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ORIGINAL ARTICLE

DETECTION OF SARS-COV-2 IN THE POPULATION AND WASTEWATER OF DOURADOS SEMI-OPEN PENAL INSTITUTIONS, MATO GROSSO DO SUL, BRAZIL

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ABSTRACT

COVID-19 pandemic exposed challenges for health authorities, especially among vulnerable groups such as inmates. This study evaluated the presence of SARS-CoV-2 RNA and anti-SARS-CoV-2 IgG and IgM in inmates of semi-open penal institutions in the Central-West region of Brazil, as well as viral RNA in wastewater from these institutions. A cross-sectional study was conducted in male and female semi-open penal institutions in Dourados, Mato Grosso do Sul, Brazil, between September 2022 and February 2023. The presence of anti-SARS-CoV-2 IgG and IgM antibodies in plasma by rapid test, and virus RNA by RT–qPCR analysis of nasal and wastewater samples were investigated. Of the 225 inmates of the male penal unit, 12.4% (28) tested positive RT–qPCR test and/or reactive IgG and IgM. Of these, 57.1% were employed, and 81.2% engaged in activities outside the prison unit (p=0.002). The prevalence was 2.8 times higher among inmates who worked outside the penal institution. Among the 20 wastewater samples collected, 10% tested positive for SARS-CoV-2 viral RNA. Of the 14 inmates of the female penal unit, 21.4% (3) tested reactive IgG and IgM; all reported working, 66.6% (2) worked outside the penal unit; both used individual transportation. The wastewater sample was negative for SARS-CoV-2 viral RNA. We detected SARS-CoV-2 RNA and anti-SARS-CoV-2 antibodies within penal institutions. Our findings may contribute to strengthening preventive medicine and controlling new outbreaks, using wastewater analysis as a relevant tool.

KEY WORDS: COVID-19 pandemic; inmate; wastewater-based epidemiological monitoring.

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INTRODUCTION

The COVID-19 pandemic posed significant challenges to health agencies, highlighting vulnerabilities in the public health system (Mohamed et al., 2022). This situation was especially worrisome for groups in vulnerable situations, such as people deprived of their liberty (Elbek, 2020). Besides being exposed to conditions that increase the risk of comorbidities, these individuals face specific obstacles, such as high population density, which make it difficult to effectively implement measures to control and prevent the spread of the disease, such as social isolation and the use of masks (Elbek, 2020; Busatto et al., 2022). Confined spaces and constant interaction with professionals and people outside the penal unit further increase the complexity of this challenge, indicating the need to develop strategies to ensure the effectiveness of these preventive measures (Hawks et al., 2020).

In October 2024, data showed that 663,906 individuals were in physical cells in Brazil, 105,104 were monitored electronically, and 115,117 were under house arrest without electronic monitors (Brazil, 2024). The State of Mato Grosso do Sul, owing to drug trafficking, has the largest inmate population in the country, with more than 17,400 people in penal units or under some form of restrictive measure. Among them, 2,300 inmates serve their sentence in a semi-open regime, i.e., they perform work outside the penal unit during the day and return to their penal units at night (AGEPEN/MS, 2025). This makes it even more challenging to apply control measures against infections, increasing the number of cases of infectious diseases, including COVID-19 (Oliveira et al., 2021). By October 17, 2022, 67,367 inmates had been diagnosed with the disease; among them, 5,145 were in Mato Grosso do Sul, with the Central-West State having the highest prevalence (CNJ, 2022).

Among the various methods of epidemiological surveillance for COVID-19, wastewater monitoring is important, as studies have shown that increases in viral detection in sewage networks precede increases in human case counts (de Sousa et al., 2022). Surveillance and understanding of the sewage system can be used to track viral circulation by analyzing case prevalence in the population, the origin of epidemiological data, and risk factors affecting public health (Kitajima et al., 2020; Naddeo et al., 2020).

In this context, the objective of this study was to evaluate the presence of SARS-CoV-2 RNA and anti-SARS-CoV-2 IgG and IgM antibodies in inmates of semi-open penal institutions in the Central-West region of Brazil, using molecular (active infection) and seroprevalence analysis of inmates, as well as the presence of viral RNA through molecular analysis in wastewater from the units.

MATERIALS AND METHODS

Study design and location

We conducted a cross-sectional study in semi-open male and female penal institutions in Dourados (22°13'18" S and 54°48'23" W), Mato Grosso do Sul, Brazil. Both units are located in different parts of the city and are considered minimum-security institutions. The main characteristic of these semi-open institutions is that the inmate works outside the penal unit during the day and returns to spend the night.

The study was conducted at the semi-open Male Penal Institution in Dourados, 12 km from the city center, between September 19, 2022, and February 07, 2023. The unit accommodates about 600 inmates and consists of 49 cells divided into pavilion A (24 cells), pavilion B (18 cells), and seven cells outside the pavilions. Each cell is about 4 m^2. Due to the unit's internal protocols, a considerable number of these inmates have no external contact; however, they share cells and common environments with those who leave daily, and in some situations, cells contain more than 10 individuals.

The study was also conducted at the semi-open Female Penal Institution in Dourados, in February 2023, which occupies a residential structure in the city center. During the study period, the unit housed 24 inmates who slept in a simple cell of approximately 60 m^2, containing several bunk beds. Twenty inmates left during the day and returned to spend the night.

Ethical considerations

The study was approved by the State Agency for the Administration of the Penitentiary System of Mato Grosso do Sul and the Ethics Committee on Human Research of UFGD (protocol No. 5.534.021). Inmates who did not agree to provide a peripheral blood sample and/or nasal swab, as well as those who refused to answer the questionnaire, were excluded. Only inmates aged 18 or older were included, selected randomly via convenience sampling. They provided written informed consent using the Free and Informed Consent Form and answered questions from a structured questionnaire to determine their demographic profile and level of social isolation. Vaccination data were provided by the health units of penal institutions. Inmates who tested received the results through the health unit of the penal institutions, which notified the Municipal Health Department and established isolation protocols at the units.

Collection of samples from the inmates

The sample of the male population was calculated from 600 inmates, considering a confidence level of 90% and a margin of error of 5%; the final sample was increased by 20% to compensate for losses, resulting in a sample of 225 individuals. The entire female population (14 inmates) was included in the study.

From each individual who participated in the study, we collected biological material (nasopharyngeal swabs) stored in a tube containing saline solution to examine SARS-CoV-2 genetic material by reverse transcription-quantitative polymerase chain reaction (RT–qPCR). Peripheral blood was also collected once from each inmate, in a tube containing EDTA, to obtain plasma and test for anti–SARS-CoV-2 antibodies. The samples were refrigerated and sent to the Health Sciences Research Laboratory of UFGD within 4 h, and the tests were conducted the next day.

Collection, processing, and concentration of wastewater samples

For sewage collection, 14 wastewater samples were collected at the male penal unit from the general outlet, and six from individual points between the cells. The sewage system of the male penal unit consists of a general outlet that connects all the points of the unit before the sewage treatment plant. Internally, every two cells have a sewage collection point that was used only when one or more inmates of the cells tested positive for COVID-19. Samples were collected for 1 h (1 L in total; about 250 mL every 15 min), during the five months of the study. Residential sewage from the female penal unit was collected using the same methodology at an outlet of the sewage system on a single day. The samples were collected at the time of the highest sewage flow, when most of the inmates were taking a shower, at about 6 pm. The sewage samples were placed in thermal boxes, sent to the UFGD laboratory, and stored at –80 °C until the processing for the assessment of SARS-CoV-2, that was conducted the next day.

Following the protocol (Wu et al., 2020) with modifications, the samples were initially centrifuged at 1,800 × g at 4 °C for 5 min. The supernatant was filtered through a sterile vacuum filtration system using a nitrocellulose membrane with a porosity of 0.45 µm (GVS Filter Technology®, Sanford, USA). Then, a 40 mL aliquot of the filtrate was transferred to a tube, and 4.0 g of polyethylene glycol (Bio Ultra 8000®, Sigma, Darmstadt, Germany) and 0.9 g of NaCl were added. The mixture was stirred for 15 min until complete dissolution. Then, centrifugation was performed at 1,800 × g at 4 °C for 60 min. The supernatant was removed, and the pellet was eluted in 1% PBS (saline solution buffered with 10 mM sodium phosphate, 0.15 M NaCl, and pH 7.2), transferred to a cryotube, stored at –80 °C, and the molecular test was conducted the next day.

Molecular research and genetic sequencing of SARS-CoV-2

RNA samples were obtained from nasopharyngeal swab samples via the Viral RNA Mini Kit (QIAamp®, Hilden, Germany) and from wastewater samples via the Quick–DNA/RNA Viral MagBead Kit (Zymo Research®, CA, USA). RT–qPCR analysis was performed using the Allplex 2019–nCovAssay Kit (Seegene®, Seoul, Republic of Korea) in a Bio-Rad CFX96 Touch Real-Time Thermal Cycler. For positive control of the reaction, a positive sample was used: a water sample with 2 µL of saline solution containing the virus was also used as a positive control. Viral concentrations were determined by gene detection DNA of the following genes: *E* of *Sarbecovirus* in the FAM channel, *RdRP* in CalRed 610, *N* in Quasar 670, and internal control in the HEX. An infection was considered active when the test was positive (Ct below 40) in at least one of the three viral genes. The kit used had a detection limit of 4,167 copies/mL (100 RNA copies/reaction).

Positive RT–qPCR samples were sent for sequencing to the Genomic Platform at FIOCRUZ Pernambuco, Brazil. Single-strand cDNA was generated using the high-capacity cDNA reverse transcription kit (Thermo Fisher Scientific Baltics® UAB, V.A. Graiciuno 8, LT-02241, Vilnius, Lithuania) following the manufacturer's instructions. Amplicons were performed with the Arctic 5.2.3 version primer sets to amplify the SARS-CoV-2 whole genome, and the library was prepared following the COVID-19Seq protocol (Illumina Inc.). Sequencing was performed on a MiSeq® Illumina system using a paired-end approach of 150 base pairs using the cartridge Miseq® Reagent kit v2, 300 cycles. After the raw sequencing read quality check, removal of low-quality reads, genome assembly, and lineage assignment, ViralFlow® 1.0.0 (https://viralflow.github.io/) (da Silva et al., 2024) was used, which performs a reference-based genome assembly and runs Pangolin v4.3.1 (O'Toole et al., 2021) to assign the SARS-CoV-2 lineages. Only genomes whose coverage breadth was greater than 70% and whose lineage was assigned were reported.

Anti-SARS-CoV-2 antibody research

Anti-SARS-CoV-2 IgG and IgM antibodies were performed using the rapid test 2019-nCoV IgG/IgM Combo Test Card (MP Biomedical® 07RDCOV19, Germany). The results were interpreted by trained professionals in accordance with the manufacturer's instructions. The test provides separate results for IgG and IgM. A positive IgG indicates past infection or immunity after vaccination, while a positive IgM indicates active infection or immunity due to vaccination administered less than three months ago. According to the manufacturer, the specificity of the test is 99.0%, and the sensitivity is 87.8%.

Statistical analysis

Only the data on the male penal unit could be analyzed statistically. The collected data were transferred to a Microsoft Excel Spreadsheet® for subsequent statistical analysis in SPSS 22. It was considered positive for COVID-19 when the RT–qPCR test was positive, and/or IgG and IgM were reactive, provided the vaccination was administered more than three months ago. Univariate analysis was performed through absolute and relative frequencies; bivariate group comparisons were performed by Pearson's Chi-square test or Fisher's exact test. For other associations, multivariate Poisson regression models were constructed, with robust variance, to estimate the magnitude of differences in SARS-CoV-2 prevalence between groups using the prevalence ratio (PR) and its 95% confidence interval (CI). For the multinomial variables, the categories were compared cumulatively. All results were considered to be statistically significant at $p < 0.05$.

RESULTS

Male penal unit

In the male penal unit, 225 inmates were analyzed. The demographic profiles of inmates divided into those who were positive for COVID-19 (28 inmates positive for RT–qPCR and/or reactive IgG/IgM) and those who were negative for COVID-19 (197 inmates negative for RT–qPCR and non-reactive IgM) are presented in Table 1.

In the positive group, 28.5% (8) were over 50 years old ($p = 0.09$), 53.6% (15) declared themselves mixed race ($p = 0.951$), and 39.3% (11) were 5–10 or 11-13 years of basic education ($p = 0.062$). The majority (57.1%; 16) of COVID-19-positive inmates worked, and 81.2% (13) of these performed activities outside the penal unit ($p = 0.002$). Among those who went out to work, six inmates worked at a cattle leather company, two at a hospital, two at a metal company, and three at a refrigeration company. Of the 13 inmates who worked outside the penal unit, eight used crowded public transport ($p = 0.002$). In the COVID-19–negative group, only 37.6% reported working ($p = 0.048$) (Table 1).

Among the 28 positive COVID-19 cases, 15 were diagnosed by IgG/IgM serology, nine by RT–qPCR, and four by both RT–qPCR and IgG/IgM serology. The Ct values found in our study for the *E* gene ranged between 5.04 and 30.13, for the *RdRP* gene between 11.14 and 42.57, and for gene *N* ranged from 6.26 to 37.11. Sequencing revealed subvariants of the Ômicron variety deposited in the GISAID Database [BE.9 (EPI_ISL_19490992, EPI_ISL_19490993, EPI_ISL_19490994 and EPI_ISL_19490995) and BQ.1.1 (EPI_ISL_19490991) derived from BA.5 in five samples (Table 2).

Of the 28 COVID-19 cases, only one did not receive any vaccine doses. Furthermore, two inmates received only one dose, 14 inmates received two doses, 10 inmates received three doses, and one inmate received four doses (Table 2). No significant difference in COVID-19 prevalence among inmates was observed with respect to the number of vaccine doses or vaccination time.

Table 1. Sociodemographic data of inmates at the semi-open male penal institution of Dourados, Mato Grosso do Sul, from September 2022 to February 2023.

Variable	Total *n*/%	COVID-19 positive* *n*/%	COVID-19 negative *n*/%	*p***
Age (years)	225/100.0	28/12.4	197/87.5	0.0958
18 – 29	57/25.3	7/25.0	50/25.4	
30 – 39	82/36.4	7/25.0	75/38.0	
40 – 49	55/24.4	6/21.5	49/24.9	
≥ 50	31/13.8	8/28.5	23/11.7	
Race/color	225/100.0	28/12.4	197/87.5	0.951
Brown	129/57.3	15/53.6	114/57.9	
White	45/20.0	7/25.0	38/19.3	
Black	24/10.7	3/10.7	21/10.7	
Others	22/9.8	2/7.1	20/10.1	
Not declared	5/2.2	1/3.6	4/2.0	
Education (in years of study)	225/100.0	28/12.4	197/87.5	0.062
1 – 4	30/13.3	6/21.4	24/12.2	
5 – 10	136/60.4	11/39.3	125/63.5	
11 – 13	51/22.7	11/39.3	40/20.3	
Graduation	3/1.3	0/0.0	3/1.5	
Not declared	5/2.2	0/0.0	5/2.5	
Working	225/100.0	28/12.4	197/87.5	0.048
No	135/60.0	12/42.9	123/62.4	
Yes	90/40.0	16/57.1	74/37.6	
Locality of work	90/100.0	16/17.8	74/82.2	
Internal	37/41.1	3/18.8	34/46.0	0.382
External	53/58.9	13/81.2	40/54.0	0.002
Collective transport	53/100.0	16/30.2	37/69.8	0.002
Yes	40/75.5	8/50.0	32/86.5	
No	13/24.5	8/50.0	5/13.5	
Accommodation location	225/100.0	28/12.4	197/87.5	0.351
Pavilion A	134/59.6	20/71.4	114/57.9	
Pavilion B	88/39.1	8/28.6	80/40.6	
No information	3/1.3	0/0.0	3/1.5	
Number of people in accommodation	225/100.0	28/12.4	197/87.5	0.7594
< 10	27/12.0	4/14.3	23/11.7	
> 10	189/84.0	24/85.7	165/83.7	
Not declared	9/4.0	0/0.0	9/4.6	
Changed accommodations	225/100.0	28/12.4	197/87.5	0.087
Yes	64/28.4	5/17.8	59/29.0	
No	156/69.3	23/82.2	133/68.0	
Not declared	5/2.2	0/0.0	5/3.0	
Smoker	225/100.0	28/12.4	197/87.5	0.875
Yes	166/73.8	21/75.0	145/73.6	
No	59/26.2	7/25.0	52/26.4	

*Positive RT-qPCR test and/or IgG/IgM reactive. **Pearson's Chi-square, considered significant $p < 0.05$.

Table 2. Data from molecular and serological tests, and vaccination, of inmates with COVID-19 in the semi-open male penal institution of Dourados, Mato Grosso do Sul, from September 2022 to February 2023.

Inmate code	Date	RT-qPCR	Sequencing	GISAID Database	IgG	IgM	Vaccine doses	Time since last vaccine (months)
10	Sep 21, 2022	Neg	-	-	Pos	Pos	2	10
26	Sep 28, 2022	Neg	-	-	Pos	Pos	4	3
46	Sep 29, 2022	Neg	-	-	Pos	Pos	2	4
53	Oct 06, 2022	Neg	-	-	Pos	Pos	3	5
57	Oct 06, 2022	Pos	-	-	Pos	Neg	2	3
72	Oct 13, 2022	Neg	-	-	Pos	Pos	2	9
79	Oct 13, 2022	Neg	-	-	Pos	Pos	0	-
104	Nov 23, 2022	Pos	BQ.1.1	EPI_ISL_19490991	Pos	Neg	3	6
105	Nov 23, 2022	Pos	-	-	Pos	Neg	3	6
109	Nov 23, 2022	Pos	-	-	Pos	Pos	3	6
110	Nov 23, 2022	Pos	-	-	Pos	Neg	2	14
112	Nov 23, 2022	Pos	-	-	Pos	Neg	2	9
119	Nov 30, 2022	Pos	-	-	Pos	Neg	2	6
124	Nov 30, 2022	Pos	BE.9	EPI_ISL_19490992	Pos	Neg	2	11
128	Dec 08, 2022	Pos	-	-	Pos	Pos	2	12
129	Dec 08, 2022	Neg	-	-	Pos	Pos	3	7
130	Dec 08, 2022	Pos	-	-	Pos	Pos	1	18
131	Dec 08, 2022	Pos	BE.9	EPI_ISL_19490993	Pos	Neg	3	12
139	Dec 08, 2022	Pos	BE.9	EPI_ISL_19490994	Pos	Neg	1	17
145	Dec 10, 2022	Pos	BE.9	EPI_ISL_19490995	Pos	Pos	2	7
168	Dec 18, 2022	Neg	-	-	Pos	Pos	2	15
173	Dec 18, 2022	Neg	-	-	Pos	Pos	3	7
185	Feb 07, 2023	Neg	-	-	Pos	Pos	3	10
196	Feb 07, 2023	Neg	-	-	Pos	Pos	2	20
203	Feb 07, 2023	Neg	-	-	Pos	Pos	3	14
205	Feb 07, 2023	Neg	-	-	Pos	Pos	2	9
222	Feb 09, 2023	Neg	-	-	Pos	Pos	3	6
225	Feb 09, 2023	Neg	-	-	Pos	Pos	2	14

Pos: positive. Neg: negative.

The prevalence of COVID-19 and the prevalence ratio (PR) related to the analyzed variables are presented in Table 3. The prevalence of COVID-19 was 2.5 times higher among inmates aged 50+ than among the other age groups analyzed (PR = 2.5; 95% CI: 1.21–5.18). Regarding education, the group that received 11–13 years of education had a 2.81 times greater prevalence of COVID-19 than the other groups (PR = 2.81; 95% CI: 1.43–5.53). The prevalence of COVID-19 was higher among inmates who performed some work (17.8%; PR = 2.0; 95% CI: 0.99–4.02), with a prevalence 2.8 times higher among those who worked outside the penal unit (24.5%; PR = 2.81; 95% CI: 1.43–5.53).

Among the 20 wastewater samples analyzed, only 10% (2) were positive, one from general sewage and one from individual sewage, but in none of them was it possible to identify the strains through genomic sequencing.

Table 3. Prevalence and prevalence ratio of the variables analyzed among inmates with COVID-19 at the semi-open male penal institution in Dourados, Mato Grosso do Sul, in February 2023.

Variable	COVID-19 prevalence (case/100)	Prevalence ratio	95% CI*	*p*-value**
Age				
18 – 29	10.4	0.79	0.35 – 1.76	0.3557
30 – 39	8.6	0.59	0.26 – 1.33	0.1388
40 – 49	13.0	1.06	0.46 – 2.46	0.1553
≥ 50	25.8	2.50	1.21 – 5.18	
Education (in years of study)				
1 – 4	20.0	1.77	0.78 – 0.1469	0.1469
5 – 10	8.1	0.41	0.2 – 0.84	0.0104
11 – 13	21.6	2.81	1.43 – 5.53	0.0244
Working				
Yes	17.8	2.00	0.99 – 4.02	0.0381
No	8.9			
Working				
Inside	8.1	0.33	0.1 – 1.08	0.0423
Outside	24.5	2.81	1.43 – 5.53	0.0025

Female penal unit

Among the 14 inmates analyzed, none tested positive by RT–qPCR, and 21.4% (3) tested positive for IgG/IgM antibodies. All reported working, with 66.6% (2) working outside the penal unit; both used individual transportation to work, but all shared the same cell. While 66.6% of individuals (2) smoked more than 11 cigarettes/day. A total of 66.7% of inmates (2) were immunized with two doses of COVID-19 vaccine, and one inmate-was immunized with three doses. The wastewater sample was negative for SARS-CoV-2 viral RNA.

DISCUSSION

Treating infected people in penal units is also a problem, as only 66% of inmates comply with restrictive measures in units that do not have a health module (Oliveira et al., 2021), making it necessary to travel to other health centers for assistance, which requires more contact with people and a greater risk of transmitting infections (Fernandes et al., 2020). A study conducted in a Ugandan penitentiary revealed that the virus was brought to the prison unit after an inmate contracted the infection during a previous hospital stay and spread in the unit through contact with other inmates. Failure to use personal protective equipment and insufficient attention to safety and hygiene measures are likely to promote the spread of infection (Migisha et al., 2020). A study shows that a hygienic environment is necessary to prevent diseases, including COVID-19, especially in prisons. In Mato Grosso do Sul, hygiene depends on the capacity of each prison unit. Personal protective equipment was distributed to police officers, and items like hand sanitizer and masks were provided to inmates, but in limited quantities (IDDD, 2021).

Going out to contact external individuals, even using public transport, facilitates and increases transmissibility within the institution. Most of the COVID-19-positive inmates reported that their cells were crowded, as they shared them with more than 10 people, ranging from 12 to 43 individuals. We also recorded that participants were moved from their previous cells within 15 days of the interview, with five inmates reporting this change; one was transferred to a cell with 36 individuals, where eight inmates tested positive for COVID-19.

Anti-SARS-CoV-2 IgM appears after 3–6 days, and IgG appears after eight days of infection. The detection of IgG/IgM antibodies may indicate a recent infection, whereas the presence of IgG alone suggests past infection or advanced disease (Lee et al., 2010; Cassaniti et al., 2020). The presence of antibodies anti-SARS-CoV-2 is also present after vaccination, with IgM remaining positive only in the first months after vaccination and IgG remaining for 6 months (Doria-Rose et al., 2021).

The constant exit and entry of people, including civil servants, as well as inmates serving sentences in a semi-open regime, makes disease prevention challenging (Muniz et al., 2020). Brazilian penal institutions reported overcrowding, even before the pandemic. Social distancing and isolation, which are not maintained strictly in these places (Fernandes, 2021; Ferreira et al., 2024), are the most effective non-pharmacological measures used to control the spread of the coronavirus until large-scale vaccination.

Regarding the use of cigarettes, alcoholic beverages, and illicit drugs, several studies reveal that inmates use drugs, especially marijuana (Carvalho et al., 2006; Guimarães et al., 2006). In our study, tobacco, alcohol, cocaine, and especially marijuana were used. Of the 28 positive cases for COVID-19

in the male penal unit, 21 retrained individuals smoked cigarettes, seven consumed alcohol, three used marijuana, and three used cocaine. In the female penal unit, of the three positive cases for COVID-19, one used marijuana and cocaine. These findings indicate that individuals who use drugs might be even more vulnerable to COVID-19 because of previous damage to the respiratory system, increasing the likelihood of contracting the disease and suffering severe consequences for their health.

The infection in the male penal unit first occurred among inmates who worked at the cowhide company, who became infected after coming into contact with external individuals at work or on public transport, and subsequently spread to other inmates due to the common cell division. In the week following the infection of the inmates who worked at the leather company, COVID-19-positive cases appeared among the inmates who worked at the hospital institution; this maintenance of infection for three consecutive weeks suggested transmissibility due to cell division.

During the study period, only monovalent vaccines were administered, totaling 518,299,004 doses across Brazil (Brazil, 2023), whereas in the prison system, 2,035,079 inmates and staff were immunized (73,186 in Mato Grosso do Sul) (CNJ, 2022). In the male penal unit, 14 inmates were not immunized, of whom only one had a positive serological result but lacked recent signs and symptoms of COVID-19. Four inmates did not present with IgG/IgM, and among them, only one was immunized. In our study, most inmates received at least one dose of immunization, which provided them with immunity and possibly prevented the disease from progressing to severe cases.

Only two subvariants were identified, both derived from the Ômicron variant, consistent with the most prevalent lineages in Brazil during the sampling period (https://www.genomahcov.fiocruz.br/dashboard-pt/). BE.9 was the most prevalent, followed by BQ.1.1, with emphasis on inmates working in a hospital environment. Studies conducted in different regions of Brazil also revealed the same subvariants, which started spreading in November 2022 (Andreis et al., 2023; de Sousa et al., 2023).

The highest prevalence of COVID-19 was among inmates over 50 years of age compared to other age groups. This is justified because older inmates face greater susceptibility to infection due to a higher prevalence of chronic comorbidities, in addition to having reduced mobility or being housed in shared dormitories with less capacity for social distancing (Kwan et al., 2022).

The highest prevalence of COVID-19 was also observed among inmates with higher levels of education and who performed some work, especially outside the prison unit. This may be due to the specific characteristics of the semi-open regime and the work dynamics of the incarcerated. It is suggested that these individuals frequently engage in labor activities, which require greater circulation and result in greater exposure to the virus. COVID-19 cases

in closed institutions show that internal mobility, collective tasks, and high turnover are critical factors in transmission, leading to greater social contact and reduced capacity for isolation (Beaudry et al., 2020; McCauley, 2022; Bretaña et al., 2024).

Only two wastewater samples from the male penal unit were positive for SARS-CoV-2: one from general sewage and one from individual sewage from a cell in which one of the inmates tested positive for COVID-19. Studies have shown that the virus is present in sewage and among treated individuals, including in locations where there are no confirmed cases yet (Fiocruz, 2020; Desdouits et al., 2021), and have demonstrated the viability of the viral RNA in different circumstances and environments, including human feces, rectal swabs, and urine from symptomatic and asymptomatic patients (Tang et al., 2020; Wölfel et al., 2020; Shutler et al., 2021). Therefore, some researchers have speculated that the concentration of viral RNA in feces may be around 10^8 copies per gram of feces and can be detected in 81.8% of samples concomitantly with a negative oral swab (Lescure et al., 2020; Bonanno et al., 2022).

Countries in Europe, Asia, and North America, among others, are investigating and monitoring COVID-19 in the population by conducting wastewater-based studies and have reported lower costs than individual tests (UFMG, 2020; Chernicharo et al., 2021). SARS-CoV-2 RNA has been detected in treated and untreated sewage samples (Fiocruz, 2020; UFMG, 2020).

In this study, we detected SARS-CoV-2 RNA and anti-SARS-CoV-2 antibodies within penal institutions, and obtained demographic profiles and adherence to the vaccination schedule of those inmates. Our findings might help develop preventive medicine and control the spread of new outbreaks. Considering the potential for vaccine-induced IgM persistence beyond two months, we highlight the limitations this imposes on the use of serological markers alone to infer recent infection. This study has social, scientific, and environmental importance, especially in epidemiological surveillance, which can serve as a promising, inexpensive alternative for evaluation and precaution. It can be used for general population testing and as an indicator of early outbreak onset.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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