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HIGHLIGHTS

• Different fields of knowledge have faced challenges due to the COVID-19 pandemic.
• Solid waste collection workers (SWCW) could be at occupational risk.
• SWCW with COVID-19 and COVID-19 cases in the SWCW's route were analyzed.
• In São Paulo highest correlation ($r$) was 0.77 analyzing concessionaries separately.

GRAPHICAL ABSTRACT

ABSTRACT

Different fields of knowledge have faced challenges due to the COVID-19 pandemic. Essential public services serving the population's needs were maintained. Previous studies have addressed the possibility of health hazards from handling solid waste (SW) among trash collection service workers, without introducing any data proving or dismissing those risks. Occupational health is stated in at least 2 of the 17 Sustainable Development Goals. Pearson Coefficient ($r$) was employed to analyze the correlation between the number of cases of COVID-19 in SW collection workers in the city of São Paulo, considering the district city halls where the COVID-19 patients live and the SW collection workers' route, from March 2020 to March 2021. Employees who collected wastes with COVID-19: 2% collected healthcare, 4% worked at the waste transshipment stations, 10% household variable route collection, and 83% in defined routes collecting household wastes. Positive and moderate correlation was confirmed ($r = 0.59$) between the total number of COVID-19 cases and the trash collection routes, and the number of contaminated COVID-19 workers from their trash collection routes. Considering concessionary companies separately, the correlation found in the Southeastern grouping is 0.77 (positive and high correlation), and the correlation found in the Northwestern grouping is 0.18 (positive but insignificant correlation). The Northwestern grouping’s concessionary had implemented more effective occupational health and safety management policies and disclosed them among their stakeholders. Results suggest concern related to occupational health and safety for SW collection workers and substantiating the vulnerability of this essential activity during the pandemic.

Keywords:
Solid waste management
COVID-19
Collection service workers
Risk management

1. Introduction

Some issues were raised regarding sustainability (Ranjbari et al., 2021) and solid waste (SW) management after the COVID-19 pandemic began (Zhang et al., 2022), focused on the possibility of waste as a pathway for
new knowledge is incremental, as further information in COVID-19 is re-
tion workers with COVID-19 in the city of São Paulo, Brazil. Constructing
who do not work in health services or collect waste from health services, is
health risks during a new disease has brought the entire world to its

cially because of the greater occupation of beds by COVID-19 patients
and health. Furthermore, it highlights the importance of transparency,
contamination (Zhao et al., 2021, Nzediegwu and Chang, 2020; Zand and
A. do Nascimento Beckert, V.G. Barros Science of the Total Environment 831 (2022) 154862
2020; Kulkarni and Anantharama, 2020; Richter et al., 2021), the variation of
street-sweeping wastes (Urban and Nakada, 2021), the production from
healthcare wastes (Zhao et al., 2021; Haque et al., 2021; Das et al., 2021;
Capoor and Parida, 2021; Klemel et al., 2020; Wang et al., 2021) and
solid waste management (Tesfaldet et al., 2022; Penteado and Castro,
2021; Chand et al., 2021; Nzediegwu and Chang, 2020; Behera, 2021).

There has been an overall 20% increase in household waste production in
the United States since the beginning of the pandemic (Kulkarni and Anantharama, 2020) and 30% In New York (Sharma et al., 2020). A change
was also observed in its composition (Sharma et al., 2020; Tripathi et al.,
2020) besides, that due to the increase in recyclable wastes (Klemel et al.,
2020; Hantoko et al., 2021), increase in organic wastes (Staub, 2020), and reduced street sweeping wastes (Urban and Nakada, 2021). Wastes
generated from the households are classified as non-hazardous solid wastes
(Hantoko et al., 2021). Healthcare wastes, classified as hazardous due to
the risk they pose (Thakur, 2021), have increased its quantity, unequiv-
cably because of the greater occupation of beds by COVID-19 patients
(Das et al., 2021; Sharma et al., 2020; Zambrano-Monserrate et al., 2020).
That increase was 600% in Wuhan, at the height of the pandemic (Tang,
2020), and 30% in Malaysia (Agamuthu and Barasarathi, 2020). In India
the increase in production was more than 101 MT per day compared to pre-
vious months, before the pandemic (Capoor and Parida, 2021).

The outbreak of COVID-19 also raise concerns in the occupational safety
and health (OSH) field (Brisolara et al., 2021). OSH is stated in at least 2 of
17 Sustainable Development Goals (SDGs) (3- Ensure healthy lives and pro-
mote well-being for all at all ages, and 8 - Promote inclusive and sustainable
economic growth, employment and decent work for all), but when sustain-
ability is taken into consideration, OSH is often forsaken, unfortunately.

Nawaz et al. (2019) observe this connection associating safety to sustain-
ability and linked safety to the three pillars of sustainability (financial sta-
stability, environmental responsibility, and social protection). Regarding
recommendations in OSH management, social, and occupational factors
can increase the risk of infection (Antonelli et al., 2021). Thus, aspects
such as the use of personal protective equipment and proper sorting,
hygiene routines, handling, and final disposition of potentially contami-
nated waste were addressed, observing the precautionary principle
(Penteado and Castro, 2021). Some countries have adopted safety protocols
for mitigating risks: the United States of America, the United Kingdom,
India, China, and Nigeria (Hantoko et al., 2021). In Brazil, specific protocols
for efficiently managing wastes on São Paulo’s (São Paulo, 2020) and
Curitiba’s city hall websites (Curitiba, 2020). The possibility of contamina-
tion risk of trash collection workers when handling solid wastes (Hantoko
et al., 2021; Tripathi et al., 2020; Haque et al., 2021; Behera, 2021), and
trash pickers (Carenbauer, 2021; Nzediegwu and Chang, 2020; Penteado
and Castro, 2021) was considered regarding waste management. However,
these articles have not provided statistical analysis on observational data
(Urban and Nakada, 2021; Chand et al., 2021; Wang et al., 2021; Richter
et al., 2021).

The purpose of this article is to reduce the gap on missing observational
data and introduce an analysis of the correlations between the number of
confirmed cases of people with COVID-19 and the number of trash collec-
tion workers with COVID-19 in the city of São Paulo, Brazil. Constructing
new term is incremental, as further information in COVID-19 is re-
leased. As an incremental contribution, it reinforces capabilities in the
short term (Wehn and Montalvo, 2018). The article is highlighting new
health risks during a new disease has brought the entire world to its
knees. Introducing information and data on the contamination of workers,
who do not work in health services or collect waste from health services, is
a novelty. Going beyond, the article contributes to the continuous improve-
ment of waste management, disaster risk reduction and occupational safety
and health. Furthermore, it highlights the importance of transparency,
disclosure, and discretization of data related to this field, which allows for
assessments and the proposition of prevention measures.

2. Methodology

2.1. Study area

The city of São Paulo, Fig. 1, is located in Southeastern Brazil. The pop-
ulation is 12,396,372, 1521.11 km² of territorial area (Instituto Brasileiro
De Geografia e Estatística - IBGE, 2020b) and it is subdivided into 96
districts that jointly make up 32 district city halls (São Paulo, 2021a, 2021b,
2021c, 2021d, 2021e, 2021f). The per capita Gross Domestic Product
(GDP) is R$ 58,691.90, constituting the highest GDP in Brazil (Instituto
Brasileiro De Geografia e Estatística - IBGE, 2020a).

In 2020, the following types of wastes were collected daily: 11,500 MT
from household waste and selective collection were collected daily, 126 MT
from healthcare wastes, and 229 MT from street sweeping wastes and util-
ity hole cleaning. The quantitative data on collected wastes are published
on the city of São Paulo City Hall website (PMSP), updated monthly (São
Paulo, 2021a).

“Autoridade Municipal de Limppeza Urbana” (Urban Cleaning Municipal
Authority) (AMLRUB) has managed urban wastes and cleaning since 2002.
AMLRUB provides services in the household collection and urban cleaning
modalities, and it is linked to the “Secretaria Municipal das Subprefeituras”
(Municipal District City Hall Department). The urban cleaning is made up
by six departments and six private consortiums assigned by public bidding.
Plus, two concessionaries (São Paulo, 2021b), operate all collection service.
The AMLRUB structure, consortium concessionaries, and the quantitative
data on the solid waste collection are published on municipal website,
(São Paulo, 2021c).

Door-to-door waste collection is performed on 100% of the streets and
encompasses 96 municipal districts, and selective collection is performed
in 94 districts, including 76% of the streets, (São Paulo, 2021b). Two con-
cessionaries are responsible, and one of the concessionaries provides its
services in the Northwestern regions (2000 employees). It serves 13 district
city halls (downtown, north, and west). The other concessionary provides
its services in the southeast areas (3300 employees) and serves 19 district
city halls (south and east), Fig. 2.

2.2. Data collection

The employee data on the waste collection were requested in the
“Sistema Eletrônico de Informação ao Cidadã” (The Electronic System of
the Citizen Information Service (e-SIC), (São Paulo, 2021d), resulting
from previously registered data input. The supplied data includes em-
ployees with COVID-19 who collect household trash, healthcare waste col-
lection, waste transshipment stations, and variable route waste collection
workers (Table 1) from March 2020 to March 2021. The concessionary
company’s region where the employees collected household waste, both
common and selective, is based on district city halls (Tables 2 and 3).

São Paulo City municipal government maintains COVID-19 cases infor-
mentation on their site, including discretized data based on district and re-
gional city halls, (São Paulo, 2021e). The available data makes it possible
to identify the number of residents with COVID-19 based on districts and
the data registered in the first year of the pandemic, from March 2020 to
March 2021 (Tables 2 and 3).

2.3. Statistical analysis

The Pearson Coefficient (r) was employed to analyze the correlation be-
tween the number of cases of COVID-19 in solid waste collection employees
in the city of São Paulo, considering the district city halls where the sick
people live and the solid waste collection workers’ route, from March
2020 to March 2021.

The purpose of the Pearson Coefficient (r) is to find the level of linear
correlation between two variables (Eq. (1)), Cov (x,y) is the covariance
between the variables and $\sigma_x, \sigma_y$, the product of the standard deviation of these variables, (Bisquerra et al., 2004).

$$r = \frac{\text{Cov} (x, y)}{\sigma_x \sigma_y}$$

(1)

$r = 1$: Perfect correlation.

$0.80 < r < 1$: Very high correlation.

$0.60 < r < 0.80$: High correlation.

$0.40 < r < 0.60$: Moderate correlation.

$0.20 < r < 0.40$: Low correlation.

$0 < r < 0.20$: Very low correlation.

$r = 0$: Null correlation.

The Pearson coefficient measure was employed to verify if the correlation is significant between the number of residents with COVID-19 in the districts and the number of waste collection employees with COVID-19 on these routes. The $p$-value hypothesis test of the $T$ statistic was adopted. Null Hypothesis ($H_0$): $p = 0$ (a non-linear relationship for evaluating the data), alternative hypothesis ($H_1$): $p \neq 0$ (linear relationship between data).

3. Results

The municipal government’s rapid and easy disclosure of electronic data made it possible to analyze the statistics regarding the solid waste collection workers during the first year of the COVID-19 pandemic. The data on the number of waste collection employees with COVID-19 on these routes. The $p$-value hypothesis test of the $T$ statistic was adopted. Null Hypothesis ($H_0$): $p = 0$ (a non-linear relationship for evaluating the data), alternative hypothesis ($H_1$): $p \neq 0$ (linear relationship between data).

4. Discussion

4.1. Healthcare wastes collection workers

There were data on 3 employees who collected healthcare wastes with COVID-19. This number represents 2% of the total solid waste collection
workers with COVID-19. This fact is related to the training and wearing of specific personal protective equipment for this task. These workers are regularly trained for handling hazardous wastes, classified as Class I in Brazil. The training of these professionals encourages risk perception and reduces the risk of contamination (Veloso Neto et al., 2021; Bleck and Wettber, 2012). Besides that, proper sorting in the location also contributes to enhanced management and safety of the employees involved in their collection.

4.2. Workers in routine door-to-door waste collection

Household waste collection workers do not get specific training on handling potentially infected wastes, then their routine should not encompass the handling of wastes classified as potentially hazardous. This situation might well explain why 93% of the waste collection employees with COVID-19 have been assigned to household waste collection. In Brazil, a hand-to-hand interaction between wastes and collectors occurs during waste collection, and there are no official safety guidelines, as observed by Kulkami and Anantharama (2020), have been proposed so far.

The data from the 52 municipal districts emphasizes the vulnerability of the solid waste collection workers (Behera, 2021; Carenbauer, 2021), considering that a positive and moderate correlation was found ($r = 0.59$) compared to the number of residents with COVID-19 in the collection routes and the number of workers with COVID-19 in these collection routes. Two concessionaries handled municipal solid waste as previously indicated; each company trains and prepares their employees; this could impact the results. There can be a difference in the degree of training and the availability of personal protection equipment worn. Therefore, the data analysis based on concessionary is more precise.

The correlation found in the Southeastern grouping is 0.77 when the companies are analyzed separately.
high correlation for the solid waste collection employees with COVID-19 and the incidence of COVID-19 cases in this region. This result sets up a warning regarding the challenge in handling solid wastes in the COVID-19 pandemic, as household wastes from people with COVID-19 become potentially hazardous wastes (Wiktorzycz-Kapischke et al., 2021; Hantoko et al., 2021). Furthermore, the high correlation found in these data can be linked to routine occupational practices and employee training (Penteado and Castro, 2021). Gwenzi (2021) report the problem of proper disposal of solid wastes before the COVID-19 pandemic had become an even more significant challenge to handle (Penteado and Castro, 2021; Manupati et al., 2021), which included making the population aware of the appropriate disposition of solid wastes and packaging. The PMSP published a Contingency Plan for handling solid wastes during the COVID-19 pandemic including communication campaigns and guidelines for the population in their communication media and through household waste collection trucks equipped with loudspeakers installed in the vehicles (São Paulo, 2020). The success of most of the recommendations depends on the awareness of the population, and for this reason, it is imperative that decision-makers can implement contingency plans. Proper handling of solid wastes is a critical key factor in reducing or interrupting the spread of COVID-19 and bringing down the hazard of solid waste collection workers (El-Ramady et al., 2021).

The Southeastern grouping displayed the highest correlation coefficient in its region, clustering the lower-income population regions of the municipality (Lorenz et al., 2021) and the worst socioeconomic condition, considering such factors as education, mobility, poverty, wealth, income, a great number of underprivileged residents, and affordability of resources and services (Bermudi et al., 2021). Those factors describe the population’s vulnerability in this region, and they can indicate the difficulties of handling solid wastes and the increased hazard of contaminating waste collection employees.

The correlation found in the Northwestern grouping was 0.18, indicating a positive correlation, however insignificant. The city’s central region is part of the Northwestern grouping and then it displays better socioeconomic ratings than other regions of the city (Bermudi et al., 2021). That shows that this region has better infrastructure and explains why there is better solid waste handling during the COVID-19 pandemic. The residents from this grouping have higher access to information and better access to guidelines on sorting solid waste. That result also can be linked to company practices such as wearing personal protective equipment while collecting wastes from that region (Torkashvand et al., 2021), training, and experience on protocols facing hazards.

There are 2000 employees in the concessionary working in the Northwestern grouping. The Pearson Coefficient is \( r = 0.18 \) while the concessionary working in the Southeastern grouping has 3300 employees, and its coefficient is \( r = 0.77 \) related to the differences in each of the companies. COVID-19 is an enormous challenge for occupational health (Burdorf et al., 2020) and the difference in the number of employees suggests that the lower number of employees enables improved safety and health management control. In addition, the Northwestern concessionary grouping displays its occupational and health policy clearly on a virtual platform. That transparency expresses the company’s commitment related to this theme, which is reflected in the daily lives of the employees.

### Table 3
Number of residents with COVID-19 and waste collection employees with COVID-19 for each São Paulo district city hall, in their concessionary region of work in the Northwestern grouping.

| District City Hall | Number of infected residents in the districts (Mar./20 - Mar./21) | Number of contaminated employees in the routes serving the districts (Mar./20 - Mar./21) |
|--------------------|---------------------------------------------------------------|==================================================================================|
| Butantá Morumbi Raposo Tavares Rio Pequeno Vila Sônia | 106,255 | 8 |
| Casa Verde Casa Verde Cachoeirinha Limão | 73,422 | 2 |
| Freguesia do Ó and Brasília | Fruguesia do Ó Brasília | 99,336 | 1 |
| São Domingos Santana and Pirituba | São Domingos Pirituba | 110,148 | 3 |
| Jaçanã and Tremembé | Jaçanã Tremembé | 63,724 | 2 |
| Lapa | Lapa Barra Funda Jaguará Jaguari Perdizes Vila Leopoldina | 64,615 | 12 |
| Mooca | Mooca Belém Brás Água Rasa Pari Tatuapé | 71,137 | 2 |
| Penha | Penha Arru Aruim Cangaíba Vila Matilde | 122,622 | 4 |
| Perus | Perus | 36,444 | 0 |
| Pinheiros Alto Pinheiros Itaim Bibi Jardim Paulista Pinheiros Frituba São Domingos Jaráguá | 50,641 | 3 |
| Pirituba and Jaráguá | Pirituba São Domingos Jaráguá | 110,148 | 3 |
| Santana and Tucuruvi | Santana Mandaqui Tucuruvi | 66,344 | 2 |
| Sê | Sê Bela Vista Bom Retiro Cambuci Consolação Liberdade República Santa Cecília Sê | 88,680 | 5 |
| Vila Maria and Vila Guilherme | Vila Maria Vila Medeiros Vila Guilherme | 66,227 | 5 |

### Table 4
Pearson coefficient \( r \) on the residents with COVID-19 and employees with COVID-19, in São Paulo, from March 2020 to March 2021.

| Location of the correlated data | Pearson coefficient correlation \( r \) | \( r \) Classification | p-value | Linear relationship between variables |
|-------------------------------|-----------------------------------------|----------------------|---------|-------------------------------------|
| 32 Municipal Districts        | 0.59                                    | Moderate correlation | 0.00    | Significant                         |
| 19 Southeastern concessionary municipal districts | 0.77                                    | High correlation    | 0.00    | Significant                         |
| 13 Northwestern concessionary municipal districts | 0.18                                    | Very low correlation | 0.55    | Non-significant                     |
Occupational health and safety risk management is crucial to reduce occupational accidents and diseases in institutions (Brisolara et al., 2021; Mohandes and Zhang, 2021), also in waste management companies (Ramos et al., 2020). A safety policy improves management during critical periods as the pandemic, reducing stress and enhancing well-being, as it is an appropriate response in occupational health (Sinclair et al., 2020) and helps to achieve sustainability (Nawaz et al., 2019). Training all the teams, including supervisors and the administrative staff, is essential for mitigating hazards. The company's safety scenario is also the result of shared perceptions among the employees on safety policies and procedures that can directly impact the safety behavior of the employees while performing their duties (Sinclair et al., 2020).

4.3. Transparency, data disclosure, and informing hazards

Transparency and data disclosure related to solid wastes is challenging in Brazil, as many municipalities do not have a reliable database (Brasil, 2020). Easy access to these data, published through electronic platforms, enables the identification of different scenarios, and based on statistical analysis, will characterize weaknesses and opportunities for improvements. Identifying hazards related to solid waste handling is part of disaster management (Haque et al., 2021) and risk assessment (Yu et al., 2020), as in the case of the COVID-19 pandemic. The solid waste collection workers need guidance on their occupational hazards (Bleck and Wettber, 2012) and are trained to mitigate the risk of COVID-19 contamination from solid wastes (Hantoko et al., 2021). That guidance must employ municipal data to address reality and hazards. For that reason, data transparency, rapid publication, disclosure, and communication are essential. The risks detected in the waste management chain also need to be clearly and effectively informed to the population so that people can truly perceive risk and accept their responsibilities in the integrated management chain of solid wastes. Control of spreading COVID-19 from managing solid wastes requires proactive efforts among the population, service providers, and government decision-makers (Kulkarni and Anantharama, 2020).

5. Conclusion

This research suggests the potential hazard of COVID-19 contamination from solid wastes and the vulnerability of employees who work in collecting wastes. Before the COVID-19 pandemic, these professionals were exposed to a variety of diverse pathogens. They are often not recognized for their work, related to their salaries and investments in their professional training and education. That lack of training or inadequate training can cause disregard for occupational risks in the routine of their work activities, especially in extreme situations such as the COVID-19 pandemic. Solid waste collection has been classified as an essential service in Brazil during the COVID-19 pandemic, to avoid interrupting this service; however, these professionals have always been crucial agents in environmental sanitation in Brazilian municipalities. The population's disregard of their importance of these agents can also generate inadequate sorting and placement for waste collection and significant contamination. The data presented in this work refers to formal workers in the waste management chain. The systems for collecting solid waste are challenging for developing countries like Brazil, where informal work is widespread. Around 75% of Brazilian municipalities declare the existence of solid waste trash pickers, and only 3.7% of these municipalities have formalized contracts with these workers, (Brasil, 2020).

Thus, more detailed studies are necessary on solid waste management as an essential source of making the systems more resilient in the future and in how to improve environmental sanitation in Brazilian municipalities. Moreover, municipal governments and solid waste management companies need to monitor the data and disclose them to perform research studies, making decisions based on actual data.

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CRediT authorship contribution statement

Aline do Nascimento Beckert: Formal analysis, Investigation, Methodology, Resources, Supervision, Validation, Writing – original draft, Writing – review & editing. Virginia Grace Barros: Conceptualization, Investigation, Methodology, Resources, Validation, Writing – original draft.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.
Fig. 4. A and B – Dispersion data on the residents with COVID-19 based on route and solid waste employees with COVID-19 in the grouping of the 19 Southeastern districts of São Paulo, from March 2020 to March 2021, \((r) = 0.77 - (4 A)\), and dispersion data on the residents with COVID-19 based on route and solid waste employees with COVID-19 in the grouping of the 13 Northwestern districts of São Paulo, during the same period, \((r) = 0.18 - (4 B)\).

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