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SMALL TOWNS IN THE METROPOLITAN REGION OF VALE DO PARAÍBA AND LITORAL NORTE PAULISTA: CONTRIBUTIONS OF NATURE-BASED SOLUTIONS AND CHALLENGES FOR THE UNIVERSALIZATION OF SANITATION SERVICES

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Abstract: Considering the difficulties of universalizing sewage services in Brazil, especially in small towns where the challenges are even greater, this study aims to present decentralized individual sewage systems as alternatives to help solve the lack of basic sanitation. It focuses on the contributions and advantages of implementing Nature-Based Solutions (BBS) for sanitation in small towns in the Metropolitan Region of Vale do Paraíba and Litoral Norte Paulista (RMVPLN), where the implementation of conventional systems is often unfeasible. Such solutions can meet sanitation needs in a sustainable way, using natural processes and local technological resources, while respecting ecological cycles and promoting environmental, social and economic benefits. We adopted a Critical Analysis approach, based on a bibliographical review of works and research related to the field of study. Studies such as those by Funasa (2015), Tonetti *et al.* (2018) and Vieira (2020) present BNS as individual and decentralized sewage solutions. This approach makes it possible to verify the patterns, benefits and limitations of these solutions. This work contributes to understanding the relevance of these alternatives in promoting health, mitigating social inequalities and sustainable sanitation.
Keywords : nature-based solutions; sewage services; Vale do Paraíba and North Coast Metropolitan Region; small towns.

INTRODUCTION

Nature-Based Solutions (NBS) and their contributions present themselves as a sustainable and economically viable form of intervention that uses natural processes to solve environmental, social and economic challenges in rural and urban areas (Villanova, 2022). According to Fraga (2020), BNS benefit the environment, promote productive economic activities and improve the quality of life of communities. Recently, such resources have

gained prominence in the field of urban and regional planning, being adopted as a response to the growing demand for sustainability and resilience. SBNs address a wide range of territorial problems, from restoring ecosystems to protect regions against extreme weather events to implementing basic sanitation infrastructure (IUCN, 2016, 2020a, 2020b).

The Metropolitan Region of the Paraíba Valley and North Coast (RMVPLN), in the state of São Paulo, created by Complementary Law No. 1,166 of January 9, 2012, is made up of 39 municipalities distributed in five sub-regions. This region, which stands out for its rich history and productive diversity, has a human occupation that dates back to the Portuguese Colonial Period and was consolidated as one of the main coffee producers at the end of the 18th century. In addition to its historical relevance, the RMVPLN is characterized by a diversified economy, with a strong industrial presence and significant tourism potential today (Gomes; Reschilian; Uehara, 2018).

The RMVPLN is home to important research and teaching centers, such as the Brazilian Aeronautics Company (Embraer) and the Technological Institute of Aeronautics (ITA). Strategically located between São Paulo and Rio de Janeiro, the region has a complex regional scenario, which includes both high-tech areas and locations with significant tourist activity and historical importance. This combination of factors contributes to a mosaic of development which, although rich, also shows significant contrasts in access to basic sanitation services (Abreu, 2015).

This study aims to present decentralized individual sewage systems as alternatives to help solve the lack of basic sanitation and to highlight the contributions and advantages of implementing Nature-Based Solutions (BBS) for sanitary sewage in small towns in the Metropolitan Region of Vale do Paraíba and Litoral Norte Paulista (RMVPLN). Based on Funasa (2015), Tonetti *et al.* (2018) and Vieira (2020), the systems chosen are those that can be applied to single-family homes and, in some cases, adapted for multi-family homes. The aim is to preserve the environment, ensure financial viability, promote tangible progress in the quality of life and health of individuals, and protect nature (Vieira, 2020).

Two concepts that deserve to be highlighted, as they are of fundamental importance for understanding the issues discussed in this study, are "Basic Sanitation" and "Sanitary Sewerage Services". These concepts are set out in Law No. 14.026 of July 15, 2020, currently called the "New Legal Framework for Basic Sanitation in Brazil", which in its article 3 amended Law No. 11.445 of January 5, 2007, defining basic sanitation as the "set of public services, infrastructures and operational facilities for: drinking water supply, sanitary sewage, urban cleaning and solid waste management and urban water drainage and management". Sanitation services" are defined as:

> [...] the services constituted by the activities and the provision and maintenance of infrastructures and operational facilities necessary for the adequate collection, transportation and final disposal of sanitary sewage, from building connections to its final destination for the production of reuse water or its adequate discharge into the environment (Brazil, 2020, art. 3).

In this article, the term "sanitation services" covers public and collective solutions (Brasil, 2020).

We adopted a Critical Analysis approach to identify patterns, benefits and limitations of Nature-Based Solutions (BBS) and their contributions to the universalization of sanitation services. We seek to provide a consistent basis for discussions and conclusions aimed at mitigating inequalities in access to sanitation services in the small towns of the Metropolitan Region of Vale do Paraíba and Litoral Norte Paulista (RMVPLN). To achieve this, we used

a methodology that includes the analysis of works, technical and scientific articles, as well as research reports (Marconi; Lakatos, 2021).

This research seeks to answer the following question: *How can Nature-Based Solutions (BBS) and their contributions, through of decentralized individual systems, contribute to the universalization of sewage services in small towns in the Metropolitan Region of Vale do Paraíba and Litoral Norte Paulista?*

CHALLENGES FACING SMALL TOWNS AND THEIR REGIONAL INTEGRATION

Analyzing small cities is essential if we are to understand that they are part of a broader urban context and are not dissociated from this larger understanding. Although smaller, these cities play a significant role within the urban landscape and contribute to the overall dynamics of metropolitan regions (Fernandes, 2018). The term "*small*" is intended to qualify and measure the size of the city within the dialectic that involves the concepts of city and urban. However, defining this term is a complex task, due to the diversity of the urban phenomenon and its multiple manifestations. This complexity arises from the variety of economic, social and cultural factors that influence the definition and functioning of these municipalities (Sposito; Silva, 2013). Given this complexity, it becomes relevant to investigate how Nature-Based Solutions (BBS) can effectively contribute to the universalization of sanitation services, addressing the specificities and unique challenges of these locations.

Understanding small towns is essential if we are to understand how they fit into local and regional socio-economic dynamics that influence the production of urban space. In these cities, we territorialize the relationship between man and nature in the production of space and the reproduction of life. In Brazil, regional diversity and territorial extension result in urban heterogeneity with cities of different sizes, characteristics and functionalities (Sposito; Silva, 2013). In this context, sanitation services become essential for urban sustainability and quality of life, especially in small towns, regardless of their territorial or population size (Vieira, 2023).

In Brazil, the smallest territorial division with administrative autonomy is the municipality, while the seat of the municipality is called the city. However, from a formal point of view, the city refers to the urban area that functions as the seat, while the municipality covers the entire jurisdiction, including urban and rural areas (IBGE, 2017). Although this distinction is clear, we have chosen to use the terms city and municipality interchangeably throughout this study, a practice also adopted by the IBGE in some of its reports, with the aim of making it easier for readers to understand when presenting municipal indicators.

In this study, we used the demographic classification proposed by Ipea, IBGE and Unicamp (2002) to define small towns as those with less than 50,000 inhabitants. We therefore divided the municipalities of the RMVPLN into two groups: those with up to 50,000 inhabitants and those with more than 50,000 inhabitants. This approach allows us to associate sanitation conditions with territorial inequalities, in line with the classification adopted by these institutions:

> Thus, a first simplification of the territorial reality will consist of identifying three large population groups, breaking down the universe into large municipalities (over 250,000 inhabitants), medium-sized municipalities (between 250,000 and 50,000 inhabitants) and small municipalities (under 50,000 inhabitants) (Ipea; IBGE; Unicamp, 2002, p. 251).

Thus, our classification of the RMVPLN municipalities is based on the demographic dimension, using the number of inhabitants as

the main criterion. The use of the term "city" in some parts of the text is a simplification to facilitate exposition, maintaining the relationship with the demographic dimensions in the study by Ipea, IBGE and Unicamp (2002). Although the Ipea, IBGE and Unicamp study uses the term municipality, its demographic classification served as the basis for the criteria adopted in this work. This is in line with our aim of examining disparities between different territories. We therefore used data from the IBGE (2022) to ensure consistency with the study's methodology. In addition, the Ipea, IBGE and Unicamp study also discusses the city from a geographical perspective, contributing to the justification for using the term in our analysis, as we can see below:

> In the tradition of geographical thinking, the city is an integral part and, at the same time, a shaper of the region. As such, it cannot and should not be treated in a separate or disconnected way. In this logic, geographical space can be defined as the *locus of* production and social reproduction, which in the capitalist economy takes the dichotomous and articulated form of the city and its region (Ipea; IBGE; Unicamp, 2002, p. 251).

In addition, small towns play important roles in the regional context, contributing to the dynamics of development. They depend on complementary relationships with nearby cities to meet needs and compensate for shortcomings, such as infrastructure and public services. The interdependence of these cities with their surroundings is vital for their development and maintenance, reflecting the complexity and richness of urban relations (Sposito, 2008).

According to Gomes, Reschilian and Uehara (2018, p. 159), the RMVPLN, established by Complementary Law 1,166 of January 9, 2012, is made up of 39 municipalities, distributed in five sub-regions, namely:

a) Sub-region 1: Caçapava, Igaratá, Jacareí, Jambeiro, Monteiro Lobato, Paraibuna, Santa Branca and São José dos Campos;

b) Sub-region 2: Campos do Jordão, Lagoinha, Natividade da Serra, Pindamonhangaba, Redenção da Serra, Santo Antônio do Pinhal, São Bento do Sapucaí, São Luiz do Paraitinga, Taubaté and Tremembé;

c) Sub-region 3: Aparecida, Cachoeira Paulista, Canas, Cunha, Guaratinguetá, Lorena, Piquete, Potim and Roseira;

d) Sub-region 4: Arapeí, Areias, Bananal, Cruzeiro, Lavrinhas, Queluz, São José do Barreiro and Silveiras; and

e) Sub-region 5: Caraguatatuba, Ilhabela, São Sebastião and Ubatuba.

The RMVPLN has diverse regional scenarios, including areas of high development, such as the Calha do Vale do Rio Paraíba do Sul, along the Presidente Dutra highway. This region is characterized by a complex production structure, with high technological integration and significant tourist activity, both on the coast and in the mountains. In addition, the RMVPLN is home to municipalities with historical and religious traditions, and has a rich environmental heritage, including conservation and sustainable use units (Gomes; Reschilian; Uehara, 2018).

The RMVPLN is characterized by a high level of productive diversity, especially in the industrial sector, and has great tourism potential (Figure 1). The region is also home to important teaching and research centers, both public and private, such as the University of São Paulo, with the Lorena School of Engineering; the São Paulo State University, with the São José dos Campos Institute of Science and Technology and the Guaratinguetá Faculty of Engineering; the Federal University of São Paulo, with the São José dos Campos Institute of Science and Technology; the University of

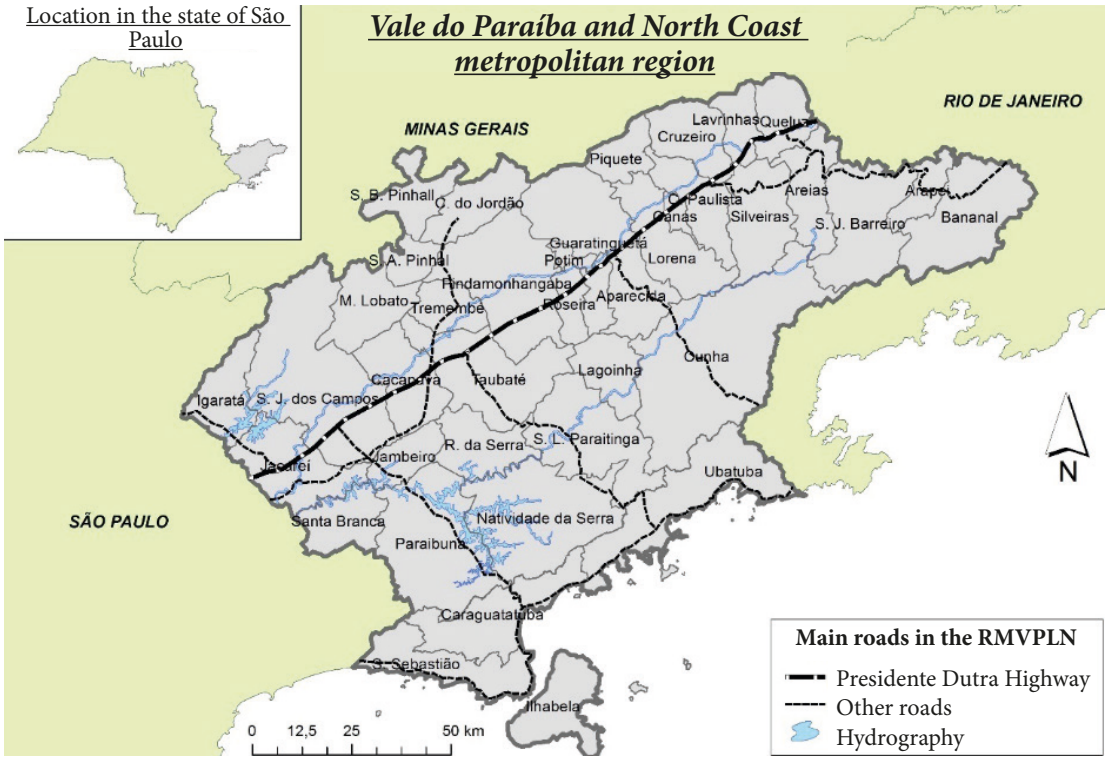

Figure 1 - Location of the Vale do Paraíba and North Coast Metropolitan Region

Source : Gomes, Reschilian and Uehara (2018, p. 156).

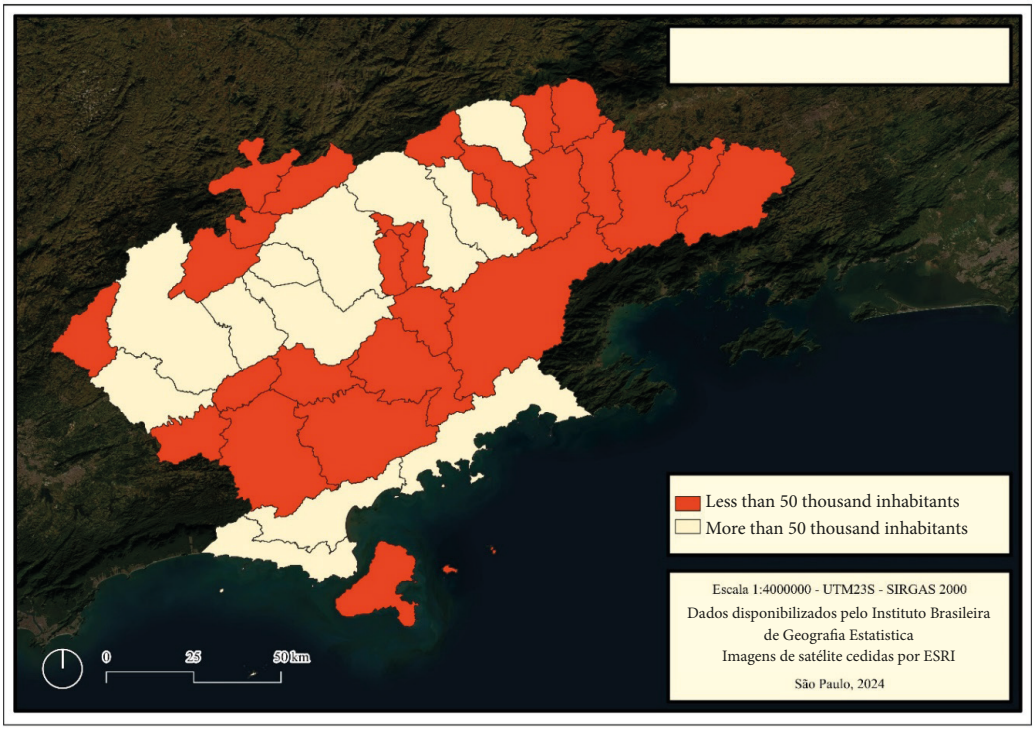

Figure 2 - Municipalities with more and less than 50,000 inhabitants in the RMVPLN

Source: prepared by Fontoura (2024) based on data from the IBGE Demographic Census (2022).

Vale do Paraíba; the University of Taubaté, among others (Andrade, 2015).

This region is also recognized as a diversified hub of industrial activities, ranging from oil refining to the production of aircraft, automobiles and transport equipment, as well as the manufacture of paper and cellulose. In addition, the RMVPLN is home to eight of the twelve development hubs established by the State Secretariat for Economic Development, encouraging sectors such as automotive; biofuels, oil derivatives and petrochemicals; metallurgy; machinery and equipment; paper, cellulose and reforestation; chemicals, rubber and plastics; health and pharmaceuticals; and textiles, clothing and accessories (Gomes; Reschilian; Uehara, 2018).

As shown in Figure 2, of the 39 municipalities that make up the Vale do Paraíba e Litoral Norte Metropolitan Region (RMVPLN), 27 have a population of less than 50,000 inhabitants. On the other hand, 12 municipalities have a population of more than 50,000 inhabitants, showing a predominance of small towns in the region.

SANITATION IN THE CITIES OF THE RMVPLN

Table 1 shows data for all the municipalities in the RMVPLN, using information from the 2022 Demographic Census with the percentage of the population with adequate sanitary sewage in 2010. These indicators are relevant to the perception and understanding of inequalities in sewage services and can contribute to the development of plans and strategies aimed at the specific needs of each location (IBGE, 2022).

Municipalities	Population (2022)	Population with adequate sanitary sewage (2010)
Aparecida	32.569	96,60%
Arapeí	2.330	58,80%
Areias	3.577	64,70%
Bananal	9.969	84,90%
Cachoeira Paulista	31.564	89,50%
Campos do Jordão	46.974	84,40%
Canas	4.931	85,00%
Caraguatatuba	134.873	88,00%
Caçapava	96.202	87,10%
Cruzeiro	74.961	96,10%
Cunha	22.110	52,24%
Guaratinguetá	118.044	91,10%
Igaratá	10.605	85,30%
Ilhabela	34.934	36,00%
Jacareí	240.275	95,10%
Jambeiro	6.397	64,60%
Lagoinha	5.083	66,90%
Lavrinhas	7.171	81,60%
Lorena	84.855	97,10%
Monteiro Lobato	4.138	50,40%
Natividade da Serra	6.999	67,90%
Paraibuna	17.667	63,00%
Pindamonhangaba	165.428	95,80%
Piquete	12.490	77,20%
Potim	20.392	97,50%
Queluz	9.159	72,80%
Redenção da Serra	4.494	42,10%
Roseira	10.832	91,40%
Santa Branca	14.975	77,50%
Santo Antônio do Pinhal	7.133	64,90%
Silveiras	6.186	71,40%
São Bento do Sapucaí	11.674	64,70%
São José do Barreiro	3.853	73,60%
São José dos Campos	697.054	94,30%
São Luiz do Paraitinga	10.337	65,60%
São Sebastião	81.595	82,10%
Taubaté	310.739	96,30%
Tremembé	51.173	86,80%
Ubatuba	92.981	60,30%

Table 1 - Vale do Paraíba and North Coast Metropolitan Region

Source: Prepared by the authors based on IBGE (2022).

Of the 39 municipalities that make up the RMVPLN, 27 have a population of less than

50,000 inhabitants, totaling 358,54 thousand inhabitants (IBGE, 2022). These municipalities are: Aparecida, Arapeí, Areias, Bananal, Cachoeira Paulista, Campos do Jordão, Canas, Cunha, Igaratá, Ilhabela, Jambeiro, Lagoinha, Lavrinhas, Monteiro Lobato, Natividade da Serra, Paraibuna, Piquete, Potim, Queluz, Redenção da Serra, Roseira, Santa Branca, Santo Antônio do Pinhal, Silveiras, São Bento do Sapucaí, São José do Barreiro and São Luiz do Paraitinga.

On the other hand, 12 municipalities have a population of more than 50,000, totaling 2.14 million inhabitants. These municipalities are: Caraguatatuba, Caçapava, Cruzeiro, Guaratinguetá, Jacareí, Lorena, Pindamonhangaba, São José dos Campos, São Sebastião, Taubaté, Tremembé and Ubatuba. The total population of the 39 municipalities in the RMVPLN is 2.50 million. This population distribution highlights the predominance of small towns in the RMVPLN, which reinforces the need for a more specific analysis to understand and address the challenges related to the provision of sanitation services in these locations (IBGE, 2022).

Table 2 shows the percentage of the population of the RMVPLN municipalities in 2010 with an adequate sewage service (IBGE, 2022).

Analysis of the data on the population with adequate sewage in the municipalities of the RMVPLN in 2010 reveals significant heterogeneity between municipalities of different population sizes. In municipalities with less than 50,000 inhabitants, the weighted average of the population with adequate sewage is 82.45%. In municipalities with more than 50,000 inhabitants, this average is 91.96%. This indicates a reduction of approximately 10.34% in the number of inhabitants with adequate sewage in the smaller municipalities compared to the larger ones. This data shows a significant inequality in basic sanitation infrastructure, suggesting that smaller cities face greater challenges in guaranteeing universal access to sewage services.

NATURE-BASED INDIVIDUAL AND DECENTRALIZED SEWAGE SOLUTIONS

Faced with the challenges related to universalizing sanitation services in the small towns of the Metropolitan Region of Vale do Paraíba and Litoral Norte Paulista (RMVPLN), this study proposes exploring Nature-Based Solutions (NBS) that can be adapted to different local contexts. Our aim is to present solutions that respect the particularities of each community, promoting not only social inclusion but also environmental conservation. These NBS aim to integrate natural processes and appropriate technologies to ensure the sustainability of sanitation services, contributing to improving the quality of life and ecological balance in the small towns of the RMVPLN.

Faced with the challenges of sanitation in the small towns of the RMVPLN, this study presents Nature-Based Solutions (NBS) as viable alternatives, respecting local particularities, promoting social inclusion and environmental conservation. The analysis considers factors such as the area required, the type of household system, the type of sewage treated and sludge removal. The following describes 16 alternatives based on Funasa (2015), Tonetti *et al.* (2018) and Vieira (2020), with emphasis on their characteristics and feasibility of implementation:

1) **Vermifilter:** a single-family or semi-collective sewage system that treats domestic sewage, including sanitary and ash water, and uses two main parts: an upper layer with sawdust, humus and earthworms, which carry out the initial decomposition of organic matter, and a lower layer with filtering materials, such as stones. The system produces humus, which can be used as fertilizer, and requires regular maintenance. With an area of 2 to 4 m², the vermifilter can treat between 400 and 1000

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Description	Municipalities with population of less than 50 thousand	Municipalities with population over 50 thousand	Reduction of approx. 10.34% in the number of inhabitants with adequate sewage in the smaller municipalities compared to the larger ones
Average weighted	29.568.624,20/ 358.543	197.556.683,70/ 2.148.180	
Average weighted	82,45%	91,96%	

Table 2 - Population with adequate sewage in RMVPLN municipalities in 2010

Source: Prepared by the authors based on IBGE (2022).

liters of sewage per day, making it ideal for small households.

2) **Biodigester septic tank: a** single-family system developed by Embrapa (2001) to treat sewage from toilets and turn it into biofertilizer. It consists of three connected 1000-liter water tanks, where the organic material degrades. The biofertilizer generated can be used on fruit trees, but not on vegetables that grow close to the ground. This system requires an area of 10 to 12 m² and does not treat gray water. The process can be improved by adding cattle manure to activate the microorganisms responsible for decomposition.

3) **Banana Tree Circle: a** single-family supplementary treatment system for sewage or gray water. The effluent is directed into a circular trench filled with branches and gravel at the bottom, where banana trees, papaya trees and other plants are planted to absorb the water and nutrients. The microorganisms in the soil degrade the organic waste. This method is effective as a complement to septic tank effluent treatment, but should be avoided in areas with sandy soil or near water tables and springs.

4) **Green Trench:** also known as an Evapotranspiration Basin (ETB), this is a single-family sanitary sewage treatment system. The system uses the evapotranspiration of plants to eliminate the effluent, and consists of a central chamber for sedimentation and digestion of the sewage, a filtering layer of materials such as gravel and sand, and an area for planting banana trees and other plants. The central chamber is waterproofed and equipped with pipes for inspection, making it an ecological and low-maintenance solution that uses the nutrients in the sewage to grow plants.

5) **Filtration Trench or Sand Filter:** single-family or semi-collective sewage systems used to treat pre-treated sewage, usually after the septic tank. The sewage is filtered through a top layer of sand and other layers of materials such as gravel and pebbles. The microorganisms present in these materials help to break down the organic matter. With depths of between 1.20 m and 1.50 m, these pits are standardized by NBR 11799/90 and NBR 13969/97, and the treated sewage must follow environmental legislation for its final disposal.

6) **Constructed Flooded Systems (CWS):** used to treat pre-treated sewage and gray water in single-family or semi-collective settings. The system consists of waterproofed ditches where the sewage is flooded. Aquatic plants, called macrophytes, act to remove pollutants, while microorganisms degrade organic matter. With a depth of up to 1 m, the SAC is sized at around 2 m² per inhabitant. It is necessary to maintain the plants, with periodic pruning, to keep the system efficient, which must comply with environmental standards.

7) **Compact Ascending Flow Anaerobic Reactor (RAFA): a** single-family or semi-collective system used to treat domestic sewage, especially toilet water. The sewage enters at the bottom and rises through the reactor, where microorganisms break down the organic matter anaerobically. At the top, plates separate the liquid from the solids and biogas. The system is standardized by NBR 12209/2011 and requires an area of 1.5 to 4 m². Annual maintenance involves internal cleaning and proper ventilation of the pipes.

8) **Biodigester: a** single-family or semi-collective sewage system that treats domestic sewage through the anaerobic digestion of organic matter. It has a closed chamber where decomposition takes place and a gasometer to store the biogas generated, which can be used as cooking gas. With an area of 5 m², the biodigester requires sludge removal every 2 to 4 years. As well as treating sewage efficiently, this system promotes sustainability by generating clean energy and reducing environmental impacts.

9) **Compartmentalized Anaerobic Reactor (RAC): a** single-family or semi-collective sewage system used to treat sanitary or domestic sewage. Unlike a conventional septic tank, the RAC is divided into several chambers in series, which increases treatment efficiency. It can be built with impermeable materials such as concrete rings, masonry or plastic drums. Sludge must be removed periodically, as necessary, to keep the system efficient.

10) **Infiltration trench: a** single-family domestic sewage system used for complementary sewage treatment, which allows the effluent, after passing through a septic tank, to be absorbed by the soil. Infiltration facilitates the mineralization of the sewage, preventing contamination of groundwater and surface water. The trenches are dug to a depth of 0.60 m to 1.00 m and a width of 0.50 m to 1.00 m. They are used to disperse the effluent safely. The system is ideal for soils that allow good percolation.

11) **Integrated Biosystem (BSI): a** single-family or semi-collective system that treats domestic sewage according to ecological principles, making complete use of the waste in a treatment cycle. The process begins with a biodigester, which treats the sewage through anaerobic digestion and generates biogas, used as fuel. The sludge accumulated in the biodigester and anaerobic filter must be removed periodically. This system treats sewage efficiently and promotes sustainable waste management, in line with the principles of sustainability and energy reuse.

12) **Dry Pit:** a human waste treatment unit that does not require water for disposal, ideal for areas where water is scarce. It consists of a hole dug in the ground, over which a small house is built, with an average depth of 2.5m. A ventilation pipe is installed to prevent the accumulation of gases, and it is recommended to cover the waste with lime, earth or ash to prevent bad smells. Construction should be done away from wells and areas subject to flooding, to avoid contamination.

13) **Fermentation Tank: a** single-family or semi-collective sewage system for the treatment of feces and urine, consisting of two independent chambers. One chamber is used until it is filled, at whi-

ch point it is isolated for the mineralization of the material, while the second chamber comes into use. After fermentation, the mineralized material can be removed, allowing for continuous reuse of the chambers. This system is efficient, sustainable and ideal for regions with water shortages or without conventional sewage systems.

14) **Septic tank:** a simple, continuous drainage system used to treat domestic sewage in homes or small buildings. It works by separating solids and liquids. The solids settle to the bottom, forming sludge, while oils and fats float on the surface. The treatment is anaerobic and takes place in a waterproofed chamber with a minimum depth of 1.5 m. The sewage is retained for 12 to 24 hours, allowing sedimentation and degradation of the organic matter. Accumulated sludge and scum must be removed periodically.

15) **Compostable Dry Toilet:** a sewage system that treats feces and occasionally urine without the use of water. The waste is collected in a waterproofed chamber and, with each use, sawdust is added to start the composting process. It can be installed in a small house outside or inside a home, with the chamber made of masonry or plastic containers. When the chamber fills up, the container is changed, facilitating safe treatment and the production of organic compost.

16) **Anaerobic filter: a** single-family or semi-collective sewage system used to treat pre-treated domestic sewage. It consists of a chamber filled with filter material, where microorganisms degrade the dissolved organic matter. Ideally, the filter is preceded by a septic tank, biodigester or anaerobic reactor to maximize its efficiency. Built with concrete or masonry rings, the anaerobic filter requires periodic maintenance to remove sludge. It is effective in reducing the organic load of sewage, improving the quality of the final effluent.

17) The comparative analysis of these alternatives takes into account aspects such as the type of household sewage system, the area needed to serve a family of up to five people, the type of sewage treated and the need for sludge removal. In Table 1, we present a synthetic technical description of each of the 16 alternative solutions to sanitation problems, assessing their characteristics and implementation requirements. These alternatives are based on Funasa (2015), Tonetti *et al.* (2018) and Vieira (2020).

Nature-Based Solutions (BBS), which employ technologies for individual and decentralized sewage disposal, can contribute to the universalization of sewage disposal in small towns in the Metropolitan Region of Vale do Paraíba and Litoral Norte Paulista (RMVPLN). These solutions address sanitation needs in a sustainable way, offering environmental, social and economic benefits. They reduce soil and water pollution and improve the quality of life of communities, creating local jobs, promoting public health and encouraging social inclusion.

SBNs stand out as a viable and sustainable alternative for tackling sanitation challenges in this context, in line with sustainable development goals and reducing inequalities in access to basic sanitation services. These solutions have reduced operating costs, diversification of products and materials, low energy consumption and the potential to reuse by-products, avoiding the need for large investments in conventional systems.

Sewage system alternatives	Area needed to cater for up to 5 people	Type of sewage treated	Type of system	Need for sludge removal
vermifilter	2 to 4 m²	toilet water, grey water, domestic and pre-treated sewage	single-family or semi-detached	yes, in the form of worm humus
biodigester septic tank	10 to 12 m²	toilet water	single-family	no
circle of banana trees	3 to 5 m²	gray water or pre-treated sewage	single-family	no
green pit or evapotranspiration basin (BET)	7 to 10 m²	toilet water	single-family	maybe
filtration trench and sand filter	2 to 5 m²	pre-treated sewage	single-family or semi-detached	no
constructed wetland system	7.5 to 15 m²	gray water and pre-treated sewage	single-family or semi-detached	no
compact rafa	3 to 8 m²	toilet water and domestic sewage	single-family or semi-detached	yes
biodigester	5 m²	toilet water and domestic sewage	single-family and semi-collective	yes
RAC reactor	3 to 8 m²	toilet water and domestic sewage	single-family and semi-collective	yes
seepage ditch	3 to 5 m²	gray water and pre-treated sewage	single-family or semi-detached	no
integrated biosystem	25 to 100 m²	toilet water and domestic sewage	single-family or semi-detached	yes
dry pit	2 to 4 m²	feces and urine	single-family	no
fermentation pit	2 to 4 m²	feces and urine	single-family	no
septic tank	1.5 to 4 m²	toilet water, grey water and domestic sewage	single-family or semi-detached	yes
compostable dry toilet	2 to 4 m²	feces and urine	single-family	no
anaerobic filter	1.5 to 4 m²	pre-treated sewage	single-family or semi-detached	yes

Table 1: Sixteen alternatives for individual and decentralized sewage systems

Source: Adapted from Funasa (2015), Tonetti *et al.* (2018) and Vieira (2020).

In addition to the technical and economic advantages, decentralized wastewater solutions offer important human, social and environmental benefits. They generate jobs and income opportunities by hiring local workers, contributing to the economy and the social fabric of communities. These solutions also improve health and quality of life, are well accepted due to their conformity with local habits and culture, and reduce pollution of soil and water bodies, positively impacting collective health and well-being.

FINAL CONSIDERATIONS

After exploring the importance of Nature-Based Solutions (BBS) and their contributions to the universalization of sewage services in small towns in the Metropolitan Region of Vale do Paraíba and Litoral Norte Paulista (RMVPLN), we present individual decentralized sewage systems as viable alternatives, highlighting their environmental, social and economic benefits.

The results indicate that Nature-Based Solutions (BBS) can be effective in mitigating inequalities in access to basic sanitation. The analyses revealed that, in small towns, the implementation of conventional sanitation systems can be unfeasible in some situations,

both economically and operationally. However, SBNs offer a sustainable approach, using natural processes and local technologies to meet sanitation needs effectively.

SBNs are emerging as a viable and sustainable alternative, promoting social inclusion, environmental conservation and the creation of local jobs. In addition, these solutions reduce soil and water pollution, improving communities' quality of life.

For future research, we suggest detailed case studies in specific small cities to deepen understanding of local challenges and develop solutions tailored to each context. In addition, comparative studies between different metropolitan regions can provide new insights into effective practices and successful policies.

Community mobilization, combined with the commitment of public managers, can transform sanitation infrastructure and improve the quality of life for all, making the small towns of the RMVPLN examples of adaptability and development.

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