



# **ENVIRONMENTAL SANITATION INDEX AND COVID-19: AN ANALYSIS IN BRAZILIAN CAPITALS**

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UMA ANÁLISE NAS CAPITAIS BRASILEIRAS**

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## ÍNDICE DE SANEAMENTO AMBIENTAL E COVID-19: UMA ANÁLISE NAS CAPITALS BRASILEIRAS

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### ABSTRACT

The urbanization process and the significant population density in large centers triggered an increase in society's production and consumption, widening waste generation, which can impact human health and the environment. In developing countries such as Brazil, diseases caused by inadequate environmental sanitation conditions result in social problems that affect mainly vulnerable regions. This article aims to analyze sanitation and diseases related to environmental sanitation in Brazilian regions for the elaboration of an Environmental Sanitation Index for Brazilian capitals based on indicators related to water supply; sanitation and water-borne diseases. The research method is exploratory and quantitative. The Environmental Sanitation Index was prepared based on the application of Factor Analysis, with the help of the SPSS Software. As a result, the correlation between the proposed Environmental Sanitation Index and cases/deaths from Covid-19 was observed, which, in turn, strengthens the concept of sanitation as the main measure for preventing and spreading the virus. In short, quality sanitation services are a measure to prevent waterborne diseases, and their universality should be seen as a priority, especially in the North and Northeast regions.

**Keywords:** Basic sanitation. Environmental sanitation. Diseases of water origin. Covid-19.

## RESUMO

O processo de urbanização e o expressivo adensamento populacional nos grandes centros desencadeou um incremento na produção e no consumo da sociedade, aumentando a geração de resíduos, o que pode impactar a saúde humana e o meio ambiente. Em países em desenvolvimento como o Brasil, doenças causadas por condições inadequadas de saneamento ambiental resultam em problemas sociais que afetam principalmente as regiões em situação de vulnerabilidade. Este artigo tem por objetivo analisar o saneamento e as doenças relacionadas ao saneamento ambiental em regiões brasileiras para a elaboração de um Índice de Saneamento Ambiental para as capitais brasileiras a partir de indicadores relacionados com o abastecimento de água; o esgotamento sanitário e as doenças de origem hídrica. O método de pesquisa é exploratório e quantitativo. O Índice de Saneamento Ambiental foi elaborado a partir da aplicação da Análise Fatorial, com auxílio do Software SPSS. Como resultados, foi observado a correlação existente entre o Índice de Saneamento Ambiental proposto com os casos / óbitos por Covid-19 que, por sua vez, fortalece a concepção do saneamento como principal medida de prevenção e disseminação do vírus. Em suma, os serviços de saneamento de qualidade é uma medida de prevenção de doenças de origem hídrica, e sua universalidade deve ser vista como prioridade, principalmente nas regiões Norte e Nordeste.

**Palavras-chave:** Saneamento básico. Saneamento ambiental. Doenças de origem hídrica. Covid-19.

## INTRODUCTION

The emergence and spread of new viral diseases in Brazil are aggravated due to the absence of adequate sanitation. The importance of epidemiology became evident and renowned scientists dedicated their time to developing studies that met the needs of the time. Gomes (2015) states that the 19<sup>th</sup> and 20<sup>th</sup> centuries were marked by the influence of microbiology in epidemiology, which not only identified infectious diseases (tuberculosis, smallpox, plague, influenza, among others), but sought the development of new therapeutic measures for diseases.

In developing countries such as Brazil, diseases caused by inadequate sanitation conditions result in numerous social problems, which directly affect minorities. The disorderly increase of the population contributes to the expansion of social disparities, compromising the basic sanitation infrastructures and, consequently, harming the quality of life of the population (Teixeira *et al.*, 2014).

According to the Brazilian Institute of Geography and Statistics (IBGE, 2021), despite the progress in the management of Diseases Related to Inadequate Environmental Sanitation (DRIES), this issue is still a public health issue, which generates severe impacts on society in general. The evolution



of the field of bacteriology contributes to the promotion of sanitary, environmental and public health, by establishing adequate means of obtaining drinking water, minimizing vectors of contamination and maximizing priority prevention actions (Heller *et al.*, 2018; DIAZ; NUNES, 2020).

In view of society's need for better conditions and more adequate means of living, Law No. 14,026, of July 15, 2020, updated the Legal Framework of Sanitation and amended Law No. 11,445, of January 5, 2007. According to Law 14.026/2020, basic sanitation involves public services, infrastructures and operational facilities of public services, infrastructures and operational facilities of (i) drinking water supply, (ii) sanitary sewage, (iii) urban cleaning and (iv) solid waste management and drainage and management of urban rainwater (Brasil, 2020a).

Basic sanitation is related to environmental sanitation. According to IBGE (2021), environmental sanitation encompasses aspects beyond basic sanitation, as:

access to drinking water supply, collection and sanitary disposal of solid and liquid waste, sanitary discipline of land use and land occupation and specialized works to protect and improve living conditions, urban drainage, environmental control of vectors and reservoirs of communicable diseases to protect and improve the living conditions of the population and the environment (IBGE, 2021, p. 126).

The joint report of the Un-Water Global Analysis and Assessment of Sanitation and Drinking-Water (GLAAS) with the World Health Organization (WHO) highlights the lack or inefficiency of sanitation services as a serious threat to human health. The study points out that the state of Water, Sanitation and Hygiene (WASH) systems are varied and that most countries have necessary components in place, but a significant part still needs to operationalize and implement measures aimed at strengthening WASH systems. Given the relevance of the topic, the report points out the gaps in the management of WASH systems and stresses the need to employ efforts in the provision of services in a sustainable and effective way (WHO; UN-WATER, 2019). In Brazil, sanitation services still present challenges, due to the fact that they do not fully serve the entire population. In addition, basic sanitation services in Brazil show a slow advance, favoring the risk of spreading diseases (ITB, 2021).

The lack of access to basic sanitation is more intense in groups of socioeconomic vulnerability, in peri-urban areas, informal settlements and favelas, areas where more than 13 million Brazilians lived (UNICEF; BANCO MUNDIAL; SIWI, 2020). These geospatial disparities in



access to basic sanitation services were identified by Rodrigues, Venson and Camara (2019) as being the micro-regions of the North and Northeast regions, as well as regions with low-income and less populated. For the authors, these regions should be the focus of improvements in sanitation services.

In general, the lack of sanitation services reinforces inequality and signals socio-spatial inequalities. In addition, the fragility that permeates the infrastructure of the sanitation sector accentuates social and economic discrepancies, adversely impacting the most susceptible individuals (Sugahara; Ferreira; Prancic, 2021).

In 2019, about 83.7% of the Brazilian population had access to water and only 54.1% had sewage collection. However, only 49.1% of the volume of sewage generated was treated sewage. This scenario led to the registration of about 273,403 hospitalizations for diseases of water origin, and an expenditure of 108,097,605.38 in this period. In 2021, inefficiency in access victimized about 35 million Brazilians, and almost 100 million did not have access to sewage collection, leading to hundreds of hospitalizations for water-borne diseases (ITB, 2021). The data highlight the strong relationship between basic sanitation services and health-related issues.

Based on the work developed by Ferreira, Silva and Figueiredo Filho (2021), this research aims to analyze basic sanitation and diseases related to environmental sanitation, in order to elaborate an Environmental Sanitation Index (ESI) for Brazilian capitals. To this end, indicators related to a) water supply, (b) sanitary sewage and (c) diseases of water origin were selected. In addition, the objective is the elaboration of the ESI through the application of Factor Analysis (FA) and its relationship with Covid-19 cases in Brazilian capitals.

## INDICATORS OF SANITATION

The indicators allow to show a situation as they contain information that helps the decision-making and planning process, and the monitoring of the values assumed by the indicators temporally allows the evaluation independently of the indicator used (Meadows, 1998).

For the evaluation of the impacts of sanitation on diseases, it is necessary to measure validated and reliable indicators, that is, indicators composed of management and infrastructure variables of the sanitation system (Ferreira; Silva; Figueiredo Filho, 2021).

In Brazil, in 1994 the National Sanitation Information System (SNIS) was developed,<sup>1</sup> which includes a large sanitation database. The database has information for 84 indicators referring to municipal, regional and state providers of (a) water supply, (b) sanitary sewage, (c) municipal solid waste management, and (d) drainage and management of urban rainwater. It should be noted that this information is consolidated from the voluntary completion of service providers (Brasil, 2020b).

The Instituto Trata Brasil (ITB) also has a strong display of information for sanitation indicators, whether at the municipal or state level. Such information is available on the platform of the Brazil Sanitation Panel<sup>2</sup>, and in annual publications of the Sanitation Ranking, based on SNIS data.

The ITB Sanitation Ranking aims to classify the 100 largest Brazilian municipalities in relation to sanitation services delimited by water supply and sewage. The study brings to light the historical problem of Brazil, and stresses that it will not be possible to achieve the universalization of services without commitment of the Federal, State and Municipal spheres (ITB, 2022a).

When comparing the 20 best municipalities with the 20 worst municipalities in the Sanitation Ranking, it is possible to verify the inequality in relation to the indicator of population with access to drinking water, 92.32% and 82.52%, respectively. However, the greatest disparity is in relation to the indicator of population with access to the sewage collection network, 95.59% for the 20 best municipalities and 31.78% for the 20 worst municipalities, characterizing a difference of 63.81% (ITB, 2022b).

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1 <http://app4.mdr.gov.br/serieHistorica/>

2 <https://www.painelsaneamento.org.br/>



The ITB (2022b) stresses that the best municipalities invest 340% more in sanitation compared to municipalities that have almost full access to sanitation services. Another point to highlight is the investment of R\$13.7 billion, made in 2020, an amount considered insufficient to achieve the goals listed by the New Legal Framework for Sanitation of 2020.

It is in this scenario that the use of sanitation indicators can contribute to maximize the efficiency of governance processes and facilitate the adjunct processes in the implementation of sanitation services, in order to contribute to the aspects of public administration (Nirazawa; Oliveira, 2018).

### **DISEASES RELATED TO INADEQUATE ENVIRONMENTAL SANITATION (DRIES)**

Incorporating environmental and health issues in the field of sanitation has generated the loss of the anthropocentric vision, giving centrality to human aspirations and new perspectives regarding the environment and society. In this way, basic sanitation began to be treated also as environmental sanitation (FUNASA, 2019). The concept of sanitation has been discussed over the years due to public health problems, environmental impacts and population density of the municipalities. Environmental sanitation can be understood as being:

[...] set of socioeconomic actions that aims to achieve Environmental Health, through the supply of drinking water, collection and sanitary disposal of solid, liquid and gaseous waste, promotion of sanitary discipline of land use, urban drainage, control of communicable diseases and other specialized services, in order to protect and improve the conditions of urban and rural life (FUNASA, 2004, p. 14).

Environmental sanitation aims to ensure environmental health, understood as the “state of hygiene in which the urban and rural population lives, both with regard to its ability to inhibit, prevent or prevent the occurrence of endemics, or epidemics transmitted by the environment” (FUNASA, 2004, p. 14). It is possible to observe that environmental health connects public health issues with environmental ones.

Sanitation-related policies aim to provide adequate and equitable access to safe water and sanitation to promote better health and well-being. It is important to identify which diseases come from inadequate sanitation, and for this purpose Cairncross and Feachem (1993) conducted a study classifying infectious-parasitic diseases. This categorization is used by the National Health Foundation (FUNASA, 2004; 2019) called Diseases Related to Inadequate Environmental



Sanitation (DRIES), this term comprises as the lack or absence of environmentally appropriate sanitation services, causing the following diseases: (I) Fecal-oral transmission diseases, (II) Diseases transmitted by vector insect, (III) Water-borne diseases, (IV) Hygiene-related diseases, and (V) Geohelminths and taeniasis.

When considering only diseases such as Diarrhea, Dengue, Yellow Fever, Schistosomiasis, Malaria and Leptospirosis, Brazil recorded approximately 273,000 hospitalizations in 2019. The control and reduction of the number of hospitalizations caused by diseases associated with lack of sanitation in Brazil is still a challenge in all Brazilian regions. Among the diseases of water origin in Brazil, diarrhea represents 78% of the number of hospitalizations (ITB, 2021). In addition, some of these diseases can potentially be prevented with adequate access to sanitation, which would minimize the occurrence of hospitalizations.

It should be noted that universal access to drinking water and sewage collection and treatment are essential for the livelihood of human life. This situation allows us to verify the impact on the health of the Brazilian population due to the lack of access to water and sanitation and its relationship with Covid-19 (Sugahara; Ferreira; Pranic, 2021).

The adoption of measures that prioritize the relationship between the management of water resources and sanitation is necessary to reduce the impacts caused by the Severe Acute Respiratory Syndrome - COrona Virus (SARS-CoV-2), which causes Corona Virus Disease 2019 (Covid-19) (Freitas; Kuwajima; Santos, 2020). Sanitation management measures fulfill the role of preserving surface and groundwater, more than that, it prevents the spread of pathogens through water transmission (Sugahara; Ferreira; Pranic, 2021). Moreover, although Covid-19 is not considered a DRIES, it is possible to perceive that the lack of sanitation contributes to the worsening of the disease.



## SANITATION AND COVID-19

The Covid-19 pandemic due to the SARS-CoV-2 virus has shown itself to be a huge and multidimensional problem, which affects in an alarming way all areas and public sectors, generating uncertainties and difficulties. A pandemic scenario generates either a health crisis and aggravates economic, social and environmental vulnerabilities.

At the beginning of August 2020, Brazil was already the second country in numbers of Covid-19 cases in the world, behind only the United States. The precarious conditions experienced in some regions of Brazil inhibit the fight against the Covid-19 pandemic. For example, the state of Rio de Janeiro with 12 million inhabitants, and of this total, one in four lives in peri-urban areas, with high population density, and most without drinking water (Spronk, 2020). In Rio de Janeiro, about 209,386 people live in subnormal agglomerations and do not benefit from the official water supply network. The sewage collection deficit is even greater, affecting 510,077 people (Martins *et al.*, 2021).

Thus, the Covid-19 pandemic must be understood from the lens of society's structural disparities. The WHO has instituted prophylaxis measures to reduce the spread of Covid-19 – mask-wearing, social distancing and handwashing. However, although such recommendations are simple, they have become almost impossible for people who did not have access to safe drinking water and adequate sanitation facilities (Spronk, 2020).

The panorama of global crisis reveals the new and existing differences and should be seen as a central theme of discussion, because throughout the pandemic period, access to drinking water for hygiene, adequate sanitation and health care presented precarious conditions, in order to highlight the urgency of the universality of such services (Nath; Godsling, 2020). The pandemic has managed to highlight the importance of water and adequate sanitation, both for countries in the Global North and for countries in the Global South that face water insecurity, making it difficult to combat the Covid-19 pandemic (Loftus; Farhara, 2020).

The conjuncture of the Covid-19 pandemic made more visible the privileges and disadvantages established in society, while part of the population enjoyed comfortable positions of access to a healthy life, another part was placed in situations of complete vulnerability, exposing the groups with greater inequality in terms of socio-economic class, race and gender (Spronk,



2020). Thus, Albuquerque and Ribeiro (2020, p. 2) reinforce “inequality as a process of spatial selectivity and concomitant production of abundance, wealth and comfort on the one hand, and scarcity, poverty and vulnerability on the other.”

Human rights, such as the realization of economic and social rights, as well as the right to water and sanitation, make people more resilient, while allowing for dialogue about the complexity of challenges and injustices that are often hidden or ignored. Recognizing the human rights to water and sanitation should be seen as a corrective measure, given the deficit of water insecurity, insufficient and inefficient water supply in the countries. The universalization of the rights to water and sanitation must establish pathways for the realization and maintenance of these rights in order to act strongly in the fight against Covid-19 (Loftus; Farhana, 2020). Aguiar and Moretti (2020, p. 23) list the following UN normative criteria on the right to water and sanitation: “a) the availability of these services; (b) quality and safety; (c) its acceptability to users; (d) accessibility; (and) low prices.”

The recognition of the United Nations (UN) aims to minimize existing social inequalities, as these contribute to the spread of diseases of water origin. Therefore, the relationship established by sanitation and the spread of pathogens should be treated as a priority. The pandemic scenario potentiates the spread of the SARS-CoV-2 virus. It is noteworthy that it is possible to detect the presence of RNA of the transmitting virus in domestic sewage, however there is no confirmation of contamination by direct contact with effluents (Freitas; Kuwajima; Santos, 2020).

Although it is possible for the virus to persist in water, there is no evidence of its presence in surface or groundwater, or that it is transmitted through contaminated water. Overall, “the Covid-19 virus is a virus enveloped by a fragile outer membrane. Generally, enveloped viruses are the least stable in the environment and are more sensitive to oxidants such as chlorine” (WHO; UNICEF, 2020, p. 2). Although evidence points to the existence of the virus in water and sewage, it is likely that the virus becomes inactive faster than non-enveloped viruses (WHO; UNICEF, 2020).

The pioneering study by Casanova *et al.* (2009, p. 1898) suggest that “different coronavirus (categories) survived and remained infectious for long periods in different types of water, including reagent water, surface water, and sedimented pasteurized sewage. “However, according to the studies



carried out so far it has not been possible to detect the presence of the Covid-19 virus in drinking water, and based on the evidence, the risk for contamination of water supply is relatively low. On the other hand, it is possible to take some preventive measures for better water security, with protection of water sources, treatment, distribution, collection and consumption, ensuring that treated water is stored properly in homes (WHO; UNICEF, 2020).

In Brazil, the Covid-19 pandemic has generated relevant social impacts in view of the precarious access to water and sanitation in some Brazilian regions. The problems linked to adequate water supply demand greater attention, presenting an emergency situation that puts a significant portion of the population on the front line, especially in coping with the Covid-19 pandemic, since it is known that the main measure of prophylaxis depends on access to water.

In addition, the pandemic has been able to revisit the importance of public policies, which include the need to ensure basic sanitation services for all (Aguiar; Moretti, 2021). However, the poor are disproportionately affected by pandemics due to factors such as lack of access to WASH, poor primary health status and susceptibility to secondary health impacts, among others (Cooper, 2020).

Although there is the development of new ways to make the approximation of health services accessible to minority groups, not all of these people receive the assistance guaranteed by law; the adoption of prevention measures is shown to be the most effective way against the spread of the coronavirus, public awareness campaigns such as frequent hand hygiene, the use of masks and rules aimed at containing crowds of people, form a set of norms propagated on a large scale, which aim to reduce the contagion of the virus (Dutra; Smiderle, 2020), however, the prevention measures listed here, unfortunately are not a reality experienced by all.

The financial crisis also experienced in Brazil is perhaps one of the greatest impediments to the mass dissemination of health care in the country. To circumvent the problems that exist as a result of Covid-19, private institutions join forces in order to minimize the impacts caused by social inequalities. In the public sector, initiatives such as emergency aid and the insertion of the social tariff aim to bring the least assisted population closer to access to water and sanitation. To think about integral health care is to think in a macro perspective to meet demands and face public health problems (Aguiar; Moretti, 2021).



The Covid-19 pandemic is not a great equalizer at all, the complexity of the effects of the pandemic have exposed the structural inequality of the economy plaguing society. It is evident that the impacts of the crisis generated by the pandemic have accentuated socioeconomic inequality (Spronk, 2020). Such a crisis is, therefore, a clear way to draw attention to the most vulnerable groups, specifically because of human rights, social injustice and human solidarity (Vieira; Monteiro; Silva, 2021). In general, this strengthens the importance of sanitation as a preventive form of diseases and quality of life.

## **MATERIAL AND METHODS**

The methodological approach used is exploratory and quantitative. According to Lakatos the quantitative method makes use of large samples and numerical information (Lakatos; Marconi, 2008), and exploratory research “seeks to raise information about a particular object, thus delimiting a field of work, mapping the conditions of manifestation of this object” (Severino, 2017, p. 132).

In this research, an Environmental Sanitation Index (ESI) was elaborated through the application of AF (statistical analysis) considering the issues of attendance of water supply and sewage and the mortality rate of diseases of water origin. This research brings as a contribution the development of the ESI from a set of indicators related to the supply of water and sewage and the mortality rate of diseases of water origin, in order to assist decision makers in the monitoring and evaluation of services in the Brazilian capitals.

For the elaboration of the Environmental Sanitation Index, the following variables were selected (Chart 1).



**Chart 1** | Description of the variables used for the elaboration of the ESI.

Variable	Description	Source
<b>IN015</b> - Sewage Collection Index	It refers to the volume of sewage collected, divided by the result of subtracting the volume of water consumed and the volume of treated water exported, multiplied by 100. <b>Unit of measurement:</b> percentual.	SNIS
<b>IN016</b> - Sewage treatment index	It refers to treated, imported treated and raw exported sewage, divided by the collected and imported raw sewage, multiplied by 100. <b>Unit of measurement:</b> percentual.	SNIS
<b>IN023</b> - Urban Water Service Index	It refers to the urban population served with water supply, divided by the urban population residing in the municipality with water supply, multiplying by 100. <b>Unit of measurement:</b> percentual.	SNIS
<b>IN055</b> - Total water service index	It refers to the total population served with water supply, divided by the resident population of the municipality. <b>Unit of measurement:</b> percentual.	SNIS
<b>IN056</b> - Index of total sewage service referred to municipalities served with water	It refers to the total population attended with sanitary sewage, divided by the total population resident of the municipality with water supply, according to the IBGE, multiplied by 100. <b>Unit of measurement:</b> percentual.	SNIS
<b>MR</b> -Mortality rate	It refers to diseases of water origin, as well as diseases that can be aggravated with inadequate environmental sanitation: cholera, typhoid and paratyphoid fevers, Shigella infection, amebiasis, diarrhea and gastroenteritis presumed infectious origin, other intestinal infectious diseases, other respiratory tuberculosis, remaining respiratory tuberculosis, remainder of other tuberculosis, leprosy, enterohemorrhagic leptospirosis, other forms of leptospirosis, Leptospirosis not specified, remainder of other bacterial diseases, trachoma, yellow fever, dengue, hemorrhagic fever due to dengue virus, remainder of other arbovirus fevers and hemorrhagic fever by virus, acute hepatitis B, mycoses, Plasmodium falciparum malaria, Plasmodium vivax malaria, Plasmodium malariae, other forms malaria confirmed by parasitological tests, unspecified malaria, Visceral leishmaniasis, cutaneous leishmaniasis, unspecified leishmaniasis, schistosomiasis, silariasis, hookworm, other helminthiasis, sequelae of leprosy, other infectious and parasitic diseases. <b>Unit of measurement:</b> percentual.	DataSUS

Source: Elaborated by the authors, 2022.



Considering that until the time of this research, the SNIS did not have more recent information, data from the year 2020 were used. The epidemiological data of the number of cases and deaths by Covid-19 for the Brazilian capitals were obtained through the Open Data SUS platform of the <sup>3</sup> Ministry of Health with the exception of Manaus which did not have data at the time of collection, for this observation in question the data were collected based on Cota (2020). Data collection covered the period from March to December 2020.

All computational routines in this study were performed with the aid of the Statistical Package for the Social Science (SPSS) version 20. In this study, we opted for the Factor Analysis (FA) method, as the technique is strongly used in the elaboration of indexes, as can be observed in the studies of Nirazawa and Oliveira (2018); Ferreira (2020); Ferreira, Silva and Figueiredo Filho (2021) and Mendes (2022).

## STATISTICAL ANALYSIS

AF is one of the most widespread multidimensional data analysis techniques, and has application in several areas of knowledge, being commonly used to reduce the dimensionality of data. AF allows to reduce the number of variables from the grouping of variables that present correlation with each other, in order to minimize the loss of information.

The AF technique makes it possible to identify a small number of factors that represent the behavior of a set of original variables, capable of capturing a large percentage of variance of the observed variables. In this sense, AF uses correlation coefficients to condense variables and generate factors (Hair *et al.*, 2009; Fávero; Belfiore, 2017; Matos; Rodrigues, 2019).

For the application of AF, it is important to observe its suitability and quality. Normally, the adequacy of AF is verified through the Kaiser-Meyer-Olkin test (KMO), which must present an index above 0.5 for the technique to be acceptable. And Bartlett's sphericity test, which points out whether the identity matrix is a correlation matrix. In this case, if the *p-value* of the test is lower than the significance level (5%), the null hypothesis can be rejected, and it is possible to continue with AF (Hair *et al.*, 2009; Fávero; Belfiore, 2017; Matos; Rodrigues, 2019). On the other hand, the

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3 <https://opendatasus.saude.gov.br/dataset>



quality of AF can be observed through i) an overview of the analysis of the factors; (ii) sample size; (iii) methods of factor extraction; iv) number of factors to retain the techniques, and v) types of rotational methods (Taherdoost; Sahibuddin; Jalaliyoon, 2020). For this study, the extraction method by Principal Components and extraction by the orthogonal Varimax method were defined.

The elaboration of the ESI from the AF allows to establish a comparative scenario between the Brazilian capitals, therefore, the capitals that present the highest ESI are the ones that have the best level of coverage for the selected indicators.

The KMO test (0.637) and Bartlett's sphericity test ( $p$ -value  $< 0.001$ ) proved to be adequate and validate the data sample. Another important point that should be observed in AF is the commonalities. The commonalities represent the ability to explain the variance of each variable that can be explained by the factor extracted from the correspondence. It is recommended that only variables with commonalities greater than 0.5 be kept in the sample (Hair *et al.*, 2009). Therefore, the results reveal that all commonalities reached values above 0.583. These criteria can be seen in Table 1.

**Table 1** | Criteria for AF evaluation

Criteria	Values	Factors	
KMO	0,637		
Test of Bartlett's sphericity	(p-valor $< 0,001$ )	<b>Factor 1</b>	<b>Factor 2</b>
Commonalities	IN015 = 0,751	<b>0,793</b>	0,348
	IN016 = 0,583	<b>0,625</b>	-0,439
	IN023 = 0,856	<b>0,923</b>	0,060
	IN055 = 0,873	<b>0,934</b>	0,035
	IN056 = 0,797	<b>0,890</b>	0,067
	MR = 0,837	0,145	<b>0,903</b>
Total variance explained	Rotation sums of loads squared		
	Component	Total	Variance %
			Cumulative %
	<b>1</b>	3,55	59,30
	<b>2</b>	1,13	18,99
			78,29

Source: Elaborated from the SPSS.

Table 1 shows that the first component has an eigenvalue of 3.55 and can explain 59.30% of the total variance of the data, and the second component, with an eigenvalue of 1.13, explains 18.99% of the variance. Cumulatively, the two components explain 78.29% of the total variance of the sample. A sample that explains more than 60% of the total variance of the data is considered

acceptable (Hair *et al.*, 2009).

After the extraction of the factors, the factor loadings are calculated – corresponding to the Pearson correlations between the extracted factors and the original variables. Subsequently, the orthogonal rotation Varimax was applied, and the variables with an absolute value greater than 0.5 were highlighted and grouped (last two columns of Table 1). Note that the variables (IN015; IN016, IN023, IN055 and IN056) that make up Factor 1 are strongly correlated with this Factor, that is, the capitals have good levels for the selected variables. Factor 2 is composed of the variable MR, which is positively related to its Factor. The fact that the variable MR is positively correlated, it can be inferred that the capitals have deaths due to lack of access to environmental sanitation and that there is a good inverse correlation between this variable and Factor 2.

Considering the specificities of the variables that compose Factor 1 and Factor 2, they were called Water and Sewage Care and Mortality from Diseases of Water Origin, respectively.

For the elaboration of the ESI, Factor 1 was considered with a positive contribution, because the higher the percentage, the greater the coverage of sanitation services, and Factor 2 with a negative contribution, considering that the higher the percentage, the higher the number of deaths due to DRIS.

In addition, the AF model generated the scores for each Brazilian capital, which have a normal distribution, with variance 1 and zero mean, in order to measure the variables within each factor. In addition, the ESI was obtained from the calculation of Equation 1.

$$ESI = X_1 * F_1 - X_2 * F_2 \quad (1)$$

Where:

ESI is the Environmental Sanitation Index;  $X_1$  is the total variance explained by Factor 1;  $X_2$  is the total variance explained by Factor 2;  $F_1$  is the Water and Sewage Service; and  $F_2$  is Mortality from water-borne diseases.

To facilitate the presentation of the results, the ESI was normalized. Normalization aims to standardize the data so that they oscillate between 0 and 1, that is, better and worse development (Equation 2).



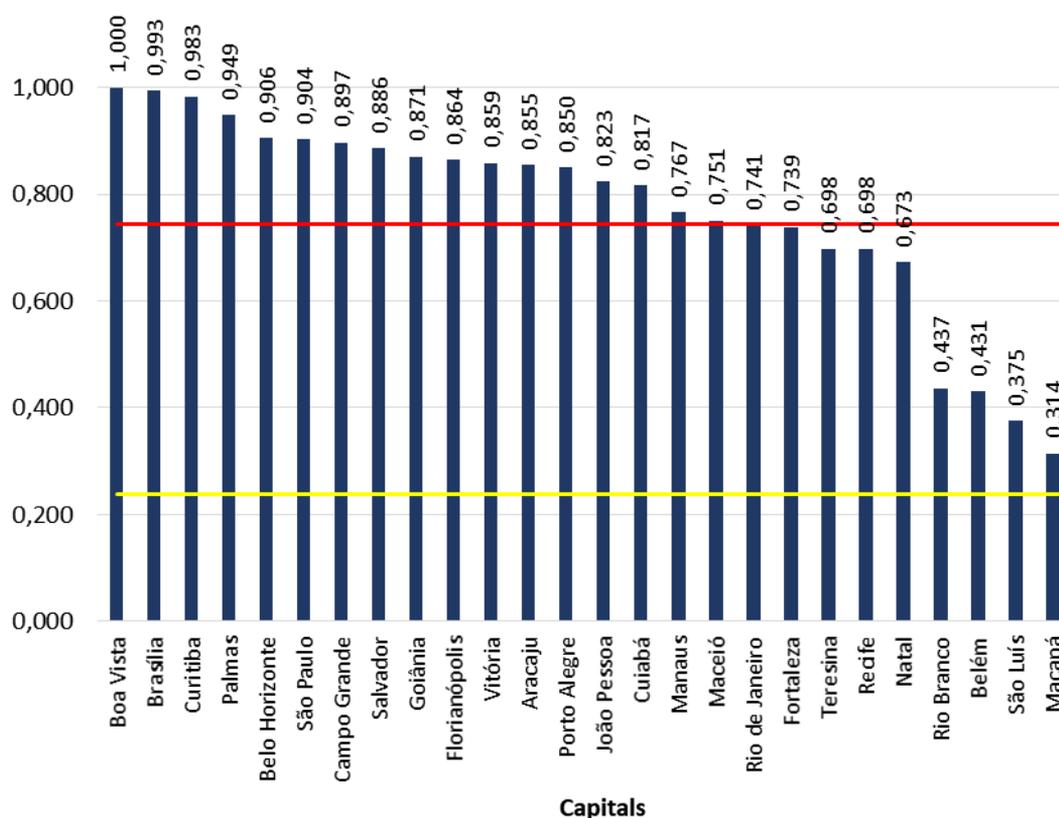
$$ESI = \frac{ESI_i - ESI_{\min}}{ESI_{\max} - ESI_{\min}} \quad (2)$$

In this case, the closer the value is to extreme 1, the more favorable the ESI is for Brazilian cities. On the other hand, the closer to 0 the value is, the worse the ESI is. Next, to examine the relationship between the ESI and the number of Covid-19 cases/deaths in Brazil, Pearson's correlation coefficient was used.

## RESULTS AND DISCUSSION

To fulfill the objective of this research, the variables that make up the ESI are related to the dimensions of water supply and sanitary sewage, since it is from them that the implications and subsequent deaths from diseases of water origin arise. In this sense, the objective was the graphic representation of the ESI for the Brazilian capitals (Figure 1).

**Figure 1** | Environmental Sanitation Index (ESI) of Brazilian capitals.



Source: Elaborated by the authors, 2022.

The red line (Figure 1) represents the mean of the ESI (0.744), and the yellow line the standard deviation (0.238). The closer the result to extreme 1 the better the access to environmental sanitation, and the closer to extreme 0 the worse the access. Therefore, the results reveal that Boa Vista (1,000), Brasília (0.993) and Curitiba (0.983) lead the classification with the best results for access to environmental sanitation. On the other hand, Porto Velho (0.000), Macapá (0.314) and São Luís (0.375) occupy the last positions, that is, they have lower rates of access to environmental sanitation with a greater possibility of contamination and spread of diseases.

It is noted that the capitals with below average values are located in the North and Northeast regions, with the exception of Rio de Janeiro. These regions were identified by Rodrigues, Venson and Camara (2019), Rossani *et al.* (2020) and Sugahara, Ferreira and Prancic (2021) as the regions that most lack access to sanitation services and consequently the furthest from achieving universalization of these services.

It should be noted that although the capital Boa Vista is located in the North region, it obtained the best ESI, possibly for presenting efficiency regarding water supply and sewage services, because according to the ITB (2022a), among the 20 largest cities that invest more in sanitation, the capital Boa Vista is the third city, with 74.64% of investment in the sector. In addition, the National Plan for Basic Sanitation (Plansab) defines the national level of annual average investment per capita of approximately R\$113.30. In this regard, Boa Vista invested more than the baseline, with R\$130.80 per capita, behind only from Cuiabá (R\$213.33), São Paulo (R\$180.97) and Natal (R\$141.21).

In general, there is an economic and demographic profile of the capitals that have more efficiency in sanitation services. Rossoni *et al.* (2020) highlight that geospatial disparities in access to sanitation services can be attributed to the preferential allocation of investments in the Southeast macro-region, unlike what happens in the North and Northeast macro-regions.

In relation to Covid-19 and the ESI, the data analyzed in this study refer to the year 2020 at the national level (Table 2). The issue of the population's access to water and sewage services, especially in the context of the Covid-19 pandemic, was highlighted as a public and service agency challenge, as evidenced by Sugahara, Ferreira and Prancic (2020).



Table 2 shows the result of Pearson's linear correlation coefficient with the number of Covid-19 cases and deaths.

**Table 2** | Correlation between ESI and Covid-19 case and death numbers for 2020.

Month	Correlation	
	Cases	Deaths
March	-0,354	-0,407
April	-0,402	-0,400
May	-0,360	-0,301
June	-0,291	-0,354
July	-0,154	-0,295
August	-0,120	-0,191
September	-0,049	-0,120
October	-0,031	-0,072
November	-0,072	-0,071
December	-0,083	-0,058

Source: Elaborated by the authors, 2022.

In the period analyzed, a decrease in the level of association between cases and deaths can be observed. In general, the period from March to July presented a higher degree of correlation. In addition, it should be noted that all observations had negative contributions, i.e., the more access to sanitation, the fewer Covid-19 cases/deaths.

The correlation presented in Table 2 shows that in April there was the highest level of association (-0.402) for cases, while the most expressive value in relation to the number of deaths was in March (-0.407). Overall, the association between ESI and the number of Covid-19 cases and deaths suggests that access to environmental sanitation services is fundamental in combating and spreading infectious diseases.

For Ferreira, Silva and Figueiredo Filho (2021) quality sanitation is directly linked to the numbers of incidence and mortality from Covid-19, and it is suggested that in areas that have more access to sanitation services, lower are the incidence and mortality rates from Covid-19. In addition, the authors emphasize sanitation as an essential prophylaxis measure in the fight against the disease.



Taking as an example the data from the study conducted by Wu *et al.* (2020), the authors suggest that the presence of the virus in feces may persist for about five weeks after respiratory samples have tested negative for SARS-CoV-2 RNA. Although the scientific framework on the viability of SARS-CoV-2 is developing, the virus can survive in the environment for several days, which can lead to fecal-oral transmission. SARS-CoV-2 RNA has also been identified in wastewater in Australia, indicating persistent elimination of the virus in the feces of infected patients, including patients in an asymptomatic state (Ahmed *et al.*, 2020). In addition, Natarajan *et al.* (2022) measured the dynamics of fecal viral RNA in patients diagnosed with Covid-19 for a period of ten months after confirmation of the disease and observed the persistence of the virus for up to seven months after positive diagnosis.

Previously, the study by Casanova *et al.* (2009) had already discussed a similar hypothesis, where the authors suggested that the event that occurred in 2003 by the SARS-CoV virus could “re-emerge in humans and populations, water contaminated with these viruses may continue to pose a risk of exposure even after infected individuals are no longer present” (Casanova *et al.*, 2009, p. 1898). This hypothesis is pointed out because the SARS-CoV and MERS-CoV viruses are two coronaviruses found in sewage in conditions that promote fecal-oral transmission. In addition, it has been noted that the potential for this category of Covid-19 transmission has serious implications, especially in areas with poor sanitation (Yeo; Kaushal; Yeo, 2020).

An analysis of sanitation indicators in the sub-Saharan Africa region revealed that approximately 783 million people lack access to good quality water, while around 320 million people face water scarcity. In this context, the association between Covid-19 cases and deaths was investigated. The results showed a significant link between deaths from the disease and lack of water and sanitation, highlighting the close relationship between mortality and the absence of adequate services. This reinforces the fundamental importance of hand hygiene with soap and water as an effective measure to contain the spread of the virus, especially among the most vulnerable groups (Amankwaa; Fischer, 2020).

The difficulties of integrating the health sectors and public services are intrinsically linked to social disparity, especially in precarious urban areas, due to the pattern of space occupation, high population density, economic inequality, lack of access to drinking water and basic sanitation. These factors amplify the risks to health conditions (Martins *et al.*, 2021).



Therefore, the results of this study offer valuable information for the management of sanitation services and for service providers, by highlighting the regions most impacted in terms of health due to insufficient water supply and sanitation conditions. A significant contribution of this study lies in the possibility of replicating the methodology in other situations and areas, especially in regions characterized by social vulnerability.

## FINAL CONSIDERATIONS

As responses to the challenges of environmental sanitation in Brazil, in relation to water-borne diseases, there is an undeniable need for investments in municipal collections, as well as investments by service providers in sanitation infrastructure, in addition to expanding public-private partnerships for the environmental sanitation management. This is particularly important from the point of view of public policy formulation, to ensure better performance in the water supply and sanitation system, as a measure to reduce the occurrence of cases and deaths from infectious diseases such as Covid-19.

As discussed in this study, quality environmental sanitation is a measure of disease prophylaxis, and depends on the availability of treated water and the sewage collection network for the entire population, especially in the North and Northeast regions. The study highlights the need to adopt measures to ensure equal access to water and sewage for the entire population, especially in regions more deprived of this service.

Strategies to mitigate the spread of infectious diseases depend on the environmental control of vectors and require efficient coverage of sanitation services, for example, through the expansion of infrastructure, since the greater the access to environmental sanitation, the lower the occurrence of cases and deaths from Covid-19.

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