

RESEARCH ARTICLE

A tale of two communities: Comparing user perceptions of condominial and conventional sewer systems in Salvador, Brazil

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Abstract

Problems of access and quality of sanitary sewage disproportionately impact the health of populations in urban peripheries of low-and middle-income countries. The condominial sewer system is a practical, low-cost, effective, and simplified engineering approach compared to conventional sewer systems. In support of meeting the sanitation needs in highly populated urban settings, there is a need to understand the residents' perceptions regarding the advantages and disadvantages of this sanitation model compared to conventional sewer systems. We conducted a cross-sectional study from September to December 2021 in two urban communities of Salvador, Bahia, Brazil, where condominial and conventional sewer systems had been implemented in the last five years. Of the 203 residents we interviewed, 50.7% lived in a site served by a condominial sewer system. Residents in the condominial sewer site reported not connecting to public sewage network (23.7% vs. 11.2%; $p = 0.022$) more often than in the conventional site. They reported more collective action to solve urban sanitation problems (69.9% vs. 54.0%; $p = 0.020$), such as manhole cleaning and unclogging efforts to fix plumbing. Despite these challenges, these residents expressed that the current service quality is better than it was in the previous two years. Our results suggest that even within urban periphery communities of a large Brazilian city, disparities exist in access to and quality of sanitation services that may be linked to sewage system implementation. Implementing simplified sewer systems is important to meet the growing sanitation demands of urban areas. However, these systems should also play a role in reducing sanitation disparities and the adoption of participatory approaches to meet the needs of populations in the most disadvantaged conditions. Despite challenging conditions, there is the potential for community engagement and active participation in sanitation-related matters, which could enhance the implementation and long-term sustainability of these systems.

participants in the survey. Researchers who wish to access the data can contact the data manager of the Oswaldo Cruz Foundation, Nivison Junior (nivisonjr@gmail.com).

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Introduction

The problems of access, coverage, and the quality of sanitary sewage disproportionately impact the health and quality of life of populations in urban peripheries of low- and middle-income countries (LMICs). In this context, low-cost sewage systems that are practical, effective, and socioculturally appropriate can and should be used to expand access to sewage services and improve the quality of life of populations. In Brazil, the condominial sewer system is a technology that has been considered an adequate solution for sewage in the face of the infrastructure conditions of the low-income urban communities [1].

Condominial sewer implementation is based on the formation of condominiums or block groups of users considered as a sewage connection unit. This system resembles sewage collection in buildings, with branches of pipes buried at shallow depths and smaller diameters, typically around 100 mm [2, 3]. The pipe pathways traverse residential properties and are designed to be as efficient as possible. As a result of this design, condominial sewers can reduce installation, operation, and maintenance costs savings by up to 50%, compared to the conventional system, which presents a compelling case for the universalization of this type of public service [3]. Given the tremendous expected growth of low-income urban communities around the world, rapid expansion of networked sewage provision is essential for achieving target six of the Sustainable Development Goal (SDG) for universal access to safe water and sanitation [4].

A key aspect of condominial sewers, which differs from more conventional and costly systems, is community participation [3]. In conventional systems implemented in Brazil, intervention management is typically the responsibility of public and private companies, with little to no engagement aimed at promoting community participation in the design and management of the intervention. Furthermore, each house has its own connection to the public sewage network, making it technically more complex and costly. Costs related to the collector system can account for up to 75% of the total system cost, and these costs are influenced by factors such as construction, terrain topography, the technology used, and the number of sub-basins in the system [2, 5]. The layout of the sewage network is closely tied to the city's topography, as sewage flow follows the natural terrain slopes. These aspects differ from those related to condominial sewage [3]. However, both systems have equal sewage treatment and disposal, which are the responsibility of the same sanitation company.

Multiple studies have highlighted the successful implementation of condominial sewage systems in Brazil, including a reduced transmission of infectious diseases [6, 7]. However, reports of limited community participation in the management of activities and insufficient promotion of communication between users and service providers during and after system implementation can result in decreased systems effectiveness [1]. Also noteworthy is the difficulty service providers face in consolidating and systematizing information arising from complaints or service provision requests related to sewage quality, such as issues with sewage overflow and network rupture or obstruction [8]. Residents of impoverished urban communities often are excluded from sanitation services and solutions aimed at improving environmental quality, which impacts their health [1]. Successful sanitation systems require more than infrastructure investments to reduce barriers to sewage connection. Additionally, the absence of community engagement, technical implementation challenges, and a lack of communication to understand users' perceptions, challenges with the system, and long-term issues are some factors that also impact the population's health [9, 10].

To address the problems, it is necessary to develop inclusive solutions that promote community involvement and participation in the planning and managing sanitation interventions, especially in sewage systems. Additionally, increasing communication between users and service providers during and after the implementation of the sewage system is crucial. This may

be enhanced by using mobile health (mHealth) technologies. mHealth strategies have been used successfully in interventions related to a wide range of public health issues [11, 12]. To better understand the potential for mHealth strategies to improve success for sanitation programs, we also investigated participants access to and use of mobile phones. Furthermore, we were interested in whether they would be willing to use their mobile phones to participate in surveys, as few studies investigate the effectiveness of mHealth approaches for environmental interventions in low and middle-income countries, such as Brazil [13, 14]. It is worth noting there is a lack of research to assess perceptions of urban sanitation, especially considering different systems common in many neighborhoods in urban areas of Brazil.

Studies on the perception of sanitation systems have focused on different issues related to sanitation including quality, safety, usage, payment, [15, 16] sewage and idle networks, [17] user satisfaction with the services provided, [18] perceptions of management and the formulation of environmental policies, [19] and evaluations of urban sanitation services as perceived by different social actors, such as civil society, managers, and providers [16]. Studies such as these are essential for understanding how individuals and communities perceive their reality and the context in which they are inserted. They can contribute significantly to a greater understanding of local problems and the potential for future transformations of this reality [17]. Furthermore, the ability to examine perceptions and identify relevant disparities in access to and quality of urban sanitation services is key. This can allow programs to examine and reduce the barriers that hinder the full guarantee of the right to safe and affordable sanitation, such as sewage and water [20, 21], as legally required in Brazil, and help define priorities for the allocation of public resources to resolve the socio-environmental issues that put at risk the health and quality of life of people living in some of the most marginalized segments of low-income communities [22–24]. Studies on access and the quality of sewage systems have been limited to assessing physical coverage without evaluating user perceptions, [25] especially among those who live in areas with the greatest lack of public urban sanitation services and with respect to sewer connections. To improve and increase the success of networked sewer provision worldwide, in addition to engineering advancements, it is important to understand the perception of service quality offered in different contexts, with coverage of condominial and conventional sewer systems, and to reduce barriers to access and effective sanitation implementation. Accordingly, the present study aimed to describe residents' perceptions of urban sanitation infrastructure in the context of two low-income communities in Salvador, Brazil—one with condominial sewer systems implemented and the other with conventional sewer systems.

Materials and methods

Study area and data collection

We carried out the study in two communities in the city of Salvador, Brazil (ca. 2,900,319 million inhabitants in 2021) [26]. The study areas were defined based on the locations where our research group works, which studies zoonotic diseases in low-income communities in Salvador, Bahia, Brazil. First, we identified all sites with similar sociodemographic and environmental characteristics as those in the group's previous work [27]. Through technical visits and conversations with residents, we evaluated the places that had sanitation interventions (condominial and conventional). We intentionally selected two communities, Pau da Lima ($n = 142$ residents) and Marechal Rondon ($n = 338$ residents), both with a high exposure to zoonotic diseases. One of these communities had implemented condominial sewer systems, while the other had conventional sewer systems installed within the last five years. We aimed to reach an equal number of households that had received both sanitation programs, selecting

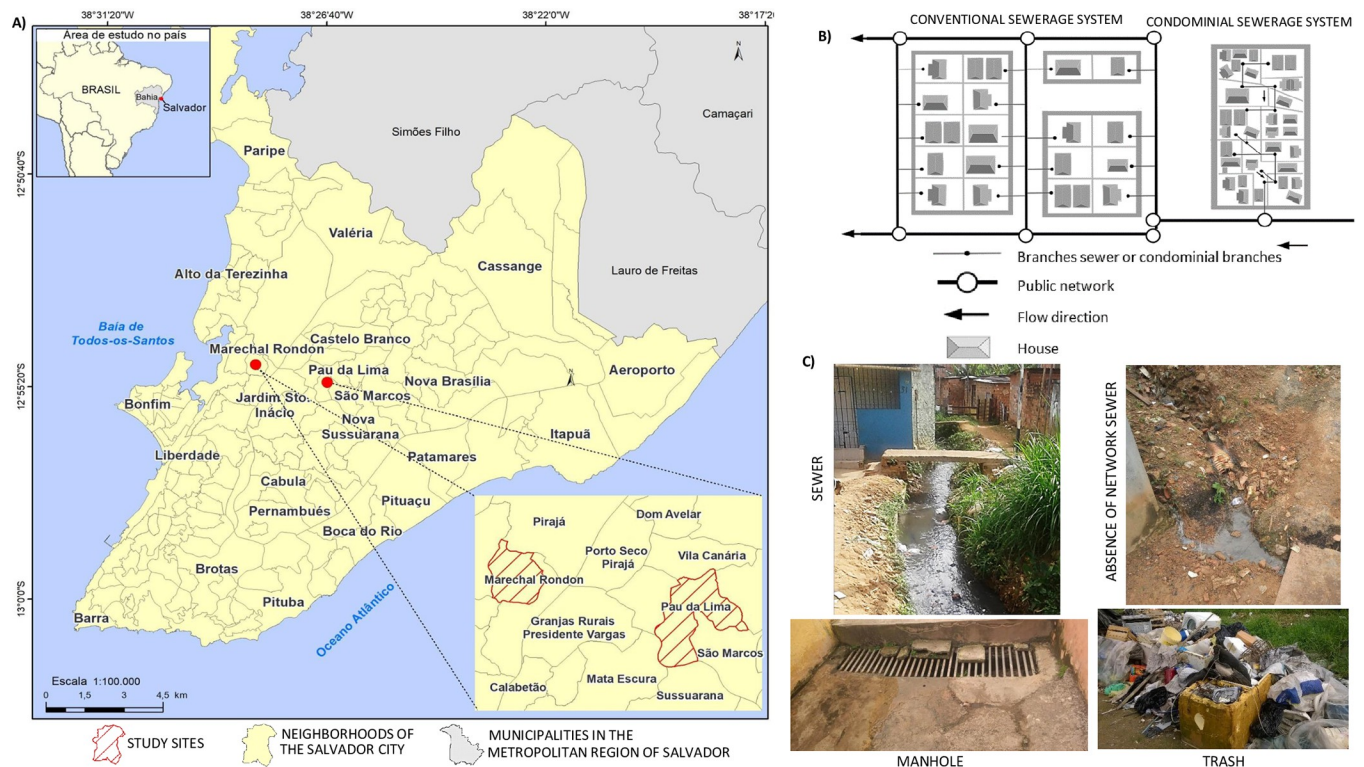


Fig 1. Panel showing. A) Map of the two sites in the city of Salvador with the location of the communities within the city. B) Conventional and condominium sewerage system design. C) Inequalities/barriers in access to sanitation public services in the community with condominium sewerage system (Pau da Lima). The authors created these figures using the findings generated from the analysis of their primary data (B, C). The map used in the publication is not copyrighted, as it was created by the authors themselves using the free and open-source software QGIS, version 3.10, available for download at https://www.qgis.org/pt_BR/site/forusers/download.html. The data used in preparing the map containing the boundaries of neighboring countries, Brazil, Bahia, Salvador, and neighborhoods, are also open data and were downloaded from the website of the Instituto Brasileiro de Geografia e Estatística (IBGE, 2021) and the Prefeitura Municipal de Salvador (Salvador, 2017). Both data can be consulted with their respective metadata on the websites: <https://www.ibge.gov.br/geociencias/organizacao-do-territorio/malhas-territoriais/15774-malhas.html?=&t=downloads>; http://mapeamento.salvador.ba.gov.br/geo/desktop/index.html#on=layer/default;bairros/bairros;scalebar_meters/scalebar_m;orto2016/Ortoimagem_Salvador_2016_2017&loc=76.43702828517625;-4278080;-1445884. <https://doi.org/10.1371/journal.pwat.0000129.g001>

approximately 100 residents from each area. The communities of Pau da Lima and Marechal Rondon (Fig 1A) are considered low-income, with a low score on the urban-environmental quality index. This index assesses the physical environment, socioeconomic conditions, services and infrastructure, as well as dimensions of well-being [28]. The seroprevalence for *Leptospira*, the bacterium that causes leptospirosis, a neglected tropical zoonotic disease prevalent in environments with precarious basic sanitation, has been estimated to be between 10–12%, which is considered elevated [27].

Eligible residents were men and women 18 years of age or older, who served as household respondents in the site where the sanitary sewage intervention was carried out, who slept in the household for at least three nights per week and had previously participated in our research studies. A trained team of interviewers visited residents between September and December 2021, explained the research objectives, obtained written informed consent from residents who agreed to participate in the survey, and subsequently administered the standardized questionnaire verbally. The survey was administered in Portuguese, with an average duration of 20 minutes, to residents who agreed to participate in the study, giving sufficient time to recall. The answers provided during the interview were confidential, and only the participant and the team members had access to them. After data collection, a highly trained database manager

Table 1. Sociodemographic characteristics of study population.

Characteristics	Overall	Site with Condominial sewage	Site with Conventional sewage	P-value ¹
	N = 203	N = 103	N = 100	
	Frequency (%)			
Sex				
Male	69 (34.0)	30 (29.1)	39 (39.0)	0.138*
Female	134 (66.0)	73 (70.9)	61 (61.0)	
Age (years)				
≤ 44	107 (52.7)	64 (62.1)	43 (43.0)	0.006*
> 44	96 (47.3)	39 (37.9)	57 (57.0)	
Ethnicity²				
Black	88 (43.3)	43 (41.7)	45 (45.0)	0.043**
Mixed	97 (47.8)	52 (50.5)	45 (45.0)	
White	12 (5.9)	8 (7.8)	4 (4.0)	
Schooling³				
≤ Primary school	90 (44.3)	51 (49.5)	39 (39.0)	0.266**
≥ Secondary school	108 (53.2)	50 (48.5)	58 (58.0)	
Household per capita income (US\$/day)^a	1.50 (0–10.3)	0.50 (0–8.8)	0.50 (0–11.8)	-
Occupation	N = 121	N = 67	N = 54	
Informal work ⁴	46 (38.0)	34 (50.7)	12 (22.2)	0.001*
Formal work	75 (62.0)	33 (49.3)	42 (77.8)	

*Chi-square test

**Fisher's exact test

¹ Bold numbers mean P-value ≤ 0.05² 6 (6.0%) participants self-declared of Asian ethnicity (site with conventional sewage).³ 5 (2.5%) participants 2 (1.9%) sites with condominial system and 3 (3.0%) site with conventional system) reported they didn't know or didn't answer the schooling. ≤ Primary school: illiteracy and incomplete primary school; ≥ Secondary school: incomplete and complete secondary school.⁴ Informal work: work-related activities for which the subject did not have legal working documents (domestic service, works in construction, recyclable materials collector).^a Interquartile ranges (for median) are shown for continuous variable of per capita household income.<https://doi.org/10.1371/journal.pwat.0000129.t001>

strictly controlled access to the database with individual participant information. Other researchers received only coded information and could not link the code to the participants in this study.

Our questionnaire was based on previously validated instruments that examined perceptions of sanitation and use of mobile phones, [29] both of which were adapted to the context and objectives of this study. The items were organized into five main sections: the sociodemographic profile of participants; perceived importance of basic sanitation; household profile and sanitation services; user evaluation of basic sanitation services (system of sewage and service provision); and access to and use of cell phones. These sections are summarized in the Tables 1–3 and supplementary tables (see S1–S3 Tables).

Statistical analysis

Our aim in this exploratory analysis was to understand residents' perceptions and to make comparisons between the two sites: one with condominial sewer systems and one with conventional sewer systems. Data were summarized using descriptive statistics. Here, the sociodemographic and economic profile of participants included of the following variables: "sex (male/female)", "age (≤ 44, > 44 years)", "ethnicity (black/mixed/white)", "schooling (≤ primary school, ≥ secondary school)", "occupation (informal work, formal work)". Data on race was

Table 2. Household profile and sanitation according to type of sewage intervention.

Household and peridomiciliary characteristics regarding sanitation	Responses	Overall	Site with Condominial sewage	Site with Conventional sewage	P-value ¹
			Frequency (%)		
Type of bathroom sewer connection	195		N = 97	N = 98	
Connected to public sewage network ²		161 (82.6)	74 (76.3)	87 (88.8)	0.022*
Not connected to public sewage network ³		34 (17.4)	23 (23.7)	11 (11.2)	
Connection of sewage to the public network	161		N = 74	N = 87	
Yes		153 (95.0)	67 (90.5)	86 (98.9)	0.025**
No		8 (5.0)	7 (9.5)	1 (1.1)	
Formal contract with State Agency Public	198		N = 99	N = 99	
Yes		65 (32.8)	3 (3.0)	62 (62.6)	<0.001**
No		133 (67.2)	96 (97.0)	37 (37.4)	
Sewage tariff	196		N = 98	N = 98	
Pay sewage tariff		81 (41.3)	4 (4.1)	77 (78.6)	<0.001**
Does not pay sewage tariff ⁴		115 (58.7)	94 (95.9)	21 (21.4)	
Open sewer within ≤ 20 meters from the home	203		N = 103	N = 100	
Yes		103 (50.7)	44 (42.7)	59 (59.0)	0.020*
No		100 (49.3)	59 (57.3)	41 (41.0)	

*Chi-square test

**Fisher's exact test

¹ Bold numbers mean P-value ≤ 0.05² Reported as connected to State Agency Public sewage network³ Reported as rainwater network and not collected/open sewer (open ditch, direct to the river, straight to the stream)⁴ Reported does not pay sewage tariff and does not receive water bill/Exempt/ Building/Condominium.<https://doi.org/10.1371/journal.pwat.0000129.t002>

also based on Brazilian Institute of Geography and Statistics data, which recognizes five different races (white, black, mixed, indigenous, Asian) [30]. Household profile and sanitation variables were “type of bathroom sewer connection (connected to public sewage network, not connected to public sewage network)”, “connection of sewage to the public network (yes/no)”, “formal contract with State Agency Public (yes/no)”, sewage tariff (pay sewage tariff/does not pay sewage tariff)”, “open sewer within ≤ 20 meters from the home (yes/no)”. For social action regarding sanitation, the data was based on the following variables: “fundraising for sewer installations (yes/no)”, “fundraising for private toilets (construction and maintenance) (yes/no)”, “formal claims for sewage services (yes/no)”, “residents’ actions (sewer services) (yes/no)”. The variables related to access to and use of cell phones were: “cell phone (yes/no)”, “cell phone type (smartphone/basic mobile)”, “family member’s cell phone (smartphone/basic mobile)”, “cell phone uses in research (yes/no)”, “cell phone uses in SMS research (yes/no)”, “use of cell phone to research with App (yes/no)”.

To investigate differences between those participants living in the site with condominium sewage and those in the site with conventional sewage for all variables, we used the chi-square test and Fisher’s exact test were used for all categorical variables. A p-value ≤ 0.05 was considered statistically significant. The analysis was performed using STATA Statistical Software version 14 (College Station, TX).

Table 3. Social action regarding sanitation among residents according to type of sewage intervention.

	Responses	Overall	Site with Condominial sewage	Site with Conventional sewage	P-value ¹
Social action regarding sanitation					
		Frequency (%)			
Fundraising for sewer installations	157		N = 78	N = 79	0.014**
Yes		6 (3.8)	6 (7.7)	-	
No		151 (96.2)	72 (92.3)	79 (100)	
Fundraising for private toilets (construction and maintenance)	159		N = 80	N = 79	1.00**
Yes		1 (0.6)	1 (1.3)	-	
No		158 (99.4)	79 (98.8)	79 (100)	
Formal claims for sewage services	203		N = 103	N = 100	0.014*
Yes		46 (22.7)	16 (15.5)	30 (30.0)	
No		157 (77.3)	87 (84.5)	70 (70.0)	
Residents' actions (sewer services)					0.020*
Yes		126 (62.1)	72 (69.9)	54 (54.0)	
No		77 (37.9)	31 (30.1)	46 (46.0)	

*Chi-square test

**Fisher's exact test

¹Bold numbers mean P-value ≤ 0.05<https://doi.org/10.1371/journal.pwat.0000129.t003>

Ethics statement

This study was approved by the Research Ethics Committee of the Institute of Collective Health/ Federal University of Bahia (CEP/ISC/UFBA), with CAAE number 32361820.7.0000.5030, and by the National Research Ethics Committee (CONEP) linked to the Brazilian Ministry of the Health under approval numbers 4.235.251.

Results

From September to December 2021, a total of 203 respondents ≥ 18 years of age, living in the communities of Pau da Lima and Marechal Rondon participated in this study. Among these respondents, 50.7% lived in a site served by a condominal sewer system, while 49.3% lived in a site with a conventional sewer system. The sociodemographic characteristics are described in Table 1.

In a comparison of the two communities, there were statistically significant differences in the sociodemographic characteristics of participants. There were a greater number of respondents >44 years of age in the conventional sewers site compared to the condominal sewers site (57.0% vs. 37.9%; $p = 0.006$). There was also a slightly higher proportion of those who self-identified as Black (45.0% vs. 41.7%; $p = 0.043$) in the site covered by a conventional sewer compared to the site with condominal sewers. A meaningful difference was found for participants who reported informal work (50.7% vs. 22.2%; $p = 0.001$) which was much greater in the site covered by condominal sewers. In both sites, the median household income was estimated to be US \$0.50 per day (Table 1).

A higher proportion of participants in the site with condominal sewers reported not being formally connected to the public sewer network (23.7% vs. 11.2%; $p = 0.022$) compared to the

Table 4. Cell phone access and use among surveyed residents.

	Responses	Overall	Site with Condominial sewage	Site with Conventional sewage	P-value ¹
Cell phone access	Frequency (%)				
Cell phone	203		N = 103	N = 100	
Yes		170 (83.7)	88 (85.4)	82 (82.0)	0.507*
No		33 (16.3)	15 (14.6)	18 (18.0)	
Cell phone type	170		N = 88	N = 82	
Smartphone		146 (85.9)	72 (81.8)	74 (90.2)	0.115*
Basic mobile		24 (14.1)	16 (18.2)	8 (9.8)	
Family member's cell phone	202		N = 102	N = 100	
Yes		120 (59.4)	61 (59.8)	59 (59.0)	0.907*
No		82 (40.6)	41 (40.2)	41 (41.0)	
Family member's cell phone type	118		N = 60	N = 58	
Smartphone		108 (91.5)	50 (83.3)	58 (100)	0.001**
Basic mobile		10 (8.5)	10 (16.7)	-	
Cell phone uses in research	202		N = 102	N = 100	
Yes		129 (63.9)	64 (62.7)	65 (65.0)	0.739*
No		73 (36.1)	38 (37.3)	35 (35.0)	
Cell phone uses in SMS research	201		N = 101	N = 100	
Yes		122 (60.7)	60 (59.4)	62 (62.0)	0.707*
No		79 (39.3)	41 (40.6)	38 (38.0)	
Use of cell phone to research with App			N = 102	N = 99	
Yes	201	112 (55.7)	56 (54.9)	56 (56.6)	0.812*
No		89 (44.3)	46 (45.1)	43 (43.4)	

*Chi-square test

**Fisher's exact test

¹Bold numbers mean P-value ≤ 0.05<https://doi.org/10.1371/journal.pwat.0000129.t004>

conventional site. Compared to the conventional sewer site, the participants living in the condominium sewer site also reported reduced access to the piped water supply via the public network (90.5% vs. 98.9%; $p = 0.025$), were less likely to have a formal contract with the water and sewer provider (97.0% vs. 37.4%; $p < 0.001$), and had a greater proportion who do not pay for the sewage service (95.9% vs. 21.4%; $p < 0.001$). Despite having increased services (formal and paid for), a higher proportion of those in the site with conventional sewage system reported being within 20 meters of open sewers (59.0% vs 42.7%; $p = 0.020$) (Table 2).

With respect to community engagement and action regarding sanitation, not surprisingly, a higher proportion of participants in the condominium sewer site reported that they raised funds for sewage facilities compared to the site with conventional sewer (7.7% vs. 0%; $p = 0.014$) (Table 3). More residents in the condominium sewer site reported carrying out community actions to solve service problems, such as plumbing repairs (69.9% vs. 54.0%; $p = 0.020$) compared to the conventional sewer site (Table 3). Participants in the site with conventional sewer reported that they made formal requests to the sanitation service provider for sewer repairs at a higher percentage (30.0% vs. 15.5%; $p = 0.014$), compared to the condominium sewer site.

As highlighted in Table 4, when asked about access to cell phones and use of cell phones, there were no significant differences between the two sites regarding most cell phone access variables with one exception: the use of smartphones by family members was higher among participants in the conventional sewer site (100% vs. 83.3%; $p = 0.001$; Table 4).

Evaluation of access and quality of public urban sanitation services, and performance of service providers is summarized in supplementary tables (see [S1–S3 Tables](#)), available in the supplementary materials. It is noteworthy that the perception of sanitation services differed significantly between the two sites. First, in terms of the perception of the provision of sanitation services, a higher percentage of participants from the condominium sewer site reported the absence of certain services compared to the conventional sewer site. There was a notable difference in reporting the lack of water supply (17.7% vs. 4.0%; $p < 0.005$), sewage collection (50.0% vs. 29.2%; $p = 0.003$), and manhole cleaning/drainage (76.0% vs. 53.2%; $p = 0.001$) ([S1 Table](#)). More residents in the condominium sewer site expressed satisfaction (whether complete or partial) with sewage collection (48.5% vs. 26.9%; $p = 0.001$) and the maintenance of sewage within the community (52.9% vs. 32.0%; $p = 0.008$) compared to the conventional sewer site. A significant majority of participants from the condominium site reported that the current service quality is better than it was in the previous two years compared to the conventional sewer site (81.4% vs. 61.5%; $p = 0.004$) ([S2 Table](#)). The majority of residents living in areas covered by condominium sewer reported that they perceive the efforts of the state public agency have not been sufficient for the entire city to have sewage collection and treatment services (56.4% vs. 70.7%; $p = 0.012$) compared to those living in areas covered by conventional sewer. ([S3 Table](#)). For more details on conventional and condominium sewerage system design and inequalities/barriers in access to public sanitation services in the community with condominium sewerage system (Pau da Lima), see [Fig 1B and 1C](#).

Discussion

In this study, we compared perceptions of urban sanitation infrastructure among residents living in communities in Salvador, Bahia, Brazil that had condominium versus conventional sewerage interventions in the last five years. We found that in condominium sewer implementation, fewer households reported connections to the state agency's public sewage network, suggesting unequal access to domestic sewage networks even in impoverished areas. This finding is consistent with previous work in Salvador [[22](#)]. More limited access to networked sewers can reflect a greater social vulnerability of the populations living in this area, as observed in the study carried out in Salvador that reported race/ethnicity and family monthly income as some of the factors that produce inequalities in access to sewage services, a pattern in the communities on the peripheries of this city [[22](#), [28](#)]. While we did not identify large socio-economic differences between the two sites, it is possible that these factors were also important in our communities. However, it is also possible that the community participation requirement to form blocks for condominium sewer implementation can impact the willingness or desire to participate in the program, as has been highlighted in other studies [[31–33](#)].

We also identified reduced access to other basic services such as piped water supply, sewage collection, and solid waste collection, which are considered important risk factors for the transmission of a wide range of diseases related to inadequate sanitation, such as leptospirosis and diarrheal diseases [[27](#), [34](#)]. These problems have also been reported in other studies on access to and perception of sanitation in other LMICs [[8](#), [15](#), [23](#), [35–37](#)]. In a study of low-income communities in the south of Brazil, one reason communities were not connected to public sewer network was due to the economic situation of families which reported the collection of the fee as unfair, in view of so many other problems they experienced [[35](#)]. In our study, socioeconomic aspects such as low income were also identified in the communities, and here we confirm that the family income of the participants was about US \$0.50 per day.

In our study, we also identified that residents who lived in the condominium sewer site reported the need to carry out more collective action to solve local urban sanitation problems,

such as cleaning the streets, clearing manholes and joint efforts to repair pipes. This makes sense as reduced services may result in problems such as presence of clogged manholes and accumulation of trash (Fig 1C). This requires collective action to solve their own problems, as they often do not have formal agreements with the sanitation service provider or pay fees. In this study, we identified that residents with condominal sewers reported fewer formal claims for sewage services in their communities. While collective action is important, community participation must occur more broadly in the implementation of sanitation interventions, and not just in solving problems that arise from insufficient of promotion of the local participation in the system's implementation. This should be seen as a potential for the development of more sustainable basic sanitation interventions, as was also observed in studies conducted in Porto Seguro, Bahia, where residents of the community used their own resources to solve problems related to the water supply service [38].

Community participation is a fundamental aspect in the implementation of the condominal sewage system. It has the potential and benefits to promote the construction of collective solutions, favor the resolution of problems and barriers to access to services, result in effective maintenance of the network, and encourage greater dialogue between service providers and the community, which has positive impacts on health and population's quality of life [31, 39]. However, previous studies have reported insufficient community participation in the implementation of condominal sewage systems and the lack of openness of service providers to the development of interventions based on the shared management of this service with the community [19]. Additionally, most of the experiences in implementing the condominal sewage system have limited the community's participation to only the bureaucratic aspects related to the installation of pipes through the residences [1] disregarding its potential in the management of the implementation of this system [3]. Problems such as these can also be attributed to the lack of communication between residents of low-income communities and those who implement sanitation interventions. This lack of communication has been considered a challenge for the realization of successful, sustainable, innovative, and consistent interventions with the sociocultural reality of users [40].

Another issue associated with the lack of communication and limited community participation in the condominal sewer system may be related to the unpreparedness of service providers to deal with socially vulnerable population groups. We observed that in the region with a condominal sewer system, the majority of participants had lower levels of education, and many of them were engaged in informal work. Historically, in areas inhabited by groups with these characteristics, there has been a lack of priority and sometimes unpreparedness on the part of local service providers to promote actions that encourage the engagement and participation of these population segments [41] in all stages of the sanitation implementation process, from planning to installation and evaluation of the services offered [1]. Despite the evidence of challenges presented by our study regarding the issues associated with sewage (sewage collection) and other basic services in areas, such as water supply, residents expressed higher satisfaction with sewage collection, treatment, and maintenance in the community. Furthermore, participants assessed the quality of sewage services as superior when compared to the two previous years.

To strengthen communication between service providers and the community in the shared management of the condominal sewer system, an innovative strategy could be the use of mHealth technologies [42, 43]. mHealth strategies have been successful in interventions for a variety of public health problems [42, 43]. mHealth could potentially offer ways to improve communication between sanitation service providers and users. Moreover, collection of community input through mHealth tools could be useful for promoting broader local participation during and after the implementation of the condominal sewer system in communities on the

urban periphery [40]. In this study, access to cell phones and use of WhatsApp were prevalent, suggesting that mHealth tools might be an option for bolstering implementation of the condominium sewer intervention.

We acknowledge the following limitations for this study. Due to the cross-sectional nature, we cannot, nor do we attempt to link the variables measured here to describe causality. In addition, the use of a convenience sample limits generalization of our findings beyond these communities. We also acknowledge the strictly quantitative nature of the study as a limitation. An integrated qualitative approach and quantitative research could enhance our understanding of the issues under examination. This combined approach would allow us to explore nuances and factors that may have yet to be fully captured through quantitative data analysis. Future studies could expand on this work using probabilistic sampling across various neighborhoods in Salvador, with a greater number of residents of the communities on the periphery of this city. Furthermore, these studies could incorporate the use of qualitative research methods to provide a more in-depth understanding of people's lived experience in these communities.

Conclusion

The results of this study highlight the importance of local perceptions in the diagnosis and evaluation of the current infrastructure and provision of public services in urban sanitation. Our findings suggest the existence of disparities in access and a variable quality of public sanitation services in low-income urban communities according to the type of sewage system implemented. Residents served by the condominium sewage system had limited access to water and sanitation services and took more actions to solve local sanitation problems. Developing community engagement and participation programs for urban sanitation implementation is valuable for increasing the potential for reach and effectiveness of these programs. Furthermore, the use of communication technologies may help to promote effective communication between communities and service providers and may enhance the success and sustainability of the interventions carried out. Ultimately, the need to enhance and improve sanitation implementation can contribute to the health, well-being, and quality of life of communities at risk of a wide range of diseases and illnesses associated with inadequate urban sanitation.

Supporting information

S1 Table. Summary of perception of sanitation services.

(DOCX)

S2 Table. Summary of sanitation services evaluation.

(DOCX)

S3 Table. Summary of perception regarding public authorities.

(DOCX)

S1 Text. Questionnaire.

(PDF)

S1 Data. Dataset.

(DTA)

S2 Data. Code analysis stata.

(DO)

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