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Sanitation and the spread of Covid-19 in Brazil

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Abstract

A well-developed sanitation system is essential for protecting human health, including for infectious diseases outbreaks. This study aimed to understand the relation of the provision of clean water and sewage collection with the spread of Covid-19 cases in Brazil. The results show that the heterogeneous levels of water and sewage coverage among Brazilian municipalities show that each percentual point of water coverage and sewage collection reduces, in average, one infection for every 100 000 inhabitants. In conclusion, one may state that advances in this sector are essential to prevent not only infectious and nutritional outcomes very well linked to the lack of sanitation, but also new diseases, such as Covid-19, for which there are still little knowledge and treatment options.

Key word

Covid-19, Sanitation, Clean water

Introduction

The provision of safe water, sanitation and hygienic conditions is essential for protecting human health (WHO, 2020). That is why the United Nation's ("UN") Sustainable Development Goals ("SDGS"), predict the need to ensure clean water and sanitation for all by 2030 (Goal n. 6). The most important effect of ensuring the availability and sustainable management of water and sanitation for all is the improvement of world health.

For instance, during infectious diseases outbreaks, the access to clean water, sanitation and hygiene ("WASH") are essential as a combat instrument (Taylor *et al*., 2015; WHO, 2020). In the outbreak of the new coronavirus disease (SARS-CoV-2, or Covid-19), this is not different.

Among the twenty countries currently most affected by the disease worldwide, Brazil figures the 6th position in number of deaths per 100 000 inhabitants (John Hopkins University of Medicine, 2020). In absolute numbers Brazil figured, by the time this paper was written, in the second place in number of cases (over 1 000 000), with over 36 000 deaths (Ministério da Saúde, 2020a). Despite important political aspects, the country's poor sanitation condition may also be pointed out as one of the main causes of such status: more than 30 million people do not have access to clean water and about half of the inhabitants (99.9 million people) do not have their swage collected (SNIS, 2019).

Considering such scenario, we seek to understand if Brazilian municipalities with worst sanitation indexes account for more cases of Covid-19. For that purpose, this paper will conduct a Negative Binomial Regression to analyze if worse sanitation conditions present positive elation to higher number of covid-19 cases, an adequate method for over-dispersed count data.

This paper is structured as it follows. After this introduction, a brief explanation of the history of the development of the Water and Sanitation (W&S) sector, the relation between sanitation and the spread of different diseases is presented and the spread of

Covid-19 in Brazil. After that, a section describing the data collected and the method chosen to verify the influence of the indicators of sanitation with the number of cases in Brazilian municipalities. The last two sections of this paper present, respectively, the results from the negative binomial regression and a discussion, contrasting the main findings with the existent literature regarding this new disease.

Brazilian sanitation development

The main features of the Brazilian W&S were implemented in the 1970s through the implementation of the National Basic Sanitation Plan ("Planasa"), when a new structural regimen was established for the sector (Heller, 2007). For Motta & Moreira, 2006, Planasa's main aim was to promote the creation of state firms for water supply and sanitation, encouraging municipalities to make long-term concessions to these firms in exchange for investments granted by the National Habitation Bank (BNH), Planasa's financial arm. However, with the bankruptcy of BNH, in 1982, the plan lost its strength affecting the sector development (Margulies, 2018).

Because of its history, one may say that the sanitation sector in Brazil is quite singular. The operators are monopolistic concessionaries in their operation areas and they can be either state public operators (regional) serving a group of municipalities within a state, or municipal-based operators serving one or more municipalities, which can be either directly managed by the municipality or by a private operator (Motta and Moreira, 2006)

Today, the W&S sector in Brazil beholds great inequality. While some municipalities have overcome universalization issues, there is a huge number of cities that require major advances to mitigate the effects of the accumulated social debt (Britto, Lima, Heller, & Cordeiro, 2012). For instance, municipalities of the North and Northeast regions of Brazil have, in average, worse performance in the sector, compared to cities on the South and Southeast regions. Table 1 presents some W&S indicators for some of the biggest cities in different Brazilian regions.

Table 1: Water and sanitation features of some Brazilian cities

City	Region	Population (million people)	Water supply rate (%)	Sewage collection rate (%)
São Paulo	Southeast	12.25	74.23	64.66
Rio de Janeiro	Southeast	6.72	58.63	42.87
Porto Alegre	South	1.5	62.06	49.1
Recife	Northeast	1.7	74.69	74.5
Salvador	Northeast	2.9	31.05	31.01
Manaus	North	2.2	74.23	64.66

Source: IBGE, 2019; SNIS, 2019.

Many studies relate poor sanitation to a number of infectious and nutritional outcomes, such as diarrhea and cholera (Lozano *et al*., 2012, , Taylor *et al*., 2015; Vasquéz & Aksan, 2015, Pruss-Ustun *et al.*, 2016), soil-transmitted helminth (STH) infections (Hotez *et al*., 2006), schistosomiasis, Trachoma (Hu *et al*., 2010) and other diseases. Contamination of water supplies has been historically recognized as a risk for human health, since water can provide a vehicle for pathogen spread, creating the conditions for outbreaks or sporadic cases of infection (La Rosa et al., 2020). In Brazil, viral agents with the greatest public health impact are hepatitis A virus, rotaviruses and noroviruses, adenoviruses, and enteroviruses, which contaminate many Brazilian aquatic ecosystems (Prado & Miagostovich, 2014).

Despite the vast number of papers that relate sanitation levels with infectious diseases, there are only a few studies that relate sanitation to specific viral infections, such as Ebola, SARS, and Covid-19. Nevertheless, with the potential for being part of the environmental transmission, a significant concern regarding the safety of drinking water, wastewater sanitation and the sewages was raised (Venugopal *et al.*, 2020).

Covid-19 in Brazil

Coronaviruses (CoV) are a large family of viruses causing a spectrum of diseases, as Middle East Respiratory Syndrome (MERS-CoV) and Severe Acute Respiratory Syndrome (SARS-CoV; La Rosa *et al.*, 2020). A new accurate respiratory disease, the Covid-19, emerged in December/2019, in Wuhan, China, and spread rapidly around the globe. The outbreak was declared a Public Health Emergency of International Concern on January 30, 2020 and, on March 11, the World Health Organization (WHO) upgraded the status of the COVID-19 outbreak from epidemic to pandemic.

In Brazil, the first official case of Covid-19 was reported on February 26, 2020. The disease spread rapidly and, on June 4th, 2020, when the data for this study were collected, 4 266 from the 5 500 Brazilian municipalities (77.56%) had reported cases of covid-19 in their population (Figure 1). In the same date, the country officially reported 614 941 cases (Figure 2) and 34 021 confirmed deaths (Figure 3).

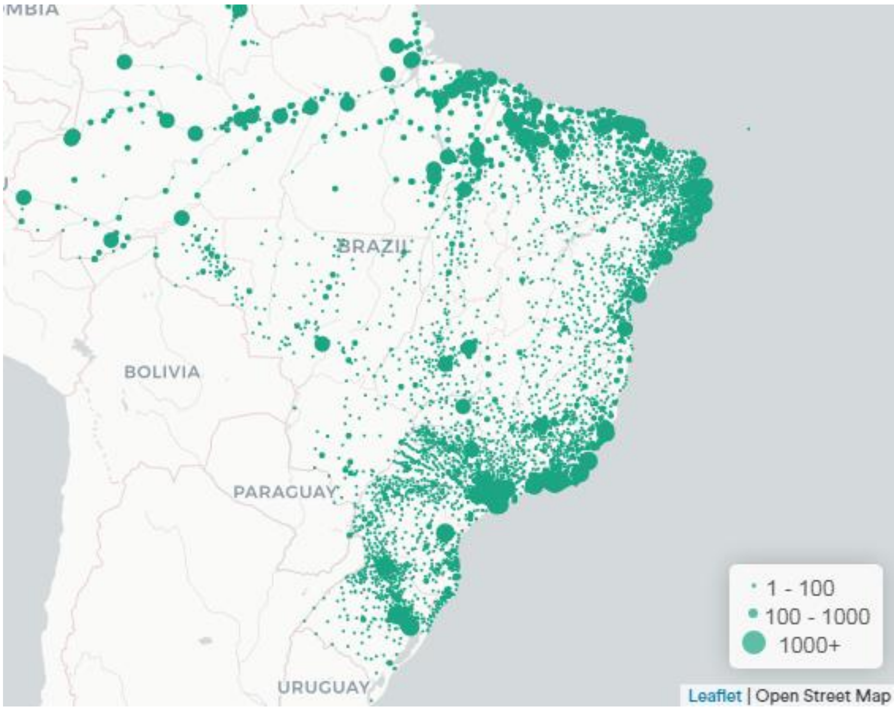

Figure 1: Notified Covi-19 cases by municipalities in Brazil. Source: Ministério da Saúde, 2020b.

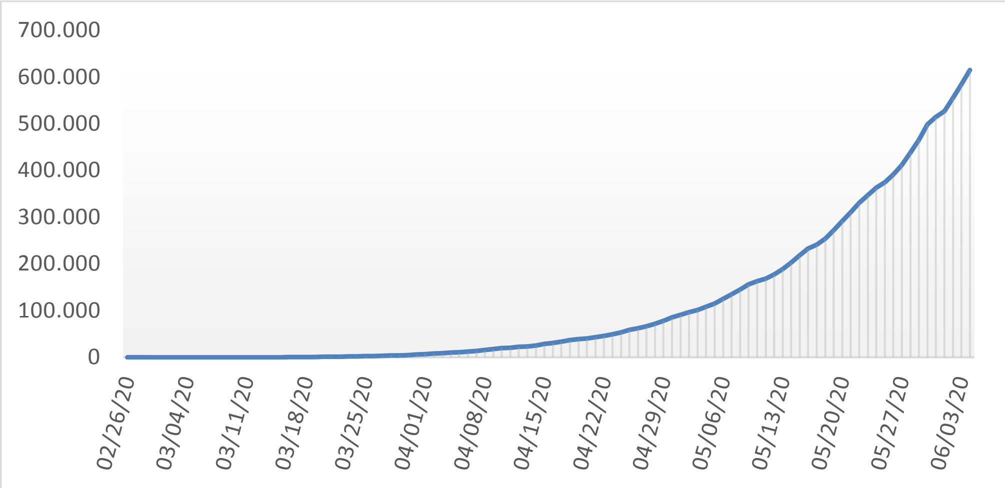

Figure 2: Evolution of the officially reported Covid-19 cases in Brazil. Source: Ministério da Saúde, 2020b.

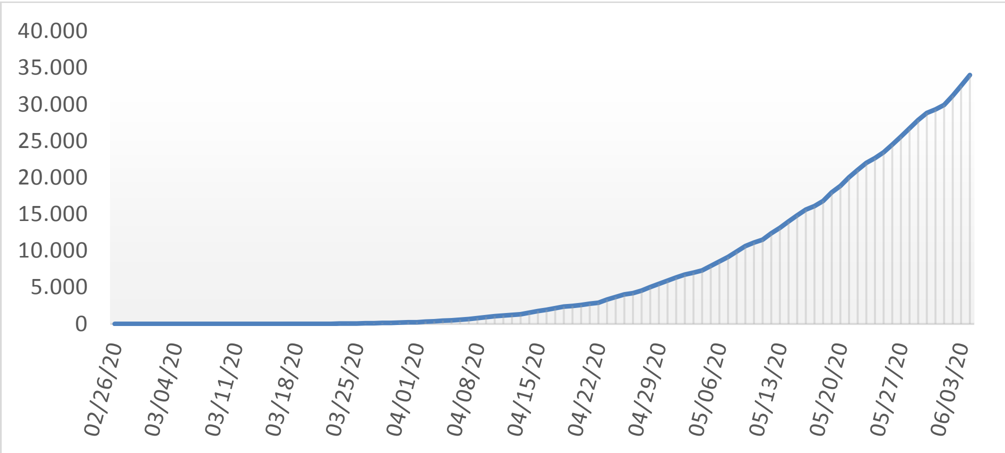

Figure 3: Evolution of the officially reported deaths Covid-19 in Brazil. Source: Ministério da Saúde, 2020b.

Material and methods

To pursue the objective of this paper, the model adopted is based on a Negative Binomial Regression. Such kind of model is a more complex variation of Poisson Regression models, and is less likely to mislead, considering that individual counts are usually more variable ("overspread") than is implied by the Poisson model (Gardner, Mulvey & Shaw, 1995). Due to the variable outcome nature, the regression coefficients are estimated using the method of maximum likelihood. The logarithm of the likelihood function is:

$$LL = \sum_{i=1}^{n} \quad Y_i.ln\ ln\ \left(\frac{\phi.u_i}{1+\phi.u_i}\right) - \frac{lnln\ (1+\phi.u_i)}{\phi} + ln\Gamma(Y_i + \phi^{-1}) - ln\Gamma(Y_i + 1) - ln\Gamma(\phi^{-1})$$

In the model, the dependent variable is the official number of total infection cases for 100 000 inhabitants in each municipality and the explanatory variables are sanitation indicators for each of these municipalities, as presented by the latest report of National System of Sanitation Information ("*Sistema Nacional de Informações sobre Saneamento* – SNIS"), from 2018. The information available on SNIS are the official data for the sanitation situation in each municipality although, since it is self-declared, there may be uncorrected information provided by the municipalities.

The defined model is shown below:

$$ln\ (\lambda)\ = \alpha + IN055\beta_1 + IN056\beta_2 +\ Per\ capita\ income\beta_3$$

In which:
λ = average incidence rate of Covid-19 in 100 000 inhabitants
β_1, β_2 and β_3 = the explanatory variables coefficients.
IN055 = total water supply rate, defined by the percent of the total population of the municipality with access to drinking water source.
IN056 = total sewage collection rate
Per capita income = the per capita income for each municipality, which is used as a control variable.

The use of another control variable, the average number of people living on each residence, was considered important to the study, once household plays an important role in transmission due to the greater strength of contacts between individuals sharing living arrangements (House & Keeling, 2009). In Brazil, in 2018, there was an increase on the percentage of residencies with excessive domiciliary compressing, i.e., households in which there are in average 3 or more people per rooms used as bedrooms (IBGE, 2019). Yet, no reliable and recent data regarding average inhabitants/household in each Brazilian municipality was found to support our study.

The data regarding cases in each municipality were obtained from the Brazilian Health Ministry. The information used refer to cumulative cases on the week 23 from the first case reported in the country. This information was released on June 4th.2020.

Results

The data used includes information of 4 250 municipalities which present cases of Covi-19 among their population on the 23rd week after the virus was firstly reported circulating in the country. An exploratory analysis was firstly conducted to understand the adequacy of negative binomial regression model to the phenomenon data.

Chart 1 shows the frequency of number of cases in each 100 000 inhabitants and Table 2 shows information of average and variance for the data. The information shown indicates, preliminarily, for this analysis, the Negative Binomial Regression model. To confirm such indication, a complementary regression model indicated data overdispersion, for which β is statistically different from zero, at the significance level of 5%, showing that indeed there is a overdispersion and showing that the negative Binomial model is the most adequate (Cameron & Trivedi, 1990).

Chart 1: Frequency of Municipalities X Total number of cases (rounded up for the nearest unity)

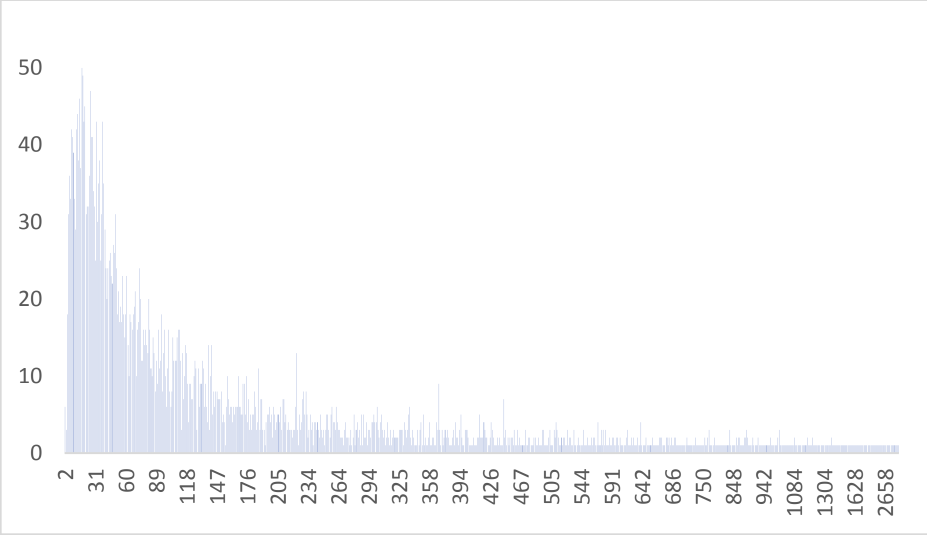

Table 2: Data Statists

Variable	Mean	Variance
Cases per 100 000 inhab.	197,10	120249.7

Table 3: Negative Binomial Regression results

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Negative binomial regression                    Number of obs     =      4,250
                                                LR chi2(3)        =     454.19
Dispersion     = mean                           Prob > chi2       =     0.0000
Log likelihood = -26285.826                     Pseudo R2         =     0.0086
```

cases100kinhab	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
IN055_AE	-.0073742	.0006446	-11.44	0.000	-.0086375	-.0061108
IN056_AE	-.0064492	.00058	-11.12	0.000	-.0075859	-.0053125
percapitaGDP	3.40e-06	8.51e-07	4.00	0.000	1.74e-06	5.07e-06
_cons	5.791537	.0409537	141.42	0.000	5.711269	5.871805
/lnalpha	.2790063	.0187831			.2421921	.3158206
alpha	1.321816	.0248278			1.274039	1.371384

Likelihood-ratio test of alpha=0: chibar2(01) = 1.2e+06 Prob>=chibar2 = 0.000

The results of the negative binomial regression show that both the water supply (IN055) and the sewage (IN056) collection indicators are statistically significant to explain the number of Covid-19 cases per 100 000 inhabitants in each municipality (P>|z| is less than 5%).

Discussion

The relation of water coverage and the incidence of Covid-19 may be explained by the fact that water is an essential aspect of hand hygiene (Freeman *et al.*, 2017), once the provision enables regular hand washing and cleaning (WHO, 2020). Performing hand hygiene and avoid touching one's eyes, nose, or mouth with unwashed hands was included by the WHO as an essential practice for protecting the health against the Covid-19. This is important because, the main routes of transmission are said to be the respiratory droplets, which may land on surfaces where the virus could remain active; thus, the immediate environment of an infected individual can serve as a source of transmission.

The importance of handwashing for the prevention of infectious diseases is known for a long time, since the study of John Snow of the outbreak of cholera in London (Snow, 1860). More recently, Curtis & Cairncross (2003) concluded that handwashing with soap could reduce the risk of diarrhea by 47% and potentially save one million lives in developing countries.

Still regarding handwashing, the World Health Organization (WHO, 2020) points out that the water used does not need to meet drinking water standards and that evidences suggests that even water with moderate fecal contamination may be effective in removing pathogens from hands, if used with soap and the correct technique (Verbyla *et al.*, 2019).

Not yet explored on the literature, but also relevant to prevent the spread of Covid-19, the access to clean water on their households facilitates social distancing by people. This is because population that receives clean water directly in their households do not need to go to wells get water for drinking and sanitize. No studies were found regarding crowding formation near clean water sources in locations where households do not have direct access to clean water. Such case must be also considered when discussing the impacts of water and sanitation on the spread of Covid-19.

In the other hand, the relation of sewage collection percentage to the incidence of Covid-19, in a similar incidence rate ratio, is more difficult to explain using facts, since the risk of transmission of the Covid-19 virus from the feces of an infected person appears to be low (WHO, 2020). Nevertheless, the WHO indicates that there are evidences suggesting that infectious Covid-19 virus may be excreted in feces, since several studies have detected Covid-19 viral RNA fragments in the fecal matter of patients throughout their illness and after recovery (Holshue *et al.*, 2020; Woelfel *et al.*, 2020; Xiao, 2020), and, therefore, places that lack a sewage treatment system may be more likely to be a Covid-19 hotspot.

This study did not include indicators of treated sewage; a great part of inhabitants in Brazil does not have even sewage collection on their households. However, this is an important issue in public policies and on the efforts to prevent infectious disease outbreaks, since the treatment of water may contribute on eliminating virus particles. Venugopal *et al.* (2020) stress that studies on previous coronaviruses, namely SARS and MERS, have shown that these viruses are less resistant and more fragile to water treatment processes than other kinds of viruses.

Another item that requests a more precise analysis are the eight municipalities that are outliers. These municipalities are in the Amazon region, in the states of Amazonas and Amapá, and all of them reported, high levels of Covid-19 incidence per capita. They also have little developed sanitation infrastructure. The main figures of these eight outliers are shown on Table 4. In four from eight Brazilian cities with more relative Covid-19 cases, the inhabitants do not have access to piped water, and in another one, less than 1% of the population have it. More worrisome, seven of them do not present sewage collection.

Table 4: Brazilian Municipalities with the highest incidence of Covid-19 per capita

Municipality	Inhabitants	Total cases	Per capita GDP (R$ in 2019)	Per capita cases	IN055 (%)	IN056 (%)
Pedra Branca do Amapari (AP)	16 502	840	18 577.96	0.050	0.18	0
São Gabriel da Cachoeira (AM)	45 564	2232	7 037.06	0.049	0	0
Serra do Navio (AP)	5 397	243	13 857.88	0.045	35.7	34.9
Japurá (AM)	2 755	122	14 735.73	0.044	0	0
Itapiranga (AM)	9 148	372	11 789.2	0.041	88.57	0
Laranjal do Jari (AP)	50 410	1761	17 885.4	0.035	31.26	0
Santo Antônio do Içá (AM)	21 602	759	7 477.54	0.035	0	0
Tefé (AP)	59 849	2106	12 008.83	0.035	0	0
BRAZIL	**210 147 125**	**610 624**	**36 215,00**	**0.003**	**83.6***	**53.2***

Sources: IBG, 2019; SNIS, 2019. *average.

Conclusions

Sanitation interventions take a considerable to be implemented, therefore, improvements on W&S figures will not take place on the short term. Nevertheless, this study indicated that advances in this sector are essential to prevent not only infectious and nutritional outcomes very well linked to the lack of sanitation, but also new diseases, such as Covid-19, for which there are still little knowledge and treatment options. Developing the W&S sector is a successful way of reducing the spread of many infectious diseases.

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