coverage of global scientific output across diverse fields of knowledge.[26] The research methodology adhered to the scientific mapping framework proposed by Zupic and Cater,[27] which delineates five sequential stages: study design for defining research questions; data compilation involving the selection and consultation of bibliographic databases; data analysis using statistical or bibliometric

tools for data processing and refinement; visualization to determine optimal data representation; and interpretation where results are discussed and analyzed.[27] The detailed methodology schema is depicted in Figure 1.

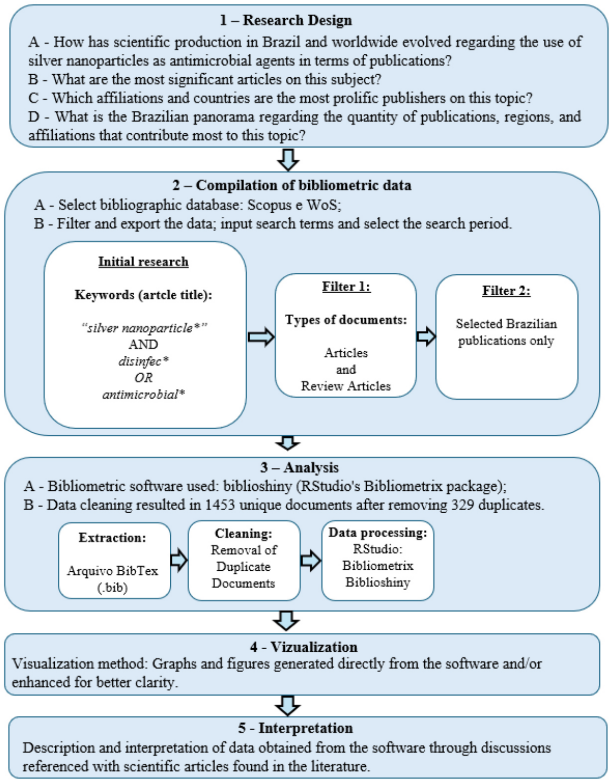


Figure 1. Workflow for conducting science mapping with bibliometric methods.

The search was conducted on April 9, 2024, encompassing documents published from 2014 to 2023, as well as those accepted in 2023 and published in 2024, by three different researchers. They used the same search terms with the objective of validating this methodology, and the results obtained were consistent across all three researchers. The search protocol focused exclusively on document titles, utilizing the search terms "silver nanoparticle*" to encompass plural forms and "disinfect* or antimicrobial*" to include variations such as "disinfection," "disinfections," "disinfectant," "disinfectants," antimicrobial, and antimicrobials. In the Web of Science database, the search strategy used the exact expression TI = ("silver nanoparticle*") AND (TI = (antimicrobial*) OR TI = (disinfect*)), while in Scopus, the expression was (TITLE("silver nanoparticle*") AND TITLE(disinfect*) OR TITLE(antimicrobial*)).

The initial search gathered bibliometric data on worldwide scientific production concerning the use of silver nanoparticles as antimicrobial agents. Subsequently, a focused examination of Brazilian scientific output was conducted by applying a country filter in both databases, yielding publications where Brazilian institutions held primary authorship.

The complete bibliographic data retrieved from both Scopus and Web of Science searches were exported in BibTeX (.bib) file format. Subsequently, the R language and the RStudio Integrated Development Environment (IDE) were utilized, with the installation of the bibliometrix package.[28-30] This software facilitated the conversion of BibTeX files into tables (dataframes).

Upon processing both dataframes from each database and eliminating duplicated entries, the Biblioshiny application was deployed.[29] Recognized as a powerful tool for bibliometric research, Biblioshiny features a user-friendly interface and encompasses a wide range of graphical and analytical functionalities.[21]

The bibliometric analysis of scientific production on the utilization of silver nanoparticles as antimicrobial agents, both in Brazil and worldwide, encompassed various key indicators. These included comprehensive data such as the total number of published articles, total authors and keywords, and national and international co-authorships, among others. Additionally, the study provided detailed insights into total publications at national and global levels, annual scientific production trends, distribution by nationality, international collaboration networks, primary scientific sources, pivotal articles in the field, total publications by domestic and international institutions, and the landscape of regional publications within the Brazilian context.

3. Results and Discussion

Between 2014 and 2023, a total of 1961 documents were published in Scopus database and 1634 in WoS database. Upon refining the search to include only articles and article reviews, these numbers decreased to 1812 and 1547, respectively. They were further narrowed down to articles where Brazilian institutions were the primary authors, reducing the counts to 90 and 81, respectively. Table 1 summarizes the data retrieved by Biblioshiny for both global and Brazilian searches.

Regarding global publications, Biblioshiny identified 2504 articles after excluding 855 duplicates. These documents involved 8128 authors across 757 journals. On average, each article received approximately 29 citations, and a total of 6288 keywords were utilized. Notably, the average co-authorship rate was approximately 5.4 *per* article, with only about 2.0% of articles authored by a single author. International co-authorship accounted for 19.7% of publications.

Regarding Brazilian publications, the software identified 109 articles, with 62 duplicates excluded. These documents involved 567 authors across 76 journals, receiving an average of approximately 31 citations *per* article and utilizing a total of 560 keywords. The average co-authorship rate was approximately 6.9 *per* article, and no articles were authored by a single individual.

The percentage of foreign co-authors was 22%, underscoring the ongoing need for increased international collaboration in scientific and technological knowledge dissemination.[31]

Table 1. General overview of global and Brazilian publications on the utilization of silver nanoparticles as antimicrobial agents

Description	World results	Brazil results
Timespan	2014 to 2023	2014 to 2023
Source	757	76
Document	2504	109
Average citations *per* document	29.0	31.0
Keywords plus	6288	560
Authors	8128	567
Authors of single-authored docs	40	0
Authors of multiple-authored docs	8088	109
Co-authors *per* doc	5.4	6.9
International co-authorships / %	19.7	22.0

3.1. Scientific production by year

According to the findings from Biblioshiny, a total of 132 publications were recorded worldwide in 2014, with only 3 originating from Brazilian institutions across the Scopus and WoS databases. From 2020 onward, global publications surged to 353, while Brazilian publications nearly quadrupled, reaching 11. Figure 2 illustrates the progression of publications over the years.

Figure 2 illustrates an increase in research studies related to nanotechnology. One plausible explanation for the rise in publications between 2020 and 2023 on a global scale could be attributed to the coronavirus (COVID-19) pandemic. This event heightened the focus and interest in utilizing nanomaterials with antimicrobial properties for developing new products such as medical protective clothing, disinfectants for inanimate surfaces, food packaging and *in vitro* studies involving cells exposed to severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2).[32-35]

3.2. Scientific production by country

Figure 3 depicts global scientific production related to the utilization of AgNPs. The regions shaded in the most intense blue indicate areas with higher contributions of publications on the topic, including both authorship and co-authorship.

Upon observing the map, it becomes evident that the topic is extensively disseminated in India, which leads to scientific publications. Figure 4 graphically illustrates the countries that have contributed the most to this issue between 2014 and 2023, with Asia accounting for 70% of the top 10 countries.

Among the countries that collaborate most frequently, Egypt and Saudi Arabia stand out with 64 jointly published articles, followed by India and Saudi Arabia with 56 jointly published articles.

Within the Brazilian context, the utilization of silver nanoparticles as antimicrobial agents has been extensively explored in scientific research. Brazil ranked sixth globally between 2014 and 2023, underscoring its significant scientific leadership in this field.

Brazil has engaged in collaborative efforts on this topic, primarily with the United States of America, with six jointly published articles. This is followed by Portugal and India, with five and four collaboratively published articles, respectively. Figure 5 illustrates a map of international collaboration between countries in terms of publications on the use of silver nanoparticles as antimicrobial agents.

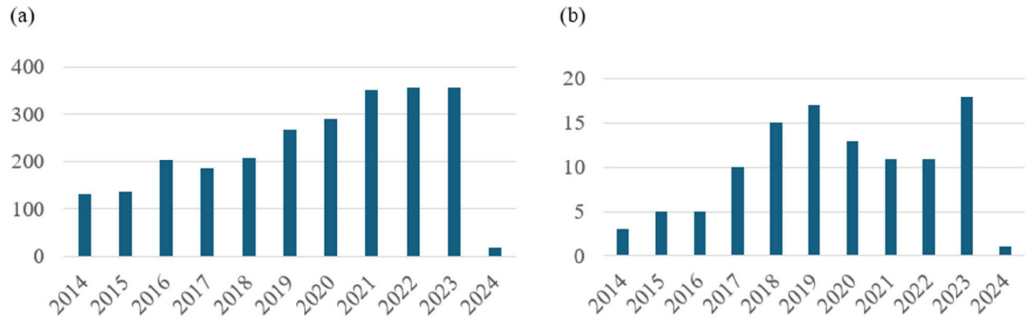


Figure 2. Number of publications in the last ten years on the use of silver nanoparticles as antimicrobial agents: (a) global scientific production and (b) Brazilian scientific production.

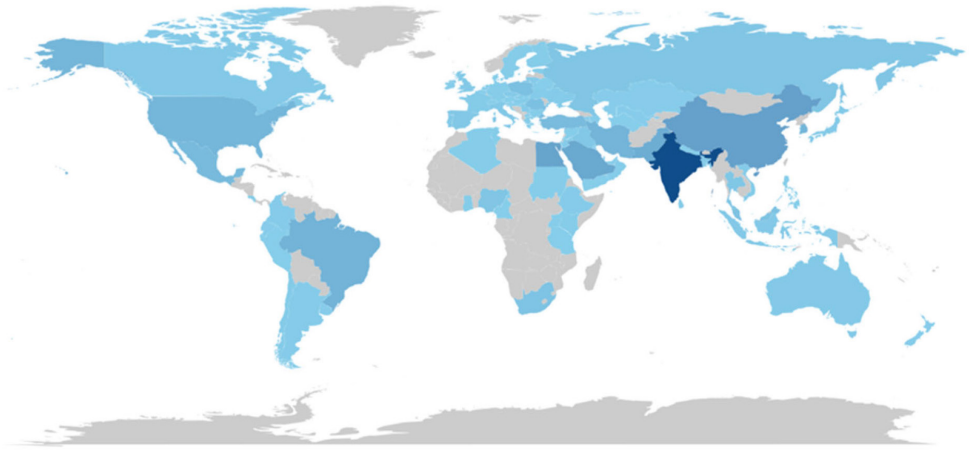


Figure 3. Map of scientific production by countries on the use of silver nanoparticles as antimicrobial agents.

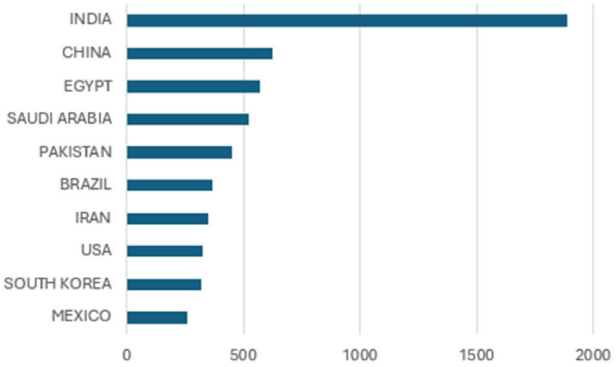


Figure 4. Global scientific production on the use of silver nanoparticles as antimicrobial agents.

3.3. Scientific Journals by articles published

In the global context, 2504 publications on the use of silver nanoparticles as antimicrobial agents were distributed across 757 different scientific sources. Table 2 presents the top scientific journals by publication quantity.

Some evaluation parameters of the sources are also displayed in this table, including the h-index, which considers the total number of articles published by the source within a specified period and correlates it with the total citations received by these documents, and the journal impact factor (JIF), a metric used to assess the quality of scientific journals based on the citations received by their articles.[36] The JIF is calculated as the average number of citations received in a particular year by articles published in the journal during the preceding two years.[37]

3.4. Publications by institutions

Figure 6a depicts the most prolific research institutions globally from 2014 to 2023. According to the findings of this bibliometric study, the top 10 institutions worldwide that have published extensively on the use of silver nanoparticles as antimicrobial agents are all located in Asia, with King Saud University in Saudi Arabia leading with 155 publications, including authorship and co-authorship.

These findings are reinforced by the StatNano portal,[38] an institution established in 2010 with headquarters in Europe and Asia dedicated to monitoring the global

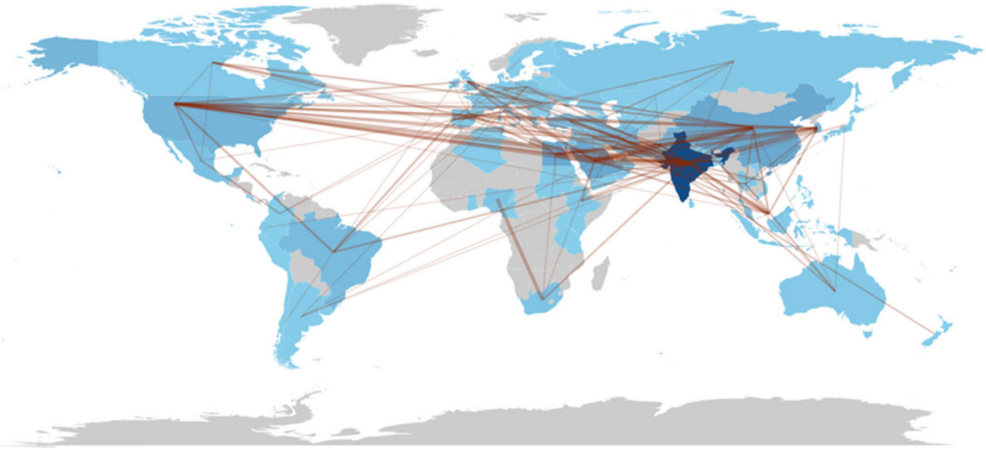


Figure 5. Collaboration map among countries in the use of silver nanoparticles as antimicrobials.

Table 2. Scientific journals with the highest volume of articles published on the use of silver nanoparticles as antimicrobial agents

Scientific Journal	Published articles	h-index	JIF
IET Nanobiotechnology	43	18	2.3
RSC Advances	42	22	3.9
Nanomaterials	39	22	5.3
International Journal of Biol. Macromolecules	37	25	8.2
Molecules	35	17	4.6
Scientific Reports	34	19	4.6
Material	33	10	3.4
Journal of Nanomaterials	32	16	3.8
International Journal of Nanomedicine	31	28	8.0
Materials Letters	26	17	3.0

JIF: Journal impact factor.

landscape of nanotechnology development and policies. According to the portal, Asia hosts nearly 80% of the top 10 universities globally that publish extensively on nanotechnology-related issues.

In Brazil, the leading contributors on the subject were Universidade Estadual de Campinas (UNICAMP), Universidade Estadual Paulista (UNESP), and Universidade de São Paulo (USP), with twenty, eighteen, and twelve publications, respectively. Figure 6b illustrates the top 10 Brazilian institutions that have published the most on the use of silver nanoparticles as antimicrobial agents.

Figure 7a demonstrates that over 62% of Brazilian publications originate from the Southeast region, with approximately 80% of these publications come from the state of São Paulo (SP), followed by Minas Gerais (MG) and Rio de Janeiro (RJ), as illustrated in Figure 7b.

3.5. Articles with the highest number of citations

Table 3 lists the top five most globally relevant articles based on citation count. Upon analyzing the titles of each article, it becomes evident that four of them link specific silver nanoparticle synthesis methodologies with their antimicrobial activity, a common theme well-documented in the literature. Different production processes for silver nanoparticles yield variations in size and shape, influencing their antimicrobial efficacy.[35] Furthermore, it is noteworthy that four of these articles were published from 2016 onward, marking a period of increased attention from researchers.

The third most cited article, titled *"Silver nanoparticles: A new view on mechanistic aspects on antimicrobial activity"* by Durán *et al.*,[41] authored by a Brazilian researcher,

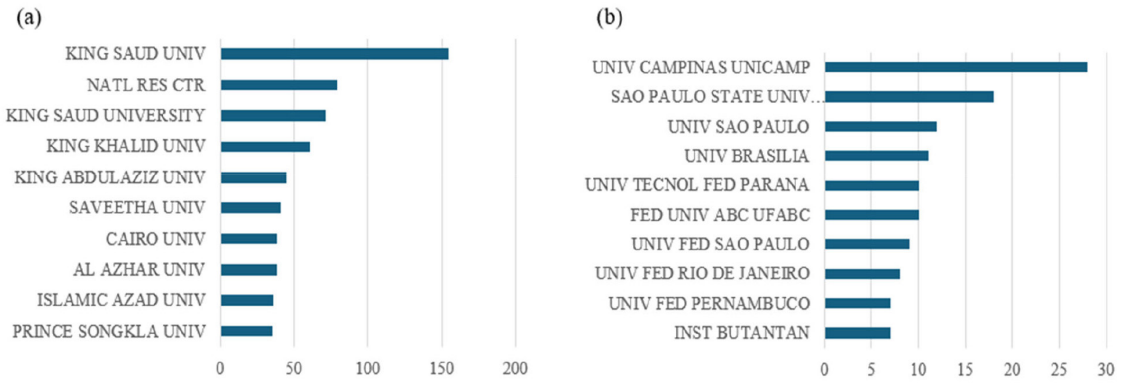


Figure 6. (a) Worldwide Publications and (b) Brazilian Publications, related to the use of silver nanoparticles as antimicrobial agents by Institutions.

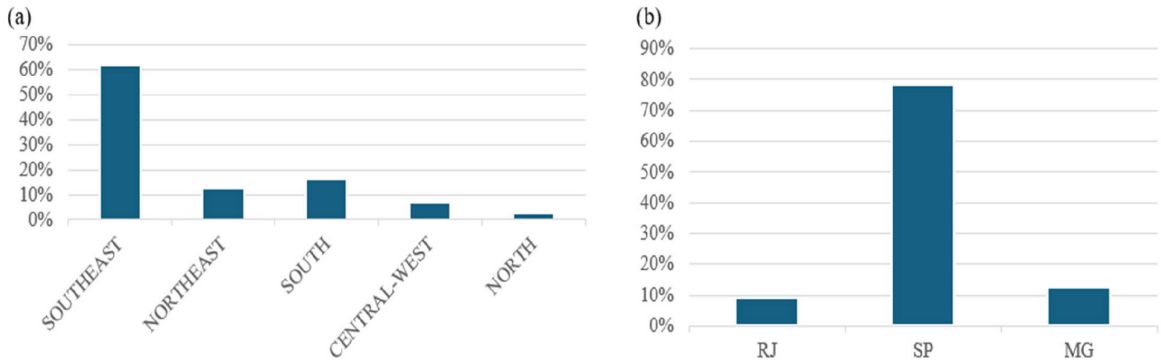


Figure 7. Percentage of publications related to the use of silver nanoparticles as antimicrobial agents: (a) by Brazilian regions; (b) by states in the Southeast region.

Table 3. Most cited article on the use of nanoparticles as antimicrobials agent from 2014 to 2019

No. citation	Title	Source	Publication year
1613	A review on plant extract mediated synthesis of silver nanoparticles for antimicrobial applications: A green expertise[39]	Journal of Advanced Research	2016
1047	Mechanistic basis of antimicrobial actions of silver nanoparticles[40]	Frontiers in Microbiology	2016
1007	Silver nanoparticles: A new view on mechanistic aspects of antimicrobial activity[41]	Nanomedicine: Nanotechnology, Biology and Medicine	2016
539	Green synthesis of silver nanoparticles: biomolecule-nanoparticle organizations targeting antimicrobial activity[42]	RSC Advances	2019
514	Leaf extract mediated green synthesis of silver nanoparticles from widely available Indian plants: synthesis, characterization, antimicrobial property and toxicity analysis[43]	Bioresources and Bioprocessing	2014

emerged from a collaborative study involving researchers from the Universidade de Campinas, Universidade Federal de São Paulo, and Universidade Estadual de Londrina. This underscores the prominence of Brazilian institutions globally in the realm of silver nanoparticles as antimicrobial agents.

Published in 2016 in the high-impact journal Nanomedicine (JIF = 8.0), this article presents a comprehensive review of the diverse mechanisms governing the antimicrobial action of silver nanoparticles, emphasizing the impact of nanoparticle size and shape on their ability to penetrate and disrupt microbial cell membranes. The study concludes with the assertion that silver nanoparticles are poised to become the primary choice for antimicrobial applications in the near future.[41]

4. Conclusion

The bibliometric analysis conducted using the Bibliometrix/Biblioshine® software provided valuable insights into publications on the use of silver nanoparticles as antimicrobial agents from 2014 to 2023. Unlike other software, Bibliometrix/Biblioshine® facilitated the compilation of results from the two largest databases, Scopus and Web of Science, by eliminating all duplicate documents, thereby organizing the content in a practical and objective manner.

Among the top 10 most cited articles, 60% are associated with green synthesis methods (derived from fungi, algae, plants, yeast, or bacteria) of silver nanoparticles, all of which were conducted at universities focusing on research into aqueous solutions of nanoparticles. Notably, there is a lack of studies and publications concerning the effects of AgNPs in various matrices of commercially available final products, which presents challenges for general sanitary surveillance efforts, including regulation, monitoring, and quality control.

The data obtained from this study revealed a gradual increase in global publications starting in 2020, and within the Brazilian context, this increase was noted particularly in 2023.

The findings from the statistical analysis of this study underscore the significance of bibliometrics as a powerful tool for guiding future research efforts with substantial impact. This approach enhances the comprehension of the topic within the scientific community by systematically mapping and evaluating research trends, identifying key contributors, and pinpointing pivotal works. Such insights not only facilitate the advancement of knowledge but also inform strategic decisions in research funding, collaboration initiatives, and policy development.

Acknowledgments

The authors are grateful to the following Brazilian agencies: Coordenação de Aperfeiçoamento de Pessoal de Nível Superior - Brasil (CAPES) - Finance Code 001, Fundação Carlos Chagas Filho de Amparo à Pesquisa do Estado do Rio de Janeiro-FAPERJ (grant: Rede NanoSaúde-E-26/2010.139/2019; E-26/2010.255/2020), Project PD&I -INCQS for financial support.

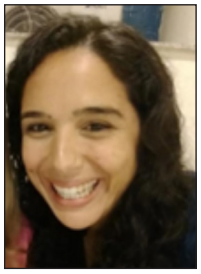
Author Contributions

Lauro S. Laurentino was responsible for conceptualization, data curation, investigation, project administration, resources, visualization, writing an original draft, writing-review and editing; Lisia M. G. dos Santos for conceptualization, data curation, investigation, project administration, resources, visualization, writing original draft, review and editing; Cristiane Barata-Silva for investigation, resources, visualization, writing-review and editing; Pamela C. L. Thomas for conceptualization, data curation, investigation, project administration, resources, visualization, writing original draft, review and editing; Ana L. R. de Barros for conceptualization, data curation, investigation, project administration, resources, visualization, writing original draft, review and editing; Josino C. Moreira for conceptualization, formal analysis funding acquisition, project administration, writing-review and editing.

Lauro S. Laurentino *was born in Rio de Janeiro-RJ, Brazil. He is graduated in Chemistry from State University of Rio de Janeiro (2004), master's in environmental chemistry by state University of Rio de Janeiro (2010) and finishing his doctorate in Sanitary Surveillance in National Institute for Quality Control and Health, FIOCRUZ-Rio de Janeiro. His research focuses on quality control of metallic nanoparticles in cosmetic and sanitizing products.*

Pamela C. L. Thomas *was born in Belém, Brazil. She obtained her Bachelor's degree in Pharmacy from the Federal Fluminense University in 2024. That same year, she joined the Multidisciplinary Health Residency Program, focusing on Health Surveillance with an emphasis on the quality of products, environments, and services at the National Institute of Quality Control in Health/Fiocruz. Currently, she works in the Inorganic Elements Sector of the Food Laboratory.*

Lisia Maria G. dos Santos *holds a degree in Biochemical Pharmacy from the Pontifical Catholic University of Rio Grande do Sul (1998), and a master's and doctorate in Health Surveillance from the Oswaldo Cruz Foundation. Currently, she is a public health technologist at the National Institute for Quality Control in Health (INCQS/Fiocruz), heading the food laboratory in the chemistry department and the Inorganic Elements Sector (SELIN). Her research focuses on quality control, nanotechnology, atomic absorption, mass spectrometry, inorganic contaminants, and sanitary products. She is part of the Health Surveillance graduate program (CAPES 6) and the Network NanoSaúde, supported by FAPERJ.*



Cristiane Barata-Silva *holds a degree in Industrial Pharmacy from the Federal Fluminense University (2010), a master's in Public Health and Environment with a focus on Environmental Toxicology from ENSP/FIOCRUZ, and a doctorate in the same program. She completed her postdoctorate at INCQS/FIOCRUZ, developing projects on inorganic elements and nanoparticles in sanitary products. Her work involves occupational health, epidemiology, environmental and occupational toxicology, and quality control of drugs, cosmetics, and food. She is part of the Health Surveillance graduate program (CAPES 6) and the Network NanoSaúde, supported by FAPERJ.*

Ana Lúcia R. de Barros *holds a degree in Industrial Pharmacy from the Federal Fluminense University (2008), a specialization and master´s in Health Surveillance from the Oswaldo Cruz Foundation. Currently, she is a quality control analyst at the National Institute for Quality Control in Health (INCQS/Fiocruz), in the cosmetics and sanitizer laboratory in the chemistry department. His current research interests center around the quality control of metallic nanoparticles in cosmetic and sanitizing products.*

Josino C. Moreira *holds a degree in Pharmacy, a master's in Analytical Inorganic Chemistry, and a doctorate in Chemistry. He is a researcher at the Oswaldo Cruz Foundation and part of the Health Surveillance graduate program at INCQS/Fiocruz (CAPES 6). With expertise in Electroanalytics, he develops projects on environmental contamination and nanotechnology. He is also a member of the Network NanoSaúde, supported by FAPERJ.*

References

1. Gubala, V.; Johnston, L. J.; Liu, Z.; Krug, H.; Moore, C. J.; Ober, C. K.; Schwenk, M.; Vert, M.; *Pure Appl. Chem*. **2018**, *90*, 1283. [Crossref]
2. ISO/TS 80004: *Nanotechnologies - Vocabulary - Part 1: Core Rerms*; International Organization for Standardization; Switzerland, 2015. [Crossref] accessed in June 2024
3. Vance, M. E.; Kuiken, T.; Vejerano, E. P.; McGinnis, S. P.; Hochella, M. F.; Hull, D. R.; *Beilstein J. Nanotechnol*. **2015**, *6*, 1769. [Crossref]
4. Bazilio, F. S.; dos Santos, L. M. G.; Silva, C. B.; Neto, S. A. V.; Senna, C. A.; Archanjo, B. S.; do Couto Jacob, S.; Abrantes, S. M. P.; *J. Food Sci. Technol*. **2023**, *60*, 654. [Crossref]
5. Barata-Silva, C.; Vicentini-Neto, S. A.; Magalhães, C. D.; Jacob, S. C.; Moreira, J. C.; Santos, L. M. G.; *Vigilância Sanitária em Debate: Sociedade, Ciência & Tecnologia* **2021**, *9*, 29. [Crossref]

6. Zhang, X.-F.; Liu, Z.-G.; Shen, W.; Gurunathan, S.; *Int. J. Mol. Sci.* **2016**, *17*, 1534. [Crossref]
7. Abou El-Nour, K. M. M.; Eftaiha, A.; Al-Warthan, A.; Ammar, R. A. A.; *Arabian J. Chem.* **2010**, *3*, 135. [Crossref]
8. Shameli, K.; Ahmad, M. B.; Yunus, W. M. Z. W.; Ibrahim, N. A.; Gharayebi, Y.; Sedaghat, S.; *Int. J. Nanomed.* **2010**, *5*, 1067. [Crossref]
9. Shameli, K.; Ahmad, M. B.; Yunus, W. M. Z. W.; Rustaiyan, A.; Ibrahim, N. A.; Zargar, M.; Abdollahi, Y.; *Int. J. Nanomed.* **2010**, *5*, 875. [Crossref]
10. Tsuji, M.; Hashimoto, M.; Nishizawa, Y.; Kubokawa, M.; Tsuji, T.; *Chem.- Eur. J.* **2005**, *11*, 440. [Crossref]
11. Garcia, D. G.; Santos, K. O.; Freitas, K. F. D.; Cardoso, M. J. B.; Fook, M. V. L.; *Braz. J. Dev.* **2021**, *7*, 31130. [Crossref]
12. Deepak, V.; Umamaheshwaran, P. S.; Guhan, K.; Nanthini, R. A.; Krithiga, B.; Jaithoon, N. M. H.; Gurunathan, S.; *Colloids Surf., B* **2011**, *86*, 353. [Crossref]
13. de Almeida, A. S. F.; Corrêa Jr., A.; Bentes, J. L. S.; *Summa Phytopathol.* **2021**, *47*, 9. [Crossref]
14. Guimarães, M. L.; Amarante, J. F.; de Oliveira, H. P.; *Rev. Mater.* **2021**, *26*, e13053. [Crossref]
15. Viana, A. V.; Viana, D. S. F.; de Figueirêdo, G. S.; de Brito, J. E.; Viana, V. G. F.; *Res. Soc. Dev.* **2021**, *10*, e11310615512. [Crossref]
16. Liao, C.; Li, Y.; Tjong, S. C.; *Int. J. Mol. Sci.* **2019**, *20*, 449. [Crossref]
17. Azizi-Lalabadi, M.; Garavand, F.; Jafari, S. M.; *Adv. Colloid Interface Sci.* **2021**, *293*, 102440. [Crossref]
18. Silveira, R.; Angioletto, E.; Arcaro, S.; Gomes, T.; *Tecnol. Metal., Mater. Min.* **2022**, *19*, e2638. [Crossref]
19. de Souza, H. M.; Savi, G. D.; Gomes, T.; Cardoso, W. A.; Cargnin, M.; Angioletto, E.; *Ozone Sci. Eng.* **2021**, *43*, 306. [Crossref]
20. Tran, Q. H.; Nguyen, V. Q.; Le, A. T.; *Adv. Nat. Sci.: Nanosci. Nanotechnol*. **2018**, *9*, 049501. [Crossref]
21. Aria, M.; Cuccurullo, C.; *J. Informetr.* **2017**, *11*, 959. [Crossref]
22. Dias, F. O.; Bonfim, H. S.; Bombardelli, J.; Matos, G. B. C.; *Rev. Gest. Soc. Ambient*. **2023**, *17*, 1. [Crossref]
23. de Lima, R. C. M.; Figueiredo, N. M.; *Ciência da Informação* **1984**, *13*, 137. [Crossref]
24. Hood, W. W.; Wilson, C. S.; *Scientometrics* **2001**, *52*, 291. [Crossref]
25. Ribeiro, C. A.: *Análise Bibliométrica da Produção Científica Mundial Sobre Apicultura de Precisão nas Bases de Dados Scopus e Web of Science*; MSc Dissertation, Universidade Federal do Ceará, Fortaleza, Brazil, 2022. [Link] accessed in August 2024
26. Silva, M. S. T.; Oliveira, V. M.; Correia, S. É. N.; *Contextus Rev. Contemp. Econ. Gestão* **2022**, *20*, 54. [Crossref]
27. Zupic, I.; Cater, T.; *Organ. Res. Methods* **2015**, *18*, 429. [Crossref]
28. Rstudio team; *R Studio*, v. 2023.12.1+402; PBC, USA, 2024. [Crossref]
29. Aria, M.; Cuccurullo, C.; *Bibliometrix/Biblioshiny®*; K-Synth Srl, v. 3.0.0, Italy, 2020. [Crossref]
30. R Core Team; *R language®*: a *Environment for Statistical Computing*, v. 4.3.2; R Foundation for Statistical Computing, Austria, 2021. [Crossref]
31. Fonseca, R. S.; de Lima, G. Â.; *Rev. Científica Multidisciplinar Núcleo do Conhecimento* **2023**, *3*, 16. [Crossref]
32. Ahmed, T.; Ogulata, R. T.; Sezgin Bozok, S.; *J. Text. Inst*. **2022**, *113*, 2825. [Crossref]
33. Souri, M.; Chiani, M.; Farhangi, A.; Mehrabi, M. R.; Nourouzian, D.; Raahemifar, K.; Soltani, M.; *Nanomaterials* **2022**, *12*, 783. [Crossref]
34. Bazilio, F. S.: *Controle Sanitário de Materiais Plásticos, com Ação Antimicrobiana pela Adição de Nanopartículas de Prata, Destinados ao Contato com Alimentos*; PhD Thesis, Fundação Oswaldo Cruz, Instituto Nacional de Controle de Qualidade em Saúde, Rio de Janeiro, RJ, Brazil, 2020. [Link] accessed in August 2024
35. Allawadhi, P.; Singh, V.; Khurana, A.; Khurana, I.; Allwadhi, S.; Kumar, P.; Banothu, A. K.; Thalugula, S.; Barani, P. J.; Naik, R. R.; Bharani, K. K.; *Sensors Int*. **2021**, *2*, 100101. [Crossref]
36. Hirsch, J. E.; *Proc. Natl. Acad. Sci. U. S. A.* **2005**, *102*, 16569. [Crossref]
37. Elsevier, https://www.elsevier.com/researcher/author/tools-and-resources/measuring-a-journals-impact, accessed in August 2024.
38. StatNano, https://statnano.com/report/s29/5, accessed in March 2024.
39. Ahmed, S.; Ahmad, M.; Swami, B. L.; Ikram, S.; *J. Adv. Res.* **2016**, *7*, 17. [Crossref]
40. Dakal, T. C.; Kumar, A.; Majumdar, R. S.; Yadav, V.; *Front. Microbiol.* **2016**, *7*, 1831. [Crossref]
41. Durán, N.; Durán, M.; de Jesus, M. B.; Seabra, A. B.; Fávaro, W. J.; Nakazato, G.; *Nanomedicine Nanotechnology, Biol. Med.* **2016**, *12*, 789. [Crossref]
42. Roy, A.; Bulut, O.; Some, S.; Mandal, A. K.; Yilmaz, M. D.; *RSC Adv.* **2019**, *9*, 2673. [Crossref]
43. Banerjee, P.; Satapathy, M.; Mukhopahayay, A.; Das, P.; *Bioresour. Bioprocess.* **2014**, *1*, 3. [Crossref]

Submitted: May 21, 2024
Published online: August 20, 2024