




Research Paper

Sanitary conditions of the third largest informal settlement in Brazil

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ABSTRACT

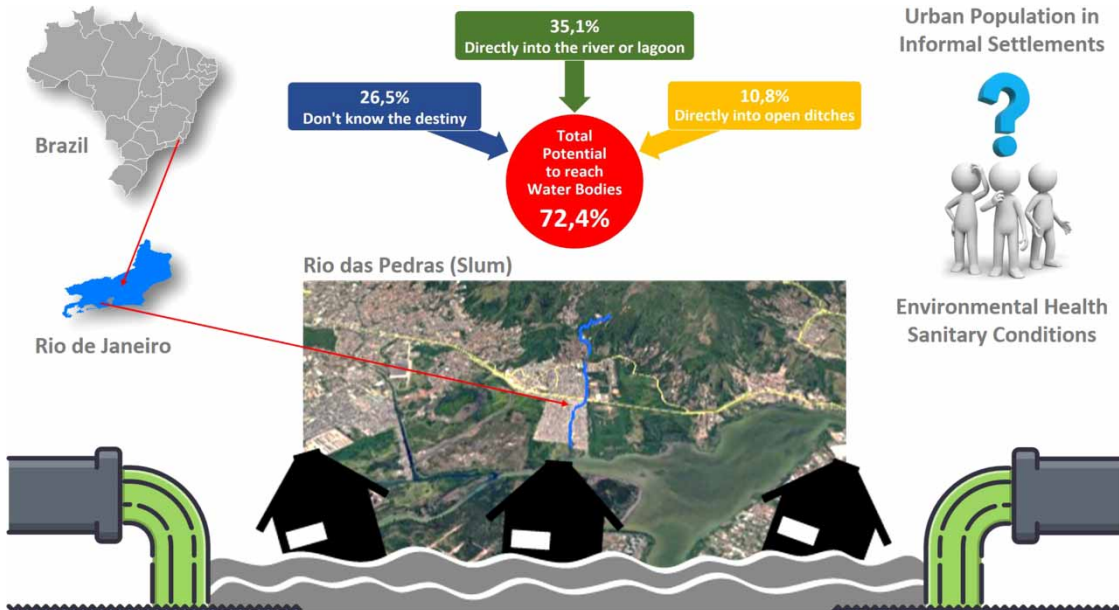
Large Brazilian cities, such as Rio de Janeiro, suffer serious environmental problems caused by informal settlements (IS), such as advances in the degradation of surface waters involving anthropic pressures resulting from uncontrolled urban growth, lack of sanitation or disasters related to climate events, creating a gap in relevant information about environmental health in urban IS. Therefore, it is essential to assess the health conditions of IS and the local population's perception of their living conditions. This study aimed to evaluate, by online form and public data, the sanitary conditions of the third largest IS in Brazil, the Rio das Pedras community, which was located on the banks of the Jacarepaguá Lagoon complex. The analysis revealed that 35% of respondents reported releasing domestic sewage directly into the river near their homes. Furthermore, 83% of the participants reported that they disposed of urban solid waste inappropriately. About 21% of residents reported falling ill due to direct contact with unsafe water after flood events. Public managers, concerned with advancing sustainability agendas and mitigating the risks to environmental health related to the lack of adequate sanitation services, should invest in actions that reflect the perception of the local population, proposing more appropriate socio-environmental solutions.

Key words: environmental health, population perception, sanitation, slums, vulnerabilities, water pollution

HIGHLIGHTS

- Analysis of the sanitary conditions of the main slum profile in Brazil.
- Perception of environmental reality reported essentially by residents.
- Pointing out the various forms of improper disposal of domestic effluents in water bodies.
- Part of the population is in constant health vulnerability due to contact with unsafe water.
- Most interviewees are aware of contributing to environmental degradation.

GRAPHICAL ABSTRACT



INTRODUCTION

In Brazil, in recent decades, there has been a substantial growth in the urban population, allowing the acceleration of the irregular development of informal settlements (IS), popularly known as *favelas* or slums (Toledo 2018; Machado & Ribeiro 2019). Combined with low investments in infrastructure, this fact has been reflected in a structural gap in urban systems, especially those inserted in the environmental protection of water bodies (Tucci 2003). The gradual increase of urban slums, following a worldwide trend, worsens the living and health conditions of many urban population groups, which already lack adequate sanitation and health conditions (Zhang *et al.* 2019; Chowdhury *et al.* 2022).

About 47% of the Brazilian population remains unassisted by the sewage collection and treatment service, according to the most recent data from 2020. In Rio de Janeiro, this portion was a little smaller, about 15% of the population was not connected to a sewage system yet, but this percentage has been growing (ITB 2020). However, the distribution of this percentage is substantially unequal depending on the region and areas of occupation of the city due to the lack of this essential health service (Toledo *et al.* 2020). This scenario represents a severe and chronic public and environmental health problem in Brazil, causing enormous concerns regarding the destination and impacts of effluents and possible contaminants close to the receiving water bodies.

The country's largest urban population and the highest disorderly urban growth rate are concentrated in the southeast region of Brazil (Brueckner *et al.* 2019). Between 2000 and 2010, the population in Rio de Janeiro grew by about 8%, between 5.8 million and more than 6.3 million (IBGE 2011, 2020). However, in the same period, the population growth in IS advanced by 19%. Although there were only 5% outside of them, increasing concerns about a population in a vulnerable position, which is still little analysed.

In most IS in Rio de Janeiro, the access to sanitary infrastructure services is unequal compared to regular neighbourhoods. A combination of geomorphological, biotic and climatic factors, in addition to inadequate infrastructure, difficulties in rainwater drainage, the disposal of untreated domestic effluent and the accumulation of solid waste on the banks of rivers, also contributes to an increase in exposure to environmental risks for both the population and associated ecosystems (Garcia *et al.* 2016).

The Jacarepaguá Lagoon complex and the Rio das Pedras community are located in the Barra da Tijuca neighbourhood where the sanitary situation is not different, and the urbanization process has intensified the anthropic pressures on the environment, such as the pollution of surface waters (INEA 2018). This reality favours the synergistic relationship between the dynamics of waterborne diseases, inadequate sanitation and poor hygiene (Nguyen & Pattanarsi 2022). Therefore, this

study aimed to evaluate, through an online form and public data, the health conditions and perceptions of the population of the third-largest IS in Brazil, the Rio das Pedras community, which was located on the banks of the Jacarepaguá Lagoon complex.

METHODS

Study area

The Rio das Pedras community is located in the metropolitan region of the municipality of Rio de Janeiro between the neighbourhoods of Jacarepaguá and Barra da Tijuca, crossed by the Pedras River (Figure 1), one of the tributaries of the Jacarepaguá's Lagoon complex, more explicitly flowing into the Tijuca Lagoon (Santos 2014).

This community has been chosen because it comprises the main profile of Brazilian slums due to characteristics such as a densely populated flat community, urban housing in subnormal conditions and location on the banks of a water body. In Brazil, more than four hundred thousand subnormal dwellings are located near riverbanks, streams or lakes and more than one million six hundred thousand inhabitants are in flat slums (Ximenes & Jaenisch 2019).

According to the data from the Brazilian Institute of Geography and Statistics – IBGE, between 2010 and 2019, in a study recently released due to COVID-19, the community of Rio das Pedras has been appointed as the third largest IS in the country, with 22,509 houses and a population of 65,276. A population increase of 19% in the last decade has been verified (IBGE 2020).

The occupation of the community began to grow significantly after the 1960s, largely in areas of environmental risk. This growth took place in a disorderly manner, with irregular allotments controlled informally by the residents' association (Costa & Britto 2014). Throughout the 1980s and 1990s, small urban interventions were carried out by the municipality, which guaranteed ownership of the land and residential units for only a tiny portion of the population (around 5%) in the central area of the community (Alves *et al.* 2020).

The Pedras' river watershed, especially in its lower course, presents an environment susceptible to flooding events, with a history of frequent urban floods in recent years and the prevalence of diseases such as hepatitis A, leptospirosis and schistosomiasis in the region (Castro & Dias 2017). The current condition of the river that crosses the community can be noted in

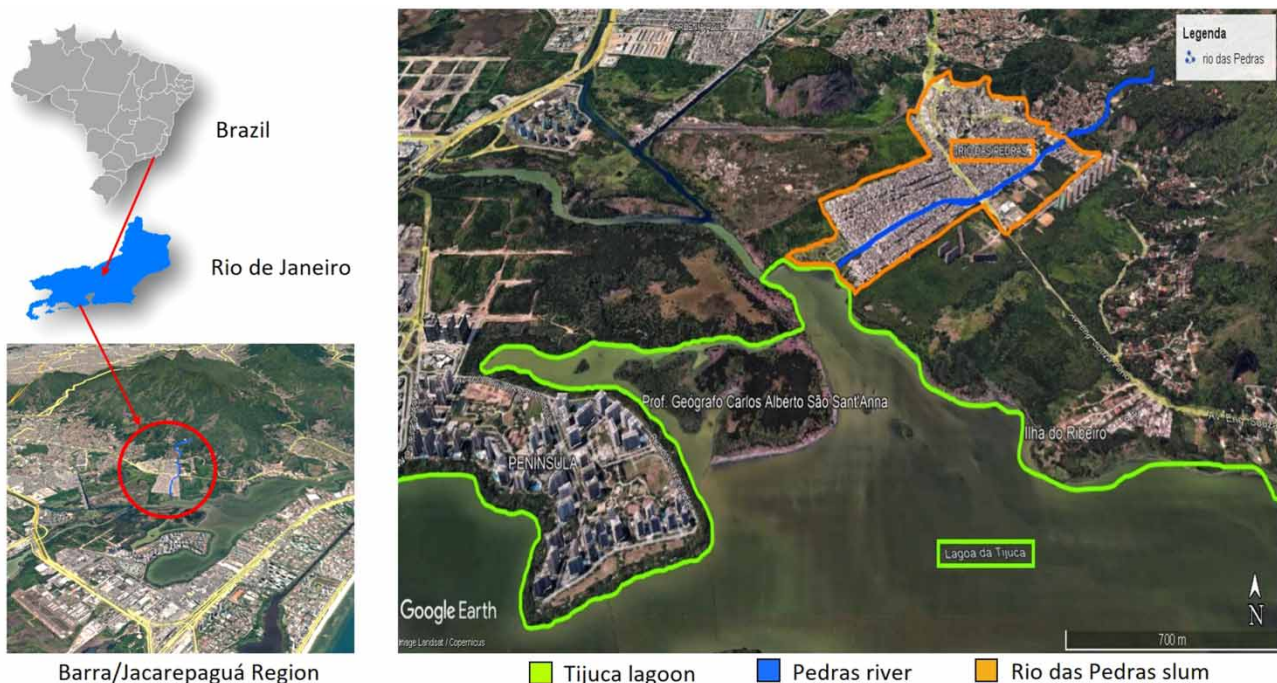


Figure 1 | Agglomeration of the Rio das Pedras community on the banks of the Pedras River and the Tijuca Lagoon, Rio de Janeiro, Brazil (Google Earth, accessed 06/12/2022).

Figure 2(a). In addition, rain events promote water retention points that can take days or weeks to drain, exposing the local population to contact with these supposedly inadequate waters.

These environmental health conditions expose people to other risks associated with climate changes and health issues, as demonstrated in studies in Africa and Asia (Okaka & Odhiambo 2018; Scoullou *et al.* 2020) and the proliferation of zoonoses in humans due to the increase in vectors that transmit diseases such as dengue, chikungunya and malaria (Bazaz *et al.* 2018).

Notably, there is a direct relationship between the garbage accumulated in the streets and floods. This direct relationship was also evidenced in a study about the carriage of residues, the formation of barriers in the beds and the increase in the flow of rivers during the rainfall, a combination capable of promoting rapid growth in level (factor 1.8) in the first flush (Honigh *et al.* 2020).

Questionnaire survey

Data collection was performed through a closed questionnaire via Google Forms, online and free (Supplementary Material). The exploratory study was directed towards a specific population belonging to or directly related to the community. The questionnaire was distributed electronically, such as social networks (WhatsApp) and websites (Instagram and Facebook), so that a potential range of the population of interest with Internet access could respond. The ‘Snowball Method’ was adopted where participants were encouraged to disseminate the survey after completing it.

The questionnaire asked socioeconomic questions related to housing, sanitation, environmental education, health and environmental perception relevant to the local context. Any person with access to the Internet, over 18 years old, with no restrictions on gender, ethnicity, education or social class, has been used as an inclusion criterion.

Besides, as an exclusion criterion, anyone who was not a resident and/or had no direct relationship with the place (work or commerce). Considering the large presence of commercial and service established in the locality, the responses of people who work in the community were included in this study as they spend most of their days exposed to the same lack of sanitary conditions as residents. The questions were prepared based on previous similar studies and technical guidelines for formulating questionnaires (Günther 2004; Maia *et al.* 2013; Quadra *et al.* 2019; Almeida & Hayashi 2020).

An online tool has been used to calculate the minimum sample size, which statically represents the local population, based on the Minimum Sample Size (MSS) equation and to estimate the margin of error, the Margin of Error (MOE) equation (Survey Monkey 2020) was used. Thus, for 65,276 residents, establishing a confidence level of 90% and a margin of error of 5%, 272 people were a minimum sample size obtained, which is necessary to validate the research. The form was available for 1 year and 2 months between May 2020 and July 2021. A licence was obtained from the research ethics committee of the State University of Rio de Janeiro (License No. 4.717.220/2021).



Figure 2 | Environmental condition of the river stretch in the central region of the Rio das Pedras community, Rio de Janeiro, Brazil (a); accumulation of urban solid waste (bucket and accumulation points) (b) in the Rio das Pedras community (author's own, 2022).

RESULTS AND DISCUSSION

The results indicated that the approach adopted to the population of interest was assertive due to the significant participation of residents among the respondents to the questionnaire, closed after reaching a total of 279 valid participants. The extracted information has been divided into three large groups: socioeconomic issues, local environmental health conditions and basic sanitation.

Socioeconomic

As shown in Table 1, most participants lived in the Rio das Pedras community. The other interviewees were divided into owners of commercial establishments such as shops, bars and restaurants; students from local schools (only non-community residents); service providers who work in the community and formal workers, such as teachers, dentists and sellers. The average age group investigated was 34 years old. The largest group of people surveyed were between 18 and 29 years old, followed by the second-largest group aged between 30 and 39.

The female gender was the most representative, with more than 60% participation (60.6%), with the male gender representing 39% and identified as other genders forming less than half a per cent of the participants (0.4%). The information about employment and main occupation collected has been divided into groups of unemployed individuals, self-employed workers, informal workers and formal workers, supported by Brazilian labour laws and other forms of activities in smaller proportions.

The results on the income of the respondents found that 54.8% had a monthly payment of one to three minimum wages (between USD 190.00 and 570.00), referring to the base year of 2020. Around 22.9% of participants live with less than one minimum wage per month (less than USD 190.00) and 8.2% had no regular monthly income (Figure 3(a)).

Table 1 | Groups of questionnaire respondents divided based on the primary relationship with the Rio das Pedras community – RJ/Brazil

Questionnaire respondent group	
Dwellers	73.5% (<i>n</i> = 205)
Traders (people in business, shopkeepers, bars, and restaurants)	5.0% (<i>n</i> = 14)
Students (local schools)	0.7% (<i>n</i> = 02)
Service providers (self-employed and small services)	2.9% (<i>n</i> = 08)
Formal professionals (teacher, dentist, seller, etc.)	6.8% (<i>n</i> = 19)
Other (informal and/or unspecified)	11.1% (<i>n</i> = 31)

n, number of respondents.

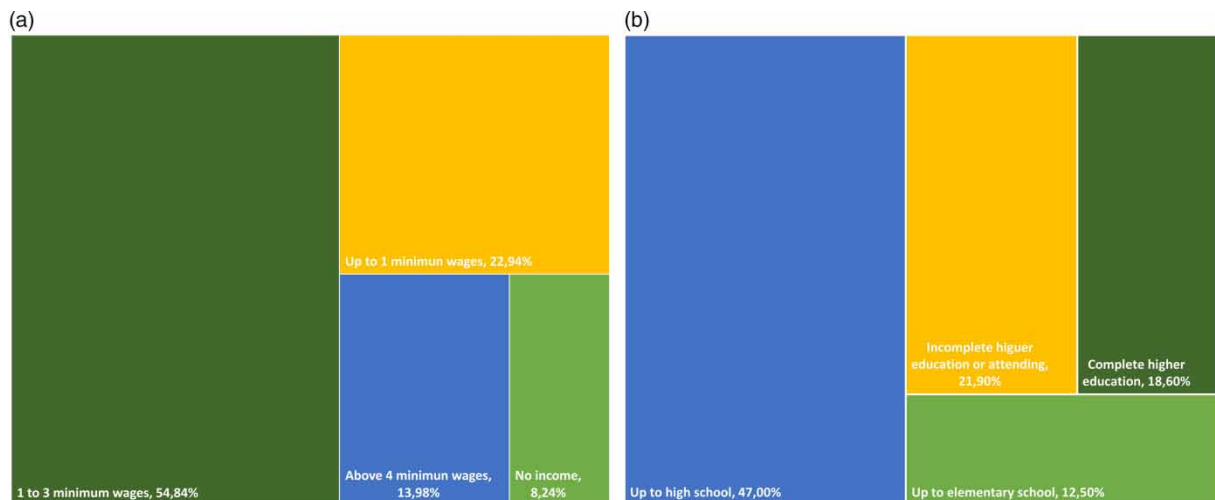


Figure 3 | Socioeconomic data on monthly family income (a) and the level of formal education (b) of respondents to the questionnaire in the Rio das Pedras community – RJ/Brazil.

Regarding the formal education and the level of education of those surveyed, the results were divided as those who completed high school, those who were attending university or did not complete higher education, individuals with complete higher education, those with a low level of education and those who only completed elementary school (Figure 3(b)).

These educational data guided a selection of residents, who had access to higher education, indicating a relevant percentage among this group of respondents who experience a lack of sanitary infrastructure daily.

The local average of residents per household in the studied community (Figure 4(a)) was 3.1 people, which translates into a correct similarity to the Brazilian national average of 3.3 residents per household (IBGE Cidades 2020), also converging with the average informed by the municipality of Rio de Janeiro of 2.9 people per household (DATA-RIO 2020). The majority of the respondents had lived or worked daily in the locality for more than 15 or 10 years, respectively, which promotes a higher quality of information and inferred perceptions about sanitation and other local issues surveyed (Figure 4(b)).

A cross-sectional analysis between education level and the time living in or working in the community was performed. According to the survey, the highest concentration of people who completed high school and higher education was those who had lived in the community for more than 10 years. This evaluation also pointed to a temporal phenomenon: older residents had a better education than younger residents. About 7.5% of individuals with a university degree (21 out of 279) lived in the community for over 15 years. Moreover, the total number of people with full graduation among the survey participants was 10% (28 out of 279).

These findings show that the formal education factor, a socioeconomic condition, was not enough for a portion of the individuals surveyed to distance themselves from the conditions of vulnerability. A social reality different from that found in a study in the largest flat IS in Thailand, with similarities in relation to unsafe WASH, but which had in education a distancing factor, for some individuals, from local vulnerabilities (Nguyen & Pattanarsi 2022). The mapping of key vulnerabilities is fundamental to understanding risks and increasing individual and local resilience (Saad 2021).

Environmental health

A positive characterization of the location is that 99% of those surveyed had at least one adequate bathroom at home, adequacy that according to the indicators proposed by the Sustainable Development Goals – SDGs are those where do not occur open defecation; there is the physical security of users; faecal waste is captured and safely conveyed with isolation at disposal (or treated inside or outside the site of use) and there are facilities for washing hands with soap and water inside the property (Hutton & Chase 2016).

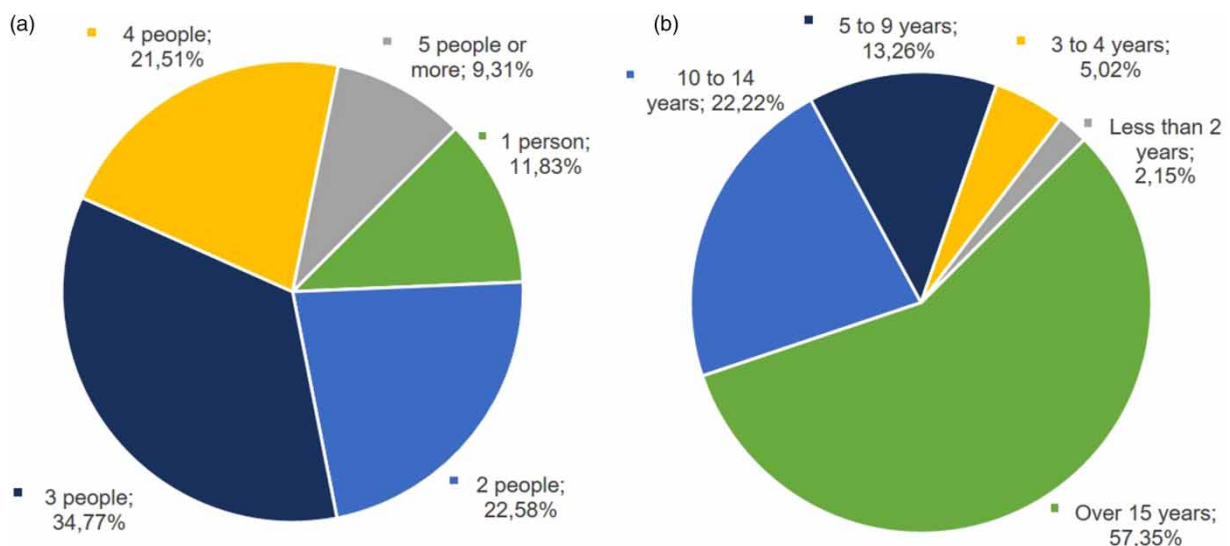


Figure 4 | Characterization of dwellings by the number of individuals residing in each household (a) and the time of residence or work of respondents (b) in the Rio das Pedras community – RJ/Brazil.

Also, 96.4% of the facilities are indoors, private and not shared. It is worth noting that there were no reports of housing without access to an indoor toilet, which allowed us to infer that there is hygienic safety regarding the indoor use of sanitary facilities.

About the destination of domestic effluent (domestic sewage), the options with direct polluting potential, in descending order of responses, were directly into the river (or lagoon); they did not know the destination of their effluent; it was thrown in an open ditch, which showed a scenario of risk to the population despite the apparent hygienic safety inside the homes. Only 24% of the participants were connected to the public sewerage collection system (Figure 5(a)). Furthermore, most surveyed reported they 'always' had contact, through flooding or inundation, with inappropriate water during or after rainy events in the region (Figure 5(b)).

At this point, it is important to reinforce that the locality presents an environment susceptible to flooding events (Castro & Dias 2017), combined with the current condition of degradation of the river that cuts through the community, reported in the study area. This scenario has as one of its consequences water retention points that can take days or weeks to drain, exposing the local population a daily contact with such supposedly contaminated waters, due to the presence of untreated domestic effluents or the widespread presence of solid waste disposed of inappropriately in various parts of the community, especially during the rainiest periods of the year.

Such environmental health conditions resulted in some participants reporting having already gotten some disease after this direct or indirect exposure to supposedly unsafe water (Table 2).

According to the studies on IS, there is an association between the growth of communities in subnormal agglomerations, the lack of sanitation and the growth of environmental degradation, especially in local ecosystems (Mahabir et al. 2016; Takyi et al. 2020). Therefore, there was a question to assess the perception of the local population as a possible polluting agent of

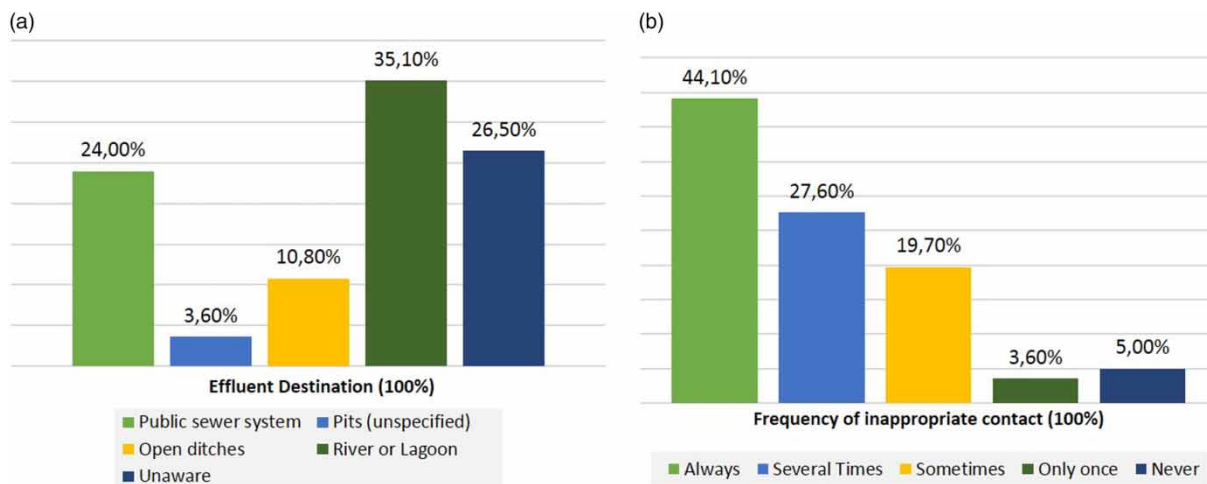


Figure 5 | The leading destination of domestic effluent (a); frequency of contact with inappropriate water during or after rainfall (b); reported by respondents from the community Rio das Pedras – RJ/Brazil.

Table 2 | Percentage of the population who became ill after contact with improper water during or after rainy events in the Rio das Pedras community – RJ/Brazil

Became ill after contact with inadequate water after rainy events (floods)

Yes	21.9% (n = 61)
No	57.3% (n = 160)
Unable to confirm	20.8% (n = 58)

n, number of respondents.

this cycle, which made it possible to know that a large majority of respondents (94.3%) were conscious that negative impacts (polluting) coming from the community could amplify the damage to the local ecosystem.

Sanitation

The deficiency in sanitation can become an extremely harmful risk to human and environmental health in the region and understanding the priority factors of this vulnerability condition became more evident after assessing the degree of concern and perception of the population about local sanitation. Few studies seek to identify patterns leading to inequality of access to safe sanitation at the household scale (Grady *et al.* 2018).

Thus, a specific question was formulated containing the topics: supply of treated water; a collection of USW; flooding (due to lack of drainage) and non-piped sewage. Considering the classification options, most respondents felt more than one topic in a 'very concerning' situation, demonstrating a rather alarming perception of the population about the lack of sanitation services in the region.

Within this panorama, Figure 6 presents the four main concerns of the community, in order of magnitude: (1) the constant flooding and inundations; (2) the lack of sanitary infrastructure for the collection of effluents (domestic sewage); (3) also of great concern was the inefficiency in the regular collection of USW, as seen through the accumulation in many parts of the community; (4) with concern between very worrying and worrying was the supply of treated water.

Concerning the form of disposal and the USW collection pattern, the survey revealed that the vast majority of those interviewed disposed of their common waste at collective accumulation points provided by the community. Only a few declared they had a regular municipal collection at home (Figure 7(a)). The USW has been disposed of at various points within the locality; these places are containers (buckets) or boundaries on the ground for later removal. The municipal urban cleaning service carries out this removal, but it needs to be more efficient since it is released daily without any control. Most of the time exposed to adverse environmental conditions, also allowing contact and unsafe handling of the population and domestic animals.

Recent analyses in the region of the Jacarepaguá and Barra da Tijuca Lagoon complex indicated the presence of emerging pollutants (EP), such as pharmaceuticals and a high organic load, related to the discharge of domestic and industrial effluents not adequately treated or even untreated in local environmental matrices (Cunha 2020; Rodrigues *et al.* 2020; Silva *et al.* 2020).

To understand the possible routes by which these drugs enter water bodies directly related to the community of Rio das Pedras, a more objective question was formulated regarding the disposal of medicines, with inadequate disposal being the main form observed, with only a tiny proportion of those surveyed giving a correct destination to the drugs, indicating that they take their waste medicines to a pharmacy or health centre (Figure 7(b)).

More than a third of interviewees (33.8%) did not know the origin of the water they consumed, which could lead to vulnerability. However, most groups (66.2%) reported knowing their drinking water comes from the public supply. To conclude,

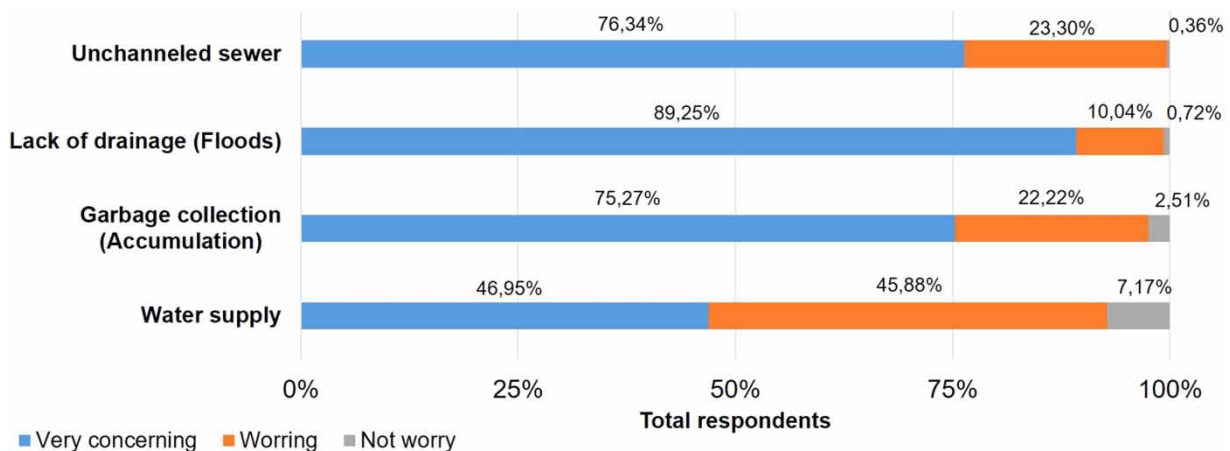


Figure 6 | Concern of the local population about the provision of the primary sanitation services in the community of Rio das Pedras – RJ/ Brazil.

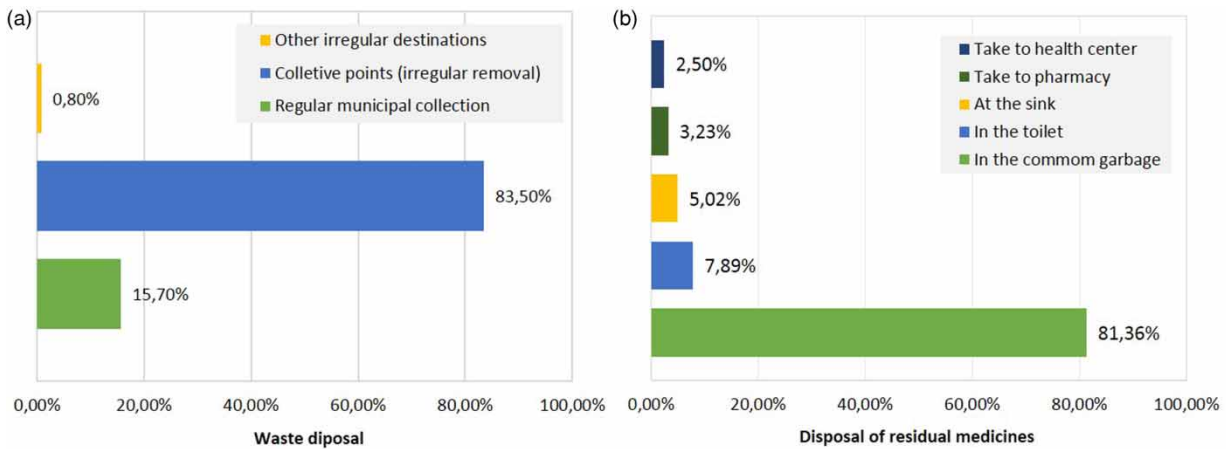


Figure 7 | Form of waste disposal (a) and destination of residual or expired pharmaceutical products (b) in the community of Rio das Pedras – RJ/Brazil.

the respondents were asked if part of the pollutants found in the Tijuca Lagoon could have as a source for the discharge of raw effluents and the irregular disposal of waste from the community. The results are compiled in Table 3.

As an essential reflection, considering the universe of households surveyed, for the perception and local diagnosis, regarding the urban sanitation conditions, it was possible to infer that there is a high percentage of untreated domestic effluents capable of reaching the water bodies adjacent to the community due to the lack of sanitation when considering a pessimistic scenario of the data surveyed (Figure 8).

CONCLUSIONS

The questionnaire survey revealed that the residents understand that the primary sanitation conditions in the locality are very worrying, precisely because of the relationship between environmental imbalance and sanitary scarcity found, collaborating to the advancement of the degradation of local water bodies.

Table 3 | Percentage of the population (%) that believes in collaborating with the pollution of the water bodies directly linked to the Rio das Pedras community – RJ/Brazil

Believe that part of the pollution in the lagoon comes from the community of Rio das Pedras	
Yes	95.7%
No	0.7%
Maybe	36%

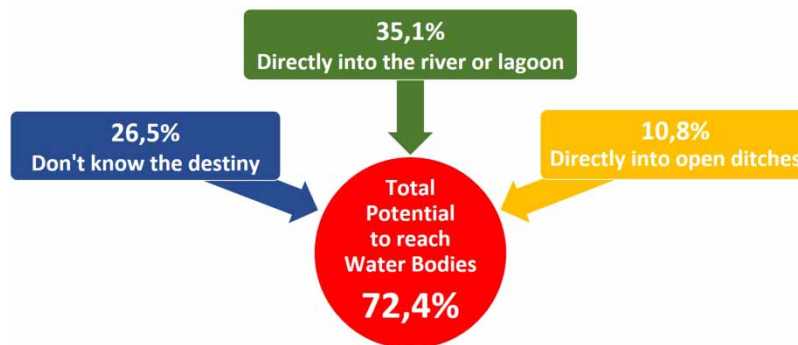


Figure 8 | Perception of the respondent population about the percentage of raw effluents with the potential to reach the water bodies (river and lagoon) directly linked to the Rio das Pedras community – RJ/Brazil.

The need for more local sanitation results from multiple variables, such as inefficient government management and low investments. The locality has a population dynamic of strong and continuous growth in recent years, inserted in a sub-basin susceptible to flooding, increasing the concern about health risks. This concern results from the frequency of exposure reported by a significant portion of the population to inappropriate water after rain events followed by flooding.

The perception of the population regarding the lack of sewage and USW collection can guide both the scientific community and public managers on the need for more adequate analyses of the local profile and more focused studies on the effects and impacts of pollutants being disposed of in nature in the local lagoon environment and on the need to implement structuring, participative and educational actions to urban sanitation.

This community reflects a national environmental, urban and social profile. It may help interpret similar contexts, being fundamental for understanding data in seeking solutions more appropriate to the reality of IS, for advances in environmental sustainability, reduction of health insecurity and gradual removal of vulnerability conditions. In this way, the result found the search for alternative solutions that promote a realistic understanding of the sanitary conditions of slum areas and the possible vulnerabilities involved to mitigate the impacts on health and local environmental sustainability.

This work shows the importance of controlling and organizing the urban growth of cities in line with environmental sustainability, as well as the need to include in this process the perception of the population directly involved, who already live on the margins of minimum sanitation services and consciously suffer adverse environmental impacts. There is an urgent need to consider more socio-environmental data for effective urban planning in order to minimize the effects of urban growth in a climate change scenario.

RECOMMENDATIONS

It is recommended that greater participation of the population, which lives and acts in IS, in studies and sustainability projects as an essential way to expand residents' perception and environmental education and strengthen dialogue and access to public managers for sanitary improvements. In this work, it was concluded that the population studied understood their share of contribution to environmental degradation. Still, this factor alone was insufficient to create a collective local awareness capable of promoting the effective removal of part of the individuals of a cycle of vulnerability and environmental degradation.

Finally, the present study emphasizes the need for further studies involving the participation of community residents to improve local conditions of sanitation services. Such studies must consider the population's perceptions and anxieties for decision-making, ensuring that actions are carried out in a more adequate way to meet the local needs of these communities.

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DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

CONFLICT OF INTEREST

The authors declare there is no conflict.

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