

# Social and environmental indicators of the Jaboatão river water basin associated with diseases related to inadequate environmental sanitation (DRIES)

## Summary

Located in the Southern Mata region of the state of Pernambuco, the Jaboatão River Hydrographic Basin (JRB) has an area of 442 km<sup>2</sup>. Part of the group of small coastal rivers (GL2), the JRB drains the municipalities of Recife, Jaboatão dos Guararapes, Moreno, São Lourenço da Mata, Cabo de Santo Agostinho, and Vitória de Santo Antão. In addition to contributing to the public supply of the Metropolitan Region of Recife, the JRB receives domestic, industrial and agro-industrial effluents along its route. The JRB runs through densely occupied municipalities with irregular land use and deficiencies in infrastructure, reflecting social, economic and environmental problems. The objective of this study is to make a diagnosis of the socio-environmental indicators in the JRB and correlate them with the main waterborne diseases related to the lack of basic sanitation. The study involved a literature review and a survey of secondary data. Regarding the water quality of the JRB, it was found to vary between Polluted and Very Polluted during the monitored period. With regard to environmental impacts, deforestation, waste dumping and irregular occupation of riverbanks were observed, causing problems for the fauna, flora and the population. In relation to the basic sanitation indicator in the municipality of Jaboatão dos Guararapes, among the obstacles raised was the fact that the municipality does not have a Municipal Policy on Basic Sanitation and the Jaboatão dos Guararapes Municipal Administration does not have a Municipal Basic Sanitation Plan; There is a scarcity of systematized information that supports the process of measuring environmental health; between urban and rural areas there are disparities in access to sanitation services, requiring the adoption of public policies to expand sanitation services in order to assist these populations and thus promote the universalization of sanitation access. The deficiency in basic sanitation in the municipality of Jaboatão dos Guararapes hinders local sustainable development, causing social, economic and environmental impacts. Regarding the number of hospital admissions caused by diseases related to inadequate environmental sanitation (DRIES) in the municipalities that are part of the JRB, Recife stood out with 13,191 hospitalizations in the study period, and in 2010 had the highest number of hospitalizations (2,204). With regard to the number of deaths caused by DRIES, Recife also stood out with 4,208 deaths during the study period.

**Keywords:** water resources, indicators, Jaboatão River, waterborne diseases

## Introduction

In urban centers, basic sanitation represents a social infrastructure service whose absence or precariousness is responsible for clear and significant negative externalities, given that such insufficiency causes several economic, environmental, social and health problems, resulting in relevant material and human losses.<sup>1</sup> In the broadest sense, basic sanitation are the measures adopted with the aim of improving the quality of life, promoting the health of citizens and preserving natural resources. Basic sanitation consists of four axes: the supply of treated water, collection of sewage, urban cleaning and management of solid waste (domestic garbage) and the conduction of rainwater runoff. The Basic Sanitation system of a municipality has a close relationship with the community it serves, being fundamental to the environmental health of the municipality and the quality of life of the population.<sup>2</sup> The almost nonexistent sanitation infrastructure in the area covered by the JRB, the release of inadequately treated industrial effluents, the inadequate disposal of solid waste, and the indiscriminate use of pesticides and chemical fertilizers, mainly motivated by temporary sugarcane crops, mean that the water quality of the river is compromised in several places along its course. The results show that the advances are not very relevant and the country is

increasingly distant from achieving the main goals of basic sanitation, especially those made official by Brazil in the UN - United Nations. The sustainable development goal - SDG 6 - has the goal of “ensuring the availability and sustainable management of water and sanitation for all and everyone by 2030”, but if the low investments of recent years are maintained, Brazil will be far from fulfilling this further international commitment.<sup>3,4</sup> The objective of this study is to make a diagnosis of the socio-environmental indicators in the JRB, enabling to assess the level of sustainability of public policies related to the area of environmental sanitation and correlate it with the main waterborne diseases related to the lack of basic sanitation.

## Materials and methods

Located in the southern Mata region of the state of Pernambuco, the Jaboatão River Hydrographic Basin (JRB) has an area of 442 km<sup>2</sup>. Part of the group of small coastal rivers (GL2), the JRB drains the municipalities of Recife, Jaboatão dos Guararapes, Moreno, São Lourenço da Mata, Cabo de Santo Agostinho, and Vitória de Santo Antão, and is one of the most important basins in the Metropolitan Region of Recife (MRR). According to the Brazilian Institute of Geography and Statistics,<sup>5</sup> the municipality of Jaboatão dos Guararapes

Volume 6 Issue 6 - 2022

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**Received:** October 15, 2022 | **Published:** October 27, 2022

has the largest area of the JRB (225 km<sup>2</sup>), while Recife has the largest urban population (Figure 1 and Table 1). The study involved a literature review and survey of secondary data regarding the indicators treated water supply, sanitation (treated water supply, sewage collection, urban cleaning and solid waste management (domestic waste), rainwater runoff (drainage) and flood risk, health and economy. For information regarding demographic and socioeconomic conditions, it was used the 2020 Census database, the National Household Sample Survey (PNAD) made available by the Brazilian Institute of Geography and Statistics (IBGE), the National Sanitation Information System (SNIS) of the National Sanitation Department (SNS)/ Ministry of Regional Development (MDR) SNS/MDR, Surveillance System for Water Quality for Human Consumption (SISAGUA) of the Ministry of Health, National System of Information on Solid Waste Management (SINIR) of the MMA and the DATASUS website for diarrhea, yellow fever, dengue, leptospirosis, malaria and schistosomiasis diseases referring to the year 2020. The Sanitation indicators were provided by Instituto Trata Brasil (2022). The data referring to the ranking of the municipalities in relation to the indicators were provided by ABES (2021). To calculate the correlation of the ranking of the municipalities with health, a survey of the Diseases Related to Inadequate Environmental Sanitation - DRSAI - of the Ministry of Health's DATASUS is done. Based on this data, the hospitalization rate for 100 thousand inhabitants is calculated.<sup>6</sup> Five indicators related to basic sanitation services were used to synthetically represent the sanitation conditions in the JRB (Table 2).

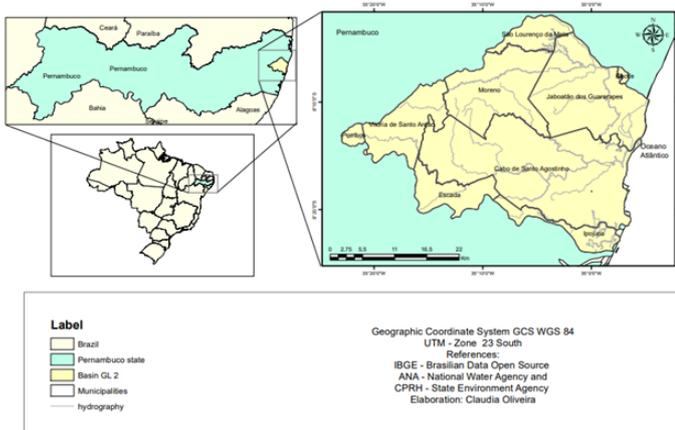


Figure 1 Location of the JRB.

Prepared by: Cláudia Oliveira.

Table 1 Municipalities inserted in the JRB with their respective areas

Municipality	Area (km <sup>2</sup> )	Area (%)
Cabo de Santo Agostinho	27	6,11
Jaboatão dos Guararapes	225	50,90
Moreno	98	22,17
Recife	4	0,90
São Lourenço da Mata	46	10,41
Vitória de Santo Antão	42	9,50
Total	442	100

Source: GOMES (2005).<sup>53</sup>

Table 2 Indicators related to basic sanitation, description and respective formulas

Indicator	Description	Indicator formula
Water supply	Index of attendance of the total population with water mains	(Total population served with water supply / Total resident population of municipality(ies) with water supply, according to IBGE) X 100
Sewage collection	Index of attendance of the total population with sewerage system	(Total population served with sanitary sewage/ Total resident population of the municipality(ies) with water supply, according to IBGE) X 100
Sewage treatment	Index of treated sewage referred to water consumed	(((Volume of sewage treated + Volume of exported raw sewage treated at the importer's premises) / (Volume of water consumed - Volume of treated water exported)) X 100)/80) X 100
Solid waste collection	Coverage rate of the household solid waste collection service in relation to the total population of the municipality	(Total population served in the municipality / Total population of the municipality, according to IBGE) X 100
Inadequate disposal of solid waste	Percentage of solid waste generated by the municipality disposed of properly	(Total waste only read destined to processing units considered adequate / Total solid waste produced by the municipality of origin) X 100

Source: ABES (2021).<sup>6</sup>

## Results and discussion

In the JRB there was a 9.44% growth in the urban area between the years 1986 and 2018 according to Souza.<sup>7</sup> This can be justified in the fact of the increased urban integration of the Metropolitan Region of Recife (MRR) that was created in the 1970s including Jaboatão, Moreno and São Lourenço da Mata since its inception, and the high economic growth of the metropolitan region from the 1990s that increased the economic importance of municipalities such as Jaboatão dos Guararapes and Cabo de Santo Agostinho. This increase in the urban area in MRR has not always been accompanied by planning in the form of occupation of space which led to serious environmental damage.<sup>8</sup> In field according to Santos and Hernandez (2012),<sup>9</sup> urban occupations were verified on the slopes in hillside areas, near the river course, among other places at risk of erosion and environmental disasters. The problems related to the lack of urban planning are mainly related to the way the watershed is occupied, not considering respecting the riparian forests and channeling the rivers, thus increasing the potential erosion and flooding of urban rivers. The new paradigm has as its approach the integrated management of multiple use of resources and sectors, aiming at regional development in a sustainable way, reducing potential adversities on the social, economic and ecological dimensions.<sup>10</sup> The use of indicators to evaluate the level of sustainability of environmental policies and actions began in the 1990s. This process reflected the very maturation of the theoretical and conceptual basis of sustainable development with the United Nations Conference on Environment and Development. In that same

period, Agenda 21 recognized the indicators as appropriate tools for sustainability assessment.<sup>11</sup>

According to the census of the Brazilian Institute of Geography and Statistics,<sup>5</sup> the population of the JRB is composed of 2,886,228 inhabitants, with 97.69% corresponding to the urban population and 2.31% corresponding to the rural population. In the municipalities of Recife and Jaboatão dos Guararapes most of the population is urban, contrasting with the other municipalities that are part of the basin, where the rural population prevails (Table 3). The Municipal Human Development Index (MHDI) is a measure composed of indicators of three dimensions of human development: longevity, education and income. The three components are grouped by means of the geometric mean, resulting in the MHDI. The index ranges from 0 to 1. The closer to 1, the higher the human development. The MHDI adjusts the HDI to the reality of the municipalities and reflects the regional specificities and challenges in achieving human development in Brazil.<sup>12</sup> Among the municipalities inserted in the JRB, the one that presented the highest HDI for income, longevity and education was Recife, followed by Jaboatão dos Guararapes, considered High. The other municipalities in the JRB were considered to have a Medium HDI.

**Table 3** Municipalities within the area of the JRB, population (urban and rural) and population density

Municipality	Population				
	Urban	%	Rural	%	Total
Cabo de Santo Agostinho	189.47	7	19.474	29	208.944
Jaboatão dos Guararapes	691.457	25	15.41	23	706.867

**Table 4** Municipalities in the JRB area, population indicators and life expectancy

Municipality	Income (HDHM-R)	Longevity (MHDI-L)	Education (MHDI-E)	HDI -2010	Class	Gini Index	Life expectancy
Cabo de Santo Agostinho	0,65	0,81	0,61	0,69	Medium	0,53	73,7
Jaboatão dos Guararapes	0,69	0,83	0,64	0,72	Upper	0,58	74,8
Moreno	0,61	0,81	0,56	0,65	Medium	0,53	73,2
Recife	0,80	0,83	0,70	0,77	Upper	0,68	74,5
São Lourenço da Mata	0,61	0,79	0,57	0,65	Medium	0,50	72,5
Vitória de Santo Antão	0,63	0,77	0,54	0,64	Medium	0,54	71,0
Average	0,67	0,81	0,60	0,69	Medium	0,56	0,56

Regarding the provider of water and sewage services, in the municipalities of the JRB, the services are operated by the State Company (COMPESA). As for regulation, all of them are regulated by the state regulatory agency (ARPE), which shows a situation of uniformity<sup>15</sup> (Table 5). According to data from MDR<sup>16</sup> it was found that 3 municipalities obtained a distribution loss greater than 50%, these being: São Lourenço da Mata (68.14%), Recife (57.49%) and Moreno (55.36%). From the water quality data published in the Report on Monitoring of Watersheds of the State of Pernambuco - 2019,<sup>17</sup> a compromise in water quality was observed throughout the JRB for the evaluated period. Among the monitored parameters, the following stand out with a greater number of non-conformities, in relation to

Municipality	Population				
	Urban	%	Rural	%	Total
Moreno	56.041	2	7.253	11	63.294
Recife	1.653.461	59	0	0	1.653.461
São Lourenço da Mata	107.291	4	6.788	10	114.079
Vitória de Santo Antão	121.814	4	17.769	27	139.583
Total	2.819.534	100	66.694	100	2.886.228

Source: Atlas Brazil (2010); IBGE (2020); INFOSANBAS, (2022).<sup>58,5,30</sup>

The Gini Index varies from zero to one, the zero value represents the situation of equality (everyone has the same income), while the value one is the opposite (only one person has all the wealth). The municipalities of the JRB followed the same trend as the HDI. Long and healthy life is measured by life expectancy at birth, calculated by an indirect method based on data from the IBGE Demographic Census. This indicator shows the average number of years that people would live from birth, keeping the same mortality patterns observed in the reference year. In this indicator, Jaboatão dos Guararapes had the highest life expectancy (74.8 years), followed by Recife with 74.5 years (Table 4). The water in the JRB is used for public supply, reception of domestic effluents and reception of industrial and agro-industrial effluents. According to the SNIS (MDR; SNS, 2019),<sup>13</sup> São Lourenço da Mata, Vitória de Santo Antão, and Jaboatão dos Guararapes presented the highest percentages of the population without access to water in the JRB with 20.55%, 20.34%, and 20.24%, respectively. Like the index of population without water, the index of water losses in distribution presents great variation among the municipalities of the JRB, where São Lourenço da Mata and Recife presented the worst performances with 68.14% and 57.49% (Table 4), respectively, according to the SNIS<sup>14</sup> (Table 4).

the Class 2 of fresh water of CONAMA Resolution 35720/05, in descending order: Thermotolerant Coliforms, Dissolved Oxygen, Total Phosphorus, Biochemical Oxygen Demand and Ammonia. The Thermotolerant Coliforms parameter presented 100% of occurrence in all stations and evaluated period, evidencing the release of sewage of domestic origin throughout the monitored stretch.<sup>17</sup> Besides the high load of organic pollution (Table 6) due to untreated domestic sewage, the Jaboatão River also suffers from the discharge of leachate from the Muribeca dump, located at JB-75 station. On its banks were also observed large animal farms, such as chickens, oxen, pigs and horses, in addition to the accumulation of garbage.<sup>18</sup>

**Table 5** Population of the JRB without access to water

Municipality	Population without access to water		Water losses in distribution (%)*	Provider of water and sewerage services	Regulation
	N	%			
Cabo de Santo Agostinho	19.428	9,30	36,88	COMPESA	ARPE
Jaboatão dos Guararapes	143.092	20,24	39,07	COMPESA	ARPE
Moreno	12.593	19,9	55,36	COMPESA	ARPE
Recife	174.425	10,55	57,49	COMPESA	ARPE
São Lourenço da Mata	23.438	20,55	68,14	COMPESA	ARPE
Vitória de Santo Antão	28.396	20,34	47,01	COMPESA	ARPE
Total	401.372	100	-	-	-

Source: SNIS (MDR; SNS, 2019; \*MDR; SNS, 2021).<sup>13,14</sup>

**Table 6** Pollutant load in the JRB by municipality

Municipality	Potential organic load	
	(kg BOD <sub>5,20</sub> /day)	%
Cabo de Santo Agostinho	51	0,21
Jaboatão dos Guararapes	21.611	89,65
Moreno	883	3,66
Recife	1.329	5,51
São Lourenço da Mata	103	0,43
Vitória de Santo Antão	128	0,53
Total	24.105	100

Source: CPRH/FACEPE (1998)<sup>58</sup>.

Among the industrial activities in the basin are chemicals, food products, metallurgy, textiles, beverages, paper/cardboard, plastics, electrical/communication materials, sugar and ethanol, clothing/artifacts/fabrics, footwear, mechanics, pharmaceuticals/veterinary products, and transport materials. The municipality of Jaboatão dos Guararapes accounts for most of the pollution load in the JRB, while the municipality of Cabo de Santo Agostinho accounts for the least (Table 6). Despite its undeniable importance, Brazil has a deficient provision of sanitary sewage. According to the National Sanitation Information System (SNIS), more than 33 million Brazilians do not have access to water supply, and only 55% of the population has its sewage collected. In some states, this reality is much more alarming.<sup>19</sup> In the JRB, regarding the population without access to sewage, the municipality of Cabo de Santo Agostinho showed the worst performance (88.43%), while Recife showed the best performance (55.99%), although it is very far from the so desired universalization (Table 7).

**Table 8** Forms of sanitary sewage in the JRB

Form of sanitary sewerage	Municipality											
	Cabo de Santo Agostinho		Jaboatão dos Guararapes		Moreno		Recife		São Lourenço da Mata		Vitória de Santo Antão	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
General sewage or rainwater network	16.272	548	51.327	171	6.19	304	258.656	23	9.067	415	22.169	904
Septic tank	7.468	2.878	39.647	922	1.692	478	73.266	91	2.19	118	1.517	824
Rudimentary pit	16.914	3.031	77.404	4.831	3.936	1.189	100.942	777	12.1	2.253	4.895	2.785
Ditch	3.123	186	9.159	219	582	55	11.777	44	1.794	96	1.767	550
River, lake or sea	1.207	157	8.38	252	1.182	21	19.228	10	1.403	50	2.193	147
Other outlet	353	189	2.626	137	155	140	3.192	16	321	76	428	536
They didn't have	273	766	1.211	557	169	360	2.445	3	260	264	184	542
Total	45.61	7.755	189.754	7.089	13.906	2.547	469.506	964	27.045	3.272	33.153	6.288

Source: IBGE Census (2010) (2012).<sup>61</sup>

**Table 7** Population of the JRB without access to sewage

Municipality	Population without sewage	
	N	%
Cabo de Santo Agostinho	184.778	88,43
Jaboatão dos Guararapes	552.93	78,22
Moreno	44.846	70,85
Recife	925.805	55,99
São Lourenço da Mata	83.142	72,88
Vitória de Santo Antão	97.926	70,16
Total	1.889.427	-

Source: Instituto Água e Saneamento (2022); IBGE 2020 (2022).<sup>59,60</sup>

Regarding the indicator of sanitary sewage in the JRB, Recife stands out with 258,656 urban households with respect to the general sewage network or pluvial, but only 23 rural households, showing a mismatch in the investment of sanitary sewage between these two populations. The other municipalities follow the same tendency. With the exception of the urban areas of Moreno and Vitória de Santo Antão, the sanitary sewerage of the rudimentary pit type predominated in the JRB. It can be seen that in the rural areas of the JRB the sanitary sewage conditions are still very critical (Table 8). The “general sewage or rainwater network” type was considered the most appropriate, because it presents a higher probability of subsequent treatment of the exhausted material. Really adequate conditions would imply not only the form of sewage collection, but the guarantee of subsequent treatment, avoiding the contamination of water resources and the proliferation of diseases.<sup>20</sup>

In the history of sanitation in Brazil, the demands of more urbanized and economically viable areas have always received greater attention from public authorities. In rural areas, the demands have been neglected in the local context, gaining visibility in programs of other government levels, with the predominance of compartmentalized actions, due to the fragmentation of the policy. This logic, which perpetuates the health exclusion of rural populations in the country, was pointed out by the National Basic Sanitation Plan, the Plansab.<sup>21</sup> The Plansab (BRASIL, 2007)<sup>22</sup> aims to assess the degree of future achievement of state and regional goals predefined for the short, medium and long term (2018, 2023 and 2033, respectively), considering 23 selected indicators that cover the various components of basic sanitation, in addition to management aspects. The accelerated and disorderly growth of Brazilian cities, associated with the large-scale consumption of industrialized and disposable products, has caused an excessive

increase in the amount of household solid waste in urban and rural areas. The collection and environmentally appropriate final disposal of this waste imply its correct management and, consequently, the expansion of access to adequate care and the reduction of the deficit.<sup>13</sup> A relevant indicator in the context of concerns about sanitation, the environment, and public health is the final disposal of solid waste. The municipality of Recife stands out with 1.45 kg/inhabitant/day with regard to the *per capita* generation rate of solid waste in the JRB, as well as in relation to the estimated generation of solid waste in the JRB with 836,640 tons/year (Table 9). With regard to the disposal of recyclable waste, São Lourenço showed the highest percentage of paper/cardboard (10%), glass (3.5%) and metals (2.4%), while Moreno stood out in the disposal of plastics (16.6%). The provider or agency responsible for the solid waste service in Vitória de Santo Antão (PE) did not send information for the diagnosis (N.I.).

**Table 9** Municipalities according to the disposal of solid waste

Municipality	Per capita generation rate (kg/inhab/day)	Estimated generation (ton/year)	Recyclables (%)				
			Paper/ cardboard	Plastics	Glazing	Metals	Total
Cabo de Santo Agostinho	1,76	68.972	1,3	14,9	2,5	0,8	19,5
Jaboatão dos Guararapes	0,70	246.892	7,8	10,2	0,6	1,8	20,4
Moreno	0,59	11.4	2,8	16,6	1,4	1,1	21,9
Recife	1,46	836.64	5,0	11,4	0,7	1,5	18,6
São Lourenço da Mata	1,23	45.31	10,0	8,9	3,5	2,4	24,8
Vitória de Santo Antão	N.I.	N.I.	N.I.	N.I.	N.I.	N.I.	N.I.

Source: BDE (GOVERNMENT OF THE STATE OF PERNAMBUCO, 2010; CARUSO JR, 2015).<sup>62</sup>

The destination of household waste in Brazil is mainly done through direct collection by cleaning services.<sup>5</sup> The municipalities of the JRB send their waste to: the Candeias CTR, private Waste Treatment Centers (Table 10), with the exception of the municipality of Vitória de Santo Antão, which deposits its waste in a dump, according to the Nossa Vitória website (2014). According to the IBGE<sup>5</sup> a permanent private dwelling was considered to be one that was built exclusively for housing and, on the reference date, was intended to serve as a home for one or more people. The process of solid waste management comprises the collection and public cleaning, as well as the final

disposal of these wastes. The stages of collection and final disposal are considered the most important, since the volume and destination of the waste collected interfere directly and indirectly with the environment and public health. The types of solid waste destination were grouped into three classes: “Adequate”, “Inadequate” and “No defined destination,” although the fact that they were collected by cleaning services is no guarantee of environmentally adequate disposal or final disposal, as defined by the PNRS,<sup>23</sup> as shown in Table 6. In rural areas, most households (63.81%) had inadequate disposal of solid waste.

**Table 10** Permanent private households by garbage destination according to household situation

Municipality/ Waste destination	Population	Suitable		Inadequate			No destination defined	
		Collected by cleaning service	Collected in cleaning service bucket	Queimado (on the property)	Buried on the property	Other destination	Discarded in a vacant lot or street	Thrown into a river, lake or sea
Cabo de Santo Agostinho	Urban 47,287 Rural 1,996	Urban 2,247 Rural 287	Urban 693 Rural 2,056	Urban 751 Rural 437	Urban 39 Rural 6	Urban 47,287 Rural 1,996	Urban 2,247 Rural 287	Urban 693 Rural 2,056
Jaboatão dos Guararapes	Urban 182,689 Rural 2,233	Urban 14,435 Rural 369	Urban 1,523 Rural 600	Urban 365 Rural 15	Urban 7,902 Rural 789	Urban 182,689 Rural 2,233	Urban 14,435 Rural 369	Urban 1,523 Rural 600
Moreno	Urban 11,886 Rural 24	Urban 967 Rural 24	Urban 238 Rural 1,473	Urban 1,566 Rural 140	Urban 23 Rural 1	Urban 11,886 Rural 24	Urban 967 Rural 24	Urban 238 Rural 1,473
Recife	Urban 445,779 Rural -	Urban 14,900 Rural -	Urban 687 Rural -	Urban 7,358 Rural -	Urban 1,310 Rural -	Urban 445,779 Rural -	Urban 14,900 Rural -	Urban 687 Rural -
São Lourenço da Mata	Urban 22,612 Rural 411	Urban 1,944 Rural 49	Urban 1,253 Rural 1,030	Urban 2,543 Rural 210	Urban 125 Rural 3	Urban 22,612 Rural 411	Urban 1,944 Rural 49	Urban 1,253 Rural 1,030
Vitória de Santo Antão	Urban 32,618 Rural 830	Urban 1,037 Rural 61	Urban 251 Rural 2,895	Urban 824 Rural 758	Urban 64 Rural 7	Urban 32,618 Rural 830	Urban 1,037 Rural 61	Urban 251 Rural 2,895

Source: IBGE Census (2010).

According to the IBGE, the municipalities are divided into two groups: small and medium size - up to 100 thousand inhabitants; large size - over 100 thousand. In this context, the municipalities of Recife and Jaboatão dos Guararapes are classified as large, while the other BRJ municipalities are classified as small or medium-sized<sup>6</sup> (Table 10). The phenomenon of urbanization is usually associated with the replacement of natural or semi-natural environments by built environments, often bringing great environmental and cultural damage. These losses become even more significant when the process of land occupation occurs in a disorganized manner.<sup>24</sup> The tributaries of rivers and flooded areas have been filled in for centuries, without any concern with the natural drainage. The canalization of urban rivers and streams, in addition to causing a series of damages to the environment, by totally mischaracterizing the natural habitat, causes the beginning of a recurrent chain of problems: favoring of clandestine sewage connections, occupation of the banks and areas of flood expansion, problems of downstream flooding and the isolation of the hydraulic connection between the aquifer and the river.<sup>25</sup>

In addition to topographic influence, soil sealing associated with climatic dynamics in the municipalities are important factors in potential flooding. In addition to river drainage through canalization, soil sealing occurs through the construction of residential, commercial and industrial structures and paved roads, which reduce infiltration areas, increasing the rates of surface runoff in interfluvies and, consequently, in watercourses. Moreover, the replacement of the natural surface by asphalt roads and concrete buildings and houses increases the absorption capacity of solar radiation, consequently increasing the temperature and humidity, and this increase in humidity leads to a greater occurrence of rainfall events.<sup>26</sup> The result is an increase in surface runoff and the impacts resulting from flooding and inundation. This situation is aggravated in coastal plains, as is the case in Recife. Storm drainage is also hampered by inefficient wastewater treatment and solid waste management, as well as planning for environmental education. The coating of the slopes with cement in the hillside areas seeks to contain erosion and prevent the infiltration of waters that are dangerous for the stability of the slopes, but it causes the acceleration of the surface runoff effect, resulting in flooding in the lower parts. As a shortcoming of the management model implemented, it is cited the dispersion of sanitation services, including those provided by different spheres of government, making it difficult to integrate them.<sup>27</sup>

Urban drainage and stormwater management services (DMAPU) are more recent, so they have not yet reached the degree of organization and consolidation of the other components. There is no population coverage index for these services, either because they are not properly organized, which makes it difficult to provide information, or because there is no agreement among experts on how to define and calculate indexes, or because the way to measure coverage is not the same as for the other components.<sup>28</sup> Regarding the percentage of the types of drainage systems in the municipalities of the JRB, it was found that in the set of municipalities that participated in the SNIS-AP (2017),<sup>29</sup> in Jaboatão dos Guararapes, Moreno and Recife, 100% is exclusive for drainage and in Vitória de Santo Antão the combined system prevails with 100% and in São Lourenço da Mata 100% corresponds to there are no drainage systems (Table 11). The floods, inundations, mudslides, flooding and landslides that occur during rainy periods show the precariousness of the urban drainage system due to the lack of management and socio-environmental analysis of the risks and vulnerabilities of each location.<sup>30</sup> According to the Trata Brasil Institute (2010),<sup>1</sup> diseases related to inadequate water and sewage systems cause the death of millions of people every year, and the neediest are the most affected in this perverse relationship

between lack of sanitation and diseases. Thus, the deficiency and or inefficiency of these services cause negative impacts on education, work, economy, biodiversity, among others.<sup>31,32</sup>

**Table 11** Percentage of the types of drainage systems in the municipalities of the JRB in 2017

Municipality	Doesn't exist.	Exclusive for drainage	Combined	Unitary** Other
Cabo de Santo Agostinho	0%	0%	100%	0%
Jaboatão dos Guararapes	0%	100%	0%	0%
Moreno	0%	100%	0%	0%
Recife	0%	100%	0%	0%
São Lourenço da Mata	100%	0%	0%	0%
Vitória de Santo Antão	0%	0%	100%	0%

\*When 100% of the drainage system is exclusively for stormwater; \*\*When part of the drainage system is exclusive and part is unitary; \*\*\*Mixed with sanitary sewer.

Public health risks are linked to some possible and undesirable factors that may occur in urban and rural areas, which can be minimised or eliminated with the appropriate use of sanitation services. The use of potable water, for example, is seen as a safe food supply for the population. The sewage system promotes the interruption of the chain of human contamination. Improved solid waste management (garbage) reduces environmental impact and eliminates or hinders the proliferation of disease vectors.<sup>33</sup> The World Health Organization (WHO) and the United Nations Children's Fund (UNICEF) mention poor basic sanitation as a serious threat to human health, and state that the second leading cause of death in children under five years of age is related to water contamination, the biggest one being diarrhea. According to these institutions, this scenario of global incidence has remained stable over the past two decades.<sup>34</sup> Considering its importance, still at the global level, sanitation is incorporated into goal 6 of the Sustainable Development Goals (SDGs), which is to ensure availability and sustainable management of water and sanitation for all.<sup>28</sup> The official SDG indicators are considered an important tool to ensure the implementation of the goals, giving them a central and political role within the Agenda's governance structure. There are, however, a number of challenges that need to be overcome for this instrument to reach its full potential.<sup>35</sup>

According to the National Policy of Basic Sanitation (PNSB),<sup>36</sup> Law No. 11,445/2007, basic sanitation services should be universal, i.e., have their access extended to all occupied households in the country. Universalization is, therefore, one of its guiding principles. Despite the investments made in recent years, there is still no universal access to basic sanitation services in Brazil. The universalization of access to sanitation would imply a reduction in hospitalizations and, consequently, in public spending on health.<sup>37</sup> Some of the possible causes for this scenario in the provision of sanitary sewage services in the country are the discontinuity of public policies in the different governments, the lack of planning, the inefficiency in the management of service providers, the lack of financial resources (federal, state and municipal governments), the weak supervision, the incipient regulation sector, the existence of feasible connections, among others.<sup>28</sup> Furthermore, the existence of households in irregular areas makes the construction of sewage networks unfeasible, i.e., there is a disarticulation of housing, urban planning and urban mobility policies with sanitation policies.<sup>38</sup> With the consolidation of this new paradigm, a classification of diseases whose transmission occurs

via sanitation, or even due to the complete absence of it, emerged. With this classification model that considers sanitation systems, the concept of Diseases Related to Inadequate Environmental Sanitation (DRIES) emerges.<sup>39</sup> The term “inadequate environmental sanitation” is associated with different risk factors, such as: poor water supply, inadequate sanitary sewage, contamination by solid waste, or precarious housing conditions.<sup>40</sup>

The lack of basic sanitation negatively affects the quality of life of citizens and increases the susceptibility of the population to waterborne diseases.<sup>41</sup> The degradation of springs such as water pollution can lead to diseases like cholera, infectious diarrhea, hepatitis, schistosomiasis, leptospirosis, dengue, among others, with direct effects on the quality of life and health of human populations.<sup>42</sup> According to Tundisi,<sup>43</sup> “the contamination and increase of toxic substances in water and vectors of waterborne diseases are directly related to basic sanitation and inadequate treatment conditions of water contaminated by various processes”. The absence of adequate solutions for the collection and treatment of sanitary sewage results in precarious sanitation conditions, favors the proliferation of parasitic and infectious diseases and causes the degradation of water bodies. Thus, the removal and treatment of sanitary sewage are essential to safeguard public health and preserve the environment, thus improving the quality of life of the population.<sup>13</sup> The Diseases Related to Inadequate Environmental Sanitation (DRIES) are reported in countries considered poor and underdeveloped, with precarious sanitation services, lack of public policies and lack of health education of the population. These factors favor a scenario conducive to the development of these diseases and the worsening of the unfavorable picture regarding public health in the country.<sup>41</sup>

The Ranking on the Universalization of Sanitation prepared by the Brazilian Association of Sanitary Engineering (ABES)<sup>6</sup> was

**Table 13** Score of the municipalities in the JRB in relation to water supply and basic sanitation

Municipality	Score						Rate of hospitalizations for DRIES
	Supply water	Sewage collection	Sewage treatment	Solid waste collection	Appropriate disposal of solid waste	Total score	
Cabo de Santo Agostinho	87,88	11,63	4,86	97,2	100	301,57	46,8
Moreno	80,58	29,39	42,1	89,22	100	341,29	66,9
Jaboatão dos Guararapes	79,47	18,94	19,14	98,24	100	315,79	48,4
Recife	89,33	43,96	93,36	100	100	426,65	60,9
São Lourenço da Mata	77,77	19,51	30,51	70,65	100	298,44	47,7
Vitória de Santo Antão	N.I.	N.I.	N.I.	N.I.	N.I.	N.I.	N.I.
Average	83,01	24,69	37,99	91,06	100,00	336,75	54,14

Source: ABES (2021).<sup>6</sup> The data refer to 2019, due to the two-year lag between data collection and disclosure by the Ministry of Regional Development through the SNIS.

In the ABES Ranking, the correlation between these two variables (health and sanitation) are addressed through the DRIES - Diseases Related to Inadequate Environmental Sanitation, defined in a research financed by FUNASA in 2001 and 2002. Most of them are typical of precarious environments, without basic sanitation or with inadequate sanitation. For this study, among the DRIES, we used the fecal-oral transmission diseases (diarrhea, enteric fevers, hepatitis A). On them, the average hospitalization rate per 100,000 was calculated. The selected diseases are: Cholera, Typhoid and paratyphoid fevers, Other Salmonella infections, Shigelosis, Other bacterial intestinal infections, Amebiasis, Other intestinal diseases by protozoa, Viral

intestinal infections, other and unspecified, Diarrhea and gastroenteritis of presumptive infectious origin.<sup>44</sup> Population growth associated with low capacity to create social and environmental infrastructure can be a risk factor to health, since a higher concentration of people in areas with poor infrastructure leads to greater exposure to an unhealthy environment (inadequate disposal of solid waste, untreated water supply, poor or nonexistent sanitation, among others).<sup>45</sup> In countries like Brazil, this scenario is present mainly in peripheral zones of urban areas that lack essential services to meet the demand of a rapidly growing population, also causing a strong pressure on the environmental situation.<sup>46</sup>

**Table 12** Scores and categories in the Sanitation Universalization ranking prepared by ABES<sup>6</sup>

Score	Category
Under 200,00	First steps towards universalisation
From 200.00 - 499.99	Commitment to universalisation
From 450.00 - 489.00	Commitment to universalisation
Over 489.00	Towards universalisation

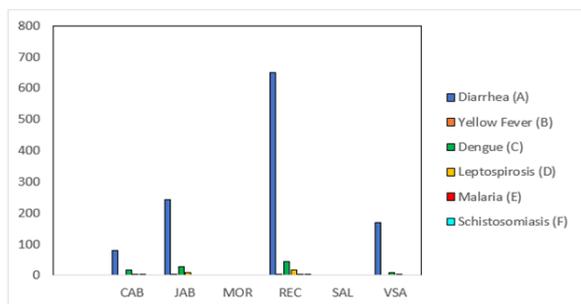
The lack of sanitation has immediate implications on the health and quality of life of the population living in environmentally degraded areas. The lack of treated water has a direct impact on health, especially among the young and the elderly, as it increases the incidence of waterborne and respiratory diseases. The lack of sewage collection and treatment services, even when there is access to treated water, also has a decisive impact on the incidence of gastrointestinal infections and diseases transmitted by mosquitoes and animals. The recurrence of these diseases harms society because it causes unrecoverable costs. There are two immediate channels linking poor sanitation to these costs: i. By increasing the incidence of these diseases, poor sanitation causes people to take time off work,

costing society in hours not worked; and ii. Society incurs public and private expenses for the treatment of infected persons. The lack of basic sanitation also impairs the performance of children who suffer from DRIES, who have weakened health and, as a consequence, their education is impaired due to the missed classes.<sup>47</sup> According to DATASUS<sup>48</sup> presented in Table 14 and Figure 2, diarrhea, followed by dengue, had the highest prevalence in Recife, corresponding to 57% and 45% of the occurrences of water veiculated diseases.<sup>48</sup> Most hospitalizations for diarrhea occur in the age group under 5 years.<sup>49</sup> The other diseases had the highest number of cases in Recife. When comparing the basic sanitation conditions among the municipalities of the JRB, inequalities are observed.

**Table 14** Municipalities and occurrences of DRIES

Municipality	Population (N)	Diarrhea(A)	Yellow Fever (B)	Dengue (C)	Leptospirosis (D)	Malaria (E)	Schistosomiasis (F)
Cabo de Santo Agostinho	208.944	80	0	17	5	1	0
Jaboatão dos Guararapes	706.867	243	1	29	10	0	0
Moreno	63.792	s.d.	s.d.	s.d.	s.d.	s.d.	s.d.
Recife	1.653.461	651	2	45	18	2	2
São Lourenço da Mata	114.079	s.d.	s.d.	s.d.	s.d.	s.d.	s.d.
Vitória de Santo Antão	139.583	168	0	8	1	0	0
Total	2.886.726	1.142	3	99	34	3	2

Source: DATASUS (2020);<sup>30</sup> INSTITUTO TRATA BRASIL (2022).<sup>63</sup>



**Figure 2** Number of cases in the JRB.

CAB, Cabo de Santo Agostinho; JAB, Jaboatão dos Guararapes; MOR, Moreno; REC, Recife; SLM, São Lourenço da Mata; VSA, Vitória de Santo Antão

Regarding the number of hospitalizations caused by DRIES in the municipalities that are part of the JRB, Recife stood out with 13,191 hospitalizations between 2007 and 2021, and in 2010 had the highest number of hospitalizations (2,204). With regard to the number of deaths caused by DRIES, Recife also stood out with 4,208 deaths in the study

period, and there was no record of death by DRIES in the range of 0 to 4 years. The analysis of indicators associated with environmental factors, such as the quality of water consumed or distributed in the municipalities and the diseases resulting from these supplies, can show important evidence.<sup>50</sup> Regarding health indicators, according to DATASUS (2020),<sup>51</sup> Vitória de Santo Antão had the highest incidence of hospitalizations for waterborne diseases and total hospitalizations for waterborne diseases among the municipalities in the JRB (Table 15). Recife stood out with respect to hospitalization costs due to DRIES. There was no record of deaths in the municipalities inserted in the JRB in the range of 0 to 4 years. There were 1,283 hospitalizations due to DRIES. Vasconcelos and Pimentel highlight that the results denote the urgency for measures to improve the municipal sewage systems of Pernambuco, given not only the low rates of collection and treatment, but also the high rates of DRIES and the need to achieve universal access with a view to achieving the sustainability of local development. Aguiar, Ceconello and Centeno (2019)<sup>52</sup> emphasize the need for greater investment by the responsible agencies in providing a good quality environmental sanitation to the population, as it is one of the main ways to avoid contracting waterborne diseases.

**Table 15** Incidence of total hospitalizations, expenditures, death rates and total hospitalizations by DRIES in the JRB

Municipality	Incidence of total hospitalizations for DRIES	Expenses with hospitalizations for DRIES	Death rate by DRIES 0 to 4 years	Total hospitalizations for DRIES
Cabo de Santo Agostinho	4.93	93.405	0	103
Jaboatão dos Guararapes	4	315,402	0	283
Moreno	s.d.	s.d.	s.d.	s.d.
Recife	4.36	651,632	0	720
São Lourenço da Mata	s.d.	s.d.	s.d.	s.d.
Vitória de Santo Antão	12.68	89,161	0	177
Total	25.97	1,149,600	0	1,283

Source: DATASUS (2020).<sup>30</sup>

According to Ferreira et al.<sup>41</sup> the inefficiency of these services directly implies increased spending on public health to treat the symptoms of waterborne diseases, generating an unsatisfactory management model. Thus, the study affirms the importance of sanitation, as a preventive and effective form, in improving public health indices in Brazil. The JRB is an example of how the poor management of natural resources and the disorderly occupation and use of the soil can affect the environmental balance of a watershed. Several environmental problems are associated with the lack or precariousness of sanitation in the JRB, such as: pollution or contamination in water abstraction for human supply, pollution of rivers, lakes, ponds, aquifers, diseases, accelerated erosion, silting, frequent flooding, with the consequent human and material losses, to mention just a few examples.<sup>53</sup> It was possible to verify the discrepancy that exists between planning and government action, concerning the projects that contemplate operations in basic sanitation.<sup>54</sup> A good Municipal Sanitation Plan contributes to the improvement of social and economic indicators of the municipalities, avoiding problems of water shortage, disease proliferation and reducing environmental pollution. Despite the improvement in economic and social indicators for most municipalities in the JRB, this was not reflected in good water quality, pointing to the urgency of increasing investments in the area of water resources infrastructure, especially basic sanitation.<sup>55</sup>

Analyzed globally, it is observed that the mismatch between the planning techniques, the available resources and the pace of occupation, allowed the occurrence of aggressions, in varying degrees, to the environment. The most striking are the reduction of the original Atlantic Forest cover to only 3.5% (1035 ha), the environmental problems resulting from sugar cane industrialization, the pollution of Jaboatão River and Olho D'Água Lagoon, the destruction of mangroves, the invasion of historical sites and the landslides and landslides caused by irregular settlements in risk areas.<sup>56</sup> Once they have access to water suitable for consumption, proper sewage disposal, solid waste management and disposal, and an adequate and well-dimensioned drainage system, there will be a reduction in the susceptibility to contracting diseases related to inadequate environmental sanitation, indicating that basic sanitation can be a policy for the prevention of waterborne diseases.<sup>57,64-72</sup>

## Conclusion

With regard to socioeconomic indicators, among the municipalities inserted in the JRB, the one that presented the highest HDI for income, longevity and Education was Recife, followed by Jaboatão dos Guararapes, considered High. The other municipalities of the JRB were considered to have a Medium HDI. The municipalities of the JRB followed the same trend as the HDI with respect to the Gini Index. Jaboatão dos Guararapes had the highest life expectancy (74.8 years), followed by Recife with 74.5 years among the municipalities of the JRB. Regarding the water supply indicator, it was observed that São Lourenço da Mata, Vitória de Santo Antão and Jaboatão dos Guararapes presented the highest percentages of the population without access to water in the JRB with 20.55%, 20.34% and 20.24%, respectively. Like the index of population without water, the index of water losses in distribution showed great variation among the municipalities of the JRB, where São Lourenço da Mata and Recife presented the worst performances with 68.14% and 57.49%. The indicators related to basic sanitation revealed inefficiency in the sanitation system of the municipalities inserted in the JRB. With the exception of the urban areas of Moreno and Vitória de Santo Antão, the rudimentary pit-type sanitary sewage system predominated in the JRB. It can be seen that in the rural areas of the JRB the sanitary

sewage conditions are still very critical. The most critical problem regarding sanitation in the JRB was the lack of sewage treatment.

In this regard, the municipality of Recife had the “best” index, with 55.99% of the population without access to sewage, although far from an ideal situation; however, the other municipalities had indexes above 70%, revealing a critical situation, compromising the quality of water and the health of the population of the JRB, requiring greater investments in the sector. With regard to the solid waste indicator, it was found that the municipality of Recife stood out with 1.45 kg/inhabitant/day with respect to the *per capita* generation rate of solid waste in the JRB, as well as in relation to the estimated generation of solid waste in the JRB with 836,640 tons/year. All the municipalities in the JRB provide adequate disposal of solid waste (100%), with the exception of Vitória de Santo Antão, whose data was not available. Regarding the disposal of recyclable waste, it was found a great waste of resources, since only a small portion with potential for recycling is collected in the municipalities of the JRB. Regarding the percentage of the types of drainage systems in the municipalities of the JRB, it was found that in the set of municipalities that participated in the SNIS-AP (2017), in Jaboatão dos Guararapes, Moreno and Recife, 100% is exclusive for drainage and in Vitória de Santo Antão the combined system prevails with 100% and in São Lourenço da Mata 100% belongs to the category does not exist. Regarding the score of the municipalities of the JRB in relation to water supply and basic sanitation, with the exception of Vitória de Santo Antão, which did not have the data informed, the other municipalities inserted in the JRB presented a score ranging between 298.44 and 426.65, situated in the category “Commitment to universalization”.

As for Diarrhea, Recife presented the highest number of cases in relation to the other municipalities of the JRB, especially diarrhea, followed by dengue. A total of 1,283 hospitalizations due to DRIES were identified. With regard to the number of deaths caused by DRIES, Recife also stood out with 4,208 deaths in the study period, and there was no record of death by waterborne diseases in the range of 0 to 4 years. The municipalities Moreno and São Lourenço da Mata did not disclose the data regarding the incidence of total hospitalizations, expenses, death rates and total hospitalizations for DRIES. Regarding health indicators, in the period analyzed, Vitória de Santo Antão had the highest incidence of hospitalizations for waterborne diseases and total hospitalizations for DRIES among the municipalities of the JRB. Recife stood out with respect to hospitalization costs due to DRIES. Regarding the expenses with hospitalizations for DRIES, R\$ 1,149,600 were spent for the treatment of victims in the municipalities of the JRB. When comparing the basic sanitation conditions among the municipalities of the JRB, inequalities are observed, especially in the rural area of the municipalities. Sanitation is a right of the population and is closely related to public health. Although in recent years there has been investment in environmental sanitation, it is clear that it is far from an ideal situation and the population of the municipalities is the one that has suffered the most from the impacts on public health. In this sense, the Union, States and Municipalities should join efforts to overcome the bureaucratic obstacles pertaining to basic sanitation and make agreements in the financing and implementation of these instruments, ensuring citizens decent conditions and quality of life.

## Acknowledgments

CAPES - Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (Higher Education Personnel Improvement Coordination).

## Conflicts of interest

The author declares there is no conflict of interest.

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