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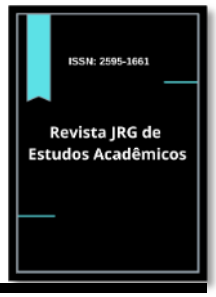

From rivers to kidneys: bacteria found in drinking water and hemodialysis units in Brazil

Dos rios aos rins: bactérias encontradas na água de consumo humano e em unidades de hemodiálise no Brasil

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Abstract

Water is an essential resource for human survival and quality of life; however, it has also become a vehicle for the transmission of infectious diseases such as gastroenteritis, colitis, and bacterial dysentery, since in many Brazilian regions it is contaminated by pathogenic microorganisms. Therefore, water monitoring is crucial to ensure sanitary safety and the preservation of public health, as microbiological contamination has a direct impact on both individual and collective health, especially in places with high water circulation, such as hospitals and schools. In order to assess the quality of water intended for human consumption in Brazilian regions, this study aimed to compile previous scientific data on water quality to identify the main bacterial

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species found in samples of drinking water consumed by the Brazilian population. It also sought to highlight the main sources of water supply, including households, schools, and hospitals, and to discuss the environmental, social, sanitary, and public management risks associated with such consumption. A literature review was conducted using databases such as PubMed, Web of Science, Virtual Health Library (BVS), Google Scholar, and university repositories. In total, 53 articles were selected for analysis. Among the bacterial groups most frequently identified, total coliforms (23.6%) and fecal coliforms (10.5%) were the most prevalent. Regarding the species identified, whether through culture or molecular methods, Escherichia coli stood out, accounting for 16.8% of the total number of pathogenic microorganisms found to be non-compliant with microbiological safety standards, followed by Pseudomonas aeruginosa, with an incidence of 8.2%. These bacteria were detected in 15 different sources of water for human consumption, including hospital drinking fountains, cisterns, rivers, springs, mineral water, wells, school taps, school drinking fountains, household taps, university drinking fountains, water tanks, clay filters, water spouts, water filters, and even water used in the hemodialysis process. In the latter case, bacteria such as Pseudomonas aeruginosa, Staphylococcus aureus, and Mycobacterium gordonae were detected in hemodialysis water samples. Furthermore, bacteria were found in both pre- and post-treatment water samples as well as in dialysate, and in some cases, the same species were simultaneously isolated from the water system and from patients' blood, confirming the correlation between environmental contamination and infections associated with dialysis therapy. Overall, the available data indicate poor microbiological quality of the water consumed by the population, as the results fall below the potability standards recommended by the World Health Organization. This reinforces the need for continuous monitoring, technical training of water supply system operators, and ongoing inspection.

Keywords: Drinking Water. Water Analysis. Coliform bacteria

Resumo

A água é um recurso essencial para a sobrevivência e a qualidade de vida humana; contudo, também tem sido um veículo de transmissão de doenças infecciosas, como gastroenterites, colites e disenteria bacteriana, pois, em muitas regiões brasileiras, encontra-se contaminada por microrganismos patogênicos. O monitoramento da água é fundamental para garantir a segurança sanitária e a preservação da saúde pública, uma vez que a contaminação microbiológica exerce impacto direto sobre a saúde individual e coletiva, especialmente em locais de grande circulação hídrica. Com o intuito de conhecer a qualidade da água destinada ao consumo, este estudo buscou compilar dados científicos prévios sobre a qualidade hídrica, a fim de avaliar as principais bactérias encontradas em amostras de água consumida pela população no Brasil, evidenciando as principais fontes de abastecimento, como residências, escolas e hospitais, para, então, discutir os riscos ambientais, sociais, sanitários e de gestão pública associados a esse consumo. Foi realizada uma revisão bibliográfica em bases de dados científicas. No total, foram selecionados 53 artigos para análise. Entre os grupos de bactérias mais frequentemente identificados, destacaram-se os coliformes totais (23,6%) e os coliformes fecais (10,5%). Em relação às espécies encontradas, seja por métodos de cultura ou por métodos moleculares, Escherichia coli se destacou, compondo 16,8% do número total de microrganismos patogênicos fora dos padrões de segurança microbiológica, seguida pela espécie Pseudomonas aeruginosa, com incidência de 8,2%. Tais bactérias foram detectadas em 15

diferentes fontes de água para consumo humano: bebedouros de hospitais, cisternas, rios, minas, água mineral, poços, torneiras de escolas, bebedouros de escolas, torneiras de residências, bebedouros de universidades, caixas-d'água, filtros de barro, bicas, filtros de água e até em água destinada ao processo de hemodiálise. Neste último caso, bactérias como Pseudomonas aeruginosa, Staphylococcus aureus e Mycobacterium gordonae foram detectadas em amostras de água para hemodiálise. Além disso, as bactérias foram encontradas tanto em amostras de água pré e pós-tratamento quanto no dialisato, e, em alguns casos, foram isoladas as mesmas espécies simultaneamente do sistema de água e do sangue dos pacientes, confirmando a correlação entre contaminação ambiental e infecções associadas à terapia dialítica. De modo geral, os dados disponíveis indicaram baixa qualidade microbiológica da água consumida pela população, visto que os índices estão aquém dos padrões de potabilidade recomendados pela Organização Mundial da Saúde. Isso reforça a necessidade de monitoramento contínuo, capacitação técnica dos operadores de sistemas de abastecimento e fiscalização permanente.

Palavras-chave: *Água para Consumo Humano. Análise da Água. Bactérias Coliformes*

1. Introduction

The water consumed is a remarkable vehicle for the transmission of infectious diseases, particularly bacterial gastroenteritis. The vast majority of these illnesses are caused by pathogenic microorganisms transmitted through the fecal-oral route (Da Silva *et al.*, 2019). This water resource must meet ideal parameters in order not to pose a risk to human health. There are microbiological, physical, and chemical standards that must be strictly followed to ensure that the water consumed has adequate quality and is free from contamination (Leal Fernandes and Vieira Gois, 2015). Such analyses correspond to physicochemical tests that evaluate color, turbidity, electrical conductivity, temperature, alkalinity, and total hardness, in addition to microbiological parameters such as total coliforms, *Escherichia coli*, cyanobacteria, and cyanotoxins.

According to the World Health Organization, several species of pathogenic bacteria have been globally detected in water bodies, with *Escherichia coli*, *Salmonella*, *Vibrio cholerae*, *Legionella pneumophila*, and *Campylobacter* standing out. These bacteria can cause severe gastrointestinal diseases, such as diarrhea and colitis, posing major public health concerns (Sinton *et al.*, 2002). In Brazilian states, the situation is similar, with *Plesiomonas*, *Aeromonas*, *Salmonella*, *Campylobacter*, *Yersinia*, and *Shigella* identified as the main agents responsible for cases of acute diarrhea (Gomes *et al.*, 1991).

In Brazil, water intended for human consumption is regulated by Ordinance GM/MS No. 888 of May 4, 2021, which establishes procedures for the control and monitoring of drinking water quality, defining national potability standards. This regulation introduced important updates to ensure the health of the Brazilian population, such as the limitation of microbiological, physical, and chemical parameters (Brasil, 2021).

Sanitation introduces evident complexity to urban infrastructure, as meeting human needs involves sanitary, environmental, and well-being conditions. Thus, although Ordinance GM/MS No. 888 establishes coherent and updated parameters that ensure the safety of drinking water, failures in the implementation of potability standards remain frequent across several Brazilian states. This situation can be

explained by structural and laboratory inefficiencies, as well as by the shortage of human resources and inequalities in access to basic sanitation—factors that hinder the continuous monitoring of water intended for human consumption, particularly in rural areas and urban peripheries. These challenges ultimately expose vulnerable populations to serious health risks caused by the ingestion of contaminated water. (WHO, 2022).

With regard to the bacteriological parameters of drinking water, Ordinance No. 888/2021 established that the maximum permissible values (MPV) for parameters such as *Escherichia coli* and total coliforms, both in public water supply systems (SAA) and in individual (SAI) or collective (SAC) alternative solutions, must be absent in 100 mL of the collected sample. Furthermore, for total coliforms, a maximum of one positive sample per month is acceptable in SAC systems serving fewer than 20,000 inhabitants, while 95% of the samples must show absence in 100 mL for those serving more than 20,000 inhabitants (Brasil, 2021). These parameters are important due to their ability to indicate post-disinfection water contamination and potential inefficiencies in the treatment system, since the analyzed samples are collected from different sampling points, such as treatment outlets, reservoirs, distribution networks, and intake points, allowing for a comprehensive assessment of bacteriological parameters across the various stages of drinking water circulation. This approach facilitates the identification of failures and the implementation of interventions to restore water potability.

In addition to identifying indicators, it is essential to understand the various sources from which water is collected, as the context directly influences the risk of contamination and the spread of diseases. Most samples come from wells and cisterns, often lacking proper sanitary control, which exponentially increases the risk of microbiological contamination. Institutional environments such as schools and hospitals require special attention, since the ingestion of contaminated water poses a health threat to vulnerable populations, including children, the elderly, and immunosuppressed individuals. Therefore, understanding the diversity of sites where water samples are analyzed is crucial for assessing the vulnerability of Brazilian states and for supporting public policies aimed at ensuring water safety (Da Silva *et al.,* 2019).

2. Methodology

This study consists of a literature review developed through the following stages: selection of the topic and formulation of the research question, identification of gaps in the literature, selection of scientific articles from databases, cataloging and evaluation of preselected articles, critical reading and assessment of the selected studies, integration of the data obtained, and elaboration of the project.

For article selection, descriptor searches were conducted on the Health Sciences Descriptors (DeCS/MeSH) platform, which is part of the Virtual Health Library (VHL) database, with the objective of constructing the most appropriate search strategies related to the topic in question across article repositories and databases. The following databases were used: PubMed (https://pubmed.ncbi.nlm.nih.gov), Web of Science (https://www.webofscience.com/wos), Virtual Health Library (https://bvsalud.org), Google Scholar (https://scholar.google.li/schhp?hl=pt-PT) and other university repositories. To ensure greater accuracy in the search, the following strategies with descriptors were used: “Water Quality” AND “Brazil” AND (“Microbiology” OR “Bacteria”); “Qualidade da água” AND “Brasil” AND “Análise microbiológica”; “Qualidade da água” AND “Brasil” AND “Bactérias.”

The searches and selections resulted in a total of 52 articles analyzed and included in the construction of this study. All articles published in any year were considered, including studies that discussed the microbiological quality of water consumed in Brazil, with emphasis on those addressing bacterial species such as *Escherichia coli* and other biological parameters, such as the presence of fecal or total coliforms. Only full-text, open-access articles published in English and/or Portuguese were included. Studies addressing other qualitative characteristics of water, such as physical parameters (density, turbidity, color, odor, taste, sediments, electrical conductivity) or chemical parameters (pH, alkalinity, hardness, nitrogen, iron, manganese, organic matter and components, among others), as well as those not available in open access or published in languages other than Portuguese and English, were excluded.

Based on the content analysis of the articles, those that presented the following sources of water for sampling and analysis were selected: drinking fountains, cisterns, faucets, bottled mineral water, rivers, wells, water filters, municipal water supply systems, and water used in hemodialysis processes. In addition, priority was given to studies that employed the following testing and analysis methods: (1) culture-based methods, such as the Most Probable Number (MPN) or multiple-tube technique, Pour Plate Method, Plate Count Agar (PCA), Colilert chromogenic substrates, total coliform and *Escherichia coli* counts, and the membrane filtration technique; and (2) molecular methods, such as PCR (Polymerase Chain Reaction), MALDI-MS, gel coagulation, and the PowerSoil DNA Isolation Kit.

All data were compiled and organized in electronic spreadsheets (Microsoft Excel 360) according to: (1) the distribution of studies across Brazilian regions; (2) the types of water analysis employed in the studies (culture-based or molecular); (3) the bacterial groups or species identified; and (4) the water source (cisterns, mineral water, faucets, etc.). Subsequently, the data were subjected to frequency and abundance analysis of the bacterial species in relation to the articles retrieved and the water sources. Graphs were constructed using the RawGraphs platform (https://www.rawgraphs.io/) and edited with Inkscape v.1.4.2 (scape.org/pt-br/).

3. Results

A total of 53 articles on the bacteriological quality of water consumed in Brazil were selected and analyzed. Among these, 40 articles addressed the presence of bacteria and coliforms in water sources such as school, hospital, and university drinking fountains; bottled or gallon mineral water; well water; cisterns; residential faucets; and collective water supply systems, while 13 studies focused on bacteria found in treated water used for hemodialysis procedures in clinics and hospitals.

Table 1 – Tabulation of the articles and studies analyzed for the construction of the results

Authors	Year	Title	Location	Water Source	Method
Alves	2007	Bactérias na água de abastecimento da cidade de Piracicaba	São Paulo	Residential taps	Molecular
Alves *et al.*	2022	Análise microbiológica de águas minerais e de água potável de abastecimento, Marília, SP	São Paulo	Bottled mineral water and well water	Culture
Alves *et al.*	2014	Water quality and microbial diversity in cisterns from semiarid areas in Brazil	Pernambuco	Cistern water	Molecular
Alves *et al.*	2016	Qualidade da água subterrânea obtida de poços em áreas urbanas na cidade de Ji-paraná - RO	Rondônia	Well water	Culture
Amorim; Porto	2001	Avaliação da qualidade bacteriológica das aguas de cisternas: estudo de caso no município de Petrolina-PE.	Pernambuco	Cistern water	Culture
Andrade *et al.*	2016	Microbiological evaluation of drinking water available in schools in Cruz das Almas, Brazil	Bahia	School faucets	Culture
Assis *et al.*	2020	A vulnerabilidade de populações indígenas: qualidade da água consumida pela comunidade Maxakali, Minas Gerais, Brasil	Minas Gerais	River water and well water	Culture
Barbosa *et al.*	2012	Qualidade microbiológica da água consumida em bebedouros de uma unidade hospitalar no Sul de Minas	Minas Gerais	Hospital drinking fountains	Culture
Bentes; Meschede	2021	Qualidade da água utilizada em serviços de hemodiálise antes e após passar por sistema de tratamento em Santarém, Oeste do Pará, Amazônia	Pará	Water for hemodialysis	Culture
Bortoloti *et al.*	2018	Qualidade microbiológica de águas naturais quanto ao perfil de resistência de bactérias heterotróficas a antimicrobianos	Minas Gerais	River water and spring water	Culture
Cartaxo *et al.*	2020	Análise microbiológica da água de um poço profundo no distrito de São Miguel, Mauriti, Ceará	Ceará	Well water	Culture

Carvalho	2019	Aplicabilidade de métodos alternativos no monitoramento da qualidade microbiológica da água tratada para diálise	São Paulo	Water for hemodialysis	Molecular
Carvalho *et al.*	2022	Reflection about the hemodialysis water microbiological quality in Brazil	Mato Grosso, Maranhão, Pernambuco, São Paulo	Water for hemodialysis	Culture
Coelho *et al.*	2010	Avaliação da qualidade microbiológica de águas minerais consumidas na região metropolitana de Recife, Estado de Pernambuco	Pernambuco	Bottled mineral water	Culture
Costa	2017	Água para hemodiálise: avaliação dos resultados gerados pelo programa de monitoramento da qualidade dos serviços de diálise do estado de Minas Gerais	Minas Gerais	Water for hemodialysis	Culture
Coutinho *et al.*	2021	Avaliação microbiológica da água para consumo humano em uma comunidade do arquipélago do Marajó, Pará, Brasil	Pará	Residential taps	Culture
Ferreira; Silva	2018	Análise microbiológica da água proveniente das fontes de abastecimento utilizadas em uma instituição de ensino pública da cidade de Januária/MG, Brasil	Santa Catarina	School faucets and school drinking fountains	Culture
Ferreira *et al.*	2017	À margem do rio e da sociedade: a qualidade da água em uma comunidade quilombola no estado de Mato Grosso	Mato Grosso	River water and spring water	Culture
Fialho *et al.*	2017	Avaliação microbiológica da água consumida por uma população rural de ilha Solteira – São Paulo	São Paulo	Residential taps	Culture
Filho; Dias	2008	Qualidade microbiológica de águas minerais em galões de 20 litros	São Paulo	Bottled mineral water	Culture
Fortuna *et al.*	2007	Análise microbiológica da água dos bebedouros do Campus da Universidade Federal de Juiz de Fora (UFJF): coliformes totais e termotolerantes.	Minas Gerais	University drinking fountains	Culture
Gomes *et al.*	2024	Physical-chemical and microbiological characterization of water destined to hemodialysis	Espírito Santo	Water for hemodialysis	Culture

Gurgel *et al.*	2020	Investigação de coliformes totais e Escherichia coliem água de consumo da comunidade Lago do limão, Município de Iranduba – AM	Amazonas	Well water and water tanks	Culture
Handam *et al.*	2020	Drinking water quality in Brazilian urban slums	Rio de Janeiro	Residential taps, household water filters and bottled mineral water	Culture
Jesus *et al.*	2022	Monitoramento da qualidade da água utilizada nos serviços de diálise móvel em unidades de tratamento intensivo no município do Rio de Janeiro	Rio de Janeiro	Water for hemodialysis	Culture
Kupper	2019	Qualidade microbiológica de água tratada para hemodiálise	Distrito Federal, Goiás, Minas Gerais, Paraná, Pernambuco, São Paulo	Water for hemodialysis	Culture
Lima *et al.*	2005	Microbiological analyses of water from hemodialysis services in São Luís, Maranhão, Brazil	Maranhão	Water for hemodialysis	Culture
Lopes; Amaral	2008	Qualidade microbiológica e nitrato em águas minerais e de poços de Jaboticabal - SP	São Paulo	Bottled mineral water and well water	Culture
Mesquita *et al.*	2014	Avaliação da qualidade microbiológica da água consumida pela população da região amazônica um estudo de casos na ilha de Mosqueiro PA	Pará	Residential taps	Culture
Miranda *et al.*	2018	Quality of water for human consumption in a rural area community from Brazil	Bahia	Residential taps and cistern water	Culture
Montanari *et al.*	2009	Microbiological contamination of a hemodialysis center water distribution system	São Paulo	Water for hemodialysis	Culture
Moraes *et al.*	2018	Avaliação microbiológica de fontes de água de escolas públicas e privadas da cidade de Santa Rita (PB)	Piauí	School drinking fountains	Culture
Nascimento *et al.*	2013	Pesquisa de coliformes em água consumida em bebedouros de escolas estaduais de Campo Mourão, Paraná	Paraná	School drinking fountains	Culture

Parreira *et al.*	2017	Monitoramento microbiológico em sistema inovador e sustentável de tratamento de água destinada à hemodiálise	Minas Gerais	Water for hemodialysis	Culture
Paulus	2017	Qualidade microbiológica da água dos bebedouros para consumo em escolas municipais de Missal - Paraná	Paraná	School drinking fountains	Culture
Peres *et al.*	2020	Potential microbial transmission pathways in rural communities using multiple alternative water sources in semi-arid Brazil	Paraíba	Cistern water	Culture
Pompeu	2011	Análises físico-química e microbiológica da água consumida em escolas municipais de educação infantil da cidade de Ariquemes - RO	Rondônia	School faucets and school drinking fountains	Culture
Rossi *et al.*	2012	Assessment of Microbiological Quality of Water Wells in Rural Properties of the City of West of Santa Catarina, Brazil	Santa Catarina	Well water	Culture
Sá *et al.*	2005	Qualidade microbiológica da água para consumo humano em duas áreas contempladas com intervenções de saneamento – Belém do Pará, Brasil	Pará	Well water	Culture
Sant'ana *et al.*	2003	Qualidade microbiológica de águas minerais	Minas Gerais e Rio de Janeiro	Bottled mineral water	Culture
Scapin *et al*	2012	Qualidade microbiológica da água utilizada para consumo humano na região do extremo oeste de Santa Catarina, Brasil	Santa Catarina	Well water	Culture
Silva *et al.*	2013	Diagnóstico da potabilidade da água de poços rasos de uma comunidade tradicional, Curitiba-PR	Paraná	Well water	Culture

Silva *et al.*	2017	Monitoramento microbiológico da água de bicas em parques públicos de Curitiba (PR)	Parana	Spouts	Culture
Silva *et al.*	2019	Avaliação da qualidade da água dos bebedouros de um campus universitário do semiárido nordestino	Piauí	University drinking fountains	Culture
Simões; Pires	2004	Água de diálise: ocorrência de leveduras, Pseudomonas aeruginosa e bactérias heterotróficas	São Paulo	Water for hemodialysis	Culture
Souza	2015	Qualidade microbiológica de água tratada para hemodiálise e caracterização de bactérias patogênicas	Goiás	Water for hemodialysis	Culture
Souza *et al.*	2018	Qualidade da água das escolas públicas de ensino fundamental de Ibirama (SC)/Brasil	Santa Catarina	School faucets and school drinking fountains	Culture
Stolf; Molz	2017	Avaliação microbiológica da água utilizada para consumo humano em uma propriedade rural de Taió – SC	Santa Catarina	Residential taps	Culture
Tristão	2014	Qualidade da água nas clínicas de hemodiálise no estado de Mato Grosso do Sul	Mato Grosso do Sul	Water for hemodialysis	Culture
Vasconcellos *et al.*	2019	Occurrence of total coliforms, Escherichia coli and Cronobacter species in commercially available 20 l bottled drinking water sold in Rio de Janeiro State, Brazil	Rio de Janeiro	Bottled mineral water	Culture
Vasconcelos *et al.*	2015	Qualidade microbiológica e físico-química da água de bebedouros consumida por estudantes da Universidade Federal do Ceará	Ceará	University drinking fountains	Culture
Xavier *et al.*	2011	Microbiological quality of drinking rainwater in the inland region of Pajeú, Pernambuco, Northeast Brazil	Pernambuco	Cistern water and clay filters	Culture

Zulpo *et al.*	2006	Avaliação microbiológica da água consumida nos bebedouros da Universidade Estadual do Centro-Oeste, Guarapuava, Paraná, Brasil	Paraná	University drinking fountains	Culture

Source: Author's own work.

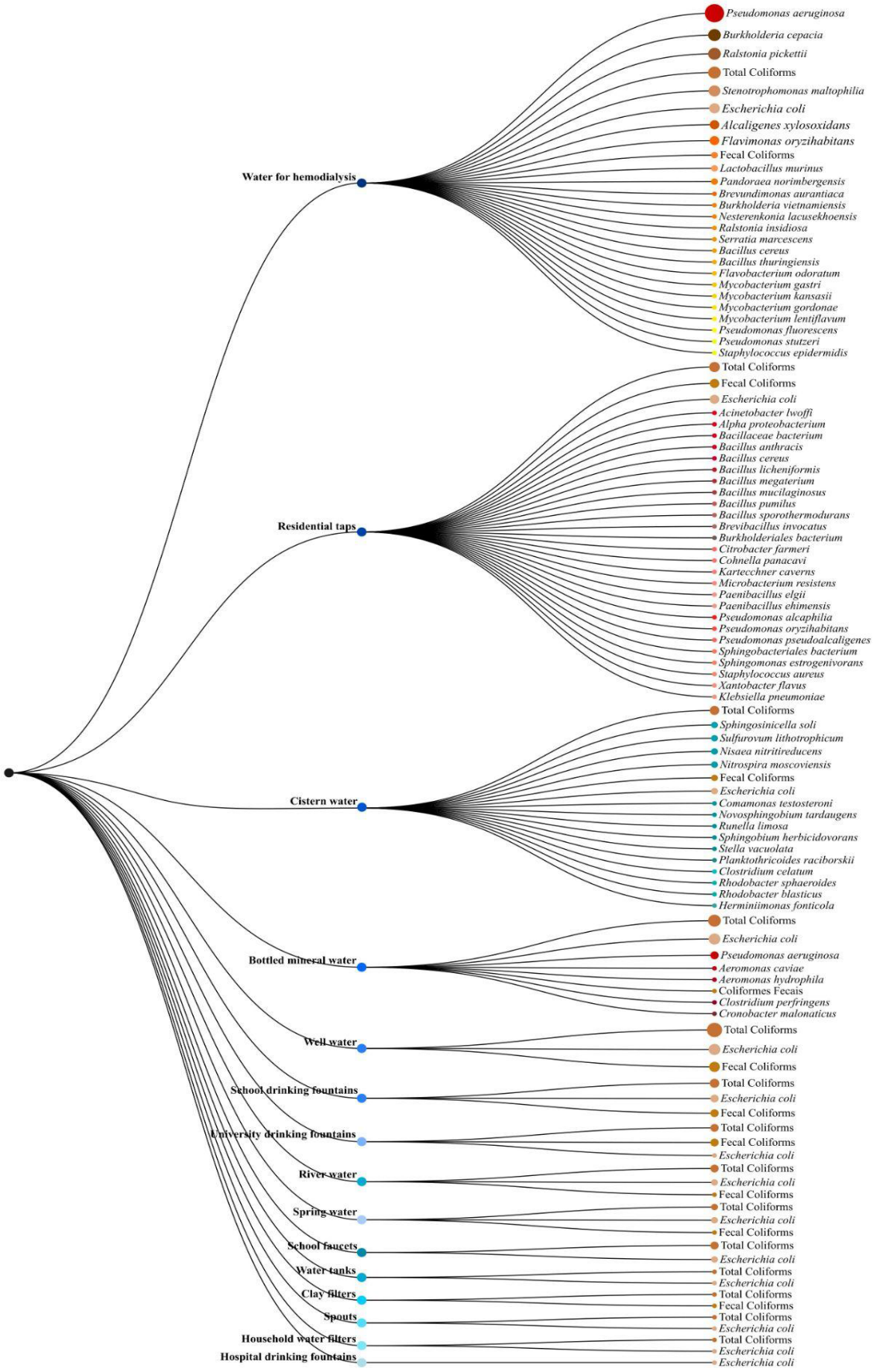
All studies were conducted within Brazilian territory, with the largest number of publications originating from the states in the Northeast (Bahia, Ceará, Maranhão, Pernambuco, and Piauí) and Southeast (Espírito Santo, Minas Gerais, Rio de Janeiro, and São Paulo) regions. Consequently, the regions with the lowest scientific output were the North (Amazonas, Pará, Rondônia, and Roraima) and the Central-West (Goiás). The state with the highest number of publications was São Paulo (11 articles), followed by Minas Gerais (8 articles), Paraná (6 articles), and Pará (4 articles).

Among the bacterial groups most frequently identified in the studies were total coliforms (23.6%) and fecal coliforms (10.5%). Regarding the species detected—through either culture-based or molecular methods—*Escherichia coli* was the most prevalent, accounting for 16.8% of the total number of pathogenic microorganisms found to be noncompliant with water microbiological safety standards, followed by *Pseudomonas aeruginosa* with an incidence of 8.2%.

Other species, although less frequent, were also relevant due to their impact on human health, including *Burkholderia cepacia* (2.7%), *Ralstonia pickettii* (2.3%), *Stenotrophomonas maltophilia* (2.3%), *Alcaligenes xylosoxidans* (1.4%), *Flavimonas oryzihabitans* (1.4%), *Bacillus cereus* (0.9%), *Lactobacillus murinus* (0.9%), *Pandoraea norimbergensis* (0.9%), *Sulfurovum lithotrophicum* (0.9%), *Nisaea nitritireducens* (0.9%), and *Sphingosinicella soli* (0.9%).

The sources from which water samples were collected were diverse. In total, 15 different types of water sources for human consumption were identified, including: hospital drinking fountains (1 article), cistern water (5 articles), river water (3 articles), spring water (2 articles), bottled mineral water (7 articles), well water (7 articles), school faucets (4 articles), school drinking fountains (6 articles), residential taps (7 articles), university drinking fountains (4 articles), water for hemodialysis (13 articles), water tanks (1 article), clay filters (1 article), spouts (1 article), and household water filters (1 article) (Figure 1).

FIGURE 1 - Distribution of water sources used in studies on the microbiological quality of drinking water in Brazil. Quantitative representation of the different types of water sources analyzed in the 53 selected studies, including school, hospital, and university drinking fountains; cisterns; rivers; springs; bottled mineral water; wells; residential and school faucets; collective water supply systems; water tanks; clay and household filters; spouts; and water used in hemodialysis processes.



Source: Author's own work.

Bacterias identified in water samples used in hemodialysis in Brazil

Studies that analyzed the microbiological quality of water used in hemodialysis services in Brazil revealed an alarming presence of pathogenic microorganisms and contamination indicators in the dialysate. Among the bacteria identified, Gram-negative species were predominant, particularly *Pseudomonas aeruginosa*, detected in approximately 73% of the studies. This bacterium's ability to form biofilms within pipelines hinders its complete eradication and indicates failures in the disinfection processes of water treatment systems (Lima *et al.*, 2004; Carvalho, 2019). In addition, other microbiologically relevant species such as *Burkholderia cepacia*, *Ralstonia pickettii*, and *Stenotrophomonas maltophilia* were reported in approximately 40% of the studies, also associated with contamination in post-treatment water samples.

Furthermore, opportunistic bacteria such as *Alcaligenes xylosoxidans*, *Flavimonas oryzihabitans*, *Serratia marcescens*, *Klebsiella pneumoniae*, and *Bacillus cereus* were also identified. Non-tuberculous mycobacteria, including *Mycobacterium gordonae*, *Mycobacterium gastri*, *Mycobacterium kansasii*, and *Mycobacterium lentiflavum*, were particularly reported in reuse water systems (Carvalho *et al*., 2022).

These studies also indicated the presence of heterotrophic bacteria at concentrations exceeding the limits established by current legislation in more than 60% of the analyzed samples. Although common in treated water, their proliferation at elevated levels favors the growth of other pathogenic species, especially in environments with stagnant water and poorly maintained filters, thereby contributing to the decline in health among dialysis patients (Bentes & Meschede, 2021; Kupper, 2019; Simões & Pires, 2004). Moreover, about 25% of the studies reported compliance with legal water quality standards, including the absence of *Escherichia coli* and adequate levels of fecal coliforms and heterotrophic bacteria, representing conditions that do not pose a microbiological contamination risk (Bentes & Meschede, 2021; Jesus *et al*., 2022).

Gram-positive bacteria such as *Staphylococcus aureus* were also found in isolated and incubated samples, showing a prevalence of up to 76% in some studies, with notable resistance to penicillin and methicillin. Other species, such as *Enterococcus faecalis* and *Corynebacterium* spp., were associated with infections in patients with central venous catheters, and approximately 25% of patients undergoing chronic hemodialysis experience infections caused by Gram-negative bacteria due to this type of vascular access (Melo, 2023).

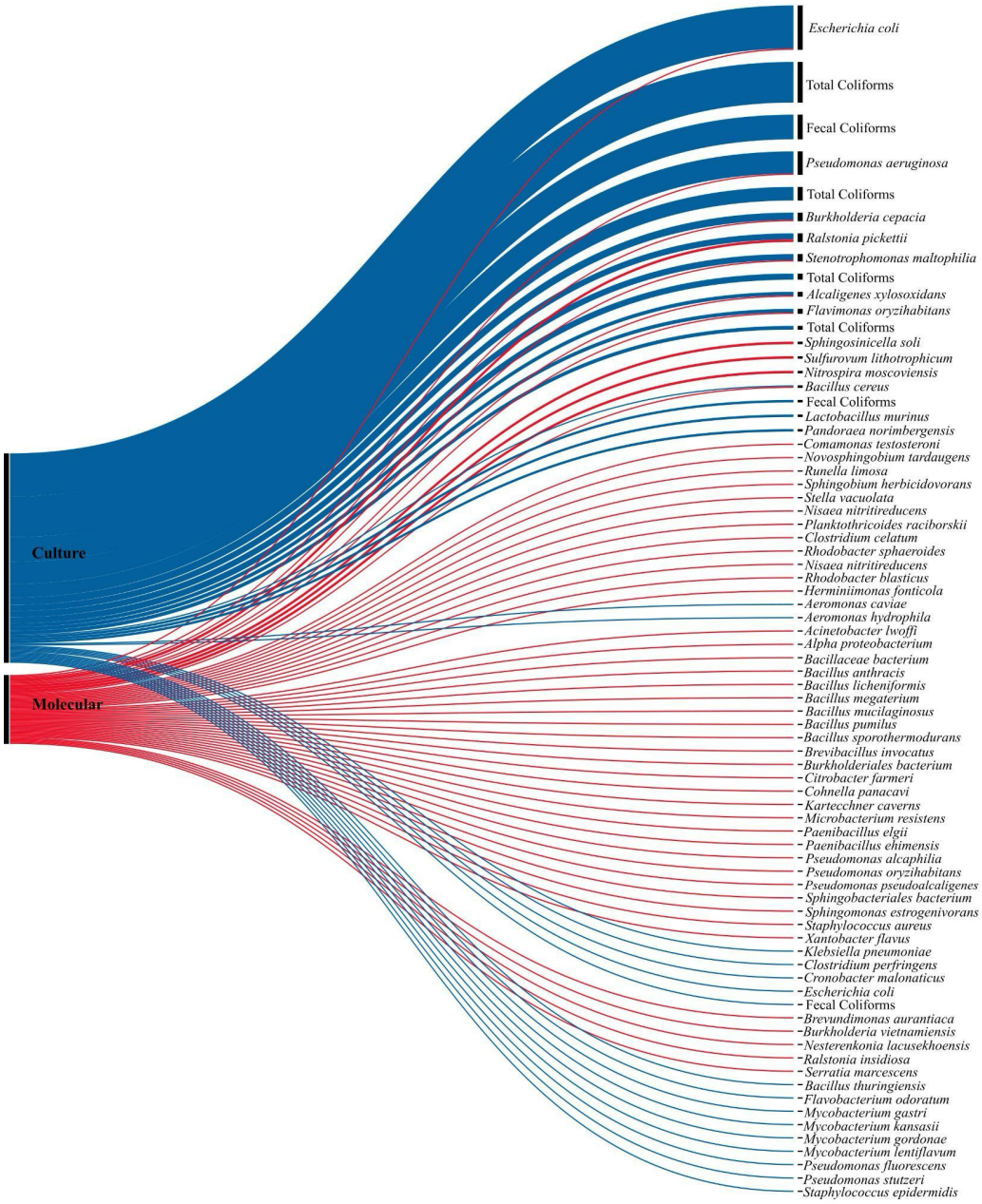
The occurrence of emblematic and alarming events reinforces the seriousness of failures in sanitary surveillance. A remarkable example is the episode known as the "Hemodialysis Tragedy," which occurred in Caruaru (Pernambuco State), where 60 patients died after exposure to microcystin, a toxin released by cyanobacteria found at high concentrations in the water used for dialysis treatment. The incident resulted in severe outcomes, including hepatic failure, fever, chills, sepsis, and death (Montanari *et al*., 2009; Carvalho *et al.*, 2022). Similarly, another event was recorded in Campinas (São Paulo State) in 1996, when an outbreak of bacteremia was associated with the presence of *Pseudomonas aeruginosa* and *Burkholderia cepacia* in 80% and 100% of the analyzed samples, respectively (Carvalho *et al*., 2022).

Microorganisms were detected in both pre- and post-treatment water samples as well as in the dialysate. In some cases, the same bacterial species were simultaneously isolated from the water system and from patients' blood samples, confirming the correlation between environmental contamination and infections associated with dialysis therapy. Chronic exposure to these microorganisms can trigger severe clinical complications, including fever, chills, headache, nausea,

hemolysis, hepatic failure, sepsis, and even death. Moreover, it contributes to the chronic inflammatory state frequently observed in renal patients, which may progress to long-term complications such as amyloidosis and cachexia due to the presence of bacterial endotoxins in significant proportions, reported in up to 77% of samples in certain studies (Carvalho, 2019; Carvalho *et al.*, 2022; Costa, 2017; Lima *et al.*, 2005).

Therefore, although some hemodialysis services in Brazil comply with the required microbiological standards, significant shortcomings in water quality control are still reported, increasing the risk of cross-contamination and infectious outbreaks. These findings underscore the need for continuous monitoring, strict maintenance of treatment systems, and effective adherence to sanitary regulations established by Brazilian legislation as essential measures to ensure the safety of patients undergoing dialysis therapy.

FIGURE 2 - Cultural and molecular methods used for the identification of bacterial species in water samples for human consumption and hemodialysis use in Brazil.



Source: Author's own work.

4. Conclusion

Based on the data obtained, it is concluded that maintaining the proper microbiological quality of water intended for human consumption and in hemodialysis systems remains a challenge for public health safety and management. The high proportion of studies reporting alarming occurrences of total and fecal coliforms, *Escherichia coli*, and *Pseudomonas aeruginosa* highlights persistent failures in water treatment, supply, monitoring, and distribution processes, which compromise potability, bacteriological quality, and suitability for human consumption. Moreover, the isolation of various opportunistic and antibiotic-resistant bacterial species demonstrates the complexity of contamination in the analyzed water systems and reinforces the need for technical and regulatory interventions by public health and sanitation authorities.

Furthermore, studies addressing bacterial species detected in water intended for hemodialysis reveal a high-risk scenario for human health, as the direct exposure of patients to potentially pathogenic microorganisms can lead to infectious outbreaks, increased morbidity and mortality, and adverse clinical outcomes.

Therefore, the implementation of strict surveillance, maintenance, disinfection, and monitoring measures for water treatment systems intended for human consumption is indispensable. These measures must be accompanied by rigorous enforcement of compliance with the standards established by Ordinance GM/MS No. 888/2021 and the Collegiate Board Resolution (RDC) No. 11/2014.

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