



Analysis of the effects of COVID-19 on the household solid waste collected in 22 Brazilian capitals

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Abstract

Objective: The principal aim was to analyze the effects of COVID-19 on the household solid waste collected in 22 Brazilian capitals.

Methodology: Descriptive approach, including the selection of Brazilian capitals and data analysis of household solid waste (RSD, acronym in Portuguese) by literature review and consultation of institutional platforms in digital media, at the beginning of the pandemic.

Relevance: The pandemic required adaptations by local managers and the establishment of guiding protocols for the prevention of the virus, which triggered emergency adaptations in the daily operations of RSD collection, especially in Brazilian capitals.

Results: In the analyzed period, the capitals with the highest number of accumulated cases of COVID-19 were São Paulo, Brasília and Rio de Janeiro. Regarding 22 capitals analyzed, three have COVID-19 contingency plans for solid waste and, 16 of them has showed complementary guidelines for solid waste management. There was a reduction of household solid waste collected in April and May 2020, soon after the virus spread in the country.

Contributions: The main contributions were a quantitative description of RSD collected in Brazilian capitals, an identification of procedures adopted in the analyzed period and, a set of preliminary initiatives to improve management in the sector.

Conclusion: The pandemic outbreak to COVID-19 generated emergency adaptations in the collection of household solid waste and lack of data disclosure, even after a year of pandemic in Brazilian capitals. In this field, the proposed initiatives have the capacity to mobilize municipalities towards sustainability and resilience in the post-pandemic.

Keywords: Household solid waste. Covid-19. Resilient cities.

Análise dos efeitos da COVID-19 nos resíduos sólidos domiciliares coletados em 22 capitais brasileiras

Resumo

Objetivo: O objetivo principal foi analisar os efeitos da COVID-19 aos resíduos sólidos domiciliares coletados em 22 capitais brasileiras.

Metodologia: Abordagem descritiva, incluindo a seleção de capitais brasileiras e análise de dados de resíduos sólidos domiciliares (RSD) por revisão bibliográfica e consulta a plataformas institucionais em meio digital, no início da pandemia.

Relevância: A pandemia exigiu adaptações dos administradores locais e o estabelecimento de protocolos norteadores à prevenção do vírus, o que desencadeou adaptações emergenciais nas operações diárias da coleta de RSD, especialmente nas capitais brasileiras.

Resultados: No período analisado, as capitais com o maior número de casos acumulados de COVID-





19 foram São Paulo, Brasília e Rio de Janeiro. Considerando as 22 capitais analisadas, três possuem planos de contingência à COVID-19 para resíduos sólidos e, 16 delas apresentam diretrizes complementares à gestão de resíduos sólidos. Houve redução dos resíduos sólidos domiciliares coletados em abril e maio de 2020, logo após a disseminação do vírus no país.

Contribuições: As principais contribuições foram a descrição quantitativa de RSD coletados em capitais brasileiras, a identificação de procedimentos adotados no período analisado e, um conjunto de iniciativas preliminares para melhoria da gestão pública no setor.

Conclusão: O surto pandêmico à COVID-19 gerou adaptações emergenciais na coleta de resíduos sólidos domiciliares e ausência de divulgação de dados, mesmo após um ano de pandemia nas capitais brasileiras. Neste campo, as iniciativas propostas têm a capacidade de mobilizar os municípios à sustentabilidade e resiliência no pós-pandemia.

Palavras-chave: Resíduos sólidos domiciliares. Covid-19. Cidades resilientes.

Análisis de los efectos del COVID-19 en los residuos sólidos domésticos recogidos en 22 capitales brasileñas

Resumen

Objetivo: El objetivo principal fue analizar los efectos del COVID-19 sobre los residuos sólidos domiciliarios recolectados en 22 capitales brasileñas.

Metodología: enfoque descriptivo, incluyendo la selección de capitales brasileñas y análisis de datos de residuos sólidos domiciliarios (RSD) por la revisión de literatura y consulta de plataformas institucionales en medios digitales, al comienzo de la pandemia.

Relevancia: la pandemia requirió adaptaciones por parte de los administradores locales y el establecimiento de protocolos de dirección para la prevención del virus, lo que desencadenó adaptaciones de emergencia en las operaciones diarias de recolección de residuos sólidos domiciliarios (RSD), especialmente en las capitales brasileñas.

Resultados: en el período analizado, las capitales con mayor número de casos acumulados de COVID-19 fueron São Paulo, Brasília y Río de Janeiro. Considerando las 22 capitales analizadas, tres cuentan con planes de contingencia COVID-19 para residuos sólidos y, 16 de ellas cuentan con lineamientos complementarios a la gestión de residuos sólidos. Hubo una reducción en los residuos sólidos domésticos recolectados en abril y mayo de 2020, poco después de la propagación del virus en el país.

Contribuciones: Los principales aportes fueron la descripción cuantitativa de las RSD recolectadas en las capitales brasileñas, la identificación de los procedimientos adoptados en el período analizado y un conjunto de iniciativas preliminares para mejorar la gestión pública en el sector.

Conclusión: El brote pandémico de COVID-19 generó adaptaciones de emergencia en la recolección de residuos sólidos domiciliarios y falta de divulgación de datos, incluso después de un año de pandemia en las capitales brasileñas. En este campo, las iniciativas propuestas tienen la capacidad de movilizar a los municipios a la sostenibilidad y la resiliencia en la pos-pandémica.

Palabras clave: Residuos sólidos domésticos. COVID-19. Ciudades resilientes.

1 Introduction

The pandemic beginning in the national territory was registered on February 26, 2020 in the state of São Paulo, and disseminated throughout the nation, especially after the identification of new variants in the country. Vaccination was an initiative, among others, which contributed to reduce the number of cases, guaranteeing the first dose to 73,58% of the Brazilian population and, practically, to 58,87% of the population immunized with one or two doses until November 2021 (BRAZIL, 2021).

At the beginning of the outbreak, information on the contamination capacity of SARS-CoV2 in human beings was incipient and, after a year of the virus permanence, there was



recognition of the importance of large-scale vaccination to decrease the number of cases in the world (WHO, 2021).

The most common symptoms of COVID-19 are fever, tiredness and dry cough, which may cause body aches, nasal congestion, headache, conjunctivitis, sore throat, diarrhea, loss of taste or smell, skin rash or skin discoloration of fingers or toes (WHO, 2020).

From the beginning of the pandemic until November 2021, preventive measures have been kept, such as washing hands with soap and water, applying alcohol with a concentration greater than 70%, using masks in collective environments, maintaining physical distance between people, as well as avoiding touching the face, nostrils and eyes (WHO, 2021).

In Brazil, the challenges of COVID-19 became recurrent due to the characteristics of transmission, when regarding a context of high social inequity, with populations in precarious conditions of housing and sanitation, without access to drinking water and in a situation of urban agglomeration (Werneck & Carvalho, 2020).

On the other hand, some researchers have identified the need to observe the permanence of the virus on surfaces, which raises concerns about solid waste collected in cities. Researches on the persistence of the virus on surfaces, contaminated objects and effluents indicates that solid waste can be a vehicle for transmitting SARS-CoV2 to the population as well as to collection, treatment and final disposal of solid waste agents, as pointed out by Araújo & Silva (2020).

The main contributions of this research were the description of the scenario of collected solid waste in Brazilian capitals, the identification of procedures adopted in the period of analysis, and the proposition of measures for improvement of the solid waste collection, addressing the cities' resilience.

2 Literature review

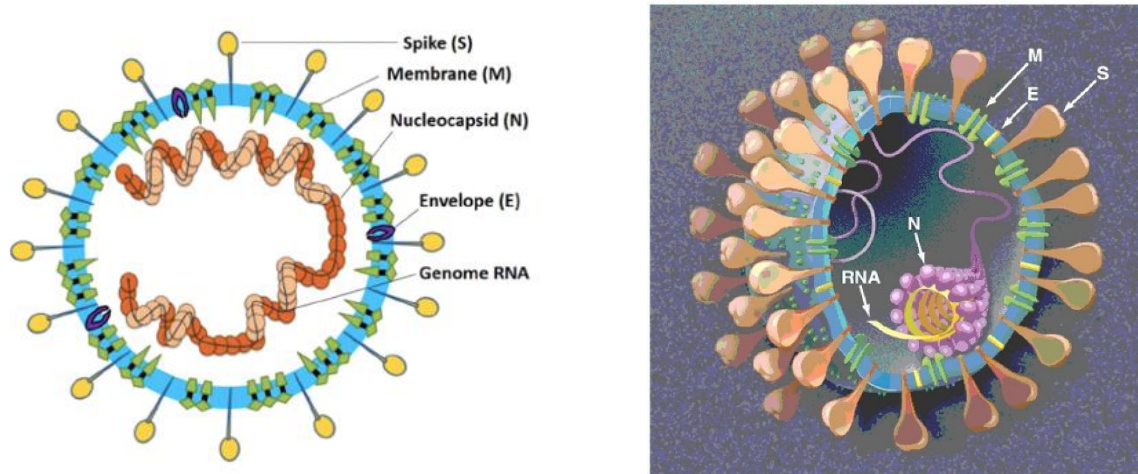
COVID-19 is transmitted through secretions or droplets from individuals contaminated via the eyes, nose and mouth (PAHO, 2020; WHO, 2020).

The virus has a spherical shape and its structure is composed of a double layer of lipids that envelop the virus (Figure 1). The infection properties of the virus come from the proteins of the aforementioned envelope, which have a crown at their end ('corona' in Latin), configuring the family name of said virus (Fehr & Perlman, 2015; Weiss & Navas-Martin, 2020).



Figure 1

Structure of SARS-CoV-2



Note: M: lipid membrane; S: virus's spike in contact with the cell receptors; E: glycoprotein wrap; RNA+: viral genetic material; N: protein capsid.

Source: Li *et al.* (2020); Uzunian (2020).

The survival of the virus in materials depends on the type of surface, the temperature of the environment, the relative humidity of the air and their inherent characteristics (Kamph *et al.*, 2020; WHO, 2020a; Nghiem *et al.*, 2020). According to these authors, the persistence of SARS-CoV2 is up to 9 days, with emphasis on cardboard (24h), stainless steel (72h), aluminum (5d), paper (5d) and plastic (9d).

The pandemic required the participation of different levels of the Unified Health System (SUS, acronym in Portuguese) to better manage the obstacles imposed by the virus, as well as the society and private companies participation to minimize the risk of SARS-CoV2 in the urban context (Fiocruz, 2020a). Thus, the principal element of public management was the municipalities' resilience to adapt to the new demands of urban and health infrastructure, culminating into the need of reviewing public policies for active mobility, energy efficiency and urban ecosystem services to thrive in the post-pandemic, according to WRI (2021).

In this context, the collection of municipal solid waste (RSU, acronym in Portuguese) becomes relevant in the pandemic, due to changes and/or maintenance of daily operations in some Brazilian capitals, as there were adaptations made to the route, frequency and resources for the hygiene and safety of employees and trucks (Fan *et al.*, 2020).

Against COVID-19, protocols for the safe management of regular collection or reduction of selective collection were carried out, considering preliminary information by national and international authorities (Ventura *et al.*, 2021). The priority of the emergency plans was to guarantee the protection of workers in the collection, transport and sorting and recycling centers of MSW and recyclable materials (Araújo & Silva, 2020).



For the safe management of solid waste, national and international authorities proposed control measures (Table 1). The main guidelines for the segregation and collection of MSW were the individual separation of material contaminated with SARs-CoV2, usage of double or triple bags with sanitizing substances and the COVID-19 identification in the collected material.

Another point worthy of attention is the social vulnerability of both the population and solid waste collection professionals. Mishra, Gayen & Haque (2020) studied the subunits of four main Indian metropolises by a vulnerability index on COVID-19 and highlighted that vulnerability, social distance and lockdown had failures in the studied areas, mainly due to non-compliance with preventive measures and the terrible infrastructure conditions in the poorest areas. Ventura *et al.* (2021) identified the importance of the researches associated with social vulnerability mapping and solid waste collection as one of the resources for studying the disease and living conditions in the municipality.

Informal waste pickers have worked individually or in cooperatives not bound to municipal service, and do not have emergency financial aid to the pandemic, making them vulnerable to the risk of contamination due to the necessity of having said service performed (Penteado & Castro, 2020).

Through the pandemic, the fragility of the SUS became evident as shown by the lack of appropriate university resources in the cities and by regional disparities. Investments in the health system increase the resilience of SUS and also allow the gradual absorption of adverse effects caused by economic and political impacts (Massuda *et al.*, 2018).



Table 1

Guidelines for solid waste management with SARS-CoV2

Solid waste management phases	Institutions
<p>Segregation 1- Advise employees about differentiated collection (handling method, use of Personal Protective Equipment (PPE) by type of collection); 2- Intensify the hygienization of PPE, changing rooms, cafeterias and other work areas, as well as vehicles and containers, whenever possible with the use of disinfectants; 3- Establish specific protocols or review those in order to protect the health of workers, especially during contact with waste; 4- Guide the population on recommendations for separating solid waste (contaminated or suspected of being) from common materials</p>	ABES CEMPRES ISWA WHO
<p>Conditioning 1- In confirmed cases of COVID-19 or suspicion of disease, guide the population about the recommended protocol for conditioning solid waste (double or triple resistant bags, sealed and identified, with referral to conventional collection); 2- The types of waste in the previous item include handkerchiefs, clothes, fabrics, masks, gloves and other contaminated items; 3- Segregate the waste from health care activities in double red bags with seals and identification</p>	ABES ABRELPE ANVISA SS-DF BMJ ISWA WHO
<p>Storage 1- All solid waste with SARS-CoV-2 must be stored separately at homes, in ventilated places, until its disposal for conventional/regular collection; 2- Store recyclable materials in open paper bags or in rigid plastic containers (bins or baskets) for at least three days (72 hours) before disposal in containers, during quarantine, before handling by waste pickers; 3- Observe the persistence of the coronavirus on surfaces for recyclable waste</p>	ABES CEMPRES BMJ WHO
<p>Collection and final destination 1- Increase the frequency of regular solid waste collection service, especially in the most precarious and peripheral regions; 2- Structuring a new collection route for households with waste identified with the label "COVID-19"; 3- Do not interrupt regular collection and urban cleaning since it is an essential service; 4- Interrupt selective collection and provide temporary social assistance to waste pickers by the local government; 5- Carry out selective collection only in homes without confirmation by COVID-19; 6- Increase the frequency of coverage of waste deposited in landfills; 7- Increase the number of work teams for cleaning and removal of waste discarded in inappropriate places; 8- Prohibit waste disposal with COVID-19 in selective collection or abandoned on public roads</p>	ABES ABRELPE CEMPRES CETESB MNCR ACR+ ISWA ONU

Note: Institutions: Brazilian Association of Sanitary and Environmental Engineering (ABES, acronym in Portuguese); Brazilian Association of Public Cleaning and Special Waste Companies (ABRELPE, acronym in Portuguese); Association of Cities and Regions for Sustainable Resource Management (ACR+); British Medical Journal (BMJ); Business Commitment to Recycling (CEMPRE, acronym in Portuguese); São Paulo State Environmental Company (CETESB, acronym in Portuguese); International Solid Waste Association (ISWA); National Movement of Recyclable Material waste pickers (MNCR, acronym in Portuguese); United Nations (UN); Federal District Health Department (SS/DF); British Medical Journal (BMJ); World Health Organization (ONU, acronym in Portuguese).

Source: Ventura *et al.* (2020).

The contingency plan for COVID-19 promotes recommendations for RSU management, among which household solid waste stands out, which mostly belong to IIA Class – non-hazardous and non-inert (ABNT, 2004). In this perspective, the collected RDO





mass in Brazilian capitals is significantly higher than the medium and small municipalities due to the population number, by diversity of offered services, class of collected solid waste and type of generator, among other factors.

The type of RSU included in this research was the household solid waste. Thus, the main objective of this research was to analyze the effects of COVID-19 on the Household Solid Waste (RSD, acronym in Portuguese) collected in 22 Brazilian capitals.

3 Methodology

The methodology was developed from a descriptive approach, considering i) the selection of Brazilian capitals with solid waste plans and guidelines in times of pandemic, along with the number of registered cases in Brazilian capitals and, ii) data analysis on collected RSD in these locations, regarding the literature review for structuring the database in an electronic spreadsheet.

As a hypothesis for this research, the pandemic outbreak of COVID-19 required fast interventions by the local administrative government, in order to adapt the collection of household solid waste and to make such adaptations available to the population in digital media. Through these adjustments, the solid waste collection in the cities decreased (ABES, 2020d).

3.1 Selection of Brazilian capitals

The daily operations of solid waste collection were affected by the outbreak of COVID-19, from the solid waste management plan. The consulted databases were Web of Science, Scopus, Journal Portal of the Coordination for the Improvement of Higher Education Personnel (CAPES), Scientific Electronic Library Online (SciELO), World Health Organization (WHO), Pan American Health Organization (PAHO), Unified Health System (SUS) and Brazilian Association of Sanitary and Environmental Engineering (ABES) with the strings COVID-19, SARS-CoV2, pandemic, solid waste management, household waste collection, safety protocols and risk management.

The existence of information on the solid waste collection, the pandemic contingency plan and the COVID-19 cases were not observed equally in every object of study, due to the absence of a unified database at the national and state scale. This stage required a long investigation time for consulting different institutions and authorities in the capitals, especially for the sake of data updating.

Thus, 22 Brazilian state capitals with common data were selected for collection, (Aracaju, Belém, Belo Horizonte, Brasília, Campo Grande, Cuiabá, Curitiba, Fortaleza,



Florianópolis, Goiânia, João Pessoa, Macapá, Maceió, Natal, Palmas, Porto Alegre, Recife, Rio de Janeiro, Salvador, São Luís, São Paulo and Teresina), from February to October 2020.

Some information could be presented until June 2021. Some capitals did not present data after the aforementioned period, which made updating said data unfeasible.

3.2 Analysis of solid waste data collected in selected capitals

The collected RSD mass was obtained from the ABES surveys (2020a; 2020b). The adherence to social isolation in capitals was obtained from municipal and/or state government documents. The registration of COVID-19 cases and deaths was obtained from the Ministry of Health's national platform.

For solid waste collection before the pandemic, the National Sanitation Information System (SNIS, acronym in Portuguese) was consulted, whose report was prepared yearly by the Ministry of Regional Development, from 2013 to 2018. Thus, the analysis was developed based on the consolidation of said data in an electronic spreadsheet, concurrently with the bibliographic review.

4 Results and Discussions

4.1 Guidelines for solid waste in the COVID-19 contingency plan

Among the 26 Brazilian capitals, the study included the analysis of 22 of them, of which are 3 in the North, 9 in the Northeast, 4 in the Midwest, 3 in the Southeast and 3 in the South. From 22 capitals, it was observed that 13 (59%) of them presented the contingency plan for COVID-19 supported by the municipal government (Table 2).

The majority of said capitals (86.4%) studied in this research (Table 1) have not presented a contingency plan for RSD, even though there is a specific plan for the prevention of COVID-19. Also, most of the capitals (72.7%) had prepared a document with another nomenclature for RSD management during the pandemic. Among the 22 capitals analyzed (Table 2), the largest number of accumulated cases of COVID-19 until June 2021 were in São Paulo (857,318), Brasília (431,151) and Rio de Janeiro (368, 354).

Thus, most of these capitals have no specific plan for solid waste during the pandemic, although the subject has been addressed/presented through guidelines or guidelines collection.



Table 2

Guidelines for Covid-19 Contingency Planning and RSD Management

Region	Capitals	Population	Date of the 1st case	Origin of the PC to Covid-19	Existence of PC to RSD	Existence of guidance RSD/ Covid-19	Accumulated cases of Covid-19 (jun.2021)
North	Belém	1.514.765	18/03/2020	PM	No	Yes	162.622
	Macapá	503.327	20/03/2020	PE	No	No	56.905
	Palmas	350.113	18/03/2020	PM	No	Yes	52.313
Northeast	Aracaju	657.013	14/03/2020	PM	No	No	120.810
	Fortaleza	2.669.342	15/03/2020	PM	Yes	Yes	249.953
	João Pessoa	809.015	18/03/2020	PE	No	No	99.212
	Maceió	1.018.948	03/03/2020	PE	No	Yes	82.860
	Natal	884.122	12/03/2020	PM	No	Yes	94.198
	Recife	1.645.727	12/03/2020	PM	No	Yes	135.212
	Salvador	2.872.347	25/03/2020	PE	No	No	224.988
	São Luís	1.101.884	19/03/2020	PE	No	Yes	42.709
	Teresina	846.845	19/03/2020	PM	No	Yes	100.323
Midwest	Brasília	3.015.268	05/03/2020	Distrito	No	Yes	431.151
	Campo Grande	905.540	14/03/2020	PM	No	Yes	120.402
	Cuiabá	612.547	19/03/2020	PE	No	No	93.427
	Goiânia	1.516.113	12/03/2020	PE	No	Yes	163.154
Southeast	Belo Horizonte	2.512.070	16/03/2020	PE	No	Yes	236.958
	Rio de Janeiro	6.718.903	05/03/2020	PM	Yes	Yes	368.354
	São Paulo	12.252.023	26/02/2020	PM	Yes	Yes	857.318
South	Curitiba	1.933.105	12/03/2020	PM	No	Yes	171.593
	Florianópolis	500.973	12/03/2020	PM	No	No	77.190
	Porto Alegre	1.483.771	11/03/2020	PM	No	Yes	135.629

Note: PC (acronym in Portuguese): Contingency plan; RSU (acronym in Portuguese): Municipal Solid Waste; PM(acronym in Portuguese): Municipal Plan; PE(acronym in Portuguese): State Plan; SUS: Unified Health System (acronym in Portuguese)

Fonte: Elaborated by the authors from SUS (Brazil, 2020).

4.2 Household solid waste collected in the selected capitals

From the average of the daily RSD collection from March to May 2020 (column 3), a significant variation of collected RSD among the capitals was seen (Table 3). Column 2 illustrates the average of the obtained values in the capitals per region, noting that the North region had the lowest collection (1.73 kg/inhabitant x d) of RSD, while the Northeast region presented the highest rate (2.58 kg/inhabitant x d). In general, the RSD collection between March and April was greater than 200 grams per capita per day (column 3), while between April and May 2020, there was a reduction in the collection of said material compared to the period in 2020 (Table 3).



By the columns 5 and 6, there was a reduction in values compared to the previous month, based on the average collected daily RSD. When analyzing the RSD collection by region (column 6), it was observed that there was a reduction in most capitals analyzed (Table 3) between April and May 2020, inversely from March and April 2020 data.

In the period of greater social flexibility, the collection of RSD suffered a retraction regarding was observed by 5 and 6. That is, the average of RSD was lower than in the previous month. Data on MSW collected in Campo Grande and Cuiabá in May 2020 by ABES (2020b) were not obtained. Thus, the average considered the months of March and April 2020 for both capitals.

Table 3

Average of collection RSD (kg/hab.d) for capitals from March to May 2020

1-Region	2-Capitals	3-Average daily collection RSD CAPITAL	4-Average daily collection RSD REGION-March	5-Average daily collection RSD REGION-April	6-Average daily collection RSD REGION-May
North	Belém	1,78			
	Macapá	1,29	1,73	0,190	-0,005
	Palmas	2,13			
North East	Aracaju	2,56			
	Fortaleza	2,05			
	João Pessoa	2,59			
	Maceió	4,24			
	Natal	2,06	2,58	0,222	-0,511
	Recife	2,50			
	Salvador	2,58			
	São Luís	2,65			
	Teresina	1,96			
		Brasília	2,13		
Midwest	Campo Grande	2,50	2,25	0,200	0,014
	Cuiabá	2,30			
	Goiânia	2,24			
Southeast	Belo Horizonte	2,25			
	Rio de Janeiro	1,97	2,20	0,200	-0,009
	São Paulo	2,39			
South	Curitiba	1,97			
	Florianópolis	2,66	2,14	0,333	-0,291
	Porto Alegre	1,80			
Average among the studied capitals		2,30	2,18	0,229	-0,160

Source: Elaborated by the authors, based on ABES (2020a, 2020b).

The average collection of RSD collection per capita (kg/inhabitant.day), between 2013 and 2018, considers the data from each of the Brazilian capitals studied, according to the SNIS. In this document, the capitals are the biggest generators of RSD in their respective





regions. The average of the collected RSD in the 22 capitals of the study were calculated (Figure 2)

Figure 2

Annual average of collected RSD mass (kg/inhabitant.day) in selected capitals, in the period from 2013 to 2020



Source: Elaborated by the authors, from Brazil (2018; 2017, 2016, 2015, 2014, 2013); ABES (2020a, 2020b).

At the beginning of the pandemic in 2020, it was observed that the five capitals with the highest annual average of RSD collected were Palmas (North), Goiânia (Midwest), São Paulo (Southeast) and Porto Alegre (South) and Maceió (Northeast), as seen in Figure 2.

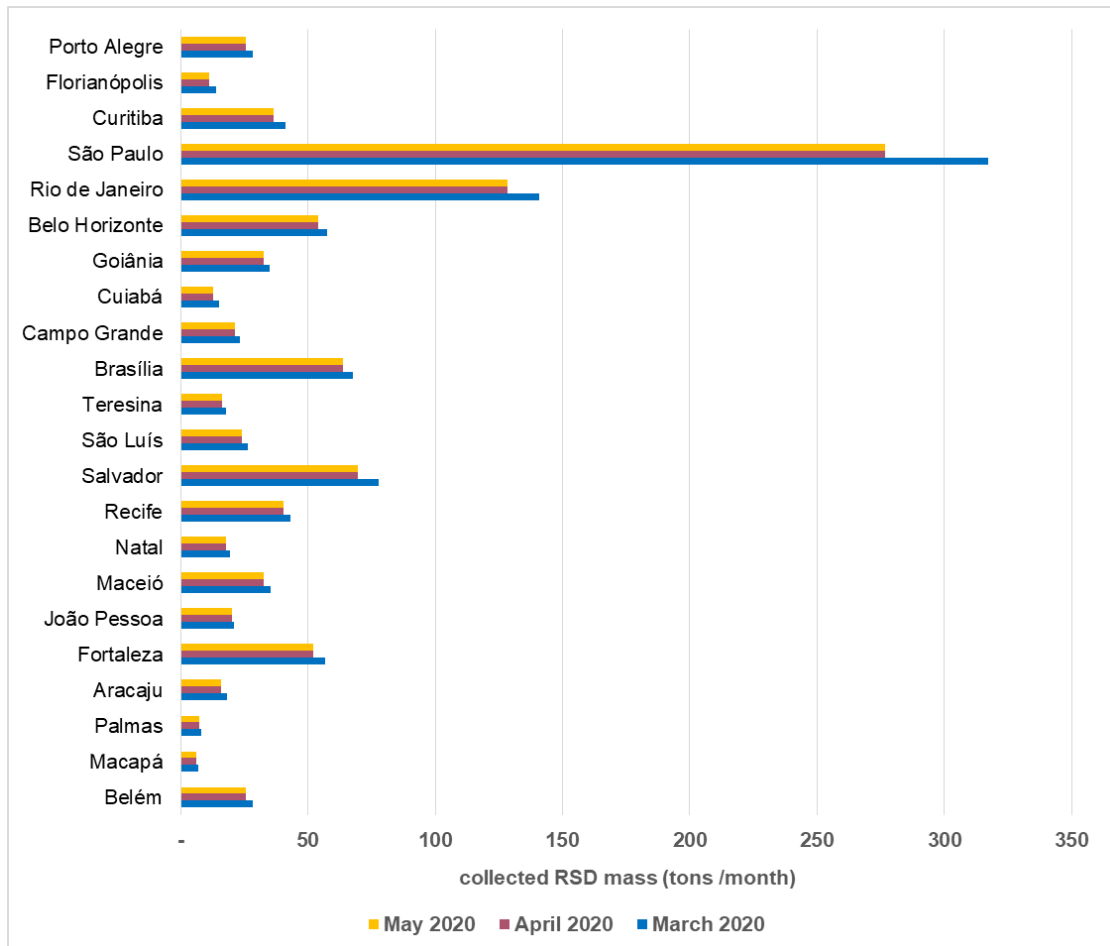
However, when analyzing the mass of RSD collected (t/month) from March to May



2020, the following highlights were observed: Belém (North), Brasília (Midwest); São Paulo (Southeast), Curitiba (South) and Salvador (Northeast), as shown in Figure 3.

Figure 3

Collected RSD mass (tons/month) in Brazilian capitals from March to May 2020



Source: Elaborated by the authors, based on ABES (2020a; 2020b).

It should be noted that for most capitals, in the period of greater adherence to social isolation, the months of April and May/2020 were those with the lowest collection of RSD, which was observed by Albuquerque (2020), who estimated the reduction of RSD in 7.25% for the month of April/2020. The RSD collection values, in the month of May 2020, for Campo Grande and Cuiabá were not obtained and are absent in Figure 3.

The ABES research (2020c) illustrated that in the period of greater social isolation, the collection of RSD was lower, in particular for the months of March and October 2020 in the capital of Belém, and between March and August 2020 in Curitiba.

Based on the presented scenario, associated with COVID-19, the concern extended to the permanence of the virus on different surfaces, such as the different materials collected in the conventional/regular and selective collection. SARS-CoV-2 is more likely to survive in



environments with lower temperatures and relative humidity. Thus, the number of cases increases in regions with a cold and dry climate, such as in temperate zones, according to Aboubakr *et al.* (2020).

The management of municipal solid waste is deemed an essential and indispensable service for contributing to the mitigation of the transmission of infectious diseases, according to Nghiem *et al.* (2020) and Penteado & Castro (2020). Thus, Kulkarni & Anantharama (2020) state that the presence of any potential source of contamination in solid waste collected in health and residential facilities with positive cases of Covid-19 externalizes the risk to the health of professionals and those handling such waste.

The inadequate management of solid waste, due to insufficient treatment or incorrect disposal, increases the risk to human and natural health, according to Klemes *et al.* (2020). However, no studies were observed that establish a correlation between the increase in cases of COVID-19 with the generation of solid waste and, mainly, the existence of scientific evidence on the effective contamination by this source.

4.3 Experiences identified with solid waste collection in Brazil

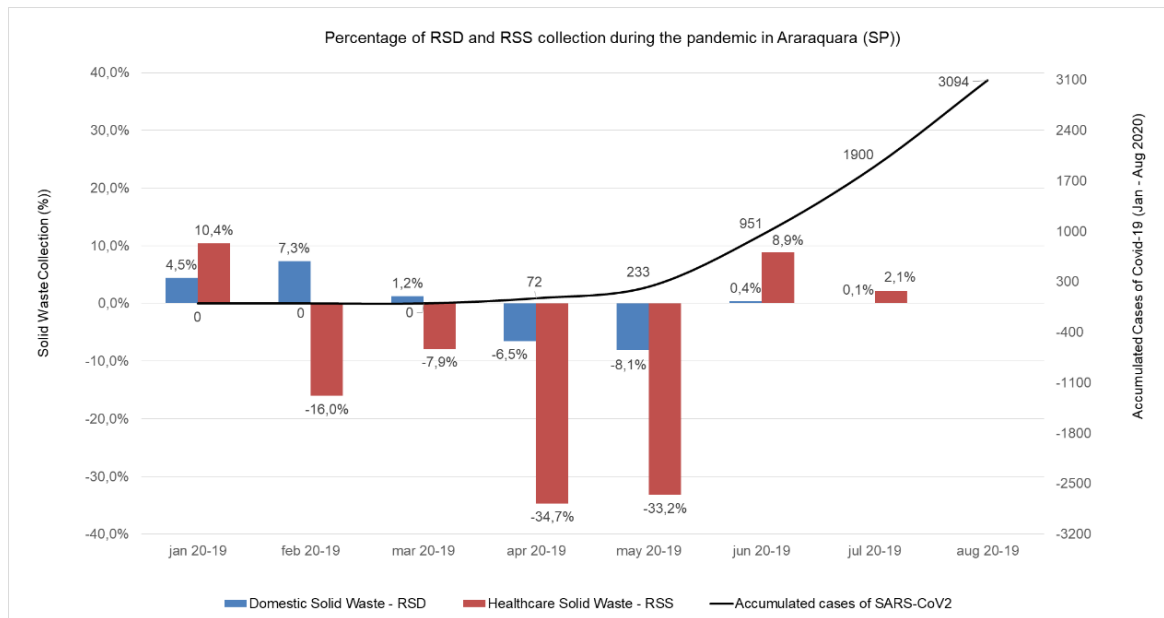
There are few studies with municipal data on the collection of RSD or recyclable solid waste. The city of Belo Horizonte has implemented the preventive sanitation of recyclable waste. The recommendation is to apply the sodium hypochlorite solution to recyclable waste after its segregation in homes and in the collection truck while receiving these materials. Waste pickers and recyclable collection operators receive personal protective equipment. When these materials arrive in the shed, they receive another application of sanitizing solution, being stored in quarantine for up to 7 days, before being handled by workers. A tarpaulin covers the materials to complete the decontamination, according to the Municipality of Belo Horizonte (2020).

Ventura *et al.* (2021) evaluated solid waste in the municipality of Araraquara (Figure 3) and observed RSD and Healthcare Waste (RSS, acronym in Portuguese) decreased at the beginning of the pandemic, when it was compared at the same period in 2019. The collected RSS suffered a retraction in the period with greater social isolation, when compared to the year 2019 (Figure 4).



Figure 4

RSD and RSS collection (%) and Covid-19 cases, from January to July 2020 and 2019 to Araraquara (SP)

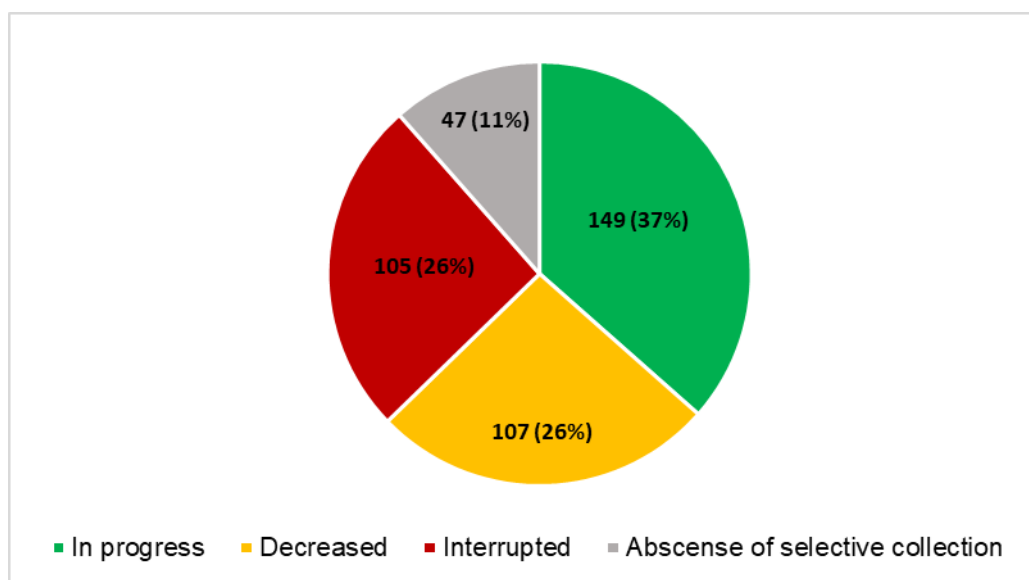


Source: VENTURA *et al.* (2021).

As for selective collection, the study of the Corporate Commitment to Recycling (CEMPRE, acronym in Portuguese) covered 408 Brazilian cities, organized by region (SE: 228; South: 78; NE: 67; CO: 28 and North: 7), as shown by Figure 5.

Figure 5

Level of selective collection operation in 408 Brazilian municipalities in the pandemic



Source: CEMPRE (2020).



According to CEMPRE (2020), 149 (37%) of the cities maintained selective collection, 105 (26%) suspended the initiative and 107 (26%) of them reduced the service (Figure 4). The survey showed that, in the Southeast and South regions, a considerable number of municipalities maintained the service operation, representing respectively 42.4% and 58.9%.

The situation of waste pickers and the recycling chain is relevant and the study by Dias *et. al* (2020) needs to be presented. The capitals studied were Belo Horizonte, Brasília, Fortaleza, Manaus and Porto Alegre, from March to May 2020. The lack of appropriate training for the use of personal protective equipment, as well as the unhealthy conditions of the sorting sheds were observed. This makes the waste pickers susceptible to the risk of viral contamination, increasing the vulnerability of the service performed by selective collection.

Evidence indicates that social isolation and protection measures, changes in the behavior of the population in homes, the need to prepare food and resort to home delivery services were influences on solid waste collection (Aligleri, 2020; Ventura *et al.*, 2021). However, until this moment, there is no scientific study developed regarding the correlation between these evidences.

4.4 Analysis of adherence to social isolation to COVID -19 in Brazilian capitals

Adherence to social isolation, in most capitals studied, does not present updated data. In these cases, the indexes of the respective state were adopted. While analyzing the average of the 22 capitals studied, an average retraction of 1.23% in social isolation between April and May 2020 (Table 4) was observed.

There was an increase in adherence to social isolation in practically all the municipalities studied between March and April. However, in May, social isolation in 12 of the 22 capitals decreased compared to the previous month, as observed in Table 4 (Inloco, 2020). Lockdown comprises a restrictive measure, preventing the full circulation of people on public roads in order to more quickly and effectively contain the spreading of the virus (Fiocruz, 2020b).

It was observed that in May 2020 a Lockdown was performed in 6 of the 22 capitals (Table 5). Among them, Belém, Macapá and Palmas stand out in the North region, as well as São Luís, Fortaleza and Recife in the Northeast region, according to Souza (2020).





Table 4

Social Isolation (%) by Brazilian capital between March and April 2020

Region	Capitals	March	April	May	March to april 2020	April to may 2020
North	Belém	39,56 *	47,25*	48,68*	7,69	1,43
	Macapá	42,09*	48,66*	51,58*	6,57	2,92
	Palmas	37,86*	40,02*	39,43*	2,16	-0,59
North East	Aracaju	38,33*	42,87*	42,19*	4,65	-0,21
	Fortaleza	42,85*	49,18*	49,18*	6,33	0,00
	João Pessoa	39,04*	44,93*	44,61*	5,89	-0,32
	Maceió	39,1*	44,92*	45,27*	5,82	0,35
	Natal	39,54	47	44,9	7,46	-2,10
	Recife	38,04	42,21	43,1	4,17	0,89
	Salvador	38,91*	45,15*	43,44*	6,24	-1,71
	São Luís	39,24*	45,58*	46,39*	6,34	0,81
	Teresina	39,29*	45,91*	44,77*	6,62	-1,14
	Midwest	Brasília	42,02*	46,84*	43,45*	4,82
Campo Grande		44,5	47,08	41,7	2,58	-5,38
Cuiabá		39,28*	42,91*	40*	3,63	-2,91
Goiânia		39,02*	43,07*	38,61*	4,05	-4,46
Southeast	Belo Horizonte	49,02	47,94	42,82	-1,08	-5,12
	Rio de Janeiro	42,65*	50,4*	47,45*	7,75	-2,95
South	São Paulo	46,79	52,33	50,71	5,54	-1,62
	Curitiba	40,76*	45,88*	40,93*	5,12	-4,95
	Florianópolis	44,46*	46,88*	41,28*	2,42	-5,60
	Porto Alegre	43,15	52,74	46,57	9,59	9,00

Note: *Data obtained in the capital information. Source of datas: Natal- Coronavirus RN (2020); Recife – MMPE (2020); Campo Grande - Jones (2020); Belo Horizonte - (SESMG, 2020); São Paulo - GESP (2020); Porto Alegre - PPA (2020); INLOCO (2020).

Source: Elaborated by the authors.

Table 5

Capitals with Lockdown, adherence to social isolation and collected RSU, in relation to April 2020

Capital	Period of Lockdown	Evolution compared to the previous month	
		Adherence to Social Isolation (%)	Volume of MSW generated from May to April 2020 (%)
Belém	07/05 to 25/05	1,43	4,59
Macapá	19/05 to 02/06	2,92	5,08
Palmas	16/05 to 25/05	-0,59	-5,94
Fortaleza	08/05 to 31/05	0	2,18
Recife	12/05 to 31/05	0,89	4,71
São Luís	06/05 to 18/05	0,81	52,00

Source: Elaborated by the authors, based on Souza (2020), ABES (2020a) e ABES(2020b).





Only Palmas has shown a reduction in the average to social isolation in May, compared to April 2020, contrary to other capitals under Lockdown. During this period, all capitals, except Palmas, showed an increase in RSU collection, compared to the monthly average of April 2020 (Table 5).

According to studies carried out by Ragazzi et. al (2020), in Italy, some of the effects resulting from the Lockdown related to RSU were i) increased production of light packaging due to online shopping and home delivery, ii) additional production of RDO and, iii) lower RSU production.

Of the 22 selected Brazilian capitals, it has been observed that 13 (59%) of them have the contingency plan for COVID-19 with the support of the municipal government, even with the increase in adherence to social isolation.

4.5 Proposition of measures for solid waste collection improvement

The United Nations established 17 Sustainable Development Goals (SDGs) which aim to support public managers and the population in general to eradicate poverty, protect the environment, promote health and well-being, equity and prosperity, among others until the year of 2030 (United Nations, 2021). In addition, factors that can make cities more creative and sustainable lead to Smart Cities (SC) and promote urban hubs focused on connectivity, information transparency to society, energy efficiency, equity, and inclusion (WRI Brazil, 2020).

In this context, it is possible to establish an association of these concepts to initiatives that can be developed by the local public manager to make cities become resilient, as shown by the propositions in Table 6.

Table 6 has pointed some preliminary initiatives to achieve the SDGs and SC principles. These initiatives were structured based on the qualitative analysis from this study information, and the technical-professional experience of public management researchers.

The betterment proposed initiatives of solid waste collection have indicated the existent opportunities for municipal governments and autarchies, civil society, and other participatory agencies.

Thereby, local governments can provide means and implement these and other initiatives, based on cities and the best thematic axes evaluated in 2020, as a preliminary reference (Urban Systems, 2020). The highlighted cities were Barueri - SP (economy), São Caetano do Sul - SP (education), Rio de Janeiro - RJ (entrepreneurship), Balneário Camboriú - SC (governance), Santos - SP (environment), São Paulo - SP (mobility and technology), Vitoria - ES (health) , Ipojuca - PE (security) and Curitiba - PR (urbanism).

Therefore, the urgent need for the state and municipal governments to implement health and environmental information systems, for the local administration itself as well as future researches has to be highlighted.





Among mentioned topics, the correlation qualitative and quantitative between RSD collection and COVID-19 cases is one of the others that might interfere in the urban sector. Geo-referenced data processing is an alternative to obtain well-defined results and propose integrated public policies for sustainability and resilient cities.

In this context, the local public manager can enable projects to advance solid waste management and urban cleaning through federal government financing lines that are available at the electronic addresses platform from the Ministries of Environment and Regional Development. Furthermore, the search for partnerships with research institutions and collaborative studies can enhance society's participation mechanisms.

Table 6

Propositions for resilient cities from the perspective of sustainability and smart cities principles

Initiatives	SDGs	SC Principels
Review of long-term environmental health and safety procedures, both in the collection of solid waste and in the prior segregation of solid waste, ensuring its energy use and proper disposal	Health and well-being (SDG 3) Sustainable cities and communities (SDG 11) Sustainable consumption and production (SDG 12)	Energy efficiency Sustainable urban development
Upgrading communication channels with society, aiming to expand the participation of civil society, and political-administrative articulation for shared management in emergency cases, such as pandemic events related to public health and environmental sanitation. Examples such as floods, environmental impacts resulting from forest fires, contamination of water resources by irregular disposal of solid waste in rural areas, among others.	Sustainable cities and communities (SDG 11) Partnerships and Means of Implementation (SDG 17)	Equity Social inclusion and participation
Data providing and standardization at municipal and regional scale (watershed or census sector)	Sustainable cities and communities (SDG 11)	Technology and innovation (cities transformation) Transparency of planned actions and suitable budget
Local and regional committees institutionalization to ensure social participation mechanisms for the integrated planning of actions referring to environmental health, sanitation, and cities resilience	Partnerships and Means of Implementation (SDG 17)	Equity Social inclusion and participation
Sharing of resources and physical structures to minimize the operational costs of solid waste management, for instance, by inter-municipal consortia	Sustainable cities and communities (SDG 11)	Energy efficiency Sustainable urban development Institutional partnership

Note: SDGs: Sustainable Development Goals / SC: Smart Cities

Fonte: Elaborated by authors, 2021.



5 Conclusion

The solid household waste collection was reduced in 22 Brazilian capitals from March to May 2020, while scientific evidence about viral contamination in materials and surfaces was in progress. In this field, the main adaptations were a) the elaboration of the virus contingency plan, b) the operational adjustments in the solid waste collection through the spraying of sanitizing substances, c) PPE usage, d) workers for essential health services vaccination, and e) new MSW management protocols.

Nevertheless, the pandemic has evidenced the absence of standardized recent data on household solid waste and its poor dissemination in digital media, which hampered data analysis over a longer period, beyond the pandemic beginning.

The developed proposals represent the preliminary initiatives for solid waste sector, in the sense of increasing the quality of urban life and urban planning with the goal of transforming cities into sustainable and resilient cities, especially in the post-pandemic period.

Lastly, the struggle against COVID-19 has brought some opportunities for reviewing and adapting the household solid waste collection, on the path to equity, governance, and resilience of the cities.

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