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TERRITORIAL CONTRASTS IN RIO GRANDE DO SUL: SANITATION RELATED DISEASES

CONTRASTES TERRITORIAIS NO RS: DOENÇAS RELACIONADAS AO SANEAMENTO AMBIENTAL

CONTRASTES TERRITORIALES EN RS: ENFERMEDADES RELACIONADAS CON EL SANEAMIENTO AMBIENTAL

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ABSTRACT

This study identified the spatial pattern of sanitation-related diseases across the macroregions and health regions of Rio Grande do Sul, along with their socioeconomic determinants, from 2018 to 2021. This quantitative, ecological study used secondary data from the State Center for Health Surveillance of Rio Grande do Sul (CEVS/RS) to perform a spatial analysis of incidence and mortality rates. Six health regions had incidence and mortality that exceeded 405.87 cases per 100,000 population and 3.52 deaths per 100,000 population, respectively. Vector-borne and contact transmission categories predominated. For incidence, rates were higher among male, White adults with higher educational attainment residing in urban areas. For mortality, the most affected were also male, White individuals, but with lower educational attainment and older people. The Missioneira and Centro-Oeste macroregions formed spatial clusters with high incidence and mortality rates. Only mortality correlated with the Gini coefficient and the Municipal Human Development Index. The profile of sanitation-related diseases in Rio Grande do Sul revealed territorial contrasts in health conditions, reflecting the state's inadequate sanitation. The findings can help guide health-promoting public policies.

Keywords: Infectious and Parasitic Diseases. Neglected Tropical Diseases. Spatial Analysis. Health Indicators. Socioeconomic Factors.

RESUMO

O estudo buscou identificar o padrão espacial das doenças relacionadas ao saneamento ambiental nas macrorregiões e regiões de saúde do Rio Grande do Sul e fatores socioeconômicos, entre 2018 e 2021. É um estudo quantitativo e ecológico, que utilizou dados secundários do CEVS/RS para análise espacial das taxas de incidência e de

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mortalidade. Seis regiões de saúde apresentaram incidência e mortalidade maiores que 405,87 casos/100 mil hab. e 3,52 óbitos/100 mil hab. As categorias de transmissão por inseto-vetor e contato foram predominantes. Para a incidência houve predominância em indivíduos do sexo masculino, brancos, adultos, alto nível de escolaridade e residentes das zonas urbanas. Para a mortalidade, os mais afetados também foram indivíduos do sexo masculino, brancos, baixo índice de escolaridade e idosos. As macrorregiões Missioneira e Centro-Oeste formaram aglomerados espaciais com altas taxas de incidência e mortalidade. Apenas a mortalidade mostrou-se correlacionada com o coeficiente de Gini e o Índice de Desenvolvimento Humano Municipal. O cenário de doenças relacionadas ao saneamento ambiental no Rio Grande do Sul apontou para contrastes territoriais de condições de saúde, que envolvem a situação sanitária inadequada do Estado, permitindo auxiliar o direcionamento de políticas públicas saudáveis.

Palavras-chave: Doenças Infecciosas e Parasitárias. Doenças Negligenciadas. Análise Espacial. Indicadores de Saúde. Fatores Socioeconômicos.

RESUMEN

El estudio buscó identificar el patrón espacial de las enfermedades relacionadas con el saneamiento ambiental en las macrorregiones y regiones sanitarias de Rio Grande do Sul, así como los factores socioeconómicos, entre 2018 y 2021. Es un estudio cuantitativo y ecológico que utilizó datos secundarios del CEVS/RS para el análisis espacial de las tasas de incidencia y mortalidad. Seis regiones sanitarias tuvieron tasas de incidencia y mortalidad superiores a 405,87 casos/100.000 habitantes y 3,52 muertes/100.000 habitantes. Las categorías de transmisión por insectos vectores y por contacto fueron predominantes. Las tasas de incidencia fueron predominantemente entre hombres, adultos blancos, personas con alta educación y residentes urbanos. Las tasas de mortalidad también fueron las más afectadas por la enfermedad. Las macrorregiones Missioneira y Centro-Oeste formaron conglomerados espaciales con altas tasas de incidencia y mortalidad. Solo la mortalidad correlacionó con el coeficiente de Gini y el Índice de Desarrollo Humano Municipal. El escenario de las enfermedades relacionadas al saneamiento ambiental en Rio Grande do Sul destacó contrastes territoriales en las condiciones de salud, que involucran la situación sanitaria inadecuada del Estado, posibilitando la orientación de políticas públicas saludables.

Palabras clave: Enfermedades Infecciosas y Parasitarias. Enfermedades Desatendidas. Análisis Espacial. Indicadores de Salud. Factores Socioeconómicos.

1 INTRODUCTION

The World Health Organization (WHO) reported positive global water, sanitation, and hygiene (WASH) indicators; however, safely managed services remain out of reach for a large share of the global population (WHO; UNICEF, 2021). The lack of sanitation continues to affect public health. The sanitation deficit accounts for roughly 1.4 million deaths worldwide and constitutes a violation of a basic human right (Wolf *et al*., 2023).

Neglected tropical diseases (NTDs) are linked to sanitation and are concentrated in developing countries. Access to sanitation is among the five key interventions recommended by WHO for their control (WHO, 2020). Brazil's sanitation legal framework establishes the goal of universal coverage for drinking water supply and sewage collection and treatment (Law Nº. 14,026/2020). In southern Brazil, state capitals rank among the highest for access compared with other regions (Ferreira*;* Silva; Figueiredo Filho, 2021), yet pockets of inadequate infrastructure persist. These conditions reflect social vulnerability, which contributes to the occurrence of infectious and parasitic diseases (IPDs).

Sanitation-related diseases can be classified from an environmental perspective. They are directly associated with deficits in drinking water supply and sanitation, solid-waste contamination, and/or precarious housing conditions. They are also grouped by transmission route: fecal–oral (diarrheal diseases, enteric fevers, and hepatitis A); vector-borne (dengue, chikungunya, Zika, yellow fever, leishmaniasis, lymphatic filariasis, malaria, and Chagas disease); contact (schistosomiasis and leptospirosis); hygiene (eye and skin diseases); and soil-transmitted helminthiasis and taeniasis (Brasil, 2010a).

In Rio Grande do Sul, low investment in sanitation has been identified as a barrier to public health (Marciano; Vaccaro; Scavarda, 2019), which, in turn, increases expenditures and burdens the Brazilian Unified Health System (SUS) (Paiva; Souza, 2018). Spatial mapping of IPDs has been used to inform actions to address precarious living conditions (Souza *et al*., 2020). Therefore, this study aimed to identify the spatial pattern of sanitation-related diseases across the macroregions and health regions of Rio Grande do Sul, as well as to examine the associated socioeconomic factors.

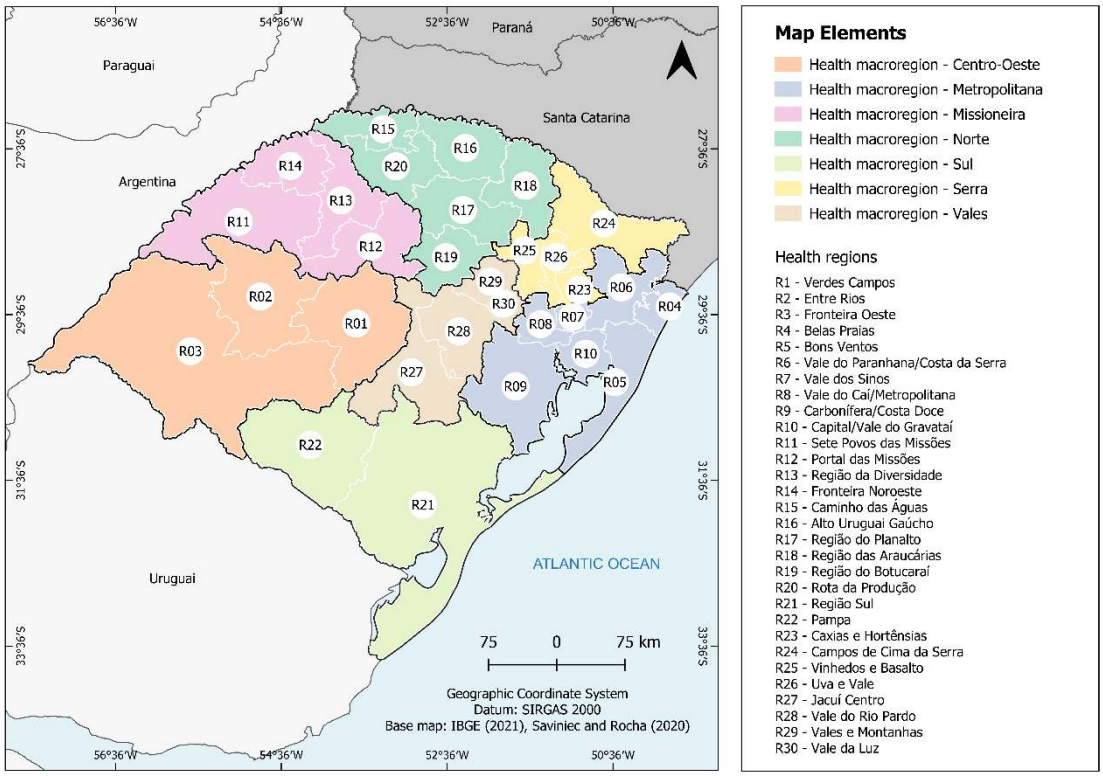
2 METHOD

This quantitative, ecological study carried out a spatial analysis of incidence rates (IR) and mortality rates (MR) for sanitation-related diseases across the health regions of Rio Grande do Sul from 2018 to 2021. Located in southern Brazil, the state covers 281,707.151

km² and is the sixth most populous, with 10,880,506 inhabitants and a population density of 38.62 inhabitants/km² (IBGE, 2023a). It comprises 30 health regions and seven macroregions (Brasil, 2018; Rio Grande do Sul, 2012) (**Erro! Fonte de referência não encontrada.**).

Figure 1

Geographic boundaries of health macroregions and health regions in the state of Rio Grande do Sul



Source: Authors (2025).

Data on reported cases and deaths were obtained from the State Center for Health Surveillance of Rio Grande do Sul (CEVS/RS) through the Notifiable Diseases Information System (SINAN Net) and the Mortality Information System (SIM), respectively, and were analyzed by biennium (2018–2019; 2020–2021). The variables were transmission category, sex, race/skin color, age group, educational attainment, and area of residence. The transmission categories used to classify reported cases were: contact (leptospirosis); fecal–oral (rotavirus, typhoid fever, and hepatitis A); taeniasis (echinococcosis); and vector-borne (dengue, chikungunya, yellow fever, cutaneous and visceral leishmaniasis, and Chagas disease).

Diseases with allochthonous or focal transmission—such as schistosomiasis, lymphatic filariasis, and malaria (Brasil, 2010b)—were excluded, as was the hygiene-related category due to lack of data in the study period. Self-identified Yellow (Asian) and Indigenous groups were excluded because of low frequency in the state (IBGE, 2023b). In addition, self-identified Black categories (black and brown) were aggregated as the Black population, in line with the Statute of Racial Equality (Brasil, 2010a). Records classified as “ignored” and/or White were not included in the statistical analysis.

Rates were calculated as the ratio between the total number of reported cases or deaths and the resident population of each health region, expressed as a rate per 100,000 population. Population estimates were obtained from the 2022 demographic census (IBGE).

Socioeconomic variables—the Gini coefficient and the Municipal Human Development Index (MHDI)—which range from 0 to 1, were extracted from the Institute for Applied Economic Research (IPEA). The Gini coefficient measures the concentration of per capita household income, with values approaching 1 indicating greater inequality. The MHDI assesses municipal development in the dimensions of longevity, education, and income, and can be classified as very low (< 0.499), low (0.500–0.599), medium (0.600–0.699), high (0.700–0.799), and very high (0.800–1) (PNUD, 2013).

To analyze the data, we applied the Mann–Whitney U and Kruskal–Wallis tests to identify differences in IR or MR by transmission category, sex, race/skin color, age group, educational attainment, and area of residence within each macroregion. Rates were summarized as medians because they are less influenced by extreme values. Data normality was assessed with the Shapiro–Wilk test. When significant differences were detected, pairwise comparisons were conducted using the Dunn–Bonferroni post hoc procedure. The significance level was set at 5% ($p \leq 0.05$).

We performed Exploratory Spatial Data Analysis (ESDA) to determine the spatial distribution of the data. A first-order queen-contiguity spatial weights matrix was specified (Almeida, 2012). Spatial autocorrelation was assessed using univariate and bivariate Moran’s I to characterize the spatial pattern of IR and MR (dependent variables) and their spatial correlation with socioeconomic variables (independent variables).

Global Moran’s I yields a single value for the study area: values near 1 indicate positive spatial autocorrelation (spatial clustering), values near −1 indicate negative spatial autocorrelation (a dispersed arrangement), and values near 0 indicate spatial independence (no autocorrelation) (Câmara *et al.*, 2004; Almeida, 2012).

Significant local clusters were identified using local Moran's I (Local Indicators of Spatial Association, LISA) and visualized on LISA cluster maps, yielding High–High and Low–Low clusters and High–Low and Low–High outliers (Câmara *et al*., 2004; Almeida, 2012). Permutation-based pseudo p-values were computed with 999 random permutations. The significance level was also set at 5% ($p \leq 0.05$).

Data were tabulated in Microsoft Excel 2019; analyses were carried out in IBM SPSS Statistics (version 20.0) and GeoDa (version 1.10); and thematic maps were produced in QGIS (version 3.14.16).

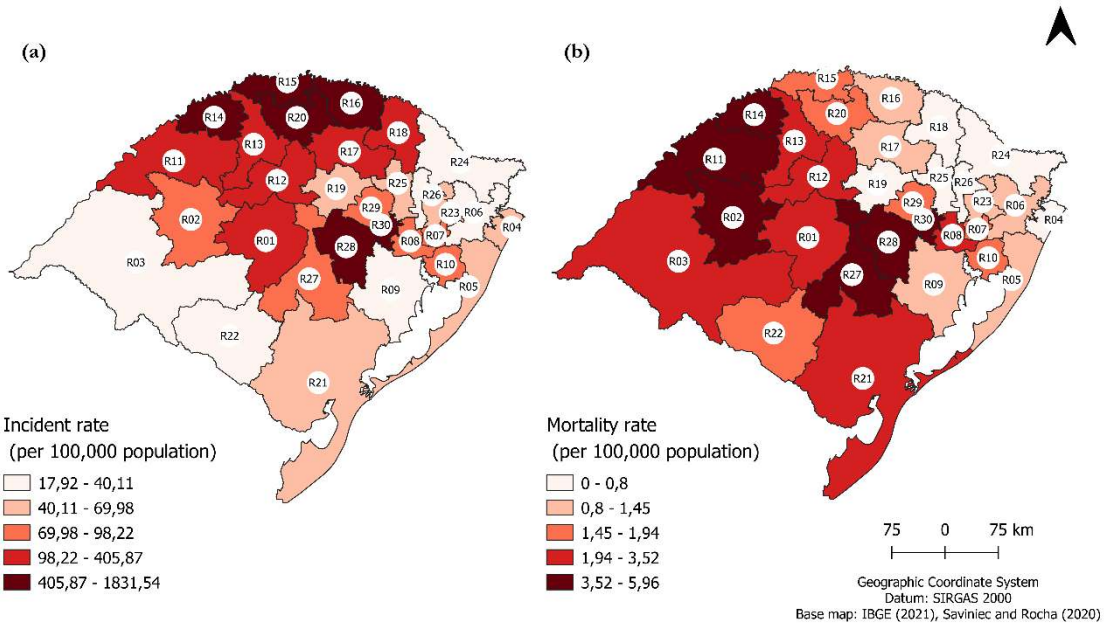
Because the study used aggregated, public-domain data with no possibility of personal identification, ethics review was not required, in accordance with Resolution Nº. 510/2016.

3 RESULTS

Between 2018 and 2021, 22,051 cases and 216 deaths from sanitation-related diseases were confirmed in Rio Grande do Sul. During this period, all health regions reported cases, with a mean incidence of 202.67 per 100,000 population. Among the health regions with the highest incidence rates (IRs), the largest values were observed in Vale do Rio Pardo (1,831.54 per 100,000), Vale da Luz (707.50 per 100,000), and Caminho das Águas (641.09 per 100,000) (Figure a). For deaths, some regions recorded none; the mean MR was 1.99 per 100,000 population. Among health regions with the highest MRs, the largest values were recorded in Entre Rios (5.96 per 100,000) and Vale da Luz (5.58 per 100,000) (Figure b).

Figure 2

Distribution of sanitation-related diseases in the health regions of Rio Grande do Sul, 2018–2021: (a) Incidence rate (per 100,000 population) and (b) Mortality rate (per 100,000 population)



Source: Authors (2025).

The 2020–2021 biennium accounted for 75.51% (n = 16,650) of reported cases, while 24.49% (n = 5,401) were recorded in 2018–2019. For deaths, the first biennium represented 54.17% (n = 117), and the second had 45.83% (n = 99). Vale do Rio Pardo had the highest incidence in 2018–2019 (172.43 per 100,000 population) and the second highest in 2020–2021 (1,659.11 per 100,000 population), second only to Alto Uruguai Gaúcho (1,696.19 per 100,000 population). For mortality, Entre Rios and Jacuí Centro had the highest rates in the first (4.26/100,000) and second biennium (3.17/100,000), respectively.

When IRs were compared by transmission category, only the Sul (South) macroregion showed no statistically significant differences among groups (Table 1). In the other macroregions, vector-borne and contact categories predominated and both differed significantly from taeniasis—except in Centro-Oeste (Central-West)—according to the Dunn–Bonferroni test. Regarding sociodemographic variables, IRs were higher among males in the Metropolitana (Metropolitan) and Serra macroregions ($p = 0.011$ and $p = 0.029$, respectively), as well as in the state overall ($p = 0.031$). Similarly, these macroregions and the state also showed differences for the White race/skin-color category (Missioneira: $p = 0.029$; Norte (North): $p = 0.015$). By age group, incidence was higher among adults, with differences

relative to children and adolescents in the Metropolitana macroregion and in Rio Grande do Sul. For educational attainment, the more-than-8-years-of-schooling category generally had the highest medians over the study period; however, differences were not statistically significant. Cases were concentrated in urban areas, with the highest median in the Vales macroregion. In Rio Grande do Sul, differences were observed across the three areas of residence.

Table 1

Distribution of incidence rates (per 100,000 population) of sanitation-related diseases and sociodemographic profile across the health macroregions of Rio Grande do Sul, 2018–2021

Variable	Health macroregion							Rio Grande do Sul
	Centro-Oeste	Metropolitana	Missioneira	Norte	Serra	Sul	Vales	
	Median							
Transmission category**								
Contact	45.35[a]	31.30[a]	68.66[ab]	38.89[a]	21.64[a]	30.69	82.60[a]	36.67[a]
FO	1.34[a]	4.13[bc]	6.54[ab]	12.28[ab]	5.60[ab]	1.89	6.54[ab]	4.58[b]
Taeniasis	0[a]	0[b]	0[a]	0.12[b]	0[b]	0.37	0[b]	0[c]
VB	28.11[a]	15.50[ac]	229.45[b]	279.12[a]	9.62[ab]	5.67	308.49[a]	22.71[a]
p-value	0.023*	<0.0001*	0.003*	0.001*	0.014*	0.083	0.005*	<0.0001*
Sex†								
Female	29.81	15.91	148.88	170.90	12.06	15.31	181.42	26.41
Male	47.70	37.13	166.63	174.21	23.98	23.30	215.80	51.77
p-value	0.7	0.011*	0.886	0.818	0.029*	0.667	0.486	0.031*
Race/skin color†								
White	72.40	41.62	304.40	311.90	26.95	31.45	379.14	68.10
Black	5.11	5.17	15.04	21.79	4.27	5.70	13.40	6.46
p-value	0.2	0.001*	0.029*	0.015*	0.029*	0.333	0.114	<0.0001*
Age group**								
CA	11.07	7.39[a]	57.73[ab]	68.20	6.05[ab]	6.04	74.73	14.41[a]
Adults	57.06	39.17[b]	214.86[a]	220.63	26.96[a]	28.46	253.06	52.14[b]
Elderly	9.37	8.16[a]	53.46[b]	43.22	5.23[b]	4.12	70.61	10.44[a]
p-value	0.113	0.001*	0.024*	0.196	0.023*	0.102	0.39	<0.0001
Educational attainment†								
≤ 8 years	19.59	14.23	80.45	47.04	9.81	12.29	110.68	21.10
> 8 years	30.23	17.08	100.86	48.69	9.60	15.07	84.92	21.87
p-value	0.7	0.71	0.2	0.818	1	1	0.886	0.813
Area of residence**								
Peri-urb.	0.45	0.46[a]	0.83[a]	1.09[a]	0.75[a]	0.18	0.4[a]	0.58[a]
Rural	14.48	5.08[ab]	30.93[ab]	41.04[ab]	9.69[ab]	4.28	52.53[ab]	13.36[b]
Urban	58.77	44.48[b]	254.67[b]	288.75[b]	28.56[b]	33.11	339.14[b]	61.71[c]
p-value	0.058	<0.0001*	0.007*	0.001*	0.015*	0.102	0.018*	<0.0001*

Legend: FO= Fecal–oral; VB= Vector-borne; CA = Children and adolescents = up to 19 years; Adults = 20–59 years; Elderly = 60+ years. ≤ 8 years = illiterate/elementary education; > 8 years = secondary/tertiary education.
* 5% significance level ($p < 0.05$).
** Kruskal–Wallis test.
† Mann–Whitney U test.
a, b Values followed by the same letter do not differ in Dunn–Bonferroni post hoc comparisons.

For MR, the vector-borne group had the highest rates compared with the contact and taeniasis categories in the Metropolitana and Missioneira macroregions, as well as in the state overall ($p < 0.0001$; $p = 0.006$; $p < 0.0001$, respectively) (Table 2).

The Kruskal–Wallis test indicated significance among transmission categories in the Vales macroregion, but no pairwise comparison was significant according to the Dunn–Bonferroni test.

As with IR, MR was higher among males and White individuals. By age group, no deaths from sanitation-related diseases were recorded among children and adolescents, and mortality predominated among older people in the Centro-Oeste, Metropolitana, Missioneira, and Vales macroregions, as well as in the state overall. Regarding educational attainment, only the Metropolitana macroregion and the state showed disparities among categories.

Table 2

Comparison of mortality rates (per 100,000 population) of sanitation-related diseases and sociodemographic profile in Rio Grande do Sul, 2018–2021

Variable	Health macroregion							Rio Grande do Sul
	Centro-Oeste	Metropolitana	Missioneira	Norte	Serra	Sul	Vales	
	Median							
Categoria de transmissão**								
Contact	0	0.56[a]	0.18[ab]	0.12	0.16	0.43	1.46[a]	0.29[a]
FO	0	0[b]	0[a]	0	0	0	0[a]	0[b]
Taeniasis	0	0[b]	0[a]	0	0	0.61	0[a]	0[b]
VB	1.83	0.79[a]	3.22[b]	0.58	0	1.37	1.31[a]	0.84[a]
p-value	0.067	<0.0001*	0.006*	0.056	0.094	0.259	0.014*	<0.0001*
Sex†								
Female	1.12	0.46	0.97	0.33	0	1.28	1.46	0.53
Male	2.06	1.03	2.46	0.69	0.16	1.13	2.20	1.04
p-value	1	0.017*	0.029*	0.394	0.486	1	0.343	0.016*
Race/skin color†								
White	1.60	1.02	3.11	0.91	0.16	2.04	3.73	1.47
Black	0.46	0.28	0.22	0	0	0.31	0.15	0
p-value	1	0.001*	0.029*	0.093	0.343	0.333	0.029*	<0.0001*
Age group**								
CA	0[a]	0[a]	0[a]	0	0	0	0[a]	0[a]
Adults	0.67[ab]	0.65[b]	0.58[ab]	0.12	0.16	0.76	1.02[ab]	0.54[b]
Elderly	1.83[b]	0.90[b]	3.14[b]	0.43	0	1.65	3.31[b]	1[b]
p-value	0.024*	0.002*	0.009*	0.131	0.303	0.095	0.012*	<0.0001*
Educational attainment †								
≤ 8 years	1.83	0.90	3.05	0	0	1.46	2.91	0.97
> 8 years	0.23	0.28	0.18	0	0.16	0.27	0.29	0.23
p-value	1	0.026*	0.057	1	1	0.333	2	0.002*

Legend: FO= Fecal–oral; VB= Vector-borne; CA = Children and adolescents = up to 19 years; Adults = 20–59 years; Elderly = 60+ years. ≤ 8 years = illiterate/elementary education; > 8 years = secondary/tertiary education.
* 5% significance level ($p < 0.05$).
** Kruskal–Wallis test.
† Mann–Whitney U test.
a, b Values followed by the same letter do not differ in Dunn–Bonferroni post hoc comparisons.

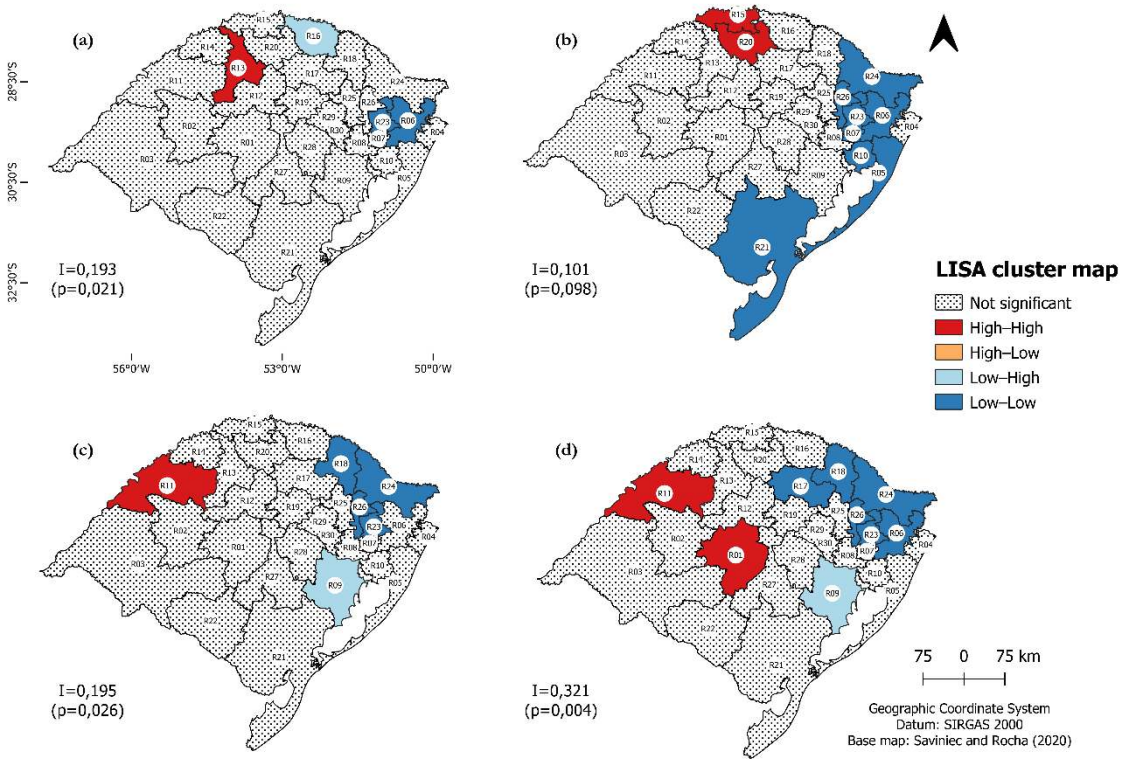
ESDA revealed spatial heterogeneity for IR in the second biennium, with a non-significant univariate global Moran's I (

Figure). All other rates indicated positive spatial autocorrelation, particularly for MR in 2020–2021.

In the decomposition of the global index via LISA, High–High clusters concentrated in the Missioneira macroregion; in the second MR biennium, another cluster appeared in the Verdes Campos region. For Low–Low clusters, rates were mostly located in the Metropolitana and Serra macroregions. Regarding Low–High outliers, the distributions differed between incidence and mortality: the former included Alto Uruguai Gaúcho, whereas the latter included the Carbonífera/Costa Doce region. In both biennia, no health region exhibited High–Low outliers.

Figure 3

Moran's I coefficient map for incidence rates (IR) and mortality rates (MR) in Rio Grande do Sul, 2018–2021. (a) IR, 2018–2019. (b) IR, 2020–2021. (c) MR, 2018–2019. (d) MR, 2020–2021



Source: Authors (2025).

The spatial correlation between MR and the Gini coefficient was positive and weak but significant (p = 0.001), with high-rate regions adjacent to regions with high income inequality (**Erro! Fonte de referência não encontrada.**). MR also showed a negative correlation with MHDI (p = 0.029), indicating that high-rate regions were distant from regions with higher development. IR showed no significant correlation with either index.

Table 3

Bivariate analysis of global Moran's I

Variable	Global Moran's I coefficient	p-value
Incidence rate (per 100,000 population)		
Gini coefficient	0.067	0.238
Municipal Human Development Index	0.015	0.427
Mortality rate (per 100,000 population)		
Gini coefficient	0.289	0.001*
Municipal Human Development Index	-0.160	0.029*

* 5% significance level (p ≤ 0.05).

4 DISCUSSION

In public health, incidence and mortality rates revealed a sanitation deficit in Rio Grande do Sul, Brazil. In this context, the study provided an overview of sanitation-related diseases from 2018 to 2021.

Mortality from IPDs has declined in Brazil since 1990. This pattern was also observed here across both biennia; however, noncommunicable diseases (NCDs) have increased mortality rates (Martins *et al*., 2021). The Vale da Luz health region showed high morbidity and mortality. Some municipalities in this region reported a higher share of excreta (feces/urine) disposed of via septic tanks (on-site sanitation) (Penso-Campos *et al*., 2019). This arrangement is more frequent in rural areas and has seen little change. Rural areas continue to lack public investment in sanitation interventions (Menicucci; D'Albuquerque, 2018).

Improvements in IPD indicators are tied to public policies, especially cash transfer programs, since infectious diseases are directly associated with poverty. At the same time, sanitation policies have contributed substantially to this reduction because adequate conditions have a protective effect. Maintaining and expanding public policies that promote equity and social inclusion are essential to prevent further increases in poverty in Brazil (Souza; Heller, 2021).

Globally, new infectious diseases continue to emerge while others re-emerge. Among those related to sanitation, dengue re-emerged in Brazil in the 1980s, followed by the emergence of chikungunya and Zika (Teixeira *et al*., 2018), causing successive epidemics nationwide. In Rio Grande do Sul, cases have risen steadily since 2019, with the Vales and Norte macroregions also trending upward (Daros *et al*., 2022). Leptospirosis, classified as re-emerging, peaked in the state in the same year and has trended upward since 2013 (Sohn-Hausner; Kmetiuk; Biondo, 2023; Teles *et al*., 2023).

The vector-borne and contact transmission categories showed the highest medians for both incidence and mortality in this study. These conditions are seasonal, with greater occurrence during periods of higher temperatures and precipitation changes. As a result, they are influenced by climate-related events and pose threats to human health (Mora *et al*., 2022). Beyond adequate sanitation, a set of actions is needed to reduce infection risk, including community-level solutions and improvements in quality of life, as well as government commitment to mitigating greenhouse gas (GHG) emissions.

The predominance of cases and deaths via vector-borne or contact transmission may also help explain the higher burden among men. National studies on these diseases corroborate these findings (Batista *et al*., 2021; Belo *et al*., 2023; Galan; Schneider; Roess, 2023; Martins-Melo; Castro; Werneck, 2021; Rosser *et al*., 2022), with broad agreement that greater exposure occurs in occupational settings. Palma *et al*. (2022) also found that men more often reported gaps in knowledge, attitudes, and practices regarding these diseases. However, no significant differences by sex were observed for dengue cases in Rio Grande do Sul (Gregianini *et al*., 2018). The increased risk stems from socioeconomic and cultural factors: the gendered division of labor inside and outside the household, daily practices, social norms and beliefs, together with age and socioeconomic context, appear to shape exposure (Ozano *et al*., 2020).

A higher incidence in the working-age population suggests occupational exposure to sanitation-related diseases. Regarding mortality, older people were most affected. Among NTDs in Brazil, Chagas disease and dengue are the leading causes of disability-adjusted life-years (DALYs) in older age groups. Greater severity at older ages may be attributable to co-occurrence with NCDs (Martins-Melo *et al*., 2018).

Mortality predominated among children and older people. According to Silva *et al*. (2024), children—who often have limited access to education—tend to neglect self-care. In Rio Grande do Sul, educational indicators have improved over time, along with the income

and health dimensions of the Human Development Index (Campos; Silveira; Périco, 2021). For incidence, no differences were observed by years of schooling; however, incomplete data were excluded from the analyses. As for the White race/skin color category, incidence and mortality align with the state's sociodemographic profile. Data from the 2022 Brazilian census indicate that 78% of the state's population self-identified as White (IBGE, 2023b).

Adequate sanitation coverage reaches fewer than 50% of Brazil's rural residents (Brasil, 2019). In Rio Grande do Sul, leptospirosis occurred more frequently in rural areas, especially in municipalities in the state's central region (Teles *et al*., 2023). The authors reported that patients had prior contact with septic tanks or sewage. The Vales health macroregion—which corresponds to the Centro Oriental Rio-Grandense mesoregion—showed the highest medians across variables.

This study found higher incidence among residents of urban areas. Aedes aegypti mosquitoes are frequently found in these areas, as extensive urbanization creates conditions that favor their proliferation (Penso-Campos *et al*., 2018). Additionally, inequities in access to adequate urban infrastructure, including housing, increase residents' susceptibility to infection (Boing; Boing; Subramanian, 2021).

When the spatial distribution of sanitation-related diseases was examined, the Missioneira health macroregion formed clusters with high morbidity and mortality. It is considered one of the regions vulnerable to poverty in the state, given the high concentration of births to mothers with no income or with income of one to two minimum wages (Lazaretti; Teixeira, 2023). The bivariate analysis is consistent with this finding, as both the Gini coefficient and MHDI correlated with mortality.

This study has limitations. It relied on secondary, public-domain data that are subject to underreporting of cases and deaths in the public health system, particularly during public health emergencies. Another limitation was the lack of up-to-date socioeconomic indices. We therefore recommend complementary methods, such as primary data collection in the health regions identified as susceptible to sanitation-related diseases.

5 CONCLUSION

The spatial distribution of sanitation-related diseases in Rio Grande do Sul during the study period identified the Caminho das Águas, Entre Rios, Vale da Luz, and Vale do Rio Pardo health regions as priorities for the design or strengthening of health promotion policies.

Improvements in living conditions, including broader coverage and higher-quality sanitation services, can help protect populations at greater risk of infection.

Health education initiatives should prioritize men, working-age adults, and older people through campaigns focused on men's health, occupational health, and older people's health. Sustained, effective surveillance and control are also essential for early case detection, given the high morbidity and mortality of conditions involving vectors and reservoirs. Achieving this requires coordination across the health, sanitation, and urban planning sectors to improve quality of life in Rio Grande do Sul and, in turn, reduce the impact of infectious and parasitic diseases.

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