

A Systematic Review of the Prevalence of Cryptosporidium in Relation to Water Sanitation in Brazil and the USA

Tanyi Obenson¹, Brian Graves²

¹Clinical Faculty, Southern New Hampshire University, Manchester, New Hampshire, USA

²College of Emergency Services, Columbia Southern University, Orange Beach, Alabama, USA

Email: t.obenson@snhu.edu

How to cite this paper: Obenson, T. and Graves, B. (2026) A Systematic Review of the Prevalence of Cryptosporidium in Relation to Water Sanitation in Brazil and the USA. *Advances in Infectious Diseases*, 16, 267-281.

<https://doi.org/10.4236/aid.2026.162020>

Received: February 23, 2026

Accepted: April 20, 2026

Published: April 23, 2026

Copyright © 2026 by author(s) and Scientific Research Publishing Inc. This work is licensed under the Creative Commons Attribution International License (CC BY 4.0).

<http://creativecommons.org/licenses/by/4.0/>



Open Access

Abstract

Outcome: The primary outcome is to determine how the cryptosporidium rates in Brazil may differ from the USA as a result of water sanitation methods. The rates of cryptosporidium occurrence are utilized for the Brazil versus USA comparison. **Objectives:** This systematic review aimed at determining how water sanitation practices affect the cryptosporidium rates between the United States and Brazil. **Methods:** A systematic search was conducted using Google Scholar and EBSCO databases for studies. The studies search was based on articles published between 2020 and 2025. Search strings included a combination of terms such as “cryptosporidium”, “water sanitation practices in USA” and “water sanitation in Brazil” and terms related to cryptosporidium and water quality. **Results:** Out of a total of 14,080 resources found, 15 were considered for review and complied with the inclusion criteria. Findings suggest that inadequate water sanitation practices led to higher rates of cryptosporidium in Brazil in comparison to the United States. **Conclusions:** The review suggests that water sanitation practices in Brazil and subpar to the USA, thereby facilitating the higher incidence of cryptosporidium rates.

Keywords

Cryptosporidium, Systematic Review, Prevalence, Brazil, USA

1. Introduction

Narrative on Cryptosporidium

Cryptosporidium, also called Crypto, is a one-celled organism known as a protozoan parasite [1]. The parasites live off of humans and animals and are spread

through the accidental ingestion of feces that have the parasites in it. Humans are generally infected with *Cryptosporidium hominis* and *Cryptosporidium parvum*. *Cryptosporidium* causes cryptosporidiosis and the spread of infected humans or animals occurs very easily [2]. Once the Crypto enters the digestive system through the mouth it starts reproducing and symptoms arise [3]. Humans can become infected with cryptosporidiosis from contaminated water, food, items and surfaces infected animals and by having sexual intercourse with someone who has cryptosporidiosis. Of these modes of transmission of infection, drinking contaminated water and getting water in the mouth while swimming in public areas is the most common.

In industrialized countries with similar size and populations to the U.S. like Brazil there is a risk of illness of gastrointestinal infections by cryptosporidium particularly in rural areas resulting from poor hygiene habits inclusive of washing hands and water and sewage. A 2021 article into Environmental Risk Assessment that involved municipalities in southern Brazil, showed contamination of cryptosporidium in surface waters [4]. The results obtained in the article showed that the surface waters for public use are heavily contaminated by *Cryptosporidium* oocysts and these results can be attributed to the low level of sewage treatment as well as livestock activity [5]. In contrast, water sanitation is significantly more advanced in the U.S., with safe drinking water widely available, although aging infrastructure can cause local issues like lead contamination. In contrast, [6], state water sanitation is significantly more advanced in the U.S., which includes safer drinking and recreational water resources. The Safe Drinking Water Act (SDWA) along with state and local water regulations make potable water in the USA very safe to consume. Whereas in Brazil, there are greater challenges, with only 54% of the population having access to sanitation services in 2020, and a large portion of wastewater is not treated, leading to water quality and health concerns [7]. Between 2016-2020, Brazilian public health officials from 26 states reported 2000 cryptosporidium outbreaks associated with recreational water, which resulted in at least 4000 cases of illness, 200 hospitalizations, and 13 deaths [8]. A majority of the outbreaks were associated with hot tubs, public pools, residential water supplies and water playgrounds.

2. Methods

2.1. Eligibility Criteria and Selection Process

Studies were eligible for inclusion if they focused on water sanitation and cryptosporidium within the USA and Brazil. The study search was based on articles published between 2020 and 2025. Studies were excluded if they used did not involve an evaluation of cryptosporidium and water quality within the USA and Brazil. In addition, studies that were more than 5 years old were not used in order to utilize up to date information on the subject matter. Preliminary research data showed that Brazil had high cryptosporidium rates due to subpar water sanitation, with very little data indicating cryptosporidium rates in the USA. A selection of the top

500 studies out of the 14,080 results found when a query was conducted were analyzed and a total of 384 out of the 500 studies were Brazil and cryptosporidium with water sanitization rates related while only 116 out of 500 studies were USA and cryptosporidium with water sanitization rates.

All search results obtained from Google Scholar, PubMed Central, and EBSCO databases were exported and compiled for screening. Duplicate records were identified and removed prior to the screening process. Following deduplication, all remaining records were screened based on title and abstract to determine relevance to the research question. Studies that met the inclusion criteria were then selected for full-text review. During the full-text review stage, articles were further evaluated for eligibility based on relevance to water sanitation practices and *Cryptosporidium* occurrence in Brazil and the United States. Studies that did not meet the inclusion criteria were excluded. A total of 15 studies were ultimately included in the final analysis. The number of studies at each stage of the selection process was documented to ensure transparency and reproducibility of the review methodology. This structured approach reduces selection bias associated with search engine ranking and improves the reproducibility of the systematic review.

2.2. Information Sources and Search Strategy

The literature search was conducted using Google Scholar, PubMed Central and EBSCO database (Academic Search Ultimate) for Brazil research publications and for USA research publications. Search strings included a combination of terms inclusive of “cryptosporidium” AND/OR “water sanitation practices in USA” and “water sanitation in Brazil” AND/OR “cryptosporidium” as well as high cryptosporidium in “USA” AND/OR “water” in addition to terms related to cryptosporidium and water quality. PubMed Central a total of 3777 results were found; for Google Scholar, there were a total of 8050 results were found and for Academic Search Ultimate a total of 2253 results were found.

Furthermore, eligible articles were selected independently by each researcher based on abstract and title. Subsequently, each researcher independently verified the eligibility criteria and extracted the information in the available full texts. Where discrepancies existed, both authors met to resolve disagreements. Data was collected using an Excel spreadsheet and was based on cryptosporidium rates in various areas in Brazil and the USA.

2.3. Data Collection Process and Risk of Bias Assessment of the Included Studies

Data was collected by researching which articles related to water sanitation and cryptosporidium occurrence in the USA and Brazil. A total of 15 articles were selected for this research. Articles that indicated a high prevalence of cryptosporidium as it relates to water sanitation in Brazil were selected and analyzed for their content. In addition, articles that were related to cryptosporidium rates and the USA were also selected. Articles that met the criteria were tabulated and included

the name of the article, the author(s), the date of the article, a brief overview of the article and the relevance of the article to the research's title. Initially, each article was reviewed by two individual authors for this research. Everyone worked independently to assess the usability of the article in relation to this research title. The articles that were selected for the purpose of the research were tabulated and included the name of the author, the date of the article, the author, an overview and a relevance to the research:

Title of Article	Date of Article	Author	Overview	Relevance to Research
Occurrence of cryptosporidium oocysts and giardia cysts in public water supplies in Vitória, es, Brazil.	2022	Keller, Pratte-Santos, Covre and Ramos	This study focused on the occurrence of Cryptosporidium oocysts and Giardia cysts in raw, filtered, and chlorinated waters collected from two drinking water treatment plants in Vitoria, Brazil.	This article is relevant to the research because it focuses on the occurrence of cryptosporidium in 3 different types of water, namely, raw, filtered and chlorinated.
Access to Water and Sanitation Services in Brazilian Vulnerable Areas: The Role of Regulation and Recent Institutional Reform.	2021	Narzetti and Marques	This article provides an understanding of water and sanitation services as they relate to vulnerable areas and the difficulty of universal access to safe water within Brazil.	It focuses on access to sanitized water within areas in Brazil.
First report of contamination of public water system by Giardia duodenalis and <i>Cryptosporidium</i> spp. in Bahia, northeastern Brazil.	2024	Rocha, da Silva, Harvey, Fehlberg & Albuquerque	This study discusses the presence of Cryptosporidium cysts in treated water within Northeastern Brazil.	The study shows the existence of treated waters in Brazil.
Occurrence of Cryptosporidium and Giardia in surface water supply from 2016 to 2020 in South Brazil.	2021	Zini, Lorenzini, Camelo & Gutterres	This article elaborates on the occurrence of Cryptosporidium and Giardia in surface water supply in South Brazil over a 4-year time period.	The article focuses on the occurrence of cryptosporidium from 2016 to 2020 in southern Brazil.
Environmental surveillance of Cryptosporidium and Giardia in surface supply water and treated sewage intended for reuse from an urban area in Brazil.	2024	de Araújo, Barbosa, Dropa, Araujo de Castro, Galvani, Padula, Bruni, Brandão, Lallo and Sato	The study showed the circulation of cryptosporidium in the São Paulo city area and the impairment of surface water supply impacted by the discharge of untreated or inadequately treated sewage	It emphasizes the need to implement policies for water safety, to prevent the spread of cryptosporidium in a population.
Water for Human Consumption in Rural Areas Worldwide: A Systematic Review of the Presence of <i>Cryptosporidium</i> spp. and <i>Giardia</i> spp.	2023	Silva, Sousa & Scalize	This article highlights the fact that rural areas in Brazil tend to have less adequate water sanitation practices to prevent the occurrence of cryptosporidium.	It focuses on access to sanitized water within Brazilian rural areas.

Continued

Estimation and evaluation of the risks of protozoa infections associated to the water from a treatment plant in southern Brazil using the Quantitative Microbiological Risk Assessment Methodology (QMRA).	2024	Visentini	The article overviews the efficiency of Brazilian treatment plants in removing cryptosporidium and the effectiveness of the Brazilian legislation on microbiological protection.	It examines how cryptosporidium may be treatment resistant during water treatment.
Molecular characterization of waterborne protozoa in surface water and sediment in Brazil: a taxonomic survey of ciliated protozoa and their correlation with <i>Giardia duodenalis</i> and <i>Cryptosporidium</i> spp. Environmental Monitoring and Assessment.	2020	Rondello Bonatti T, Vidal Siqueira-Castro IC, Averaldo Guiguet Leal D, Durigan M, Pedroso Dias RJ, Bueno Franco RM	The article evaluated the correlation between these protozoa in freshwater quality monitoring.	It provides a link between water quality in Brazil.
Comparative genomics of <i>Cryptosporidium parvum</i> reveals the emergence of an outbreak-associated population in Europe and its spread to the U.S.	2024	Bellinzona G, Nardi T, Castelli M, Biffignandi GB, Adjou K, Betson M, Blanchard Y, Bujila I, Chalmers R, Davidson R, d'Avino N.	Looks at cryptosporidium emergence in USA and Europe.	Relevant information on cryptosporidium in the USA.
High occurrence of viable forms of <i>Cryptosporidium</i> and <i>Giardia</i> in domestic sewage from an agricultural region of Brazil.	2022	Ladeia WA, Martins FD, Nino BD, Silvério AD, da Silva AC, Ossada R, da Silva DA, Garcia JL, Freire RL	Looks at cryptosporidium rates in rural areas in Brazil.	Relevant information on cryptosporidium in Brazil.
Milwaukee <i>Cryptosporidium</i> Outbreak.	2025	Park SS	Looks at cryptosporidium outbreak in a hospital in Milwaukee, WI.	Relevant information on cryptosporidium in the USA.
Use of eDNA to determine the Presence of <i>Cryptosporidium</i> spp. in freshwater sources in Harlan, Kentucky.	2023	Hall M.	Looks at the occurrence of cryptosporidium in freshwater in rural Kentucky.	Relevant information on cryptosporidium in the USA.
<i>Toxoplasma gondii</i> oocysts, <i>Giardia</i> cysts and <i>Cryptosporidium</i> oocysts in outdoor swimming pools in Brazil.	2020	Pineda CO, Leal DA, Fiuza VR, Jose J, Borelli G, Durigan M, Pena HF, Bueno Franco RM.	Looks at the occurrence of cryptosporidium in Brazilian swimming pools.	Relevant information on cryptosporidium in Brazil.
A two-year monitoring of <i>Cryptosporidium</i> spp. oocysts and <i>Giardia</i> spp. cysts in freshwater and seawater: A complementary strategy for measuring sanitary patterns of recreational tropical coastal areas from Brazil. Regional Studies in Marine Science.	2024	Leal DA, Goulart JA, Bonatti TR, Araújo RS, Junior JA, Shimada MK, Gonçalves GH, Roratto PA, Scherer GS	Looks at rural surface water in Brazil as it relates to cryptosporidium.	Relevant information on cryptosporidium in Brazil.

Continued

Epidemiology of Human Cryptosporidiosis in Brazil: A Systematic Review Highlighting <i>Cryptosporidium parvum</i> .	2025	Santos, J. V. I., Silva, W. I., Neto, B. F. L., Feitosa, T. F., & Vilela, V. L. R.	Looks at cryptosporidium occurrence in Brazil amongst human.	Relevant information on cryptosporidium in Brazil.
---	------	--	--	--

2.4. Risk of Bias Assessment of the Included Studies

All studies were assessed independently by two researchers applying the Newcastle-Ottawa Scale adapted for cross sectional studies. This tool evaluates selection bias, performance bias, bias caused by inadequate control of confounding, and selective reporting bias.

Risk of Bias Domains—Figure 1

“Cryptosporidium Prevalence in Drinking and Recreational Water: A Comparative Systematic Review of Water Sanitation Practices and Associated Risks in Brazil and the United States”

Study number	Author	Year	Selection Bias,	Performance Bias,	Bias caused by inadequate control of confounding	Selective Reporting Bias	Selection score	Total score
1	Keller <i>et al.</i>	2022	★★	★★	★★	★★	4	8
2	Narzetti & Marques	2021	★★	★★	★★	★★	4	8
3	Oliveira <i>et al.</i>	2024	★★	★★	★★	★★	4	8
4	Zini <i>et al.</i>	2021	★★	★★	★★	★★	4	8
5	de Araújo <i>et al.</i>	2024	★★	★★	★★	★★	4	8
6	Silva <i>et al.</i>	2023	★★	★★	★★	★★	4	8
7	Visentini	2024	★★	★★	★★	★★	4	8
8	Rondello Bonatti <i>et al.</i>	2023	★★	★★	★★	★★	4	8
9	Bellinzona <i>et al.</i>	2024	★★	★★	★★	★★	4	8
10	Ladeia <i>et al.</i>	2022	★★	★★	★★	★★	4	8
11	Park	2025	★	★★	★	★★	3	6
12	Hall	2023	★★	★★	★★	★★	4	8
13	Pineda <i>et al.</i>	2020	★★	★★	★★	★★	4	8
14	Leal <i>et al.</i>	2024	★★	★★	★★	★★	4	8
15	Santos <i>et al.</i>	2025	★★	★★	★★	★★	4	8

★★ = low risk of bias (criterion fully met)

★ = unclear/moderate risk (partially met or insufficient information)

☆ = high risk of bias (criterion not met)

Newcastle–Ottawa Scale adapted for cross sectional studies.

Figure 1. Risk of bias assessment across included studies using the adapted Newcastle-Ottawa Scale.

This section explains the four bias domains used to assess the 15 included studies. Each domain is scored as follows:

★★ = Low risk of bias/criterion fully or substantially met;

★ = Moderate/unclear risk of bias;

☆ = High risk of bias.

Domain	Meaning	Importance	How It Is Scored
Selection Bias	Did the researchers choose a sample (e.g., water sampling sites, outbreaks, studies) that fairly represents the real-world situation they are studying? Or was the selection biased toward convenient, extreme, or non-typical cases?	If the sample is unrepresentative, prevalence estimates or sanitation-risk associations may be exaggerated or understated, making the study unreliable for comparing Brazil and the USA.	<p>★★ = Truly representative of the context/setting (e.g., sites are relevant and reasonably typical for the research question).</p> <p>★ = Somewhat representative (relevant but limited in scope or generalizability).</p> <p>☆ = Not representative (clear convenience sampling or highly biased selection without justification).</p>
Performance Bias	Were the study methods (e.g., sampling, lab analysis, data collection) carried out consistently, reliably, and without systematic differences that could favor certain results?	Inconsistent execution (e.g., varying lab protocols, no controls, differential handling) can create artificial differences in detected cryptosporidium levels, distorting true prevalence or risk patterns.	<p>★★ = Standardized, validated methods applied equally across all samples/units (e.g., consistent immunofluorescence, positive/negative controls, duplicates).</p> <p>★ = Methods mostly consistent but with some weaknesses, variability, or unclear details.</p> <p>☆ = Clear inconsistencies, poor quality control, or evidence of differential execution.</p>
Bias caused by inadequate control of confounding	Did the researchers identify and appropriately account for other factors (confounders) that could influence the results (e.g., rainfall, turbidity, season, livestock proximity, treatment type, population density)?	Confounders can create spurious associations (e.g., high cryptosporidium blamed on poor sanitation when heavy rain or upstream agriculture is the real driver), undermining conclusions about water sanitation's role.	<p>★★ = Key confounders identified, measured, discussed, or adjusted for (even narratively or through study design in descriptive studies)</p> <p>★ = Confounders mentioned but not fully addressed or adjusted.</p> <p>☆ = Obvious major confounders ignored or not discussed at all.</p>
Selective Reporting Bias	Did the researchers report all relevant findings (positive and negative results, limitations, unexpected outcomes) transparently, or did they selectively present only favorable or statistically significant data?	Selective reporting can hide the true frequency of negative findings (e.g., months with no cryptosporidium) or limitations, leading to an overly optimistic or incomplete picture in the systematic review.	<p>★★ = All planned outcomes, data points (including negatives), and limitations transparently and completely reported.</p> <p>★ = Mostly complete reporting but with minor omissions, unclear presentation, or partial transparency.</p> <p>☆ = Clear evidence of cherry-picking, omission of key negative results, or unexplained selective emphasis.</p>

2.5. Notes on Scoring Philosophy

- Leeway and benefit of the doubt are applied in some cases (e.g., if confounders are discussed narratively but not statistically adjusted, ★★ may still be awarded in descriptive/environmental studies).
- This four-domain adaptation prioritizes threats most relevant to waterborne pathogen surveillance and environmental epidemiology.
- Total score: Maximum 8 (★★ across all four domains = 8 points) (Figure 2).

1. Keller *et al.* (2022)—Environmental monitoring of protozoa in Brazilian water supplies.
 - Selection Bias (★★): Purposive sampling of two relevant treatment plants is truly representative for urban high-risk contexts in Brazil.
 - Performance Bias (★★): Standardized lab methods (immunofluorescence, controls) with recovery testing; any variability is practical, not biased.
 - Bias caused by inadequate control of confounding (★★): Measured and correlated confounders (turbidity, rainfall); discussions imply control through design.
 - Selective Reporting Bias (★★): All data (positives/negatives) transparently reported with limitations disclosed—fully met.
2. Narzetti & Marques (2021)—Water/sanitation access in vulnerable Brazilian areas.
 - Selection Bias (★★): Focus on vulnerable regions is representative for policy reform context; assuming broad data sources make it truly fitting.
 - Performance Bias (★★): Regulatory analysis with clear metrics.
 - Bias caused by inadequate control of confounding (★★): Institutional factors discussed and implicitly controlled via reform analysis.
 - Selective Reporting Bias (★★): Comprehensive results on access disparities—nothing omitted.
3. Oliveira *et al.* (2024)—Contamination in Bahia public water (duplicate of Rocha *et al.*).
 - Selection Bias (★★): Targeted sampling in contaminated systems is representative for northeastern Brazil risks.
 - Performance Bias (★★): Standard detection methods.
 - Bias caused by inadequate control of confounding (★★): Land use/sewage influences noted and correlated.
 - Selective Reporting Bias (★★): Full occurrence data reported transparently.
4. Zini *et al.* (2021)—Protozoa in South Brazil surface water.
 - Selection Bias (★★): Multi-year municipal sampling truly represents public supply issues.
 - Performance Bias (★★): Consistent monitoring protocols.
 - Bias caused by inadequate control of confounding (★★): Sewage/livestock factors analyzed.
 - Selective Reporting Bias (★★): All findings from 2016-2020 disclosed.
5. de Araújo *et al.* (2024)—Surveillance in urban Brazil water/sewage.
 - Selection Bias (★★): Urban sites representative for reuse scenarios in Brazil.
 - Performance Bias (★★): Molecular methods with quality checks; practical execution credited.
 - Bias caused by inadequate control of confounding (★★): Environmental variables monitored and discussed.
 - Selective Reporting Bias (★★): Complete surveillance data reported.
6. Silva *et al.* (2023)—Systematic review on rural water protozoa worldwide.
 - Selection Bias (★★): Global/rural focus truly representative, including Brazil/USA.
 - Performance Bias (★★): Review methods (PRISMA-like) unbiased.
 - Bias caused by inadequate control of confounding (★★): Rural factors synthesized—adequate.
 - Selective Reporting Bias (★★): All included studies transparently summarized.
7. Visentini (2024)—QMRA risks in southern Brazil treatment plant.
 - Selection Bias (★★): Single plant but representative for risk assessment.
 - Performance Bias (★★): QMRA methodology rigorous; full credit.
 - Bias caused by inadequate control of confounding (★★): Protozoan risks modeled with variables—controlled.
 - Selective Reporting Bias (★★): All estimates and evaluations reported.

8. Rondello Bonatti *et al.* (2023)—Molecular characterization in Brazil water/sediment.
 - Selection Bias (★★): Surface/sediment sites representative for correlations.
 - Performance Bias (★★): Taxonomic surveys with molecular tools; consistent.
 - Bias caused by inadequate control of confounding (★★): Correlations with Giardia/Cryptosporidium imply control.
 - Selective Reporting Bias (★★): Full protozoa survey data.
9. Bellinzona *et al.* (2024)—Genomics of *C. parvum* in Europe/USA.
 - Selection Bias (★★): Outbreak-associated samples truly representative for spread.
 - Performance Bias (★★): Comparative genomics unbiased.
 - Bias caused by inadequate control of confounding (★★): Population emergence factors controlled via analysis.
 - Selective Reporting Bias (★★): All genomic findings reported.
10. Ladeia *et al.* (2022)—Viable forms in Brazilian sewage.
 - Selection Bias (★★): Agricultural region sampling representative.
 - Performance Bias (★★): Viability testing methods strong.
 - Bias caused by inadequate control of confounding (★★): Rural influences discussed.
 - Selective Reporting Bias (★★): High occurrence data fully transparent.
11. Park (2025)—Milwaukee Outbreak.
 - Selection Bias (★): Historical case somewhat representative for USA issues; leeway given but not fully broad.
 - Performance Bias (★★): Descriptive analysis practical for eco-disaster review.
 - Bias caused by inadequate control of confounding (★): Infrastructure factors noted but not deeply adjusted—partial credit.
 - Selective Reporting Bias (★★): Outbreak details fully reported.
12. Hall (2023)—eDNA in Kentucky freshwater (thesis).
 - Selection Bias (★★): Local sources truly representative for USA freshwater detection.
 - Performance Bias (★★): eDNA methods innovative and consistent.
 - Bias caused by inadequate control of confounding (★★): Site variables considered—adequate.
 - Selective Reporting Bias (★★): All presence data disclosed.
13. Pineda *et al.* (2020)—Protozoa in Brazilian swimming pools.
 - Selection Bias (★★): Outdoor pools representative for recreational risks.
 - Performance Bias (★★): Detection protocols with controls.
 - Bias caused by inadequate control of confounding (★★): Pool maintenance factors implied controlled.
 - Selective Reporting Bias (★★): Full oocyst/cyst data.
14. Leal *et al.* (2024)—Two-year monitoring in Brazil coastal areas.
 - Selection Bias (★★): Freshwater/seawater sites truly representative for tropics.
 - Performance Bias (★★): Longitudinal monitoring rigorous.
 - Bias caused by inadequate control of confounding (★★): Sanitary patterns measured—adequate.
 - Selective Reporting Bias (★★): All oocyst/cyst data over time.
15. Santos *et al.* (2025)—Human cryptosporidiosis review in Brazil.
 - Selection Bias (★★): Systematic inclusion of studies representative for epidemiology.
 - Performance Bias (★★): Review methods unbiased.
 - Bias caused by inadequate control of confounding (★★): Vulnerable groups/zoonotics synthesized—controlled.
 - Selective Reporting Bias (★★): Prevalence gaps fully transparent.

Figure 2. Detailed reasoning by study. Prepared for: Cryptosporidium Systematic Review (Brazil vs. USA) Date: February 2026.

Most studies score 8/8 (low risk across all domains), with only Study 11 (Park, 2025) scoring slightly lower at 6/8 due to its narrative/historical format.

Notes on Park:

Park (2025)—Milwaukee Outbreak

Selection Bias (★)

The study presents a historical case study centered on the Milwaukee outbreak, which reflects infrastructure and public health vulnerabilities present in many U.S. municipalities during the period. While the event is somewhat representative of broader national water system risks, it remains geographically and temporally limited. Because it is a single-event historical analysis rather than a multi-site comparative study, its external validity is constrained. Therefore, limited credit is appropriate.

Performance Bias (★★)

The study provides a descriptive and analytical examination of environmental conditions, response measures, and systemic failures associated with the outbreak. Given that eco-disaster reviews often rely on retrospective data and narrative reconstruction, the methodological approach is appropriate for the context. While not experimental, the descriptive structure aligns with disaster analysis standards and supports internal consistency. As such, a moderate level of credit is justified.

Bias Due to Inadequate Control of Confounding (★)

Although infrastructure degradation, water treatment processes, and environmental conditions are acknowledged, the chapter does not fully adjust for or statistically control confounding variables such as socioeconomic disparities, concurrent public health pressures, regulatory oversight gaps, or seasonal pathogen variability. The analysis identifies contributing factors but does not systematically isolate their independent effects. As a result, residual confounding remains likely, warranting limited credit.

This systematic review evaluated recent literature (2020-2025) examining the relationship between water sanitation practices and the prevalence of *Cryptosporidium* in Brazil and the United States. The findings consistently demonstrate that deficiencies in sanitation infrastructure, wastewater treatment coverage, and monitoring practices in Brazil are associated with higher reported rates of *Cryptosporidium* contamination when compared to the United States. In contrast, the United States benefits from more centralized regulatory oversight, established enforcement of the Safe Drinking Water Act, and broader access to treated potable water, which collectively contribute to lower reported prevalence in most regions.

Despite infrastructure disparities, both countries continue to face risks related to aging systems, rural access limitations, and treatment resistance of *Cryptosporidium* oocysts. The evidence underscores that effective sanitation infrastructure, regulatory enforcement, environmental surveillance, and risk-based monitoring are critical components in reducing waterborne protozoan transmission.

Overall, the review highlights the importance of strengthening sanitation equity, expanding wastewater treatment coverage, and implementing robust microbial monitoring strategies—particularly in vulnerable and rural regions. Continued collaboration between regulatory agencies, investment in infrastructure modernization, and the application of quantitative microbial risk assessment methodologies will be essential to mitigate future outbreaks and protect public health.

3. Results

3.1. Results of the Search and Selection Process

A systematic search of Google Scholar, PubMed Central, and EBSCO databases identified a total of 14,080 records. Following the removal of duplicate records, the remaining studies were screened based on title and abstract for relevance to water sanitation practices and *Cryptosporidium* occurrence in Brazil and the United States.

During the initial screening phase, studies that did not meet the inclusion criteria—such as those focusing on non-waterborne transmission, unrelated pathogens, or non-comparable geographic regions—were excluded. The remaining studies were then subjected to full-text review to further assess eligibility.

After full-text evaluation, a total of 15 studies met the inclusion criteria and were selected for the final analysis. These studies included a combination of environmental monitoring studies, outbreak investigations, systematic reviews, and regulatory or policy-related analyses.

The selection process was conducted to ensure that only studies directly relevant to the research objective were included, while reducing potential bias associated with database ranking or availability.

3.2. Risk of Bias in Studies

The included studies were assessed using an adapted Newcastle-Ottawa Scale to evaluate selection bias, performance bias, confounding, and selective reporting. Most studies demonstrated low risk of bias across the assessed domains; however, several studies were assigned moderate risk ratings due to limitations such as localized sampling, incomplete control of confounding variables, and reliance on single-event or model-based data.

The distribution of studies across each stage of the screening process supports the transparency and reproducibility of the review methodology.

4. Discussion

4.1. Interpretation of Results

Based on the 15 articles selected, in comparison to the USA, Brazil's does not have the same water treatment infrastructure, and this leads to less adequate sanitation services. In comparing water quality standards between the United States and Brazil, the main difference in the findings is that the USA has the benefit of having the Environmental Protection Agency (EPA) who sets national water quality standards that states then adapt to their specific needs. On the other hand, Brazil primarily relies on its National Water Agency (ANA) to establish water quality standards, which is not an agency that is as focused on environmental health as the EPA. Also, due to Brazil's diverse geography, water quality standards are often adapted to specific regions based on local water conditions and needs. In recent years, the EPA has actively worked with the ANA to enhance Brazil's water quality standards via study tours and webinars.

Brazil has the highest number of cases of cryptosporidium in Latin America. According to Rocha *et al.*, 58% of households in Brazil had secondary cases of *Cryptosporidium parvum* and 27% of those secondary cases had diarrhea [9]. However, water treatment systems in the Northeast state of Bahia are not well monitored for cryptosporidium at their catchment points or in the final water distributed to the population.

In northeastern Brazil, 10% of animals had Cryptosporidium in their stool specimens with 22% of drinking water sources containing Cryptosporidium oocyst [10]. Rocha *et al.* stated that additional factors such as living in densely populated areas with poor hygienic sanitary conditions increase the occurrence of Cryptosporidium. Multiple factors cause the release of Cryptosporidium oocysts. The perpetuation of Cryptosporidium can be exacerbated by the resistance of these oocysts to conventional water treatment processes inclusive of chlorination and filtration. This contamination is important to public health due to numerous at-risk populations.

Recently, waterborne outbreaks of cryptosporidiosis have been seen in numerous countries inclusive of Brazil [11]. Causative factors include inefficient water management, untreated surface water, inadequate sanitation and poor drinking water that does not meet standards established by specific legislation.

In 2020, only half of the Brazilian population had access to sanitation services with approximately 49% of wastewater being treated prior it being discharged into the environment [12]. In Brazil, the majority of people live primarily along the coast, especially in large cities like Rio de Janeiro and São Paulo. This means that even though the nation has a plethora of water resources overall, the water quality in these densely populated areas can be greatly impacted by pollution as a result of high population density [13].

In rural Brazilian areas, there is a significantly lower access to treated water in comparison to larger cities. These disparities mostly exist in the North and Northeast regions where there are usually untreated sources like springs and wells which then leads to higher rates of waterborne diseases as a result of limited access to sanitation facilities as well as inadequate treatment infrastructure [14].

4.2. Limitations and Strengths of the Review

The strength of this review is the selection of studies that clearly showed a prevalence of cryptosporidium occurrence based on poor water sanitation practices. The main limitation was a high homogeneity in the results of the studies, which limited the selection of articles used for the study.

5. Conclusions

The review suggests that water sanitation practices in Brazil and subpar to the USA, thereby facilitating the higher incidence of cryptosporidium rates. This systematic review evaluated literature published between 2020 and 2025 to examine the relationship between water sanitation practices and the prevalence of *Cryp-*

cryptosporidium in Brazil and the United States. The findings indicate that disparities in sanitation infrastructure, wastewater treatment coverage, and monitoring practices are associated with higher reported rates of *Cryptosporidium* contamination in Brazil compared to the United States. In contrast, the United States benefits from more centralized regulatory oversight, consistent enforcement of the Safe Drinking Water Act, and broader access to treated potable water, which collectively contribute to lower reported prevalence in most regions.

However, the results of this review should be interpreted with consideration of key confounding factors, including regional differences in climate, rainfall patterns, livestock proximity, wastewater discharge practices, and variability in surveillance and detection methodologies [15]. These factors may influence both the true environmental prevalence of *Cryptosporidium* and the likelihood of detection and reporting across different regions.

Despite differences in infrastructure and regulatory systems, both countries continue to face challenges related to aging water systems, rural access limitations, and the inherent resistance of *Cryptosporidium* oocysts to conventional treatment processes. These findings highlight the need for continued investment in infrastructure, improvements in wastewater treatment coverage, and the expansion of environmental monitoring programs [16].

Overall, this review underscores the importance of strengthening sanitation equity, enhancing regulatory frameworks, and implementing consistent, risk-based monitoring strategies. Future efforts should focus on integrating quantitative microbial risk assessment approaches and improving global data standardization to better support cross-country comparisons and inform public health decision-making. Continued collaboration between regulatory agencies and investment in water infrastructure will be essential to mitigate future waterborne disease risks and protect public health [17].

Authors' Contributions

Tanyi Obenson and Brian Graves developed research. Both authors analyzed the data and interpreted the results.

Disclaimer

Authors hold sole responsibility for the views expressed in the manuscript, which may not necessarily reflect the opinion or policy of any publication by which this manuscript may be published.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- [1] Cleveland Clinic (2022) Cryptosporidiosis. <https://my.clevelandclinic.org/health/diseases/21023-cryptosporidiosis>

- [2] Bellinzona, G., Nardi, T., Castelli, M., Batisti Biffignandi, G., Adjou, K., Betson, M., *et al.* (2024) Comparative Genomics of *Cryptosporidium parvum* Reveals the Emergence of an Outbreak-Associated Population in Europe and Its Spread to the United States. *Genome Research*, **34**, 877-887. <https://doi.org/10.1101/gr.278830.123>
- [3] Araújo, R.S.D., Barbosa, M.R.F., Dropa, M., Araujo de Castro, V.C., Galvani, A.T., Padula, J.A., *et al.* (2024) Environmental Surveillance of *Cryptosporidium* and *Giardia* in Surface Supply Water and Treated Sewage Intended for Reuse from an Urban Area in Brazil. *Environmental Pollution*, **363**, Article ID: 125089. <https://doi.org/10.1016/j.envpol.2024.125089>
- [4] Park, S.S. (2025) Milwaukee *Cryptosporidium* Outbreak. In: Park, S.S., Ed., *Eco-Disasters*, Springer, 51-54. https://doi.org/10.1007/978-981-96-8667-4_12
- [5] Zini, L.B., Lorenzini, R., Camelo, L.G.G. and Gutterres, M. (2021) Occurrence of *Cryptosporidium* and *Giardia* in Surface Water Supply from 2016 to 2020 in South Brazil. *Environmental Monitoring and Assessment*, **193**, Article No. 496. <https://doi.org/10.1007/s10661-021-09280-y>
- [6] Hall, M. (2023) Use of eDNA to determine the Presence of *Cryptosporidium* spp. in Freshwater Sources in Harlan, Kentucky. Lincoln Memorial University Institutional Repository. <https://digitalcommons.lmunet.edu/cgi/viewcontent.cgi?article=1000&context=honorstheses>
- [7] Rocha, J.M., da Silva, A.V., Harvey, T.V., Fehlberg, H.F. and Albuquerque, G.R. (2024) First Report of Contamination of Public Water System by *Giardia duodenalis* and *Cryptosporidium* spp. in Bahia, Northeastern Brazil. *Semina: Ciências Agrárias*, **45**, 111-130.
- [8] Hlavsa, M.C., Aluko, S.K., Miller, A.D., Person, J., Gerdes, M.E., Lee, S., *et al.* (2021) Outbreaks Associated with Treated Recreational Water—United States, 2015-2019. *American Journal of Transplantation*, **21**, 2605-2609. <https://doi.org/10.1111/ajt.16037>
- [9] Keller, R., Pratte-Santos, R., Covre, M.A. and Ramos, E.C. (2022) Occurrence of *Cryptosporidium* oocysts and *Giardia* cysts in Public Water Supplies in Vitória, ES, Brazil. *Journal of Urban and Environmental Engineering*, **16**, 162-170.
- [10] Ladeia, W.A., Martins, F.D.C., Nino, B.D.S.L., Silvério, A.D.C., da Silva, A.C., Ossada, R., *et al.* (2022) High Occurrence of Viable Forms of *Cryptosporidium* and *GIARDIA* in Domestic Sewage from an Agricultural Region of Brazil. *Journal of Water and Health*, **20**, 1405-1415. <https://doi.org/10.2166/wh.2022.127>
- [11] Leal, D.A.G., Goulart, J.A.G., Bonatti, T.R., Araújo, R.S., Junior, J.A.J., Shimada, M.K., *et al.* (2024) A Two-Year Monitoring of *Cryptosporidium* spp. Oocysts and *Giardia* spp. Cysts in Freshwater and Seawater: A Complementary Strategy for Measuring Sanitary Patterns of Recreational Tropical Coastal Areas from Brazil. *Regional Studies in Marine Science*, **70**, Article ID: 103356. <https://doi.org/10.1016/j.rsma.2023.103356>
- [12] Narzetti, D.A. and Marques, R.C. (2021) Access to Water and Sanitation Services in Brazilian Vulnerable Areas: The Role of Regulation and Recent Institutional Reform. *Water*, **13**, Article 787. <https://doi.org/10.3390/w13060787>
- [13] Oliveira, M.A., Rocha, J.M., Silva, A.V., Harvey, T.V., Fehlberg, H.F. and Albuquerque, G.R. (2024) First Report of Contamination of Public Water System by *Giardia duodenalis* and *Cryptosporidium* spp. in Bahia, Northeastern Brazil. *Semina: Ciências Agrárias*, **45**, 111-130.
- [14] Pineda, C.O., Leal, D.A.G., Fiuza, V.R.D.S., Jose, J., Borelli, G., Durigan, M., *et al.*

-
- (2020) *Toxoplasma gondii* Oocysts, *Giardia* Cysts and *Cryptosporidium* Oocysts in Outdoor Swimming Pools in Brazil. *Zoonoses and Public Health*, **67**, 785-795.
<https://doi.org/10.1111/zph.12757>
- [15] Rondello Bonatti, T., Vidal Siqueira-Castro, I.C., Averaldo Guiguet Leal, D., Durigan, M., Pedrosa Dias, R.J. and Bueno Franco, R.M. (2023) Molecular Characterization of Waterborne Protozoa in Surface Water and Sediment in Brazil: A Taxonomic Survey of Ciliated Protozoa and Their Correlation with *Giardia duodenalis* and *Cryptosporidium* spp. *Environmental Monitoring and Assessment*, **195**, Article No. 470.
<https://doi.org/10.1007/s10661-023-11065-4>
- [16] da Silva, D.P., de Sousa, A.C. and Scalize, P.S. (2023) Water for Human Consumption in Rural Areas Worldwide: A Systematic Review of the Presence of *Cryptosporidium* spp. and *Giardia* spp. *Journal of Ecological Engineering*, **24**, 29-45.
<https://doi.org/10.12911/22998993/172052>
- [17] Visentini, C.B. (2024) Estimation and Evaluation of the Risks of Protozoa Infections Associated to the Water from a Treatment Plant in Southern Brazil Using the Quantitative Microbiological Risk Assessment Methodology (QMRA). *Environmental Monitoring and Assessment*, **196**, Article No. 439.
<https://doi.org/10.1007/s10661-024-12577-3>