Environmental Sanitation in Porto Alegre City, Brazil: A Basic Step towards Sustainable Development

Marina Ziliotto, José Artur Bogo Chies, and Joel Henrique Ellwanger

Abstract: Porto Alegre city, the capital of Rio Grande do Sul State, is an important medical, educational, and technological hub in Brazil. However, Porto Alegre faces critical challenges in achieving adequate environmental sanitation, hampering the development of the city, and negatively impacting the most socially vulnerable segments of the population. Although Porto Alegre’s sanitation plan aims at universal access to sewage collection and treatment services by 2035, some of the city’s sanitation indicators have deteriorated in recent years compared to other Brazilian cities. The inadequate or lack of proper sanitation (e.g., shortcomings in sewage collection and treatment, suboptimal management of solid waste, deficiencies in the distribution of treated water) contribute to the proliferation of disease vectors like mosquitoes and to the spread of infectious and parasitic diseases (e.g., toxoplasmosis, leishmaniasis, arboviral diseases). Recently, Porto Alegre’s population experienced a significant number of dengue infection cases. Climate change, social issues, and unplanned urbanization will further favor disease transmission in the region. In this Review, we provide an overview concerning the ecological, socio-economic, and public health aspects of Porto Alegre, drawing attention to the insufficient environmental sanitation in the city, a neglected problem by local authorities. We argue that this issue needs to be seriously addressed if Porto Alegre wants to realistically achieve sustainable development, protecting ecosystems and human health.

Keywords: ecodevelopment; ecology; disease; health; Lake Guaíba; pollution; Rio Grande do Sul; sewage; urban ecology; water

1. Introduction: A Brief Overview of Porto Alegre

Porto Alegre city is the capital of Rio Grande do Sul State (the southernmost state of Brazil; Figure 1), being the most populous city of the State, with approximately 1.3 million inhabitants in 2022 [1]. Porto Alegre is the eighth richest city in the country based on Gross Domestic Product [2], and has a Human Development Index of 0.805, classified as “very high” [3]. Porto Alegre is also considered a reference city for medical treatment in Brazil, having high-quality hospital facilities in several medical specialties [4]. Moreover, the city has some universities ranked among the best institutions in Brazil [5,6], and is considered an emerging hub of technological innovation in Latin America [7,8].

Beyond the good socio-economic indicators described above, Porto Alegre is located on the shores of Lake Guaíba and its streets and public spaces are densely forested [9], which creates beautiful natural landscapes that attract many tourists to the region (Figure 1). In this way, Porto Alegre could be considered as a potential model of a technological and sustainable city. As defined by Goodland [10], environmental sustainability “seeks to improve human welfare by protecting the sources of raw materials used for human needs and ensuring that the sinks for human wastes are not exceeded, in order to prevent harm to humans”. In the context of cities, sustainability also needs to take into account other inherent aspects of urban reality. The foundational framework of sustainability
revolves around three key pillars: social, economic, and environmental aspects. Hence, true sustainability is attainable only when the principles of equity, economic growth, and environmental protection are collectively embraced [11]. These conceptual foundations guide our exploration of environmental sanitation, urban ecology, and the endeavor to create a sustainable city.

The city of Porto Alegre does indeed have great potential to be a benchmark for sustainability in Brazil. However, an important aspect is being neglected for this objective to be fully achieved: adequate “environmental sanitation”, which encompasses not only sewage treatment and water supply but also effluent and rainwater drainage, waste management, vector control, and other environmental determinants of disease in urban settings [12].

The Sustainable Cities Development Index—Brazil (Índice de Desenvolvimento Sustentável das Cidades—Brasil: IDSC-BR) serves as a comprehensive online tool, providing an integrated perspective on Brazilian cities concerning each of the Sustainable Development Goals (SDGs) [13]. Its purpose is to foster adherence to the United Nations 2030 Agenda. IDSC-BR computes individual scores for each city’s performance regarding the SDGs.
culminating in a final score. This score determines the city’s ranking on the Brazilian stage, accompanied by a classification within the spectrum of sustainable development: “very high”, “high”, “medium”, “low”, or “very low”. Currently, Porto Alegre shows a “medium” IDSC-BR (score 51.56 out of 100) [13], facing significant environmental challenges, including major sanitation issues [14].

In this narrative Review, we aimed to revisit Porto Alegre’s current situation regarding sanitation, discussing how sanitation-related problems prevent the city from achieving sustainable development. To achieve this objective, we reviewed scientific literature retrieved from international databases (i.e., PubMed/MEDLINE, Scientific Electronic Library Online—SciELO, Google Scholar), as well as consulted grey literature, reports from different institutions, and trustworthy journalistic content related to the topic of sanitation in Porto Alegre, considering publications in both English and Portuguese. The choice of this variety of information sources was important because this Review addresses the situation of a specific Brazilian city, which often has relevant information published in local sources or only in Portuguese. In this Review, we (I) provide an overview of Porto Alegre, (II) detail the city’s current situation concerning sanitation, (III) discuss the consequences of insufficient sanitation in the Porto Alegre region, and (IV) argue that Porto Alegre must address its sanitation issues to realistically achieve sustainable development. Finally, we (V) present some conclusions and suggest future directions. Notably, in this article, the term “sanitation” is occasionally employed as a synonym and abbreviation for “environmental sanitation”.

2. Porto Alegre’s Current Situation Concerning Sanitation

Porto Alegre showed advances concerning environmental sanitation until 2015. The last Basic Sanitation Municipal Plan (Plano Municipal de Saneamento Básico—PMSB) [15] of Porto Alegre (published in 2015) contemplates the provision of essential public services, covering water supply, sanitary sewage, management of rainwater, and solid waste. Also, the PMSB targets the universalization of the sewage collection and treatment services as one of the goals to be achieved by 2035, with an expected direct impact on improving the quality of life of the population [15]. However, even with large investments through the Integrated Socio-Environmental Program (Programa Integrado Socioambiental—Pisa) that increased the capacity of sewage collection and treatment in the city to 80% (currently, this capacity is underused), the period between 2016 and 2018 showed worsening rates in the sewage treatment network [16–18]. The observed deterioration in sewage treatment can be attributed to various factors, including the requirement for new collection networks and household system connections, operational challenges, insufficient maintenance and staffing, and a population increase in specific regions of the city [17].

Porto Alegre’s eleven Wastewater Treatment Plants (WWTPs) employ various cloacal sewage treatment methods, including stabilization ponds, activated sludge, upflow anaerobic digesters, oxidation valves, and the unitank process. Among these, the two expanded WWTPs, Serraria and Sarandi, boast maximum treatment capacities of 4115 L/s and 203 L/s, respectively. Sarandi’s WWTP incorporates preliminary waste treatment, utilizes the activated sludge method for effluent treatment, and includes secondary decantation in its process. Serraria’s WWTP also features preliminary waste treatment and activated sludge treatment. Additionally, it incorporates a unitank post-treatment system, achieving the third level of treatment for the collected effluents. In Porto Alegre, both stormwater and treated sewage are directed to Lake Guaíba [19].

An analysis of Porto Alegre’s treated sewage revealed a capacity for micronucleus formation and elevated chromium levels [20]. Additionally, a high detection of enteric viruses, including adenovirus and enterovirus, was observed [21]. More recently, free-living amoebae, such as Acanthamoeba lenticulata and Acanthamoeba polyphaga, associated with pathogenicity, have been identified in the treated sewage [22]. Despite these findings, the treated effluent from Porto Alegre’s WWTPs is currently considered as environmentally “safe” [19]. As mentioned previously, Porto Alegre’s treated and non-treated effluents are
discharged into Lake Guaiaba, the same location where the water for the consumption of a significant portion of Porto Alegre’s population is sourced. Lake Guaiaba is considered a heavily polluted water body [23].

Although Porto Alegre has already achieved the goal of universal access to drinking water by the resident population [24], the situation concerning sewage collection and treatment is worrying. The Ranking of Basic Sanitation of Trata Brasil Institute [25], which uses official data from the National Sanitation Information System (Sistema Nacional de Informações Sobre Saneamento—SNIS) to assess the evolution of water, sewage, investment and water loss indicators in the 100 largest cities in Brazil, showed that Porto Alegre continues to lose positions, dropping to the 49th position in 2023 [24]. Figure 2 details the deterioration of Porto Alegre in the ranking of the Trata Brasil Institute based on data from 2017 to 2023 [24,26–30]. Even with a substantial sewage treatment capacity installed, the lack of expansion and maintenance of the sewage services, and therefore the lack of connections between houses and communities and the potential points of sewage treatment, leads to raw waste being dumped directly into Lake Guaiaba [17], a waterbody with important environment, economic, and historical–cultural value to the city [31]. In addition to pollution caused by industrial and domestic sewage, Porto Alegre is affected by emerging pollutants, such as microplastics that are already abundant in Lake Guaiaba [32].

![Figure 2.](image_url)

Figure 2. Examples of Porto Alegre’s pollution. Stream Dilúvio in Porto Alegre is heavily contaminated by sewage disposal, flowing into Lake Guaiaba (panel (A); photo: J.H. Ellwanger). Improper disposal of solid waste in Lake Guaiaba (panel (B); photo: M. Ziliotto). Porto Alegre’s positions in the sanitation ranking of the Trata Brasil Institute from 2017 to 2023 (panel (C)) [24,26–30].

Approximately 90% of Porto Alegre’s population has a sewage collection service [18,24]. However, according to data from the Trata Brasil Institute, Porto Alegre showed the worst
result in the indicators of total sewage treatment among the capitals of the south and southeast regions of Brazil, with only 52.72% [24]. These data differ slightly from the data of Porto Alegre’s Municipal Department of Water and Sewage (Departamento Municipal de Agua e Esgotos—DMAE), which indicates that 57% of sewage in the city is treated [18]. The technical reasons for the discrepancy between these data are not clear, highlighting the need for more attention to this problem. In any case, data from both sources indicate a major insufficiency in sewage treatment. Of note, two cities in the metropolitan region of Porto Alegre, namely Gravataí and Canoas, were ranked among the municipalities in the 20 worst places in the Trata Brasil ranking in the last decade [24].

Even though the south and southeast regions in Brazil have the two highest Gross Domestic Product values in the country [33], most of the regions’ capitals showed a decrease in the 2023 Trata Brasil ranking compared to 2022, with the exception of Vitória (Espírito Santo State) and Florianópolis (Santa Catarina State) (Table 1). Porto Alegre had the third lowest average investment per capita [BRL (Brazilian real)/inhabitant] among those capitals [24] (Table 1). According to data from the National Basic Sanitation Plan (Plano Nacional de Saneamento Básico—PLANSAB), the annual average investment per capita required for the universalization of the sanitation service should reach BRL 203.51/inhabitant [24,34], a value far above that currently invested by Porto Alegre’s administration (BRL 64.85/inhabitant) [24].

Table 1. Sanitation data from the capitals of the south and southeast regions of Brazil *.

<table>
<thead>
<tr>
<th>Capitals of the South and Southeast Regions of Brazil</th>
<th>Population in 2010</th>
<th>Position in the 2023 Ranking of Trata Brasil Institute</th>
<th>Position in the 2022 Ranking of Trata Brasil Institute (Variation)</th>
<th>Total Sewage Treatment Indicator (%)</th>
<th>Total Investment from 2017 to 2021 (BRL MM)</th>
<th>Average Investment per Capita (BRL/Inhabitant)</th>
</tr>
</thead>
<tbody>
<tr>
<td>São Paulo (São Paulo State)</td>
<td>12,396,372</td>
<td>7</td>
<td>4 (−3)</td>
<td>71.35</td>
<td>12,974.76</td>
<td>209.33</td>
</tr>
<tr>
<td>Curitiba (Paraná State)</td>
<td>1,963,726</td>
<td>15</td>
<td>12 (−3)</td>
<td>95.62</td>
<td>898.40</td>
<td>91.50</td>
</tr>
<tr>
<td>Vitória (Espírito Santo State)</td>
<td>369,534</td>
<td>41</td>
<td>53 (+12)</td>
<td>81.71</td>
<td>166.53</td>
<td>90.13</td>
</tr>
<tr>
<td>Belo Horizonte (Minas Gerais State)</td>
<td>2,530,701</td>
<td>47</td>
<td>37 (−10)</td>
<td>77.92</td>
<td>559.73</td>
<td>44.23</td>
</tr>
<tr>
<td>Rio de Janeiro (Rio de Janeiro State)</td>
<td>6,775,561</td>
<td>48</td>
<td>44 (−4)</td>
<td>73.96</td>
<td>1166.44</td>
<td>34.43</td>
</tr>
<tr>
<td>Porto Alegre (Rio Grande do Sul State)</td>
<td>1,492,530</td>
<td>49</td>
<td>43 (−6)</td>
<td>52.72</td>
<td>483.98</td>
<td>64.85</td>
</tr>
<tr>
<td>Florianópolis (Santa Catarina State)</td>
<td>516,524</td>
<td>59</td>
<td>60 (+1)</td>
<td>65.14</td>
<td>341.77</td>
<td>132.33</td>
</tr>
</tbody>
</table>

* The sanitation rankings of Trata Brasil Institute use twelve indicators that can be subdivided into three distinct groups: “Service Level”, “Service Improvement”, and “Efficiency Level”. Scores are assigned to the 100 most populous municipalities in Brazil, according to the Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística—IBGE). The database used to compose the rankings is Brazil’s National Sanitation Information System (Sistema Nacional de Informações sobre Saneamento—SNIS), which gathers information from state, regional and municipal service providers of access to water, sewage collection and treatment, as well as solid waste. BRL: Brazilian real. Porto Alegre’s data are shown in bold. Data source: Trata Brasil Institute [24].

In 2020, a new federal law (No. 14,026/2020) sanctioned the New Legal Sanitation Framework (Novo Marco Legal do Saneamento). Among other characteristics, this new framework encouraged the granting of public basic sanitation services to private companies [35].
The New Legal Sanitation Framework represents a comprehensive update of the previous law No. 11,455/2007. This update introduces a new ambitious target of reaching 99% of the population with access to drinking water and 90% with sewage collection and treatment by 2033. Despite aiming for universalization of services, the government did not incorporate the United Nations resolution on water and sewage as Human Rights into the framework. Including these rights in national sanitation legislation would serve as a means of regulating the United Nations resolution at a national level, given Brazil’s status as a signatory [35].

The law is organized around tax incentives and financing concessions, both for regulatory agencies and for new service provision contracts. Generally, the new law encourages the involvement of the private sector in new service contracts through concessions or public-private partnerships (PPPs), while prohibiting new program contracts, which typically involved agreements between state public companies and municipalities [35].

This strengthened the debate on the privatization of companies responsible for sanitation in Porto Alegre. However, it is important to stress that Porto Alegre’s DMAE has the capacity to cover the demands for sewage treatment in the city, without the need to privatize the service [36]. Prioritizing universal access to services for the population is imperative. In-depth discussions on the privatization of sanitation services have been thoroughly examined by Neves-Silva et al. [37] and Félix and Neto [38]. In the context of the global landscape, the New Legal Sanitation Framework established in Brazil runs counter to the prevailing global trend. Various countries have undertaken processes of “(re)municipalization” or “de-privatization”, reclaiming services that were previously under private control [37,39]. Therefore, it is important to emphasize that the lack of access to sanitation is a complex issue involving income inequality and other socioeconomic factors. This social complexity disfavors the resolution of the sanitation problem by private companies.

3. Consequences of Insufficient Sanitation in Porto Alegre Region

Environmental sanitation is a determining factor for population health. Insufficient sanitation is directly related to the proliferation of disease vectors and facilitates the transmission of diseases associated with inadequate environmental sanitation (in Portuguese: doenças relacionadas ao saneamento ambiental inadequado—DRSAI) [40], including soil-transmitted parasites, arboviral infections and water-borne diseases, among others. This problem is currently fueled by social inequality, climate change, and many other social and environmental challenges observed in Brazil [41,42]. Between 2010 and 2014, DRSAI caused 13,929 hospitalizations in Porto Alegre [40].

Some examples of DRSAI observed in Porto Alegre are very characteristic of the relationship between inadequate sanitation and disease. Porto Alegre’s areas with the highest incidence of *Toxoplasma gondii* infection in the elderly (South/Centro South and Northwest/Humaitá/Navegantes/Ilhas) showed worse housing and public structure conditions than other regions of the city [43]. Multiple areas of Porto Alegre show soil contamination with eggs and larvae of soil-transmitted helminths (e.g., *Ascaris lumbricoides*, hookworms, *Trichuris* spp.), parasites strongly associated with poor sanitation [31,44]. This problem was reported by Vargas and colleagues in 2013 [44] and observed again in 2022/2023 in new studies carried out by our group [31,45]. The lack of sanitation facilitates the disposal of human and animal excrement into the environment, contaminating soil, water, and food with parasites, bacteria, and viral species [45,46]. This phenomenon, known as “pathogen pollution”, is directly linked to inadequate sanitation in Brazil, contributing to the spread of multiple diseases [46].

Vector-borne diseases are also a significant problem in Porto Alegre. For example, the city is infested by many mosquito species, including *Aedes (Stegomyia) aegypti*, *Ae. (Stg.) albopictus*, and *Culex (Culex) quinquefasciatus*, facilitating the transmission of dengue, Zika, and chikungunya viruses, among other pathogens [47]. Inadequate sanitation and stagnant water are conducive factors for the breeding of mosquitoes, heightening the risk of outbreaks of mosquito-borne diseases [46,48]. Recently, Porto Alegre faced an important
A dengue outbreak, with 4986 cases in 2022 and 3041 in 2023 (until July 2023) [49]. Moreover, Brazil is currently grappling with a noteworthy decline in vaccine coverage rates, thereby facilitating the re-emergence of various viral diseases [50]. These outbreaks pose significant threats to population health. The dissemination of medically relevant viruses such as Zika, West Nile, and enteroviruses has become more prevalent on a global scale in recent decades. This trend is especially concerning due to the potential of certain viruses to induce central nervous system (CNS) infections in children. Their underdeveloped immune defenses and immature blood–brain barriers make them more vulnerable to neurotropic viruses [51]. Detrimental impacts on child health can affect the social development of future generations, including sustainability issues.

Porto Alegre also faces cases of leishmaniasis, a zoonotic disease caused by protozoan of the genus *Leishmania* and transmitted by phlebotomine vectors [52,53]. Environmental factors related to the lack of sanitation (high humidity, standing and/or exposed water) can increase the incidence of sandflies [54]. Leishmaniasis is a disease with high morbidity and lethality, especially among vulnerable individuals. In Brazil, dogs are considered the main reservoirs of *Leishmania* in urban areas [55]. The first notification of leishmaniasis in Porto Alegre occurred in 2016, and since then, 113 notifications of suspected cases have been reported [53,56]. Of note, 19 out of 20 confirmed autochthonous leishmaniasis cases occurred in residents of irregular occupations in regions close to the forest and without access to environmental sanitation [53].

Anthropogenic pressures on ecosystems, such as unplanned urbanization, biodiversity loss, and climate change, may facilitate the reproduction and dispersal of disease vectors [41,42], directly influencing the increase in vector-borne disease cases in the city. In this sense, high temperatures, climate variability, vegetation cover and human land use have been linked to an increased number of disease cases in Porto Alegre [57,58]. The city has one of the highest daytime urban heat island (UHI) values among the capitals of Brazil, showing the highest values of heating trends (0.3 °C/decade) among the Brazilian metropolises [59]. The increase in the near-surface air temperature and the frequency of heat waves is expected in different urban clusters. As an effect of anthropogenic influences on climate, global warming coupled with UHI will lead to increased temperatures in cities [59,60]. Considering the climate crisis, controlling the proliferation of disease vectors through improvements in sanitation systems is an urgent need in Porto Alegre and other Brazilian cities.

4. Porto Alegre Must Face Its Sanitation Issues to Realistically Achieve Sustainable Development

Although sanitation is often neglected because it is considered commonplace or an old solution, it is one of the main determining factors for urban health. Cities can favor the spread of zoonotic and vector-borne diseases due to the greater concentration of humans living in proximity, which facilitates the transmission of pathogens, and the complex social issues observed in human–nature–animal interfaces (“urban health penalties”) [61]. On the other hand, cities must allow faster and more democratic access to health services, education, and financial resources, thus promoting public health (“urban health advantages”) [61]. This urban disease paradox is regulated by multiple aspects, and sanitation is a key factor in transforming cities into health-promoting environments [61].

Universal access to environmental sanitation and proper housing conditions is also related to social equality and reduction in environmental degradation [62,63], suggesting that actions to promote human and environmental health (in biological and social terms) cannot be approached independently of each other. In this sense, Porto Alegre should focus on investments for maintenance and expansion of sewage collection and treatment services in association with better communication with the population, engaging the communities in the demands and solutions of sanitation-related issues. The expansion of environmental sanitation services in Porto Alegre would guarantee a basic right of the local population [64,65], and would bring great benefits to Porto Alegre’s economy.
(e.g., more investments by the private initiative in the city, reduction in public health expenses). Also, a better sanitation structure would create environmental and aesthetic benefits, contributing to the preservation of Lake Guaiaba, an important tourist spot in the region [66]. We emphasize that Lake Guaiaba is currently severely polluted by various classes of contaminants [67–72], and certainly, improvements in the sanitation of Porto Alegre would bring significant advancements in the de-pollution of this lake.

Porto Alegre demonstrates great potential to become a model of a sustainable city, but we stress that this objective will not be fully achieved until the problems associated with insufficient sanitation are adequately addressed. Of note, sustainability encompasses parameters intricately tied to both environmental and social concerns, necessitating careful consideration of both aspects. Porto Alegre, with its historical significance in sociological discourse, exemplified by hosting the inaugural World Social Forum (Fórum Social Mundial) in 2001 [73], has the potential to play a pivotal role in combining social and environmental action. It is fundamental to increase the prominence of social issues within environmental discussions concerning the sustainable development of Porto Alegre, and vice versa. In summary, scientists, environmental agencies, urban planners, non-governmental organizations, and legislators must recognize that sanitation issues represent a social and environmental problem requiring urban planning that considers both aspects.

5. Conclusions and Future Directions

The current state of environmental sanitation in Porto Alegre is a cause for concern. Deficiencies in sewage collection and treatment contribute to the pollution of Lake Guaiaba, posing risks to human health and ecosystems. Of note, water distribution and drainage issues, coupled with shortcomings in waste management, create conditions conducive to the proliferation of disease vectors (mosquitoes and other species). These challenges cut across both environmental and social realms, requiring holistic solutions for Porto Alegre to reach its potential of becoming a sustainable city. As a reflection of Brazilian society, the segments of Porto Alegre’s population most impacted by issues related to inadequate sanitation are presently concentrated in communities with higher social vulnerability. In contrast, the wealthier communities in Porto Alegre experience fewer challenges associated with these problems. It is crucial to allocate financial and human resources towards the implementation of a universal and efficient sanitation system that serves all citizens in Porto Alegre effectively and inclusively.

Considering that Porto Alegre already has the structural capacity to treat a significant part (80%) of its sewage, the city should update its sanitation plan, focusing on (I) establishing better communication with the communities most affected by the lack of sewage treatment, engaging the population in the demands for a better sanitation system; (II) advancing the infrastructure works to connect the sewage collection system from houses to treatment stations; (III) strengthening Porto Alegre’s existing sanitation department (DMAE); (IV) integrating discussions on social problems into the environmental agenda, and vice versa; and (V) prioritizing realistic annual achievement sanitation goals to fulfill the universal sanitation plan by 2035. Decision makers, public managers, universities, and communities must openly recognize Porto Alegre’s sanitation issue so that better initiatives can be taken to solve this problem. Improving environmental sanitation indicators is a basic step for Porto Alegre to become a modern, healthy, and sustainable city.

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