Sustainable city of Rio de Janeiro (RJ)? Analysis of the evolution of planning for Sanitary Sewage

Cidade do Rio de Janeiro (RJ) sustentável? Análise da evolução do planejamento para o Esgotamento Sanitário

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ABSTRACT This article aimed to analyze the panorama of Sanitary Sewage, from 1992 to 2016, against the evolution of the strategic and directors plans of the city of Rio de Janeiro (RJ), proposing sustainable measures. It was developed from exploratory and descriptive research, with primary and secondary sources. After analyzing the urban plans, a series of goals that were not applied in the city was found, due to budgetary and political issues, that contributed to the unsustainability of the city in terms of Sanitary Sewage.

KEYWORDS City planning. Urbanization. Sewage. Sustainable development.

RESUMO *Este artigo teve por objetivo analisar o panorama do Esgotamento Sanitário, de 1992 a 2016, frente à evolução dos planos estratégicos e diretores da cidade do Rio de Janeiro (RJ), propondo medidas sustentáveis. Desenvolveu-se a partir de pesquisa exploratória e descritiva, com fontes primárias e secundárias. Após a análise dos planos urbanísticos, encontrou-se uma série de metas descritas que não se aplicaram na cidade, por questões orçamentárias e políticas, que contribuíram para a insustentabilidade da localidade em termos de Esgotamento Sanitário.*

PALAVRAS-CHAVE *Planejamento de cidades. Urbanização. Esgotos. Desenvolvimento sustentável.*

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Introduction

In order to promote a sustainable future, it is essential to protect the environment and, as a consequence, the health of the population. Thus, sanitation services are essential[1].

The 2030 Agenda, of the United Nations (UN), "[...] is the plan of action for people, planet and prosperity"[1(1)] that is composed of 17 Sustainable Development Goals (SDGs). Among these, the sixth stands out, which addresses sanitation and aims to "ensure the availability and sustainable management of water and sanitation for all"[1(25)].

One of the sewage sectors that has a low coverage rate (collection and treatment) is the Sanitary Sewage (ES), which remains a challenge for the different instances of the federation. The cost of implementation is relatively high and requires a joint effort by different sectors of society[2].

It is noteworthy that the implementation of water supply and ES services aims at a rapid and appreciable improvement in the health and living conditions of the population, constituting the best investment for the benefit of public health[3]. It is necessary to sustainably manage the basic consumption resources available in cities, which are part of the main demands of the urban community, since the universalization of sewerage services reduces health problems[4].

In Brazil, only 46% of the sewage generated is treated, and 73.7% of the sewage collected undergoes some type of treatment, according to data from the National Sanitation Information System (SNIS) in 2017. As in the Country , in the City of Rio de Janeiro (CRJ) there is also a precarious treatment of sewage: of what is collected, 44.84%, only 64.49% is treated[5].

This low rate has consequences for environmental and human health, with poor sanitation related to the transmission of diseases such as cholera, dysentery and hepatitis A. Thus, the proper final disposal of sewage is of paramount importance for public health[6,7].

The CRJ has already been the target of several strategic plans, aiming to make it sustainable and, in addition, to achieve the SDGs of the UN. However, measures that demonstrate the sustainability of depletion have not been addressed or have not achieved their objectives during the various governments. And the scenario in which the CRJ finds itself is worrying.

According to the Brazilian Institute of Geography and Statistics (IBGE)[8], currently, about 3.050 households at CRJ do not even have a bathroom/toilet, which results in a precarious final disposition. In its territory, there are six Sewage Treatment Plants (ETE) and two undersea outfalls[9]. In terms of flow, the volume collected reaches 546.966 m³, and the treated, 352.728 m³, about 65%. In comparison with other Brazilian cities, CRJ has the highest total collection in ES services: around R$ 228 million, in the year 2017[5]. Such data reflect the lack of sewage and planning service in one of the main capitals of the Country.

Therefore, the general objective of this article was to analyze the panorama of ES, from 1992 to 2016, in view of the evolution of CRJ's strategic plans and master plans, proposing sustainable measures.

Methodology

For this study, a documental analysis was carried out – descriptive and historical research – using primary and secondary sources, in the following databases: a) Library of the Secretariat of Urbanism; b) Rio de Janeiro State Water and Sewage Company (Cedae); c) Government of the State of Rio de Janeiro; d) Ministry of Planning, Development and Management; and e) City Hall of the City of Rio de Janeiro. The primary sources used were the CRJ's urban plans.

For the identification of these plans, a retrospective survey was carried out, from 1992 to 2016. The delimitation at the beginning of the research was due to the implementation

of the first Master Plan of CRJ, in 1992, considered a set of phases of urban planning Brazilian, since 1875. It was sought to strengthen proposals that included social policies, protection of the environment and cultural heritage[10,11].

Searching words were used: 'master plan'; 'strategic plan'; 'sanitation program'; 'depollution projects'; 'growth acceleration program'; and 'rio 500 vision project'. Inclusion criteria were established: documents that addressed the strategic plans and urban plans of CRJ, and that contained aspects related to the ES network.

From the search, the following were found: Master Plan (MP) of the CRJ (1992); Strategic plan 'Rio always Rio' (1994-2008); Guanabara Bay Pollution Clean-Up Program (PDBG 1995-2006); Growth Acceleration Program (PAC-2007); MP of the CRJ (2011); Environmental Sanitation Program of Municipalities Surrounding Guanabara Bay (PSAM-2012); 'Post 2016: A more integrated and competitive Rio' (2009-2012; 2013-2016); and 'Rio 500 Vision Project' (2015).

For the analysis of secondary sources, a survey was conducted in the database of the Ministry of Planning, where data from the SNIS – Historical Series: sanitary sewage were found. The search was carried out from 1995 to 2015, using the locator words 'snis' and 'sanitary sewage'. The period indicated refers to the entire history present in the system, until data collection. The indicators analyzed were: ES001 (total population served with ES), ES005 (volume of sewage collected, in 1.000 m³/year) and ES006 (volume of treated sewage, in 1.000 m³/year); FN024 (investment made in ES by the service provider [R$/year]) and FN043 (investment made in ES by the state [R$/year]); IN006 (average sewage tariff [R$/m³]), IN015 (sewage collection index [%]), IN016 (sewage treatment index [%]) and IN046 (treated sewage index referring to water consumed [%])[12]. For the construction of the graphics, the program Origin, version 8, was used.

Results and discussion

Analysis of urban plans in relation to ES

The first plan executed was the PDCRJ of 1992. This aimed at the organization and development of the CRJ, mainly in regions not previously covered by infrastructure works, especially in relation to the expansion of the ES network. The plan included works to expand sewage collection only in the neighborhoods of Planning Areas (AP) 2, 3 and 4[10].

For the planning of the CRJ's sewage program, it was requested: (a) inclusion of an absolute separator system between the ES and drainage networks, gradually; (b) permanent monitoring of this system; (c) existence of sewage treatments to preserve public health; (d) sewage treatment that still used the municipal drainage networks for its drainage, until the implementation of the absolute separator system; and (e) the establishment of an ES program by the city, in partnership with the state agency responsible for sewerage system[10].

Because it was the first MP of the CRJ, it was expected that the entire location would be included in the expansion of the sewage service. However, what was presented excluded AP1 and AP5. However, the MP can be considered as the starting point for the planning of the CRJ, since, from it, the first strategic plan began, the 'Rio always Rio', in November 1993, which aimed at transforming it into a metropolis and increase the quality of life of its population. There were strategies outlined for each CRJ sewage problem, such as the clean-up of the bays (Guanabara and Sepetiba) and the Jacarepaguá hydrographic basin (lagoon complexes)[13]. In this plan, the Favela-Bairro Program was inserted in one of the strategies (Integrated Rio), with the following goals: improving the quality of life of the

residents of communities and the basic services provided by the government[14].

For ES, the construction of new collection networks and the connection of residences to such networks were prioritized. *Chart 1* lists the number of households, the extension of the network (in meters), the population served and the home sewage connections that the Favela-Bairro Program served[15]. The impact caused by the Program for the sewage system was to increase the collection rate by 20% in the first six years of implementation. After the construction works, all the inserted communities had, at least, 78% of the households with access to the network of the ES[16].

According to Guanais and Fischer[17], this plan adopted an analytical stance, since it was fragmented from 1 central objective to 7 strategies, which were subdivided into 21 goals, with 61 actions and 159 projects. It was demonstrated that the objective would be achieved if all the strategies outlined were completed. The possibility of not meeting these goals was excluded and a sophistry was adopted: the prediction of the future. In the execution of the plan, the uncertainty of the future of the CRJ was not taken into account, especially when the local reality was perceived at the time of the implementation of the projects contained in the plan.

Chart 1. Construction works related to the sanitary sewage of the Favela-Bairro Program, from 1994 to 2008, and the Growth Acceleration Program (PAC) in the City of Rio de Janeiro, with its location, support in execution, construction works, progress and investment

Favela-Bairro Program						
AP	**Favela**	**Neighborhood**	**Nº of households**	**Population served**	**Network (m)**	**Sewage connections**
4	Vila Sapê	Jacarepaguá	834	3.393	3.486	1.327
5	Vila do Céu	Santa Cruz	2.497	9.988	11.766	*
2	Vila Santo Amaro	Catete	919	2.337	2.600	*
3	Vigário Geral / Parque Jardim Beira-Mar / Te Contei	Vigário Geral	5.122	19.080	**	*
2	Vila Cândido / Guararapes / Cerro-Corá	Cosme Velho	872	3.339	4.206	*
5	Três Pontes	Paciência	1.341	4.005	4.000	350
2	Vidigal	Vidigal	2.567	9.943	9.394	*
4	Santa Maria	Jacarepaguá	708	2.347	4.403	*
3	Serrinha	Madureira	420	1.763	2.800	568
4	Rio das Pedras	Jacarepaguá	12.000	50.000	16.800	*
2	Salgueiro	Tijuca	1.084	4.367	10.390	1.127
3	Parque Royal	Ilha do Governador (Portuguesa)	1.063	4.146	3.948	980
1	Quinta do Caju	Caju	819	886	4.283	*
1	Parque Boa Esperança / Parque Vitória	Caju	1.600	4.860	3500	*
3	Parque Proletário do Grotão	Penha	867	2.110	3.832	460
3	Morro São João	Engenho Novo	1.325	4.504	9.268	*
3	Morro União	Coelho Neto	1.036	4.504	9.268	*
2	Morro dos Macacos / Parque Vila Isabel	Vila Isabel	4.296	12.189	**	*

Chart 1. (cont.)

Favela-Bairro Program						
AP	**Favela**	**Neighborhood**	**Nº of households**	**Population served**	**Network (m)**	**Sewage connections**
1	Morro dos Prazeres / Morro do Escondidinho	Santa Tereza	2.151	9.075	7.749	*
1	Morro do Tuiuti	São Cristóvão	1.357	5.275	5.116	1.600
3	Morro do Urubu	Pilares	996	2.532	2.574	*
3	Morro do Juramento / Parque Silva Vale / Vila Primavera	Tomás Coelho	2.978	12.758	1.886	*
3	Morro do Sereno / Morro da Paz/ Morro da Caixa D'Água / Morro do Caracol	Penha	2.752	6.418	9.695	1.701
2	Morro do Borel / Chácara do Céu	Tijuca	2.557	8.252	**	*
3	Morro do Fubá / Vila do Campinho / Iguaíba / Comendador Pinto	Cascadura	2.650	13.250	5.345	*
2	Morro da Formiga	Tijuca	1.899	5.801	2.647	*
2	Morro do Andaraí / Jamelão	Andaraí	1.904	6.989	*	*
3	Morro da Cotia	Méier	394	1.260	1.886	*
3	Morro da Fé	Penha	705	2.441	2.365	345
3	Morro da Cachoeira Grande	Méier	336	1.892	3.775	*
2	Morro da Casa Branca	Tijuca	807	3.018	1.252	*
2	Mata Machado	Alto da Boa Vista	619	2.302	4.051	615
2	Morro da Bacia / Morro do Encontro	Grajaú	1.557	7.624	4.034	1.557
1	Ladeira dos Funcionários / Parque São Sebastião / Vila Clemente Ferreira	Caju	927	3.274	5.034	981
1	Mangueira / Morro dos Telégrafos / Parque Candelária	Mangueira	4.229	7.189	1.243	80
5	Jacaré	Campo Grande	2.120	8.400	11.050	2.120
3	Jacarezinho	Jacarezinho	12.000	50.000	11.766	*
4	Floresta da Barra da Tijuca	Barra da Tijuca	1.081	2.230	4.344	8.62
3	Grota	Madureira	636	1.008	2.204	*
4	Fazenda do Mato Alto	Jacarepaguá	927	3.800	5.730	*
3	Fernão Cardim	Engenho de Dentro	875	3.412	2.000	350
4	Canal das Tachas / Vila Amizade	Recreio	902	2.737	8.873	822
3	Chácara Del Castilho	Del Castilho	644	2.532	2.050	561
3	Complexo do Sapê	Madureira	2.985	6.432	22.168	2.507
5	Divinéia	Santa Cruz	1.341	6.348	12.595	*
3	Bairro Nova Aliança	Jardim América	1.725	2.629	8.139	2.764
3	Bairro Proletário do Dique	Jardim América	1.184	4.284	5.747	*
3	Cachoeirinha / Santa Terezinha	Méier	644	1.931	5.482	*
3	Caminho do Jô	Pavuna	732	2.416	1.952	430

Chart 1. (cont.)

Growth Acceleration Program (PAC)				
Local	**Execution Support**	**Construction works**	**Progress / Year**	**Investment**
Ilha de Paquetá	Government of the State of Rio de Janeiro / Cedae	Creation of the Sanitary Sewage Systems (SES)	In 2008, the SES expansion was carried out by Cedae. Until December 2008, it was in the process of hiring a company to carry out the service. Between January and April 2009, the state government became responsible, and the project was in the contracting phase of the company again. In the months of July to September 2011, the works began, still with no prediction of completion	The estimated investment for the project was R$ 19.165,2 million, having been changed to R$ 25.845,32
Santa Cruz	Rio De Janeiro City Hall	SES	In August 2009, the contracting process of the company responsible for the project began. By 2015, the project was under construction. Prediction of, until the year 2018, progress of the venture	The initial investment was R$ 218.153,2 million. There was an increase to R$ 280.701,49 million
Sepetiba	Rio De Janeiro City Hall	Improvements of the SES, in the Sewage Pumping Stations (EEE) of the sub-basins of the rivers Alagados and Ary Chagas. The collection network and building connections in the neighborhood in question were expanded	The works started in August 2007. By the end of 2014, the project was already concluded	Initial: R$ 17.023,1 million. The final expense was R$ 17.269,14 million
Manguinhos	City Hall and State of Rio de Janeiro	Works for integrated sanitation and urbanization. The neighborhood was divided into two sectors: A and B. The City of Rio de Janeiro developed and coordinated the works in sector A and the state was responsible for sector B	Both projects started in June 2007. The end of both sectors was foreseen for the year 2018	In 2007, R$ 94.531,2 million (sector A) and R$ 567.742,00 million (sector B) were invested. In 2011, investment increased to R$ 577.022,56, in sector B. In 2014, sector A reached R$ 95.239,55
Complexo da Tijuca	Rio De Janeiro City Hall	Sanitation/urbanization integration works.	Began in July 2007. The completion of the work took place at the end of 2014	R$ 70.660,17 million
Pedra de Guaratiba	Rio De Janeiro City Hall	SES	Em julho de 2008, o projeto encontrava-se em contratação de empresa. Iniciaram-se as obras, até o mês de dezembro de 2008	R$ 13.831,00 milhões
Alegria System	Cedae / Government of the State of Rio de Janeiro	Complementing and expanding the works on the sewage system of Alegria ETE, building a trunk collector in the Faria-Timbó basin	In December 2008, the project was in the contracting phase. Until 2014, the expansion and complementation of Alegria SES were under bidding. In 2015, construction works began, with completion scheduled for 2018	R$ 94.500,00 million. In 2015, the budget went to R$ 175.804,25 million
Pavuna	Cedae	Project 1: proposed the construction of a sewage collection and transportation system. Project 2: the implementation of the SES of the neighborhood	Until December 2008, project 1 was in the contracting phase. Project 2: started in 2011, it was under construction until 2015. There is no data for the completion of the construction works	The investment earmarked for project 1 was R$ 110 million. Project 2: budgeted at R$ 35.000,00
Deodoro, Realengo, Padre Miguel e Magalhães Bastos	Rio De Janeiro City Hall	Integrated sanitation of the Bacia de Marangá	Until September 2011, the project was in the contracting phase of a company	The investment will reach a margin of R$ 166.390,71 million

Chart 1. (cont.)

Growth Acceleration Program (PAC)				
Local	**Execution Support**	**Construction works**	**Progress / Year**	**Investment**
Planning Area 5	Foz Águas 5 (Cedae)	Expansion of SES in relation to the neighborhoods of AP5	In March 2013, the construction works were started. For the project, until 2018, it was underway	The investment was R$ 610.619,16 million, in 2013. In 2015, the budget was raised to R$ 642.753,01

*Not informed. **Construction works carried out by the Sanitation Program for Populations in Low Income Areas (Prosanear), of the state government of Rio de Janeiro, which has as a guideline the reconciliation of intercessions in sanitation with other actions that are entirely aimed at supporting poor populations[12,15,29].

Oliveira[18] considered the plan incoherent, as it did not cover the entire territorial area of the CRJ. It was only implemented differently in each area, using specific strategies and with spatial restrictions. Despite the criticisms, the Program was able to expand the sewage collection network in places where the service was precarious.

In line with 'Rio always Rio', CRJ underwent spatial transformations from the PDBG, which was designed in the 1990s and implemented in 1994. It was not a municipal program, but it was important for the sanitation of CRJ. It lasted 12 years, with an investment of US$ 760 million[19].

The PDBG presented itself as one of the largest projects aimed at sanitation infrastructure in the state. There were three central objectives: 1) recovery of the ecosystems present around the Guanabara Bay (BG); 2) improvement of water quality in the hydrographic system, from the implementation of a sanitation belt; and 3) strengthening of government institutions linked to BG. Its planning also took place in three phases: 1) PDBG; 2) Environmental recovery program for the BG basin; and 3) Complementary environmental programs[19].

In phase 1 (short term), the objectives that could be implemented, referring to ES, were contained until the 2000s. In phase 2 (medium term), the objectives until 2010. Phase 3 did not establish a deadline, as the goals would be executed and their results would be perceived in the long term[19].

Data from the Court of Auditors of the Municipality of Rio de Janeiro[20] reported that, after ten years of construction (1995-2005), the results were not satisfactory. However, expenditures on ventures increased by 70%. The works began in February 1995 and extended to four state governments (1994-2005), with a high cost of U$760 million to U$1,04 billion, due to delays and adjustments in corporate contracts[21].

As a consequence, water quality was lost due to the continuous urban expansion and, also, to the inconclusion of works in the collection network, which intensified the irregular disposal of domestic and industrial effluents[22,23]. The PDBG did not bring technical innovations for sewage treatment. Most of the plants built were provided with primary treatment only, with the secondary one being carried out only in the continuation of the Program. This fact occurred due to the cost of treatment[22-24].

For political reasons, the PDBG was not concluded, and new programs were required to be implemented. After its closure in 2006, the government reported having invested approximately R$ 100 million/year in constructions works[25]. As of 2011, financing was requested for PSAM, which had its planning started in 2012, with the beginning of some construction works in 2013. The Program included new projects in those initiated by the PDBG, in addition to a set of plans for the ES, whose works were due to end in 2016. Its

objective was to reverse the environmental degradation of BG[26].

The PDBG was responsible for the creation of the Alegria, Tijuca and São Cristóvão trunks, and for the implementation of the primary treatment at the Alegria ETE, with the capacity to treat about 5.000 L/s of sewage. In the Pavuna system, the collection network was expanded and the Pavuna ETE was built, with a capacity to treat 1.000 L/s, benefiting 256 thousand inhabitants. Penha ETE treatment capacity was increased to 1.600 L/s. In Ilha do Governador, 41 km of collecting network and the Tauá ETE were built, treating about 525 L/s. Finally, the ETE and the undersea outfall on the island of Paquetá were built, in addition to 5 km of collecting system[27].

The additional actions, implanted at PSAM were: the expansion of the Alegria system (sewage collection from 41 neighborhoods) and Pavuna, with secondary treatment (about 2.500 L/s and 1.500 L/s, respectively); the creation of the Marina da Glória system, with a waist gallery and a Sewage Pumping Station (EEE); the Sena Limpa Program: Urca EEE, São João Fountain and the increase in building connections and collecting trunks. The projects predicted an increase in the collection and treatment of sewage that flowed directly into the BG to 80%, by 2018[27].

PSAM also did not complete all the targets set by the end of 2014[28]. Again, the low commitment of the government to the issues of sewage compromised the quality of water courses and the health of the population.

During the interval between the construction works of the PDBG and the PSAM, the federal government invested in several sectors of the CRJ, with the PAC. As a strategy for CRJ, the PAC advocated an improvement in the population's living conditions, in addition to ensuring the expansion of the sewage system, through which it proposed to clean up the Guanabara and Sepetiba bays[29].

The repetitions of the depollution proposals in the different projects implanted in the CRJ reflect the incompetence of the public authorities to meet the goals established throughout the 1990s and 2000s.

PAC construction works began in 2007 (many are still being executed), financed, in part, by the federal government and the state and municipal governments, in addition to sanitation companies.

In *chart 1*, after the construction works of the Favela-Bairro Program, the following are listed: the locations of the construction works (giving priority to those contained in the CRJ), support in execution (the sphere of government responsible for developing and coordinating), progress (beginning and, if completed, completion) and investment (partial or total).

In 2017, according to data from the Ministry of Planning[30], the only work completed at CRJ was in the Manguinhos neighborhood, delivered in June of the same year. The Sanitary Sewage Systems (SES) Alegria, Paquetá Island and Pavuna (the latter carried out by the state government), and the SES of the AP5 (carried out by the Foz Águas 5 Company) were still under construction. What was observed is that the problems related to the fulfillment of the execution of the works extended to the federal government, with the PAC. At CRJ, no program implemented until 2016 had 100% of its works completed.

Still with the PAC works in progress, in 2009 the city launched its second strategic plan, with a duration of four years, aiming at the major events that the CRJ would host: the FIFA men's World Cup and the Olympic Games[31].

The plan highlighted historic lack of investment in sanitation of the CRJ, which was identified as one of the main problems found in the Western Region, in addition to silting up bays (Sepetiba and Guanabara), lagoons (Jacarepaguá, Barra da Tijuca and Rodrigo de Freitas) and beaches (Ramos, Flamengo and Botafogo)[31].

Five guidelines for the environment were presented. The one that included sewage aimed to "expand the collection and treatment systems in sewage, especially in the Western region"[31(101)] and had, as a goal, "to increase the coverage rate

of the sewage collection network with treatment to 30% on AP5 until 2012"[31(101)].

It was proposed, then, the construction and operation of a sewage treatment system at AP5, given that the situation at that time was still precarious (local sewage would rise from 5% to 30% in just two years) and directly impacted life quality of the local population, public health conditions and the degradation of Sepetiba and Guanabara bays[31].

In 2011, Complementary Law nº 111, of 1st February, which provided for the urban and environmental policy of CRJ, instituted the MP of sustainable urban development, the second MP of the locality in a period of 19 years[32].

The actions for sewage system highlighted the universalization of the service, in a balanced way, in all APs. However, priority was given to the favela areas of the CRJ located in the Western Region. In these regions, direct actions would be taken to capture and dispose of sewage in the basins that flowed into Sepetiba Bay[32].

In 2013, the third strategic plan was launched by the municipality for the years 2013 to 2016. This was the first revision of the previous plan (2009-2012), with the CRJ's vision expanded until 2030.

One of the aspirations was for CRJ to be "recognized as a world reference in sustainable development, with the preservation of our environmental heritage"[33(15)]. The CRJ has its metropolitan area integrated and located in the largest urban vegetation cover in the world. The goal for sewage system is found in the field of sustainability, aiming to make the sewage collection and treatment system universal and effective, in addition to preserving water bodies. The objective was to increase the coverage rate of the sewage network treated in AP5 to 55%, one of the areas with the lowest collection rate, by 2016[33].

As an emergency measure, River Treatment Plants (UTR) were built in some watercourses. These are found in the rivers Arroio Fundo (AP4), Carioca (AP2) and Canal da Rocinha (AP2)[33]. However, RTU are not able to solve the real problem of pollution, which is the irregular discharge of sewage. On the contrary, in the treatment carried out, aluminum sulfate is added, which can have negative environmental consequences, such as changing the water pH. Thus, it is considered a solution with low environmental sustainability, since the water body continues to receive inputs from pollutants, mainly downstream from the UTR1.

The last plan was the 'Rio 500 Vision Project'. In it, optics were created for the next 50 years of CRJ, a period in which it will complete 500 years of existence. In the theme 'Green, sustainable and resilient city', the proposal for sanitation was inserted in sub-theme 3: 'City of waters: beaches, bays, lagoons and healthy rivers', with a concern with the depollution of the basins and with sustainable development[35].

The major deficiencies in ES of the CRJ were addressed, mainly in the West and North regions. The targets for increasing sewage in the plan were: (a) in the Sepetiba Basin, to 80% in 2020, and to 95% coverage in 2025 (in 2008, it corresponded to only 5%); (b) in the Jacarepaguá Basin, to 80% in 2020, and to 90% in 2025 (it was 20% in 2008); (c) in the South Region, 80% in 2020, and to 90% in 2025 (in 2008, the rate was 70%)[35].

According to IBGE[8,36], CRJ has improved its sewage collection index in recent years, in all APs, going from the deficit from 6.02% to 2.2% in AP1; in AP2, from 3.1% to 1.57%; in AP3, from 12.69% to 2.91%; in AP4, from 31.48% to 9.06%; in AP5, from 49.87% to 9.27%. These data corroborate the proposals contained in the plans, which, although some were repeated and others were not carried out, they contributed to increase the percentage of the collection network in the CRJ.

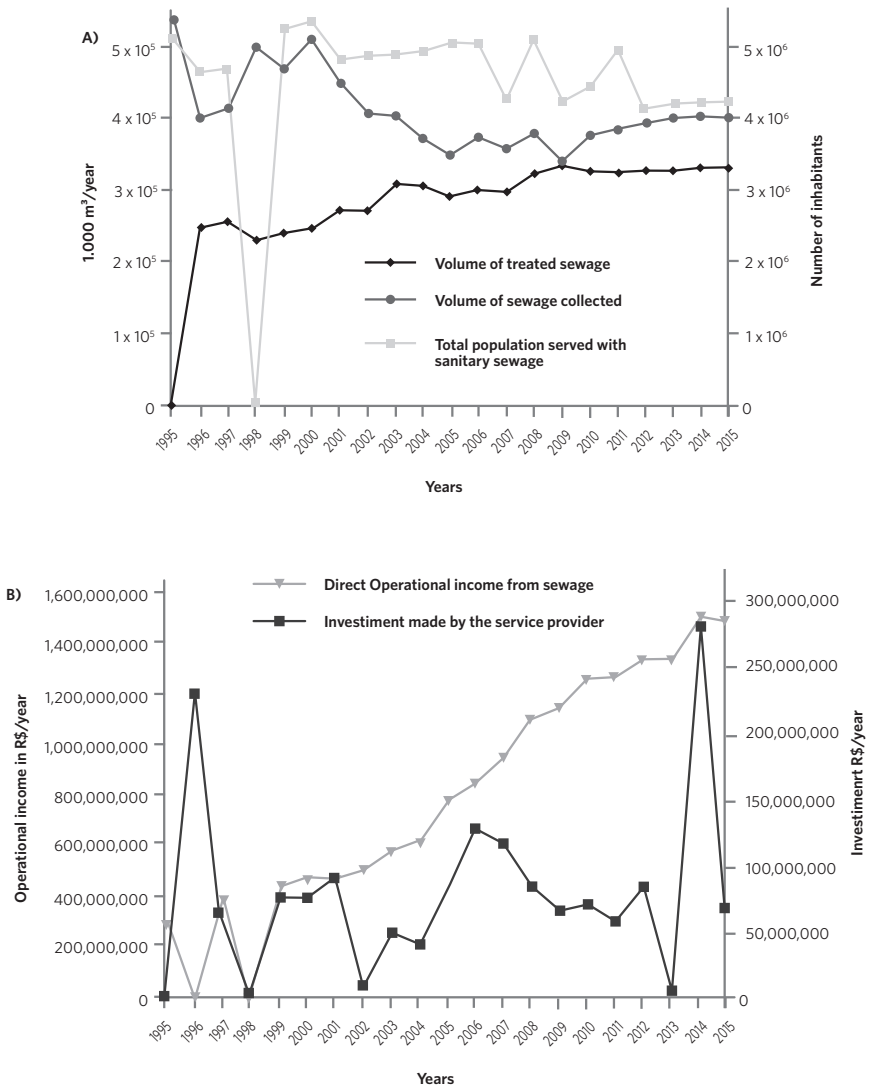
Data from the National Sanitation Information System

Graph 1 (a) shows the data on the volume of treated and collected sewage, and the total population served with sewage. Taking into

account the total population of the CRJ, according to IBGE[37], of 6,5 million inhabitants, and the total population served with depletion in 2015, around 4 million, there is a gap of about 2,5 million people. In addition, there has been also, over the years, a deficit between the volume of sewage collected and what has been treated.

Regarding direct operating revenue and investments made by the service provider, over ten years, in *graph 1 (b)*, the increase in revenue is evident, going from R$ 200 million/year in 1995 to approximately R$ 1,5 billion/year, in 2015. On the other hand, investment by the service provider is not accompanied by an increase in revenues, showing a variation in annual investment over the years, with R$ 50 million in investments in 2015, and revenue of R$ 1,5 billion for the same year. The discrepant value of the annual revenue is not reflected in the investments, given the precariousness of the service.

Graph 1. SNIS data regarding sanitary sewage system in the city of Rio de Janeiro from 1995 to 2015. a) population served, volume of treated and collected sewage, b) direct operational sewage income (R$/year) and investment made in sanitary sewage system by the service provider (R$/year)[12,38]



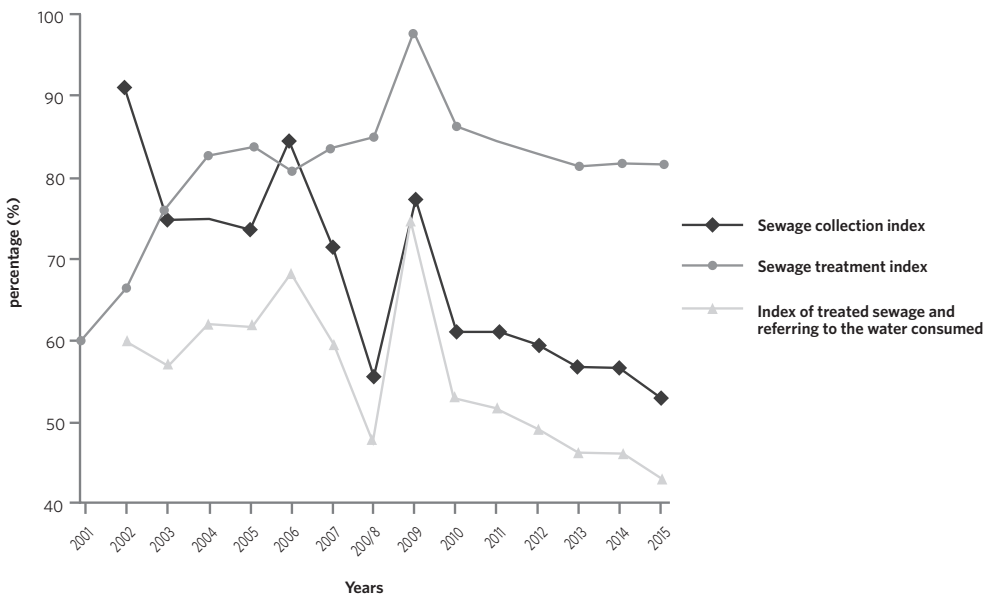
The disparity in the data revealed by the SNIS corroborates the sewage treatment rates referring to the water consumed and the sewage collection, according to *graph 2*. One of the most important cities in the Country is far from reaching its goals related to sewage, since in 2015, CRJ had an 81.65% sewage treatment rate and only about 40% treated sewage rate referring to the water consumed. Such data are reflected in the quality of CRJ's aquatic environments.

The latest bulletin from the State Environmental Institute (Inea)[39] pointed out that the rivers in the hydrographic region V, which flow into the BG and the Jacarepaguá Lagoon Complex (CLJ), have poor or very bad ratings. Inea's data reconciled with the SNIS data, as a percentage of the sewage collection index, which, in 2015, reached 52.99%. Approximately 47% of all sewage generated at the CRJ is still drained without any treatment in the receiving bodies of the locality. It was evidenced that all the investments applied (with PDBG, PSAM and others) were not sufficient for the depollution of lagoon complexes, rivers and bays.

It proved impossible to remedy the pollution of BG, CLJ and Sepetiba Bay in a few years, as proposed in the plans. The problem resulted from the distant precariousness of the public sewage collection and treatment service. Not only at CRJ, but also throughout Brazil, there was no investment in sanitation for more than 20 years, until the 2007 PAC. This generated a historic delay in service[40].

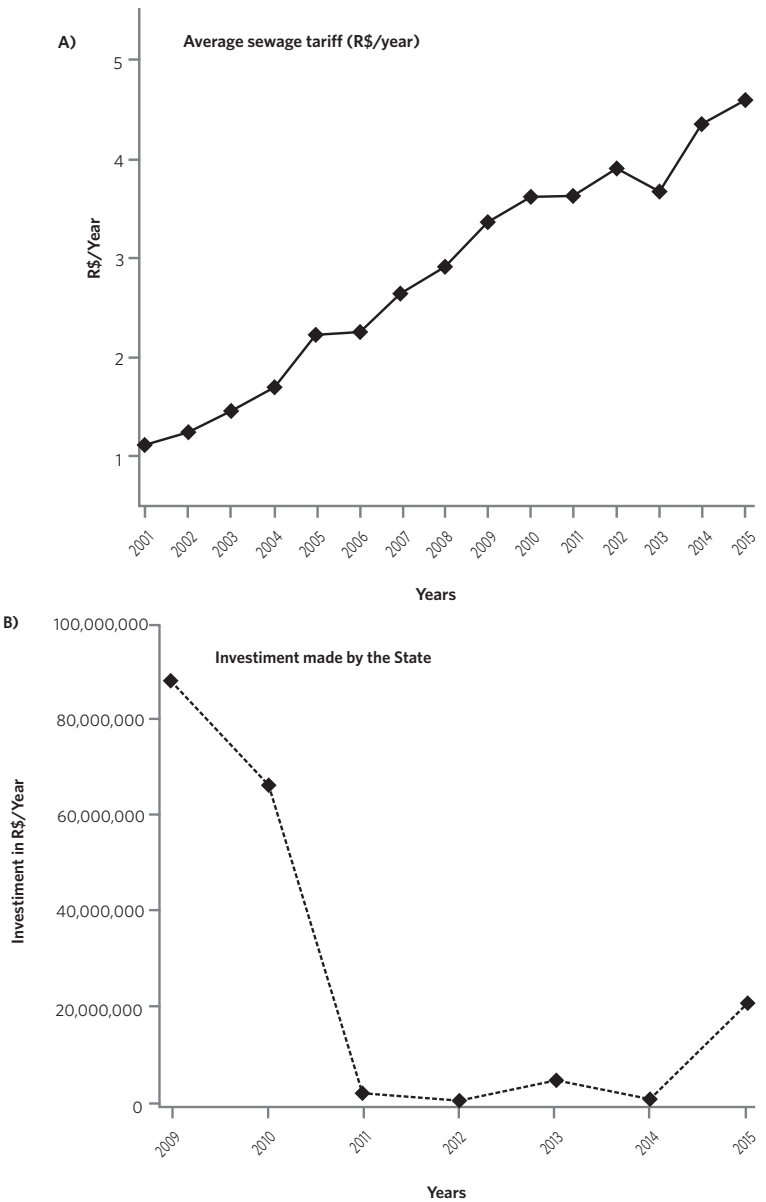
The deadlines established for the depollution of the water bodies in question were very small, considering, for example, that the River Thames, in London, took about 150 years to be completely clean and had investments from the public and private sectors. There was investment in the collection and treatment of sewage, both domestic and industrial. CRJ lacks national projects, investments, commitment and adaptation to the local reality[41].

Graph 2. Data referring to the collection rate, sewage treatment and treated sewage referring to the water consumed in the city of Rio de Janeiro, from 2001 to 2015[12,38]



Data on the average sewage tariff started to be reported in the SNIS as of 2001. In *graph 3*, the average tariff value *(graph 3 (a))* and the investment (R$/year) *(graph 3 (b))* in ES in the CRJ. It is noticed that the value imbued in the collection and treatment of sewage has been increasing, which is not reflected in the quality and amplification of the service, a fact verified by the decrease of about R$ 70 million/year in investment by the state, in six years (2009-2015). In the beginning year (2001), the average value was R$ 1,13 and until 2015, it reached R$ 4,59.

Graph 3. SNIS data in relation to the tariff and investment in Sanitary Sewage in the city of Rio de Janeiro. a) average sewage tariff (R$/year) from 2001 to 2015. b) investment by the State (R$/year) from 2009 to 2015[12,38]



Kazmi and Furumai[42] developed a cost estimate, according to the type of treatment used in the ETE and the economic size of a city. According to the authors, for the CRJ, which has an industrial economy, it would be necessary to invest between US$ 100 and US$ 150 (per person/year, at the tertiary treatment level). As already mentioned, according to IBGE (2016), CRJ currently concentrates about 6,5 million inhabitants. With two calculations, the average tariff is adequate for the reality in Rio de Janeiro: U$ 6,5 thousand x U$ 100 = U$ 650 thousand, which, converted to reais, would result in R$ 2.151.110,00, in the exchange rate on 10/11/2017. The costs per person, in one year, would be R$ 331,99, for a monthly amount of R$ 27,66. If it reached US$ 150, the cost would be U$ 6,5 thousand x U$ 150 = U$ 975 thousand, which, in reais, would total R$ 3.226.665,00. Per person, per year, this would total R$ 480, or R$ 41,5/month.

There is a considerable discrepancy in the collection of the sewage tariff and in the investment. As a result, there is a huge scrapping of ES services in the CRJ. It is necessary to modify the treatment methods used in the ETE of the locality. The Barra da Tijuca ETE performs only preliminary and primary treatments. The remaining residues are sent, practically in natura, to the undersea outfall of the neighborhood[9].

In cities like Rio de Janeiro (RJ), with 6,5 million inhabitants, the decentralization of sewage treatment services is necessary. Difficulties were observed in connecting all residences in the collection networks, due to several factors, such as the geomorphological issue of the CRJ and its irregular occupation.

Given these data, there was a need for comprehensive and simplified sewage collection and treatment systems. According to the economic profile of the CRJ, such systems must be: (a) inexpensive, both in implementation and in operation; (b) easily operated, with the use of technical labor force; (c) minimal mechanization; and (d) sustainable (self-sufficient in energy, with little replacement of easily replaceable parts and equipment)[43].

Another sustainable option would be the reuse of water from treatment. The state of Rio de Janeiro has two current laws, which support the initiative: Law nº 7.424/16 and Law nº 7.599/17. The first law highlights the use in agriculture, in the irrigation of green areas (parks, gardens, tourist areas), in the washing of public vehicles, patios, floors and public places, among others[44]. The second law covers the mandatory use of these waters by industries located in Rio de Janeiro, to install equipment to treat their waters, so that they can be reused[45].

It also became evident that the state needs to promote permanent campaigns for clarification and awareness, in order to encourage and support the reuse of non-potable water for all the purposes described in the laws. However, there was a certain conservatism on the part of the population in this use, due to lack of knowledge of the processes that involve the treatment of sewage capable of generating such waters.

Conclusions

The analysis of the CRJ's plans, with measures for sanitary sewage system, showed that much was planned for the service to be expanded. However, little has been done over 24 years. Investments were made in ES, as shown in this article. However, given the discrepancy in coverage, collection and treatment, it was evident that the amount applied was not sufficient.

Projects such as Favela-Bairro and PAC had funds to improve ES infrastructure in several subnormal agglomerations of the CRJ, a fact that did not reach 40% of execution.

Buildings such as Alegria ETE reveal the abyss of incapacity and/or the lack of commitment of public managers to carry out works that would benefit communities susceptible to various environmental and social factors, and that would improve the water quality conditions of CRJ water courses and the health of its population.

The data present in the SNIS corroborated the situation found: the lack of collection and treatment of sewage affected not only environmental health, but also human health, especially in communities that lack infrastructure, where sewage is improperly disposed of. Such data, together with information from the plans, show a large discrepancy in terms of collection and treatment. Despite all the investment in the plans for the CRJ, the discovered population is over 1 million. In addition, the amount collected from the sewage does not match the invested capital, and the lack of management in the service is evident.

The vision of the future for CRJ is stormy, despite the fact that it was the recent stage of two major world events. Incentives and reasons for investments in various sectors of the locality were not lacking. Therefore, the questions that remain are: what to expect for the year 2035? Will the targets for the depollution of the bays be achieved? Will sustainable measures be applied to sewage system? Will sewage collection and treatment be universalized?

It is concluded, then, that there are no criteria present in the plans that demonstrate sustainable options for the ES of the CRJ.

Collaborators

Toledo GA (0000-0002-0842-6108)* participated substantially in the conception, planning, analysis, interpretation of data, critical review of the content and approval of the final version of the manuscript. Cohen SC (0000-0001-6228-6583)* participated significantly in the conception, planning, analysis, interpretation of data, critical review of the content and approval of the final version of the manuscript. Kligerman DC (0000-0002-7455-7931)* participated significantly in the conception, planning, analysis, interpretation of data, critical review of the content and approval of the final version of the manuscript. Saggioro EM (0000-0000-2570-2013)* participated significantly in the conception, planning, analysis, interpretation of data, critical review of the content and approval of the final version of the manuscript. ■

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