SEWAGE ATLAS

River Basin Clean-Up

NATIONAL SECRETARIAT FOR SANITATION

ANA

NATIONAL WATER AND
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SEWAGE ATLAS

River Basin Clean-Up

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SEWAGE ATLAS

River Basin Clean-Up

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Sector Policial Sur, Área 5, Manzana 3, Bloques B, L, M, N,O e T.
CP: 70610-200, Brasília-DF.
PABX: (61) 2109-5400 | (61) 2109-5252
Website: www.ana.gov.br

Publishing Committee
Vitor Eduardo de Almeida Saback
Director

Reginaldo Pereira Miguel
Representative of the Federal Prosecutor's Office - ANA

Humberto Cardoso Gonçalves
Joaquim Guedes Corrêa Gondim Filho
Flávio Hadler Tröger
Superintendents

Rogério de Abreu Menescal
Executive Secretary

Publishing Team

Editorial Supervision: Sérgio R. Ayrimoraes Soares
Célio Bartole Pereira
Ana Paula Montenegro Generino
Rafael Fernando Tozzi

Preparation and Reviewing of the Originals: Water Resources Planning Superintendency – SPR
COBRRAPE – Brazilian Projects and Enterprises

Thematic Mapping: Christian Taschelmayer

Graphic design and electronic publishing: Alessandra Gava
Cristine de Noronha

Graphic illustration treatment: Alessandra Gava
Cristine de Noronha

Cover: Adílio Lemos da Silva

Translation: Miqueias Rodrigues

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Esplanada dos Ministérios, Bloco E, S/N - Zona Cívico-Administrativa
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COORDINATION AND PREPARATION

National Water and Sanitation Agency (ANA)
Water Resources Planning Superintendency (SPR)

Sérgio Rodrigues Ayrimoraes Soares
Water Resources Planning Superintendent

Célio Bartole Pereira
Grace Benfica Matos
João Augusto Bernaud Burnett
Renata Bley da Silveira de Oliveira

TECHNICAL MONITORING

National Water and Sanitation Agency (ANA)

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Jacson Storch Dalfior
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Patrícia Rejane Gomes Pereira

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Veronilton Pereira de Farias

COLLABORATORS

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National Health Foundation – FUNASA

Ricardo Frederico de Melo Arantes

Federal University of Minas Gerais (UFMG)

Marcos Von Sperling
Sonaly Cristina Rezende Borges de Lima

PREPARATION AND IMPLEMENTATION

COBRAPE – Brazilian Projects and Enterprises

Carlos Alberto Amaral de Oliveira Pereira
General Coordination

Rafael Fernando Tozzi
Executive Coordination

Main Team

Alceu Guérios Bittencourt
André Di Angelo Trevizan
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SERGIPE: Capela (SAAE); Estância (SAAE).

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PRESENTATION

The deficit in sanitary sewage services in Brazil has resulted in substantial amounts of untreated sewage that is often disposed into the water bodies, compromising water quality for multiple uses and causing harm to public health and to the environment.

The National Water and Sanitation Agency (ANA), in the role of water resources manager, has the goal of promoting the proper management and the rational and sustainable use of water resources, including water bodies used as recipients for domestic sewage. In turn, the National Secretariat for Environmental Sanitation of the Ministry of Cities (SNSA/MCidades) is the coordinating body for the implementation of the Federal Sanitation Policy, which guides actions and investments in sewage collection and treatment.

Aware of the great challenge represented by this theme, ANA and SNSA/MCidades have joined forces to increase knowledge about the issue through the analysis of all of the sanitary sewage systems of Brazil's municipal seats and the proposition of collection and treatment actions, focusing on the protection of water resources, its sustainable use for the dilution of effluents and the best strategy for rationally and gradually moving forward towards the universalization of the services. This strategy also dialogues with goals relating to access to sanitation and the improvement of water quality established by the Sustainable Development Goals of the 2030 Agenda for UN-member countries.

It is in this context that the present study *Sewage ATLAS: River Basin Clean-Up* was developed and is added to the Brazil ATLAS: Urban Water Supply, a study carried out for the entire national territory in 2011. Both publications approach the relationship between sanitation and water resources, with the goal of qualifying decision-making processes and guiding the development of actions and the allocation of financial resources from the sanitation sector, with a view to river basins and the sustainable use of water resources.

The National Water and Sanitation Agency and the SNS/Ministry of Regional Development are certain that this partnership will result in a valuable planning tool to society as a whole and a monitoring instrument regarding the actions necessary for the evolution of sewage treatment in Brazil

National Water and Sanitation Agency (ANA) and SNS/Ministry of Regional Development

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CONTENTS

1 | SEWAGE ATLAS SYNTHESIS **13**
1.1 | CONTEXT AND GOALS 14
1.2 | THE ORGANIZATION OF SEWAGE TREATMENT SERVICES 16
1.3 | THE PREPARATION PROCESS 18
1.4 | MAIN RESULTS 22

2 | THE SITUATION OF SEWAGE COLLECTION AND TREATMENT **27**
2.1 | SEWAGE LOAD GENERATED 28
2.2 | COVERAGE INDEXES 30
2.3 | TREATMENT TECHNOLOGIESO 32
2.4 | ASSESSMENT OF THE CURRENT SITUATION 37
2.5 | RESULTS BY MUNICIPALITY 46

3 | THE WATER RESOURCES SITUATION **49**
3.1 | EFFECTS OF SEWAGE ON WATER QUALITY 50
3.2 | ASSESSMENT OF THE SEWAGE DILUTION CAPACITY 56

4 | SEWAGE TREATMENT PLANNING AND INVESTMENTS **63**
4.1 | EVALUATION AND DEFINITION OF THE REQUIRED TREATMENT 64
4.2 | COLLECTION AND TREATMENT COSTS 70

5 | IMPLEMENTATION STRATEGY AND RECOMMENDATIONS **77**
5.1 | INSTITUTIONAL ASSESSMENT OF THE PROVISION OF SEWAGE TREATMENT SERVICES 78
5.2 | IMPLEMENTATION STRATEGY 82
5.3 | CONCLUSIONS AND RECOMMENDATIONS 86

1 | SEWAGE ATLAS SYNTHESIS

1.1 | CONTEXT AND GOALS

1.2 | THE ORGANIZATION OF SEWAGE TREATMENT SERVICES

1.3 | THE PREPARATION PROCESS

1.4 | MAIN RESULTS

1.1 | CONTEXT AND GOALS

Water management in Brazil, nationally instituted by Federal Law No. 9,433/1997, is based on multiple water uses and on management by river basin, and one of its main goals is to "ensure the necessary availability of water to future generations, with quality and standards appropriate for the respective uses". Reaching these goals has proved more challenging in metropolitan cities and regions, where there is an increasing complexity in guaranteeing the supply for urban populations.

A sequence of critical events, in Brazil and in the world during the recent years has evidenced the importance of the system of water resources management and the need for infrastructure investments in order to guarantee the water offer necessary for the country's social and economic development.

Considering this, in 2011 ANA published the B*razil ATLAS - Urban Water Supply*, a valuable decision-making instrument that aims to guarantee water supply for the country's entire urban population.

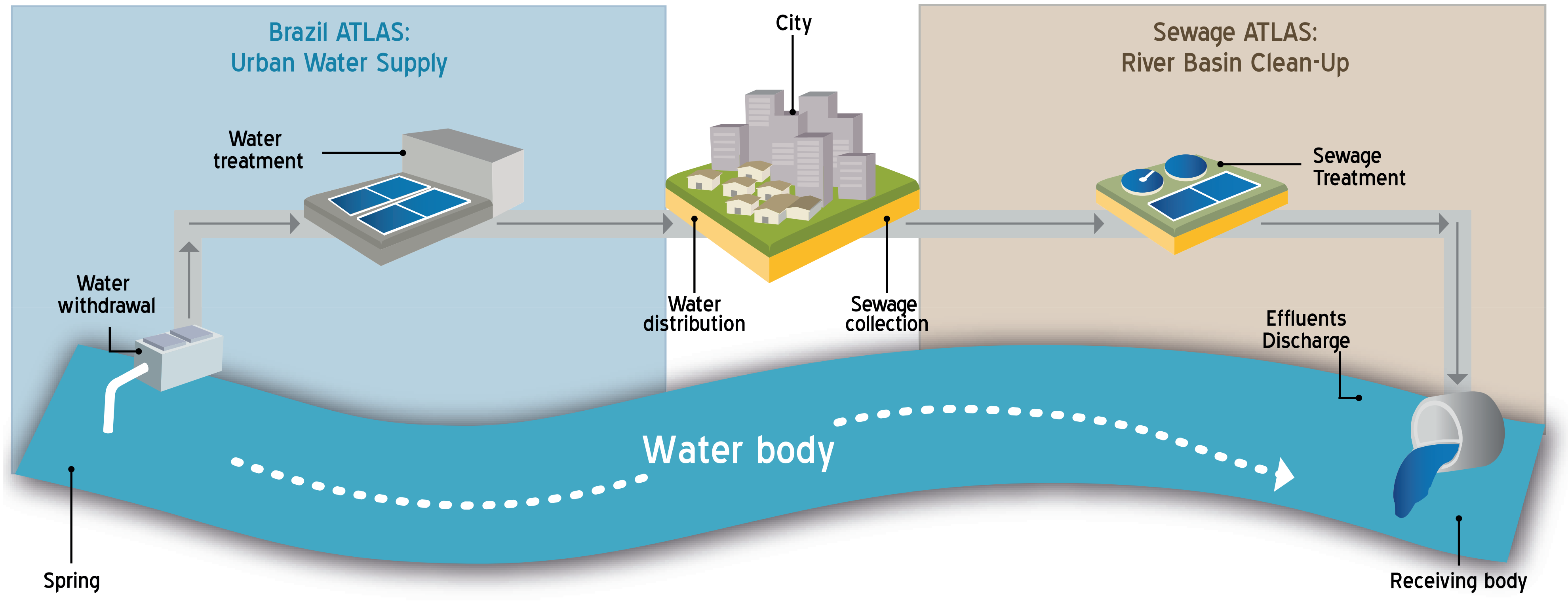
The interface between Water Resource Management and sewage treat-ment in cities, however, is not limited to the guarantee of the necessary volumes for water supply. The guidelines of the National Water Resources Policy also consider other components, especially those related to water pollution control. The integration between policies is, therefore, essential for the achieving of these goals.

The basic sanitation law (Federal Law No. 11,445/2007) incorporates a series of essential guidelines for this integration, such as the adoption of the river basin as a reference unit for the planning of actions and the need to make sanitation plans more compatible with basin plans. Even with the advances incorporated into laws and other regulations, incorporating this integration into planning processes is still complex. The multiple combination of factors that are specific to each geographic area and that involve physiographic, institutional, socio-cultural and economic aspects, demands analytical and methodological efforts necessary for the tacking of the sanitation issue focusing in the protection of water resources.

Sewage treatment is one of the sanitation services in greater need of analyses and solution proposals, especially regarding water management. The sewage collection and treatment deficit in Brazilian cities has resulted significant parcel of pollution load being discharged into water bodies with negative implications to multiple water uses.

As policies on water and sanitation resources become more consolidated a more robust institutional structure will result. The conditions for overcoming this deficit of institutional structure will also improve and will simultaneously consider local and regional characteristics.

In this context, ANA partnered with the National Secretariat for Environmental Sanitation of the Ministry of Cities to prepare the Sewage *ATLAS: River Basin Clean-Up*. The ATLAS contains the sewage treatment diagnosis for Brazil, focuses on its implications to the receiving water bodies, the treatment investments necessary, and proposes guidelines and an integrated strategy for implementing the actions.



The *Sewage ATLAS* applies the water resources approach to sanitation planning considering the river basin as a planning unit. The following goals were defined based on the universalization of sewage treatment services and focused on the protection of water resources:

- To characterize sewage treatment situation of the country's 5,570 municipal seats, assessing the impact of effluent loads on water bodies;
- To propose sewage related actions focusing on treatment, protection of water resources, sustainable ways of cleaning urban effluents and on the rationalization of investments.

Even though it is a national study, detailed assessments were carried out for each of the 5,570 urban seats in Brazil, always considering the regional diversities and employing the river basin approach. This methodology represents a great advancement in the sewage treatment situation in the country and its potential impact on water resources. According to the study's scope and the goals set, only urban house loads were considered and solutions were not assessed for rural areas.

The information for each urban seat was summarized in the form of sketches that contain the complete current characteristics, as well as the solutions proposed from the modeling carried out or obtained from a service provider. The sketches are available on ANA's website (www.ana.gov.br) and the National Water Resources Information System (SNIRH) website (www.snirh.gov.br).

This integrated approach, which is unprecedented in Brazil, creates a technical and strategic basis, and thus makes the *Sewage ATLAS* a reference document for decision-making, and water resources management and in orientation for the sanitation investments.

The final result is presented in this Executive Summary, which is structured as follows:

- **Chapter 1:** synthesis of the *Sewage ATLAS* elaboration methodology, overview of the sewage services organization in Brazil and the main results of the analyses, which are better detailed in the following chapters;
- **Chapter 2:** diagnosis and evaluation of the current conditions of sewage collection and treatment services in Brazil, including data on the main treatment technologies used and their efficiency in removing pollutants;
- **Chapter 3:** impact analysis of sewage discharge in the receiving water bodies, compromising of water quality classes and evaluation of the dilution capacity of the country's water bodies;
- **Chapter 4:** evaluation of treatment efficiency and proposing of required standards and associated costs, considering the universalization of sewage treatment in Brazil and listing the different complexity levels of the solutions necessary for achieving water quality targets;
- **Chapter 5:** analysis of the institutional conditions of the sewage treatment services in Brazil, which proposes a strategy for implementing the solutions by considering the complexity of the treatment required and the institutional and financial capacity of providing this service.


ETE Arrudas / Belo Horizonte, MG
COPASA Image Bank

1.2 | THE ORGANIZATION OF SEWAGE TREATMENT

The organization of sewage treatment services in the cities may be carried out indirectly, when a delegation of services to a municipal autarchy, state or private company, or directly, without an institutionalized service provider.

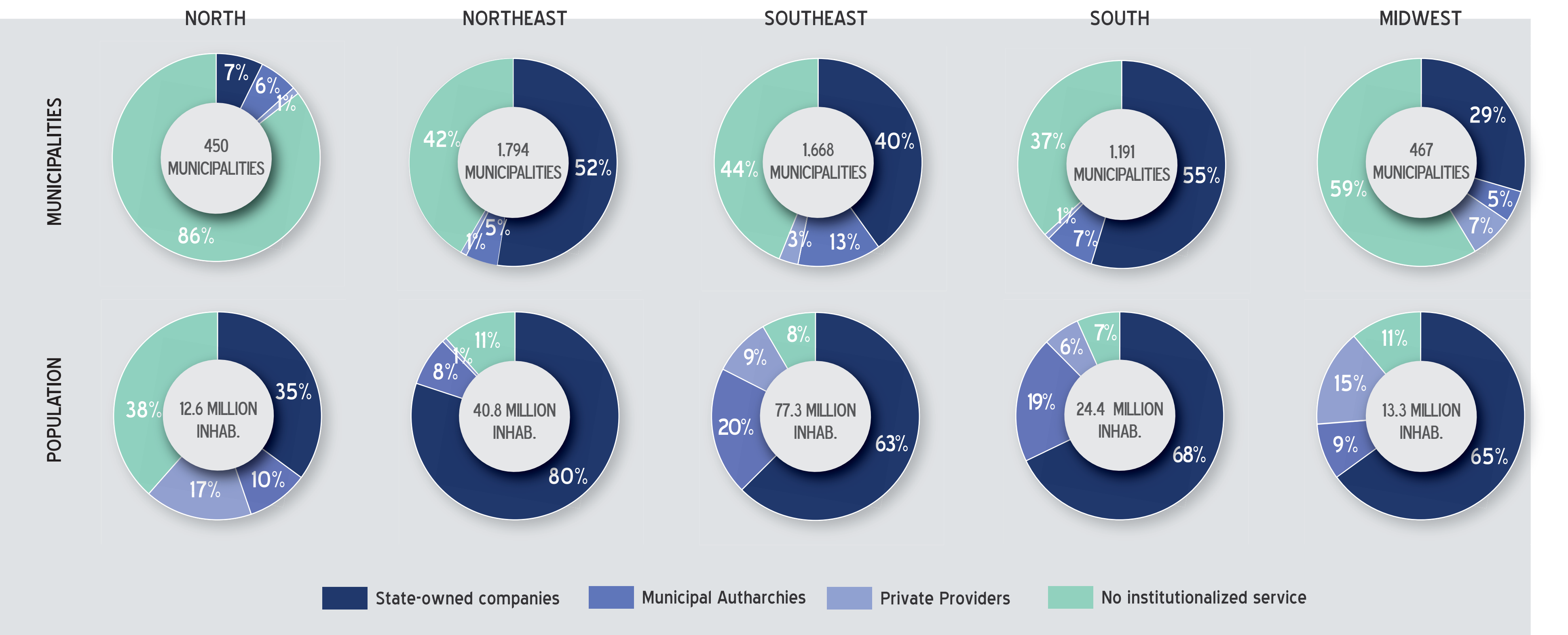
In this context, there are two predominant arrangements are in force in terms of service provision. The first is regarding 2,982 cities that receive services from a municipal autarchy, the state or a private company; the second the 2,588 cities that do not have an institutionalized provider (no outsourcing).

It should be noted that in the two arrangements there are cities that do not offer sewage treatment services to the population. The absence of these services is more common in the second group, where less than 5% of the cities have no institutionalized service and are only provided with treatment in the form of sewage collection services, while in the first group about 50% of the cities have sewage collection and treatment services that reach at least 10% of the population.

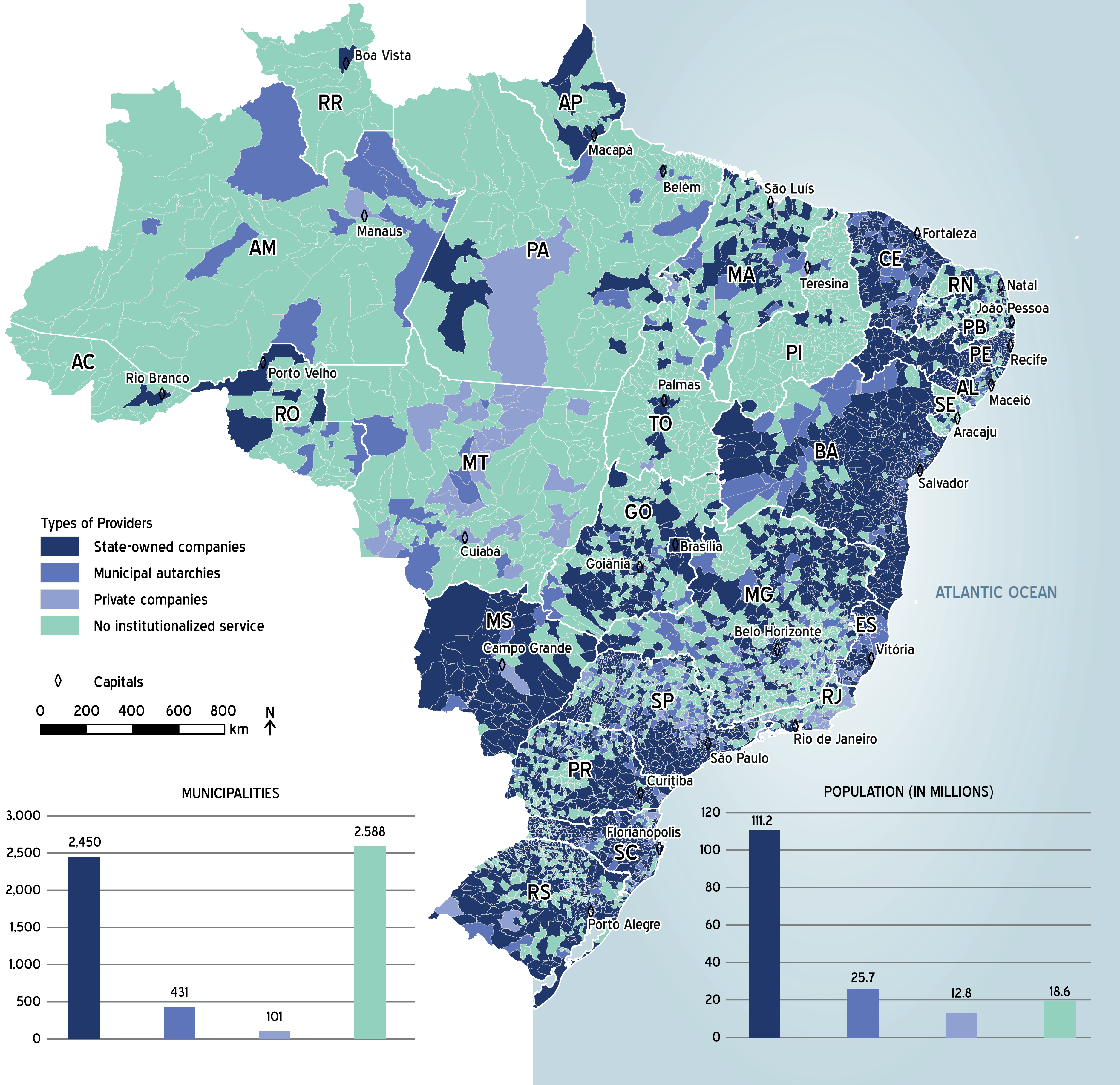
Despite the similar number of cities, the first group, where the services are mostly provided by state companies, concentrates a population of 149.7 million inhabitants (89.9% of the country's urban population), while the second group, where there are no institutionalized services, correspond to 18.6 million people, mostly in small municipalities.

This difference is also reflected in the regional scope. In the eastern part of Brazil (northeast, southeast and south regions), sewage treatment services are outsourced in most cities, while in most of the western cities (north and midwest regions) the services are the responsibility of the city's own administration structure (municipal mayor's offices).

TYPES OF SERVICE PROVIDERS BY GEOGRAPHIC REGION



PROVIDERS OF SEWAGE TREATMENT SERVICE



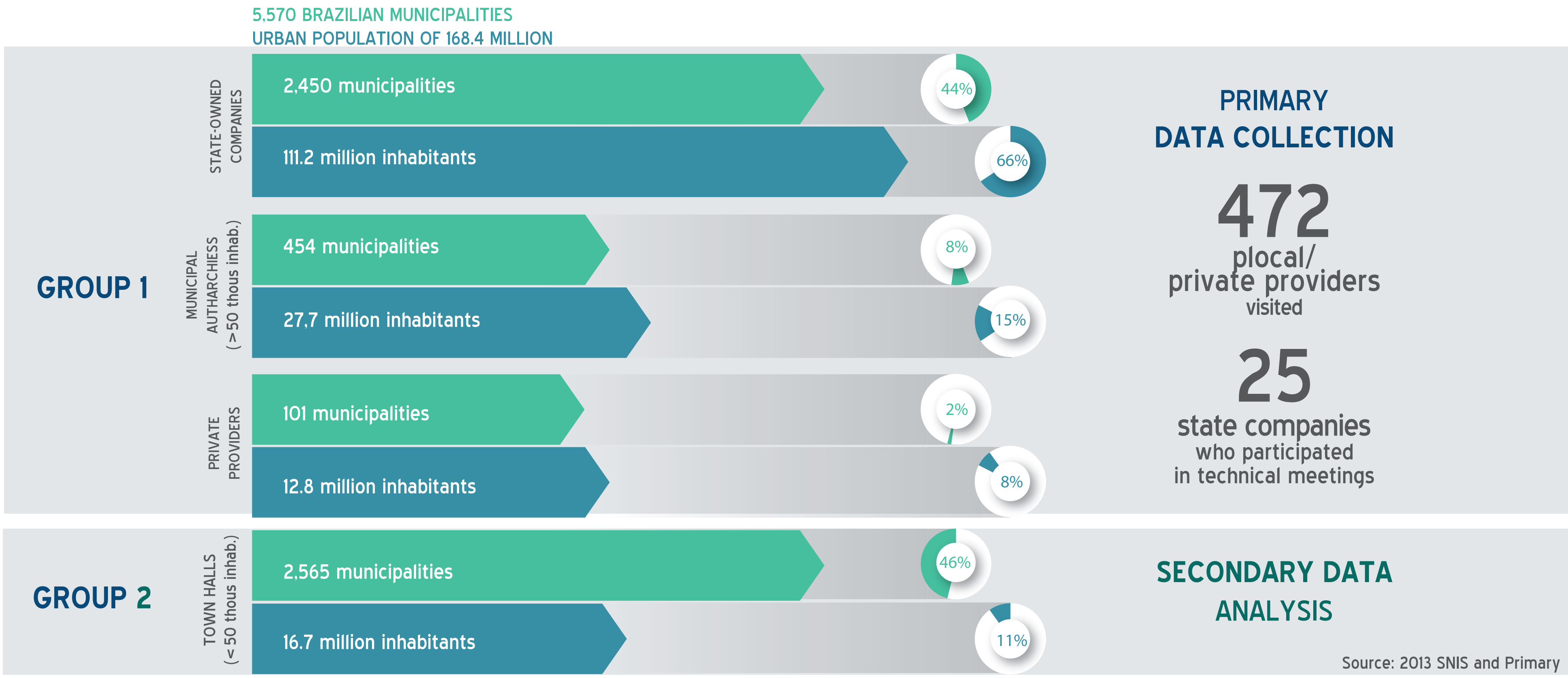
1.3 | THE PREPARATION PROCESSE

The *Sewage ATLAS* was prepared in partnership with SNSA/ Ministry of Cities and received collaborations from federal (especially Funasa and Codevasp) state and municipal agencies. Technical meetings were held to consolidate data collection, validation strategies and work methodologies. To make a survey of the information the 5,570 Brazilian municipalities were separated into two groups considering the modality of provision of the sewage treatment service adopted.

Group 1 was made up of municipalities with institutionalized service providers (state companies, municipal autarchies and private companies). Primary data was collected for this group through field visits and technical meetings. With **regard** to municipalities without institutionalized service providers, those with an urban population of over 50,000 inhabitants were incorporated to Group 1, considering that they represent more significant sources of pollution loads.

The municipalities with population inferior to 50,000 inhabitants, which are dependant on city halls, were organized into a second group (Group 2), for which secondary data was used. The consultation sources in these cases were the National Sanitation Information System - SNIS and studies by the Brazilian Institute of Geography and Statistics - IBGE, including the 2010 Demographic Census, the 2000 National Basic Sanitation Survey - PNSB and the 2001 and 2011 National Household Sample Service - PNAD.

The detailing of information provided by the surveying of primary data for Group 1 municipalities, which concentrates most of the urban population, represented another significant particularity if compared to other national studies carried out, because it allowed the characterization of the situation of sanitary sewage and receiving water bodies in these municipalities beyond the coverage indexes normally used.



The work was basically divided into four activity groups:

- **Data Collection** corresponded to the characterization of sewage treatment systems based on information collected in field visits and tech-nical meetings, encompassing 3,005 municipalities (Group 1) and secondary data for the other 2,565 municipatlities (Group 2). All the information collected was organized into a georeferenced database, allowing structured consultations and spatial analyses. The receiving bodies were also identified in the characterization of the sewage treatment systems and an estimate was made of the organic load stemming from population-generated sewage. Once this information was gathered, one estimated the data-collection areas (with and without treatment), the areas where information was not collected and that are without treatment, and information related to individual solutions such as septic tanks. This information subsidized the analyses carried out and the respective graphic representation for the distribution of loads generated in the municipalities in schematic sketches for each of the 5,570 Brazilian municipalities.

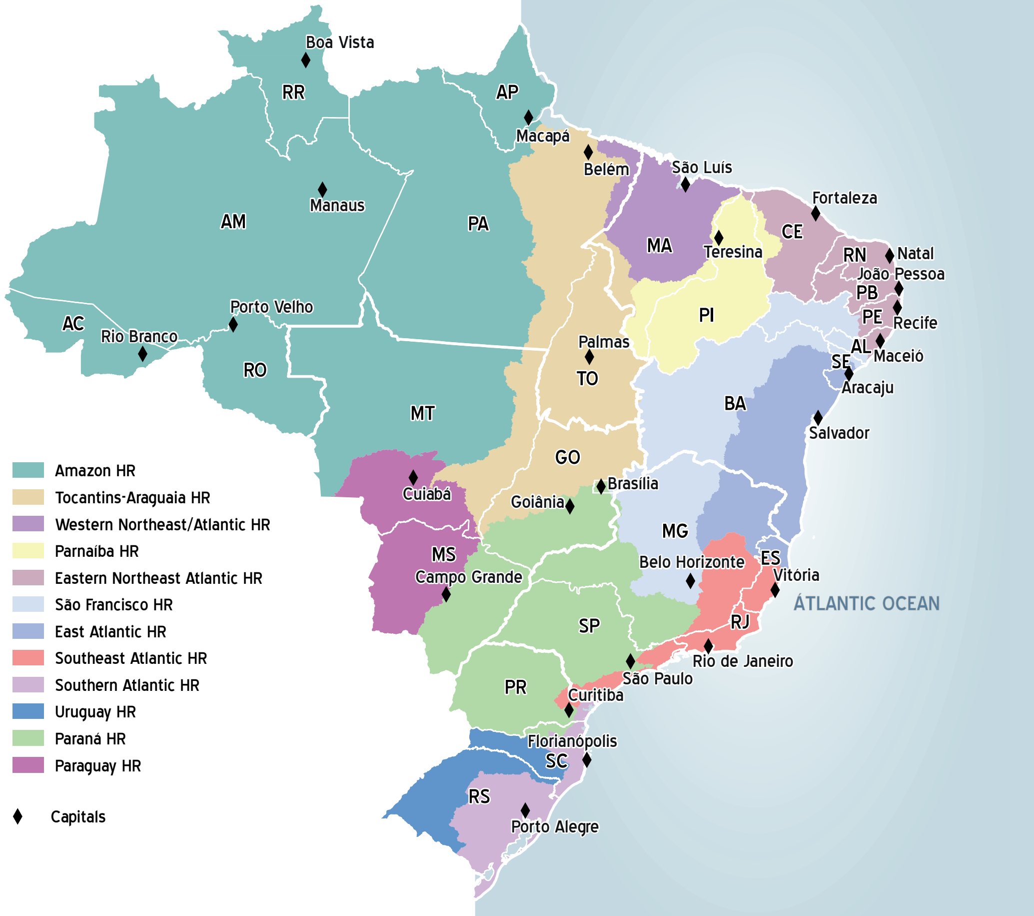
- The **Diagnosis** included the assessment of the offer of sewage collection and treatment with respect to the population's access to these services and the fulfilment of water quality requirements in the receiving bodies. The impact of the sewage on the receiving bodies was evaluated using a mathematical model applied to simulate Biochemical Oxygen Demand -BOD, based on the national hydrographic base prepared by ANA.
- La **Planning** involved future river basin analyses carried out up to 2035, aiming to ascertain the need for integrated or individualized solutions from the identification of organic load (expressed in BOD) removal efficiency, with additional nutrient analyses (phosphorus and nitrogen) based on simplified modeling. Taking as an example the representation used for the current situation, the proposed solutions were materialized in schematic sketches for the Brazilian municipality headquarters. An estimate of the investments in sewage collection and treatment was also carried out for this group, based on the deficits to be overcome.
- The **Implementation Strategy** involved and assessment of the sewage services institutional overview and the elaboration of guidelines to allow proposed alternatives to be implemented and guarantee the operational management for sewage treatment solutions. The model of the evaluation of the institutional arrangement was based on the listing of the main administrative, economic and operational characteristics of sanitary sewage services.

Considering the focus on water resources protection, the river basin was adopted as a reference and planning unit for modeling and evaluation, based on the Hydrographic Regions, established by National Water Resources Council (CNRH) Resolution No. 31/2003. The river basin is the area where, due to terrain and geography, rainwater is drained to a main river through its tributaries. It is a natural and easily outlined system that was defined as the water resources planning and management unit by the National Water Re-sources Policy (Federal Law No. 9,433/1997).

In this way, in addition to the commonly adopted results of representation by Brazilian State and Geographic Region, this document also presents results grouped by the 12 Hydrographic Regions - HRs in Brazil, which are:

- **Amazon HR:** The Brazilian portion of the Amazon basin and river basins at the Marajó Island and Amapá rivers that flow into the Atlantic Ocean, contemplating the states of Acre, Amapá, Amazonas, Mato Grosso, Pará, Rondônia and Roraima. The state capitals, Manaus, Rio Branco, Porto Velho, Boa Vista and Macapá are among the main urban centers in this region
- **Tocantins-Araguaia HR:** the Tocantins river basin and its main tributary, the Araguaia river. This basin covers the states of Goiás, Tocantins (including the capital, Palmas), Pará (including the capital Belém), Maranhão, Mato Grosso and the Federal District.
- **Western Northeast Atlantic HR:** hydrographic basins for rivers that flow into the Atlantic - western northeast stretch. This basin is mostly located in Maranhão (including the capital, São Luís) and in a small eastern part of Pará.
- **Parnaíba HR:** Parnaíba river basin, which has the Poti river featured as one of its main tributaries. This region drains almost all the state of Piauí (including the capital, Teresina) and a small part of the states of Maranhão and Ceará.
- **Eastern Northeast Atlantic HR:** this is the river basin for the rivers that flow into the Atlantic - eastern northeast stretch, including the Paraíba, Jaguaribe, Piranhas-Açu, Capibaribe, and Acaraú rivers. The basin covers 6 states in the Northeast region (Piauí, Ceará, Rio Grande do Norte, Paraíba, Pernambuco, and Alagoas), including the metropolitan regions of the state capitals, Recife, Fortaleza, Maceió, Natal and João Pessoa.
- **São Francisco HR:** the São Francisco river basin covers the Federal District and the states of Bahia, Sergipe, Alagoas, Pernambuco, Goiás and Minas Gerais, including the Belo Horizonte metropolitan region. Its territory is expressive in the semiarid geographic region.
- **East Atlantic HR:** the river basins for the rivers that flow into the Atlantic - eastern stretch (Minas Gerais, Espírito Santo, Bahia and Sergipe). The southern portion is composed of the Jequitinhonha, Mucuri and São Mateus river basins. The metropolitan regions of Salvador and Aracaju are also located in this territory.
- **Southeast Atlantic HR:** The hydrographic basins for rivers that flow into the Atlantic - western southeastern stretch. Its main rivers are Paraíba do Sul and Doce. It has significant population concentrations, including the metropolitan regions of Rio de Janeiro, Vitória and Baixada Santista (SP) metropolitan regions. This basin covers the states of Minas Gerais, Rio de Janeiro, Espírito Santo and São Paulo.
- **South Atlantic HR:** The river basins for rivers that flow into the Atlantic - south stretch, extending from its nothernmost portion, next to the border between the states of São Paulo and Paraná, to the Chuí stream, in the south. This basin covers the states of Paraná, Santa Catarina and Rio Grande do Sul, and includes the Florianópolis and Porto Alegre metropolitan regions.
- **Uruguay HR:** The Uruguay river basin located in Brazilian territory covers the central and western parts of Santa Catarina and the western part of the state of Rio Grande do Sul.
- **Paraná HR:** The Paraná river basin located in the Brazilian territory. It covers the Federal District and the states of Goiás, Mato Grosso do Sul, Minas Gerais, São Paulo, Paraná and Santa Catarina. The Paraná basin includes the most populous city in South America, São Paulo, as well as other capitals (Brasília, Curitiba, Goiânia and Campo Grande) and important population centers such as Campinas (SP) and Uberlândia (MG). Much of the population is concentrated in the Grande and Tietê river basins (including their tributaries the Piracicaba, Capivari and Jundiaí rivers, areas that pioneered most water management actions in the country). It also includes the Parnaíba, Paranapanema and Iguaçu river basins.
- **Paraguay HR:** The Paraguay river basin located in the Brazilian territory, covering the states of Mato Grosso and Mato Grosso do Sul, including the Cuiabá metropolitan region and the Pantanal Plain.

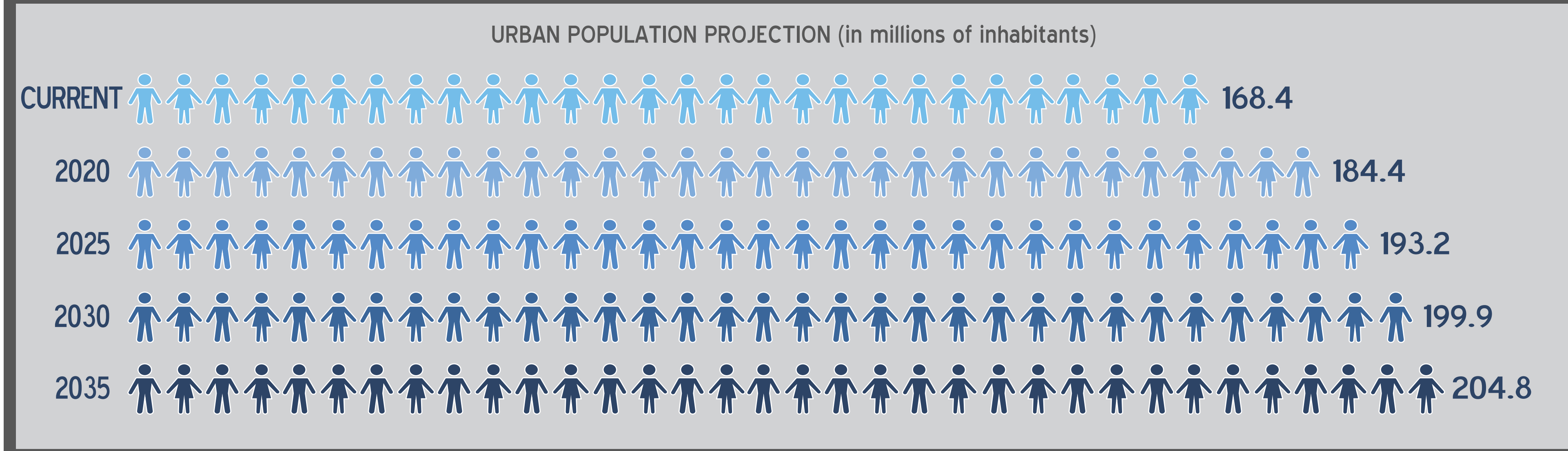
BRAZILIAN HYDROGRAPHIC REGIONS



POPULATION DATA

The sewage loads produced and remaining, wich were assessed throughout the study, both for the current situation and for the future scenario, were estimated and based on each municipality's urban population. Data obtained from sewage service providers was used to obtain the current population figures in addition to data from the National Sanitation Information System -SNIS, with 2013 as the reference year.

In order to estimate future populations, a population projection study was based on 2010 IBGE Census data. Urban population growth rates were obtained from this study, which allowed for urban population estimates for the years of 2020, 2025, 2030 and 2035 when applied to the 2010 census data.



GEOGRAPHIC REGION	URBAN POPULATION (IN MILLION OF INHABITANTS)																								
	CURRENT					2020					2025					2030					2035				
	N	NE	SE	S	CO	N	NE	SE	S	CO	N	NE	SE	S	CO	N	NE	SE	S	CO	N	NE	SE	S	CO
Up to 50 thous (5.068 urban centers)	4.2	16.3	14.7	8.3	3.9	5	18.4	16.2	9.2	4.5	5.4	19.5	17	9.6	4.7	5.7	20.3	17.6	9.9	4.9	5.9	20.9	17.9	10.1	5
Between 50 and 250 thous (396 urban centers)	2.6	8.5	18.4	7.9	2.8	3	9.5	20.4	8.6	3.3	3.2	9.9	21.4	9	3.5	3.4	10.3	22.2	9.3	3.7	3.5	10.6	22.7	9.6	3.8
Over 250 thous (106 urban centers)	5.9	16	44.2	8.2	6.5	6.5	17	46.6	8.8	7.6	6.9	17.7	48.1	9.2	8.1	7.2	18.1	49.4	9.5	8.5	7.4	18.8	50.1	9.8	8.8
TOTAL	12.7	40.8	77.4	24.4	13.3	14.5	44.9	83.2	26.6	15.4	15.5	47.1	86.5	27.8	16.3	16.3	48.7	89.2	28.7	17.1	16.8	50.3	90.7	29.5	17.6

1.4 | MAIN RESULTS

The main results obtained throughout this study are summarized in this topic and are detailed, discussed and better explored in the following chapters.

The Brazilian sewage services situation may be characterized as follows: 43% of the population is attended by a collection system (collection network and sewage treatment station); 12% of the population employs an individual solution (a septic tank); for 18% of the population the sewage is collected but not treated; and 27% is not provided with any kind of service, that is, there is no sewage collection or treatment.

The Basic Sanitation National Plan (2014) considers septic tanks or collection and treatment as appropriate sewage services. Within this concept, 55% of the Brazilian population has access to appropriate services.

CONAMA Resolution No. 430/2011, which provides conditions and standards for effluent discharge, states that effluent treatment must remove 60% of BOD in the case of direct discharge into receiving bodies.

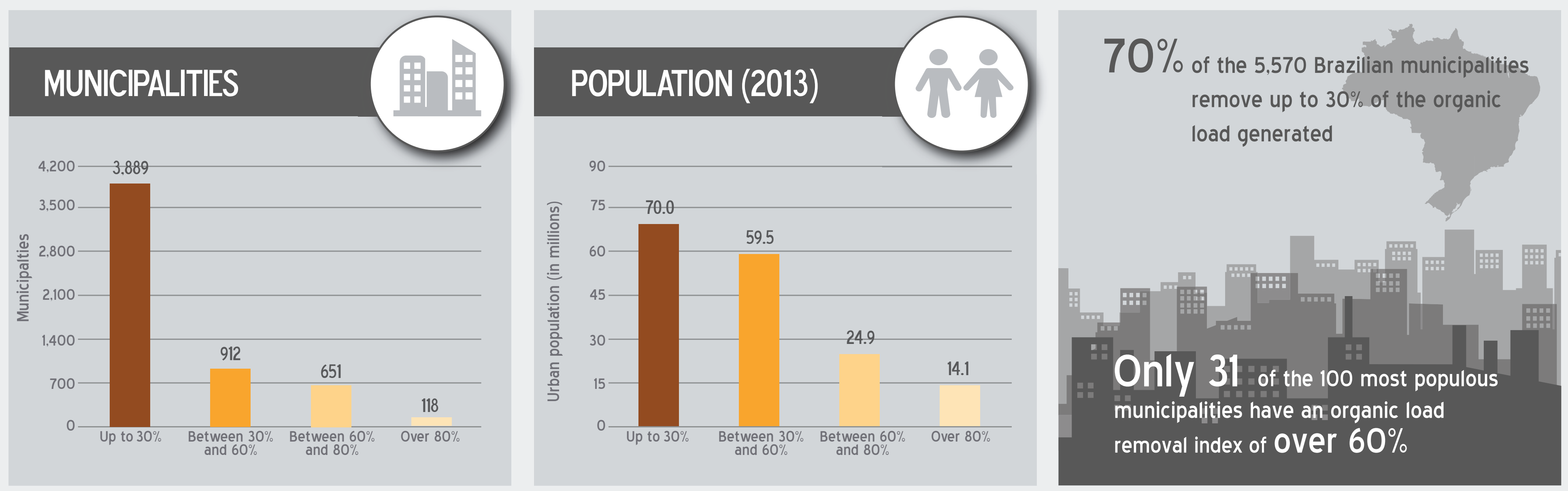
However, the great majority of Brazilian cities (48,801 cities, totalling 12.5 million inhabitants) presents BOD removal levels below 60% of the generated load. There is a predominance of cities with low levels of organic load removal in all geographic regions, especially the North and Northeast.

In the other extreme, only 769 cities (14% of the total) indicate BOD removal indexes superior to 60%, considering that the Southeast Region concentrates a great majority of these cities.

From a Federation Units standpoint, only the Federal District removes over 60% of the sewage load generated. The states of São Paulo and Paraná come close to this index, while all other states have low removal indexes that contribute to reduce the national average.

Of all the organic load generated in the country (9.1 thousand tons of BOD/day), only 39% is removed through the sewage treatment infrastructure existent in the Brazilian urban centers. As a result, about 5.5 thousand tons BOD/day can reach the receiving bodies.

URBAN SEWAGE LOAD REMOVAL

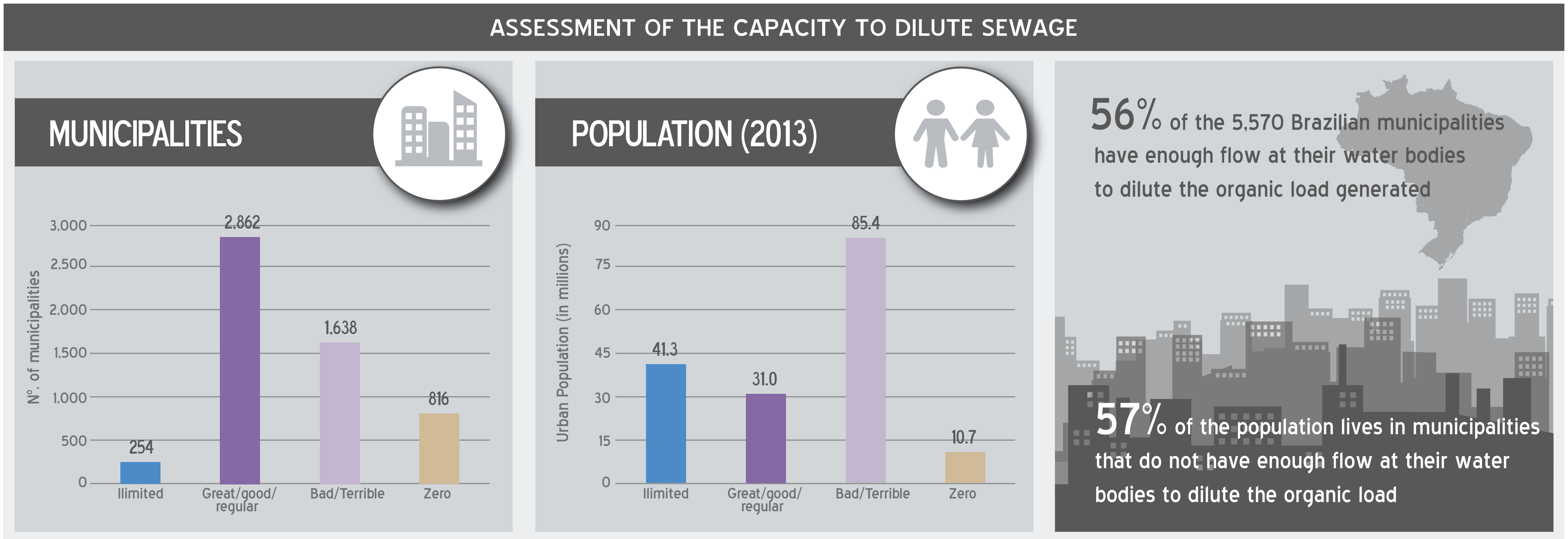


The discharging of domestic sewage into water bodies without proper treatment or not in accordance with the current legal standards for effluent discharge, results in the compromising the water quality of the receiving bodies and may impair water supply for current and future uses downstream of the discharge. This occurs mostly in urbanized areas.

In a Water Quality Index - WQI evaluation carried out in 2013 by ANA for water quality data obtained in 1,683 locations throughout the entire country in 2013, 19% of the measured locations presented quality considered regular/bad/terrible. This number increases to 39% if we consider only the monitoring points located in urban areas.

In the *Sewage ATLAS* the ability of the receiving bodies in assimilating urban sewage was evaluated for each municipal seat. Urban population data in each contributing basin was took into consideration the reference flow usually employed in the water resources management processes (Q 95%, flow in the water body that occurs or is exceeded in up to 95% of the historical records), the remaining organic load estimated and compliance with the water classes according to the BOD parameter, as provided by CONAMA resolution No. 357/2005. In the case of coastal cities there is the possibility of discharging treated effluents into the ocean through submarine emissaries, therefore, an unlimited dilution capacity was considered for effluents of these urban centers.

As a result, it was observed that over half the Brazilian municipalities have receiving bodies with enough capacity to dilute the remaining sewage effluent load in the urban centers (great, good or regular dilution capacity). However, in terms of the population contingent, it is observed that 57% of the urban population resides in municipalities that do not have enough flow to dilute the urban load without resorting to more efficient treatment processes or resulting in water quality that is only compatible with less restrictive classes (3 or 4), especially in the Western and Eastern Northeast Atlantic, Parnaíba, São Francisco and East Atlantic hydrographic regions.



Based on the needs identified in the diagnosis having as reference the year 2035, the required capacity of organic load removal (represented by BOD) was evaluated. This evaluation was supported by mathematical water quality modelling and the interaction between the discharges in all cities in the water basin was considered.

The solutions obtained always sought to adjust water quality levels in the receiving bodies to the most demanding uses, having as a minimum requisite the fulfilling of requirements for the classes established by CONAMA Resolution No. 357/2005.

The results formed the basis for the definition of the technical alternatives identified, which considered the required efficiency and complementary arrangements, and classified the municipalities within the following types:

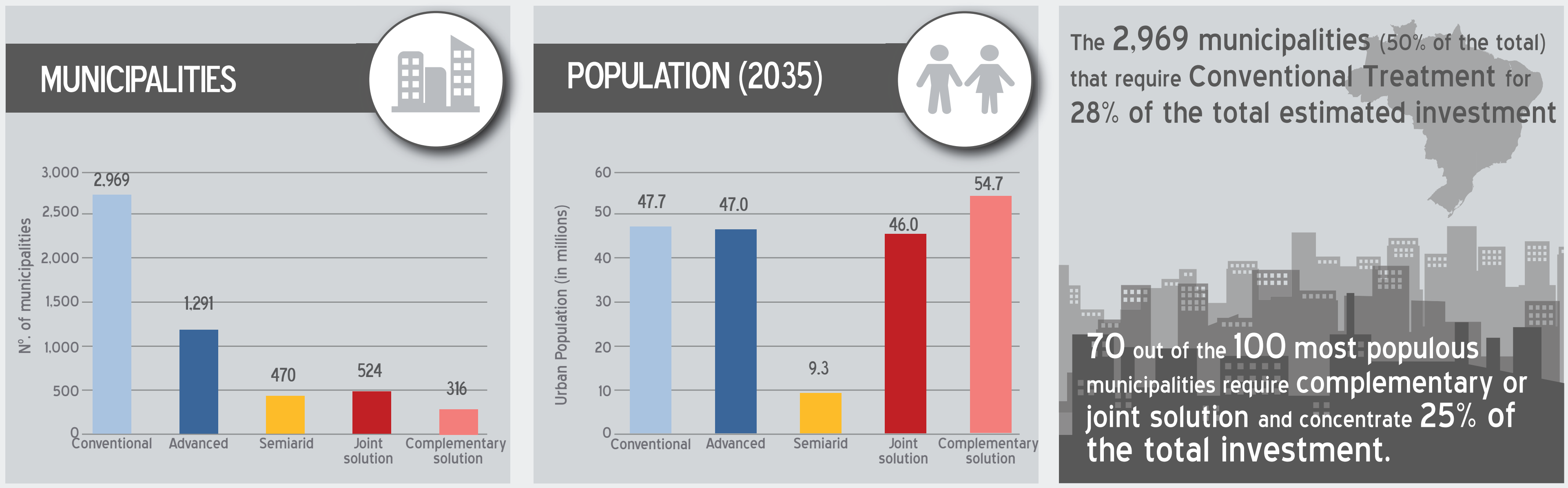
- Solution with **Conventional** Treatment: requires removal of BOD between 60% and 80%;
- Solution with **Advanced** Treatment: requires removal of BOD over 80%;
- **Complementary** Solution: this is a solution that requires complementary solution such as the identification of a new receiving body, land disposal or effluent reuse, depending on the municipality presenting an insufficient relationship between water availability and organic load discharged, without the influence of upstream discharges;
- **Joint solution:** requires a joint definition of the level of treatment of the municipalities of the basin, due to the impact of discharge(s) in municipalities upstream;
- **Solution for the semiarid region:** requires giving priority to processes with a high removal of pathogenic microorganisms or reuses of the effluent.

Even though the conventional treatment is enough for 2,969 municipalities, most of the Brazilian population is located in 840 urban centers that demand complementary or joint solutions (54.7 million and 46 million people, respectively, in 2035) to solve the sewage treatment problem. Almost 55% of the treatment investments foreseen are destined to these municipalities and are mostly concentrated in the Paraná and Eastern Northeast Atlantic hydrographic regions.

In addition to the BOD analyses the impacts of phosphorus loads in the reservoirs (eutrophication) or nitrogen in water withdrawal for public supply (nitrates), one identified that 1,519 of the urban centers need special attention regarding nutrient removal.

The investment necessary to universalize sewage treatment services in the 5,570 urban centers in Brazil was estimated at 150 billion BRL, considering the year of 2035 as a reference. The *Sewage ATLAS* serves as an important subsidy for PLANSAB because it details these in-vestments by municipality. The relationship between collection and treatment costs is greatly varied depending on the region, the highest and lowest costs are in the North (4.1x) and Southeast (1.3x) geographic regions, respectively. The collection investments for Brazil, as a whole, cost 2.7 times more than the treatment costs foreseen.

TREATMENT COMPLEXITY CONSIDERING BOD REMOVAL



The technical discussions held during the study's preparation led to the finding that only the investment necessary to implement sewage services solutions will not have the necessary effects should the investment be allocated without the institutional capacity necessary to provide the services in the municipality.

There are several examples in the country of sewage systems that were abandoned or are unfinished due to these types of problems. It was found that although most of the Brazilian municipalities (4,288) have a sewage services provider that needs to improve its institutional capacity or have no institutionalized sewage services provider, a significant part of the population foreseen for 2035 is located in municipalities where the service provider has a consolidated institutional situation (85 million inhabitants).

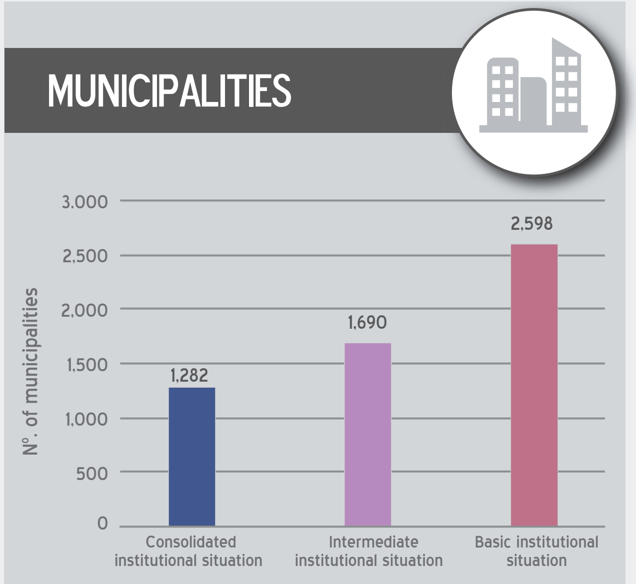
In this context, in addition to the identification of the required sewage treatment levels and associated investments, an institutional evaluation of the sewage services was carried out, so as to design a more efficient implementation strategy. The institutional situation was evaluated based of four main criterion: institutional status, operational capacity, financial capacity, and context of the municipality for adequating the sewage services (if necessary).

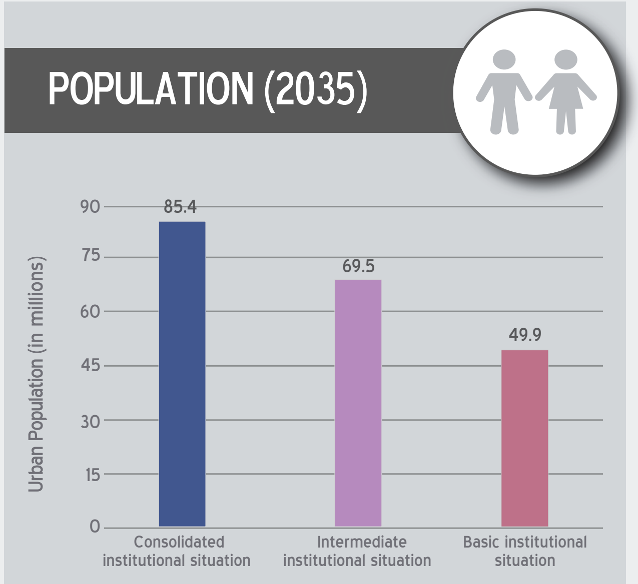
It was also identified that most organic and remaining load generated in the country stems from urban centers with consolidated institutional situation, mostly located in the Southeast geographic region. In turn, out of the 1,282 municipalities in this situation, 711 demand more complex sewage treatment solutions.

The institutional situation was analyzed in association with the sewage treatment solutions required and this analysis' results based the establishing of a strategy for implementing actions, indicating effort levels in terms of institutional and/or organic load removal for the universalization of sewage services and the mitigation of the impacts caused by this pollutant source in water resources.

For the implementation of the sewage treatment system to result in the expected benefits it is fundamental that the municipality have a structured service provided with an appropriate level of institutional development.

THE INSTITUTIONAL STATUS OF SEWAGE SERVICES PROVISION





Investment necessary for the universalization of sewage services and **required actions** divided by group of municipalities:

- **Basic institutional situation:**
  i. Structuring of the provider
  ii. Instituitional development
  iii. A 53.3 billion BRL investment in construction
- **Intermediate institutional situation:**
  i. Institutional development
  ii. A 54.2 billion BRL investment in construction
- **Consolidated institutional situation:**
  i. A 42.0 billion BRL investment in construction

2 | THE SITUATION OF SEWAGE COLLECTION AND TREATMENT

2.1 | SEWAGE LOAD GENERATED
2.2 | COVERAGE INDEXES
2.3 | TREATMENT TECHNOLOGIES
2.4 | ASSESSMENT OF THE CURRENT SITUATION
2.5 | RESULTS BY MUNICIPALITY

2.1 | SEWAGE LOAD GENERATED

Sewage generation in urban areas is directly associated with population size. In turn, most population concentrations occur in the capitals of Federal Units and their metropolitan areas, considering the availability of services, infrastructure, logistics and other elements that stimulatethe development of all kinds of activities in these regions. It is, therefore, natural that capitals and the main urban concentrations in Brazil generate more sewage.

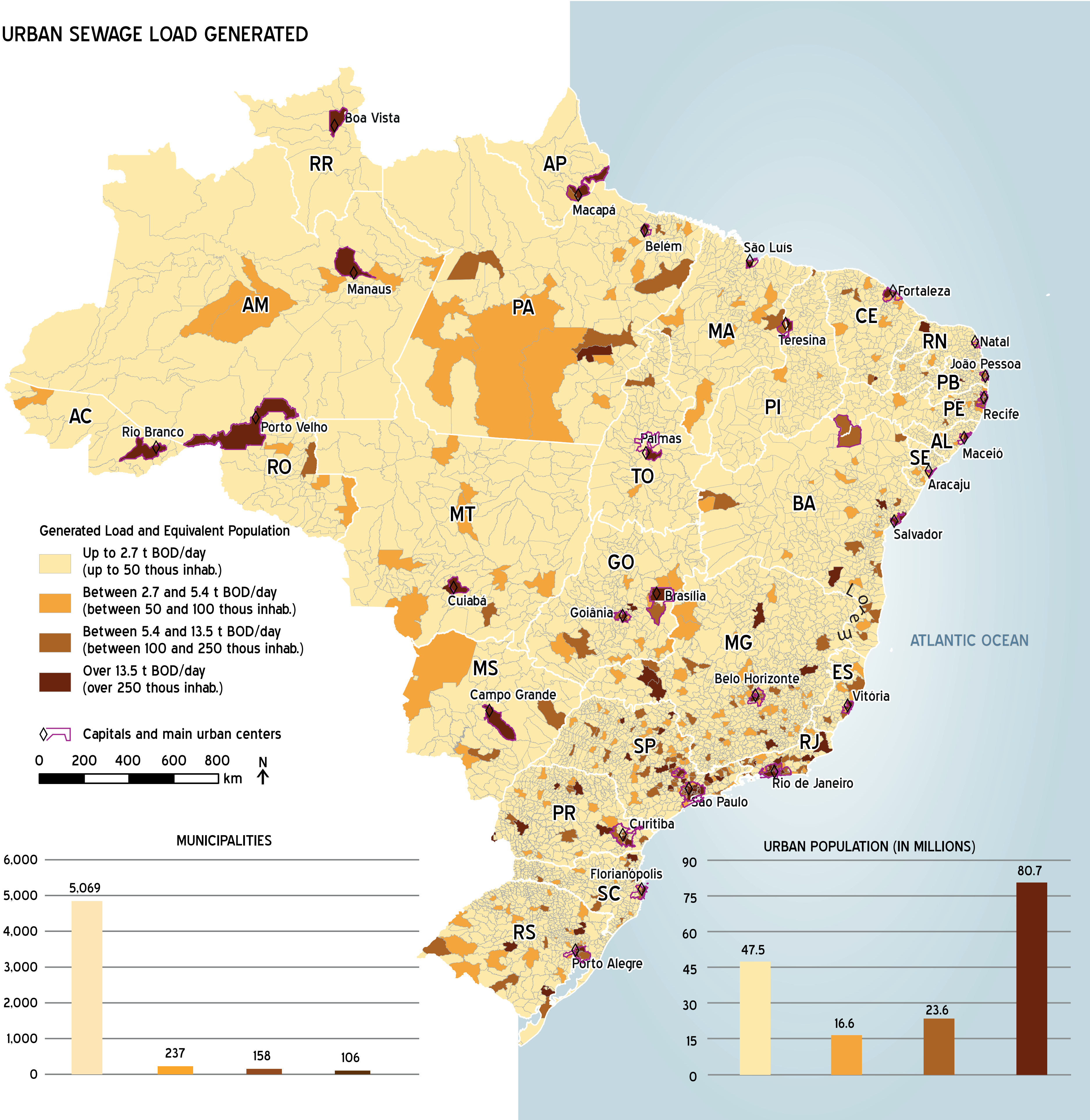
The sewage load was estimated based on the Biochemical Oxygen Demand - BOD, a parameter that characterizes the organic loads of sewage effluents usually employed in the evaluation of impact on the receiving bodies and in the dimensioning of treatment processes.

In this estimate one considers the "per capta" value of 54 g BOD/inhab.day and urban population data obtained from the IBGE projection or directly provided by sewage services providers for each municipality.

About 9.1 thousand tons BOD/day are generated in Brazil, and the 106 municipallities with a population over 250 thousand inhabitants are responsible for 48% of this total.

Eastern Northeast Hydrographic Region
Photo by Zig Koch Cavalvanti / ANA Image Bank

URBAN SEWAGE LOAD GENERATED



2.2 | COVERAGE INDEXES

The coverage indexes in terms of sewage collection and treatment in urban areas are still unsatisfactory, in spite of the latest investments, and these indexes reflect historical problems.

Sewage collection networks reach 61.4% of the Brazilian urban population, with 65.1 million people in Brazilian cities which do not have a collection system for sewage and its treatment. Not all sewage collected is directed to a treatment plant. The parcel of the population supplied with sewage treatment and collection services represents 42.6% of the total urban population. Therefore, it is concluded that 96.7 million people do not have access to sewage collection and treatment.

The uncollected sewage has different destinations, such as routing to septic tanks, discharge into rainwater networks or gutters, direct discharge to the soil or in water bodies. The septic tanks reduce these effluents impact on the water bodies, provided that this solution is properly performed in conditions that are conducive to its application.

Among the Brazilian geographic regions, the southeast region presents the best sewage collection and treatment rates and is the only region where sewage treatment reaches more than half of its urban population. The southern, northeast and midwestern regions have similar collection rates, covering approximately half of their urban population, with higher treatment levels in the midwestern region. The northern region lacks collective sewage services the most.

Even though 14 FUs are partially provided with sewage treatment in relation to the sewage collected, over 75%, these rates are not a good indicator since a large part of these FUs still have low collection rates.

The coverage rates were established from the information obtained from sewage service providers in the cities and supplemented with secondary data available. In addition to these indexes,traditionally used by the sanitation sector, it is also important to identify treatment efficiency levels in the country and to quantify remaining sewage loads with the potential of reaching water bodies.

SEWAGE COVERAGE RATES IN BRAZIL

SEWAGE COVERAGE RATES IN BRAZIL BY STATE AND GEOGRAPHIC REGION						
GEOGRAPHIC REGION	FEDERAL UNIT	NUMBER OF MUNICIPALITIES	URBAN POPULATION (in 1,000 inhab)	PART OF POPULATION ATTENDED		PART TREATED IN RELATTION TO COLLECTED
				Sewage collected	Sewage treated	
NORTH	Acre	22	562.8	35%	33%	94%
	Amapá	16	658.8	7%	7%	92%
	Amazonas	62	3,014.2	22%	19%	84%
	Pará	144	5,611.0	9%	4%	45%
	Rondônia	52	1,277.3	9%	4%	41%
	Roraima	15	374.1	19%	15%	79%
	Tocantins	139	1,169.2	30%	29%	96%
	TOTAL	**450**	**12,667.4**	**16%**	**12%**	**75%**
NORTHEAST	Alagoas	102	2,426.3	26%	17%	64%
	Bahia	417	10,865.0	63%	51%	81%
	Ceará	184	6,569.3	44%	40%	91%
	Maranhão	217	4,283.4	17%	4%	23%
	Paraíba	223	2,956.4	59%	43%	72%
	Pernambuco	185	7,383.6	45%	27%	61%
	Piauí	224	2,096.9	12%	10%	81%
	Rio Grande do Norte	167	2,619.7	31%	25%	80%
	Sergipe	75	1,616.8	32%	22%	67%
	TOTAL	**1,794**	**40,817.4**	**43%**	**32%**	**74%**
SOUTHEAST	Espírito Santo	78	3,136.5	61%	41%	68%
	Minas Gerais	853	17,705.0	86%	44%	51%
	Rio de Janeiro	92	15,922.1	73%	42%	58%
	São Paulo	645	40,521.4	87%	64%	74%
	TOTAL	**1,668**	**77,285.0**	**83%**	**54%**	**65%**
SOUTH	Paraná	399	9,397.5	65%	64%	98%
	Rio Grande do Sul	497	9,477.2	54%	26%	48%
	Santa Catarina	295	5,557.4	33%	24%	74%
	TOTAL	**1.191**	**24,432.1**	**54%**	**40%**	**75%**
CENTRO OESTE	Distrito Federal	1	2,694.3	83%	83%	100%
	Goiás	246	5,801.9	50%	48%	95%
	Mato Grosso	141	2,617.2	25%	22%	91%
	Mato Grosso do Sul	79	2,170.4	43%	42%	98%
	TOTAL	**467**	**13,283.8**	**51%**	**49%**	**97%**
BRAZIL		5,570	168,485.7	61%	43%	70%

2.3 | TREATMENT TECHNOLOGIES

Overall, the urban sewage treatment aims to reduce organic matter, pathogenic microorganisms, suspended solids and, in special cases, nutrients present in sanitary sewage, assuming the absence of toxic industrial waste.

The selection of sewage treatment processes is related to the characteristics of the receiving body and the current legislation. The regulations require broad quality standards, so that effluents can be discharged without causing risks to the health of the population or significant damage to the environment. However, the choice of a treatment process by a Sewage Treatment Plant - STP is not solely focused on environmental, public health and/or legal requirements. Economic, social and operational aspects are also considered in addition to area availability and the community's demands.

A wide variety of treatment processes are currently in place in Brazil. To give an overview of the types of sewage treatment, the processes were grouped by efficiency rates of organic load removal (in terms of BOD), as follows: less than 60%, between 60% and 80%, higher than 80% and higher than 80% with the possibility of removing nutrients (phosphorus and/or nitrogen). It should be noted that CONAMA Resolution No. 430/2011 recommends a minimum removal efficiency of 60% BOD. Its removal also implies in the removal of much of the other pollutants present in urban sewage.

Throughout the study 2,768 operational Sewage Treatment Plants were identified in 1,592 cities, with an estimated population of 71.7 million inhabitants. Information on load removal efficiency was obtained for 96% of those STPs. In this group, that information was very different from the efficiency indicated in the literature. Most of the country's STPs have average efficiency rates between 60 and 80%. This range includes several processes that are capable of meeting the current standards, provided that the receiving body has enough dilution capacity. A small parcel of the treatment units existent in the country use simplified treatment processes, with the risk of generating effluents that do not meet the standards provided for in the legislation.

970 STPs operate with more elaborated processes able to reach BOD removal efficency over 80%. These processes are usually employed in more densely populated areas that provide the greater portion of the urban population with sewage services (just over 42 million people). 131 units were projected to remove nutrients within this group.

Sewage treatment plant - ETE / Jaguariuna, SP
Photo Tomás May/ANA Image Bank

BOD REMOVAL CATEGORIES FOR THE MAIN TREATMENT PROCESSES IN BRAZIL					
BOD REMOVAL CATEGORIES	MAIN TREATMENT PROCESSES IN BRAZIL	ACRONYM	EQUIVALENT POPULATION (in thous. Inhab)	AVERAGE EFFICIENCY (%)	NUMBER OF UNITS
Up to 60%	PRIMARY	Pr	7,947.6	35%	21
	FILTER/SEPTIC TANK + AEROBIC FILTER/IMHOFF TANK + BIOLOGICAL FILTER	FosFil/FosSép+FilAer/TqImh+FilB	340.1	49%	215
	SEPTIC TANK/IMHOFF TANK	FosSép/TqImh	49.2	51%	23
	TOTAL				**259**
60% to 80%	FILTER TANK/ (SEPTIC TANK + BIOLOGICAL FILTER) + GROUND LAYOUT/SINKHOLE	FosFil/(FosSép+FilB)+DispS/Sum	6.4	66%	10
	ANAEROBIC REACTOR + ACTIVATED SLUDGE	RtrAn+LodAt	26.3	80%	2
	AEROBIC LAGOON	LagAn	812.8	68%	68
	PRIMARY WITH PHYSICAL CHEMICAL(AEROBIC FILTER/DECANTATION/CEPT/FLOTATION)	PrFisQ(FilAer/Dec/Cept/Flt)	1,902.5	68%	13
	ANAEROBIC REACTOR	RtrAn	3,876.5	69%	328
	ANAEROBIC REACTOR + DECANTER	RtrAn+Dec	226.7	72%	16
	ACTIVATED SLUDGE FIXED MEDIUM (BIOLOGICAL FILTER)	LodAtMF(FilB)	323.1	73%	22
	ANAEROBIC REACTOR + BIOLOGICAL FILTER	RtrAn+FilB	1,300.0	75%	177
	OPTIONAL LAGOON	LagFac	1,421.0	76%	203
	ANAEROBIC LAGOON + OPTIONAL LAGOON	LagAn+LagFac	5,533.8	77%	364
	ANAEROBIC REACTOR + GROUND LAYOUT	RtrAn+DispS	183.3	77%	16
	ANAEROBIC REACTOR + AEROBIC FILTER	RtrAn+FilAer	635.8	77%	64
	ANAEROBIC REACTOR + ANAEROBIC/OPTIONAL/MATURATION LAGOON	RtrAn+LagAn/Fac/Mat	3,023.5	78%	145
	TOTAL				**1.428**
> 80%	AERATED LAGOON	LagArd	743.6	80%	42
	ANAEROBIC REACTOR + AEROBIC FILTER + DECANTER	RtrAn+FilAer+Dec	4,436.9	80%	121
	ANAEROBIC REACTOR + BIOLOGICAL FILTER + SOIL DISCHARGE	RtrAn+FilB+DispS	70.6	80%	15
	ANAEROBIC REACTOR + BIOLOGIC FILTER + DECANTER	RtrAn+FilB+FilAer+Dec	76.5	80%	10
	EXTENDED AERATION ACTIVATED SLUDGE	LodAtAerPln	4,479.0	88%	91
	ANAEROBIC LAGOON + OPTIONAL LAGOON + MATURATION LAGOON	LagAn+LagFac+LagMat	1,930.4	81%	134
	OPTIONAL LAGOON + MATURATION LAGOON	LagFac+LagMat	1,212.5	81%	119
	AERATED LAGOON + DECANTING/OPTIONAL/MATURATION LAGOON	LagArd+LagDec/Fac/Mat	2,349.0	82%	64
	ANAEROBIC REACTOR + AERATED LAGOON	RtrAn+LagArd	611.2	83%	12
	ACTIVATED SLUDGE (CONVENTIONAL/DEEP SHAFT)	LodAt(cnv/DpS)	16,538.9	84%	110
	ANAEROBIC REACTOR + AERATED LAGOON + OPTIONAL/MATURATION LAGOON	RtrAn+LagArd+LagFac/Mat	322.9	85%	7
	ANAEROBIC REACTOR + ACTIVATED SLUDGE	RtrAn+LodAt	3,964.8	86%	90
	AERATED LAGOON + OPTIONAL LAGOON + MATURATION LAGOON	LagArd+LagFac+LagMat	658.2	87%	14
	ANAEROBIC REACTOR + EXTENDED AERATION ACTIVATED SLUDGE	RtrAn+LodAtAerPln	53.4	88%	4
	ANAEROBIC REACTOR + OPTIONAL LAGOON + SOIL DISCHARGE	RtrAn+LagFac+DispS	226.7	89%	6
	TOTAL				**839**
> 80% (with remo-val of nutri-ents)	ANAEROBIC REACTOR + BIOLOGIC FILTER + DECANTER	RtrAn+FilB+FilAer+Dec	0.6	87%	1
	BATCH ACTIVATED SLUDGE (CONVENTIONAL/UNITANK) - REM. N	LodAtBat(cnv/utk)-RemN	1,431.8	88%	80
	ACTIVATED SLUDGE - REM. N (MBBR/IFAS)	LodAt-RemN(MBBR/IFAS)	365.5	88%	7
	ANAEROBIC REACTOR + PHYSICAL CHEMICAL (DECANTATION/FLOTATION) - REM. P	RtrAn+FisQ(Dec/Flt)-RemP	2,401.4	88%	33
	ACTIVATED SLUDGE WITH CHEMICAL PHYSICAL REMOVAL OF NUTRIENTS - REM. N & P	LodAtRemFisQNut-RemNP	95.3	91%	5
	ACTIVATED SLUDGE WITH BIOLOGICAL REMOVAL OF NUTRIENTS - REM. N	LodAtRemBNut-RemN	153.5	93%	3
	ACTIVATED SLUDGE WITH BIOLOGICAL REMOVAL OF NUTRIENTS - REM. N & P	LodAtRemBNut-RemNP	46.6	95%	2
	TOTAL				**131**

As a general rule, Sewage Treatment Plants (STPs) have preliminary treatment as a first stage (bar screen and grit chamber). This first stage promotes the removal of bigger solid particles and rapid sedimentation materials. In the preparation of a project for a plant treatment technologies compatible with the required solution must be evaluated, which may result in the selection of one or more treatment processes.

The most common processes in Brazil are: anaerobic lagoon followed by optional lagoon, known as the Australian system, adding up to 364 STPs; only the anaerobic reactor, 328 units; a septic tank associated with an anaerobic filter, 215; only the optional lagoon, 203; and an anaerobic reactor followed by a biologic filter, with 177 identified units. The Australian system is more representative of the Southeast geographic region, while anaerobic reactors are predominant in the northeast, southern and midwestern regions.

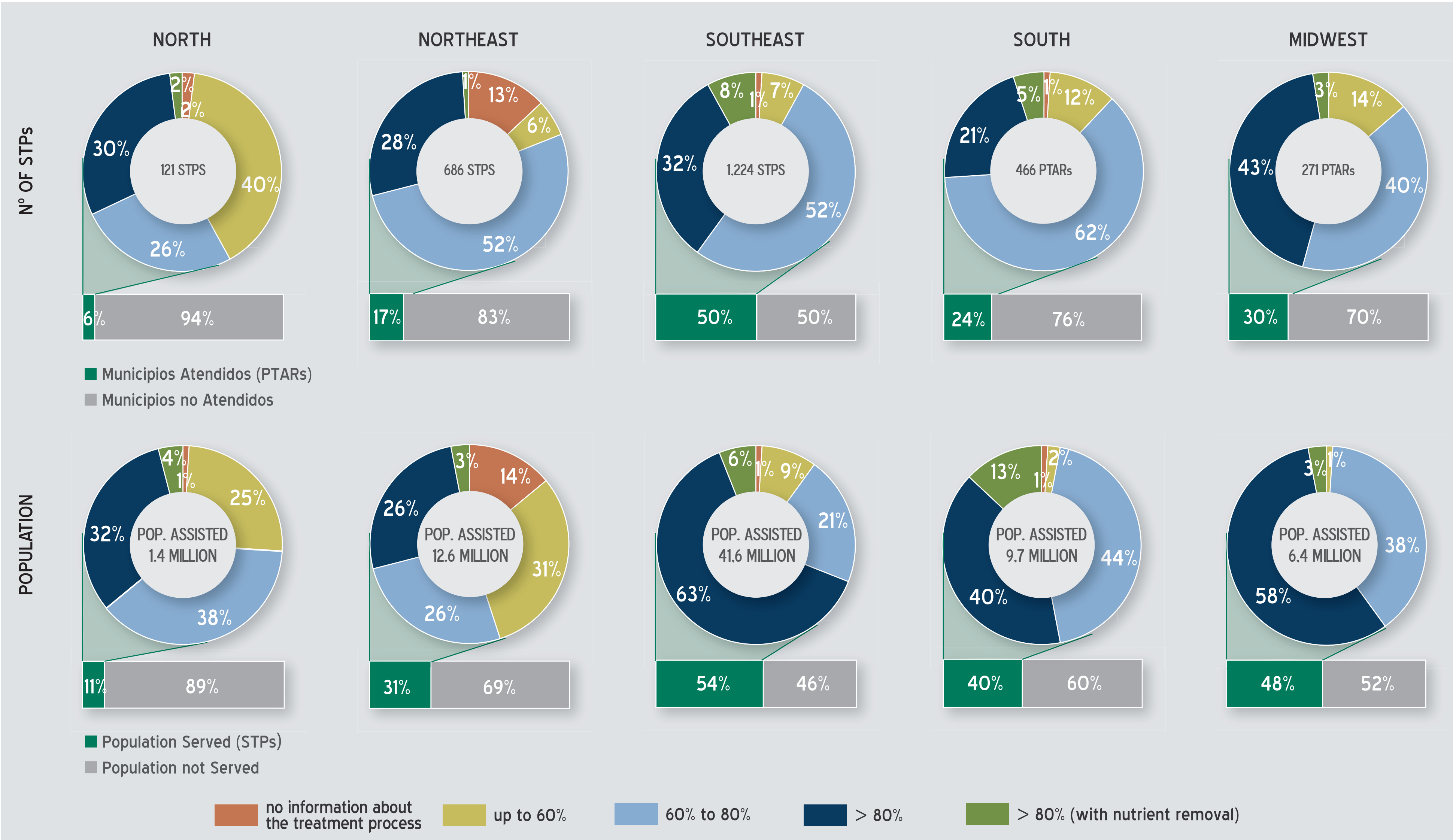
The lagoon treatment requires simple and low-cost operation but needs large areas available for its implementation. The Australian system requires a smaller area than the implementing of the optional lagoon alone, which explains the larger number of units adopting this arrangement. Anaerobic reactors require smaller areas for implementation and its operation is also relatively simple. Favourable environmental conditions and the development of local research boosted the use of this process in the country, which began in the 1980s.

As for the population served, the most used processes are:

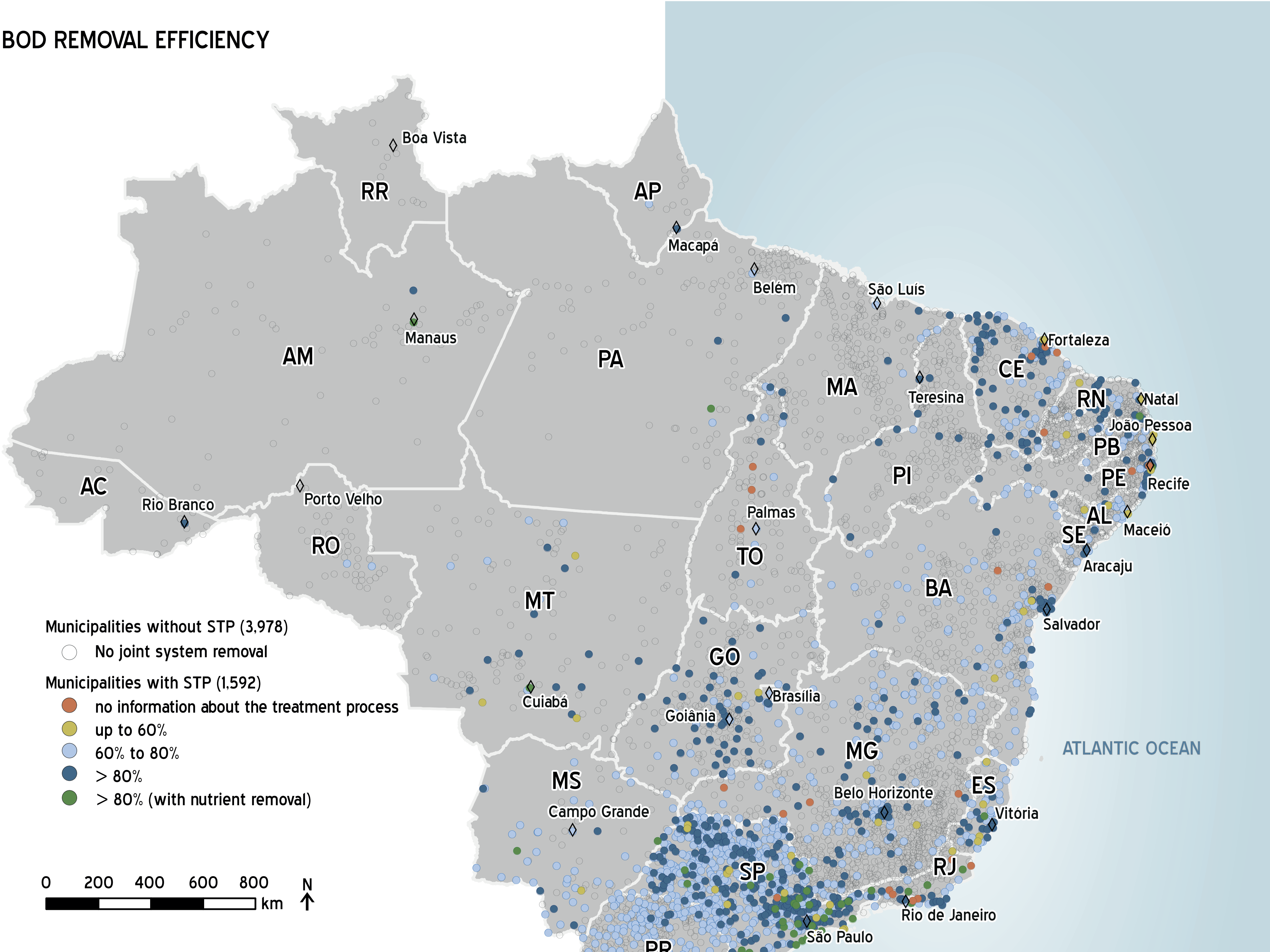
- Conventional activated sludge, despite the identification of few units in the country (110), they cover 24% of the population served by STPs (around 16.5 million people), mainly in the Southeast and Midwest regions;
- Primary level treatment, used in treatment plants covering 11% of the population served by STPs, that is, 7.9 million people. This process is, in most units, associated with a submarine emissary;
- Anaerobic lagoon treatment followed by optional lagoon, reaching about 5.5 million people (8% of the total population supplied by STPs); and
- Anaerobic reactor followed by aerobic filter and decanter, and extended aeration activated sludge. The latter cover 4.4 million people each representing, together, 13% of the population with access to sewage treatment.

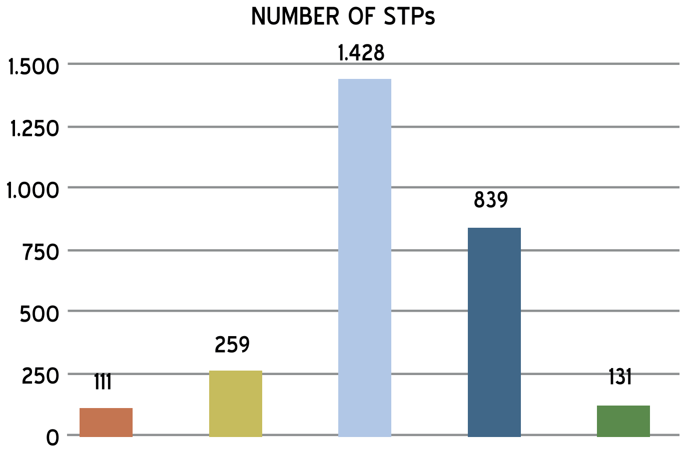
The conventional activated sludge process is highly efficient in the promotion of BOD and demands a smaller implementing area. However, it requires a more sophisticated operation and higher energy consumption.

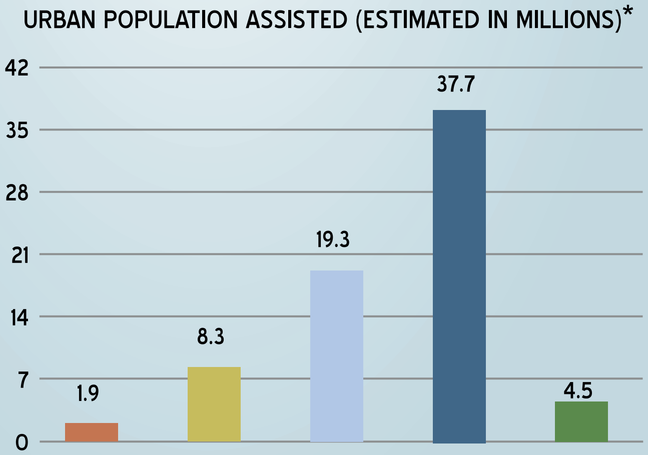
BOD REMOVAL EFFICIENCIES BY GEOGRAPHIC REGION



BOD REMOVAL EFFICIENCY







*Estimated population based on the collection and treatment rates for the municipalities and the size of the STPs..

MOST COMMONLY USED TREATMENT PROCESSES

Treatment processes can be divided into physical, biological and chemical. Physical processes are those that remove larger solids, sediments and floating materials (oils, greases, etc.) through physical grit chamber, such as bar screen, sieving, grit chamber, sedimentation and flotation. They are generally used as preliminary treatment and/or part of other processes.

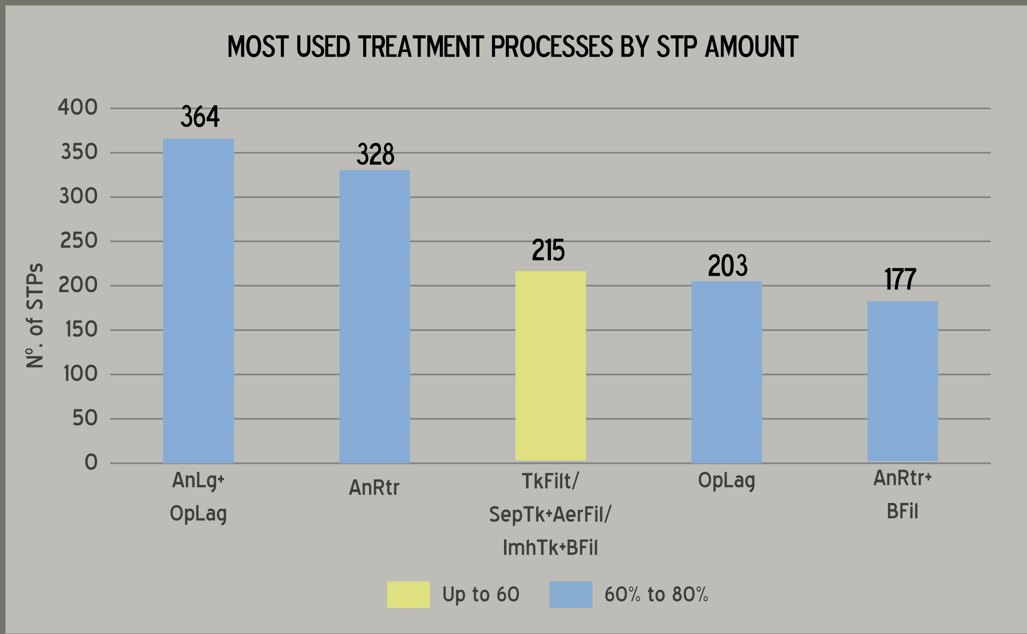
Biological processes use microbial activity to achieve good wastewater purification levels. They are widely used in sewage treatment for the removal of organic matter and nutrients and are derived from aerobic and anaerobic processes that occur in nature. The main biological processes for sewage treatment are:

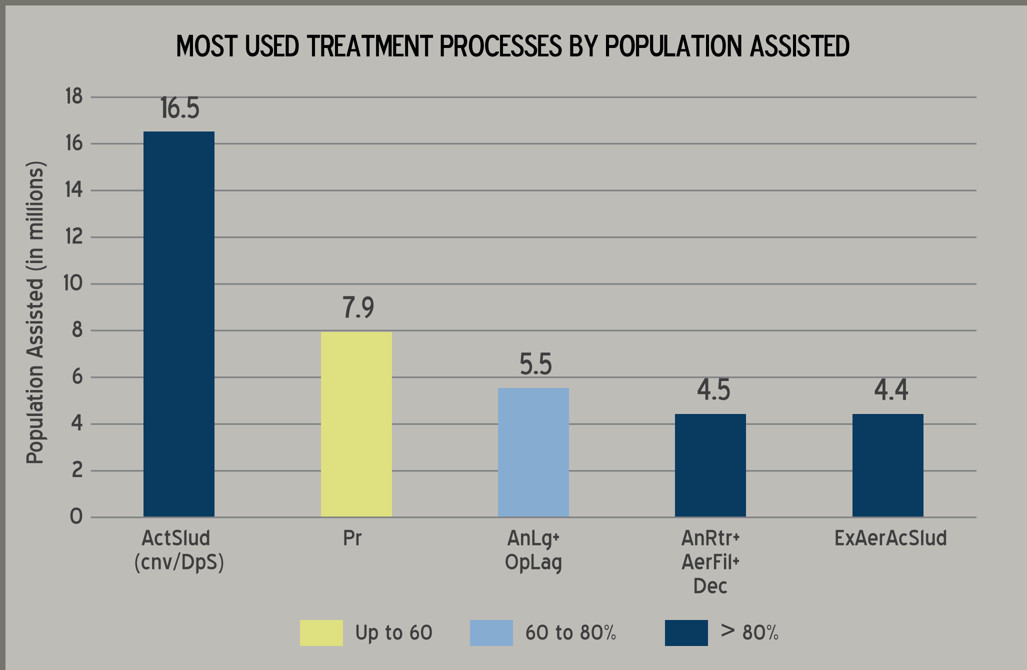
- Stabilization Lagoons: optional lagoons, optional aerated lagoons, anaerobic lagoons, high rate lagoons, maturation lagoons. They can remove organic matter and pathogenic microorganisms with satisfactory efficiency, but their effluents can also present high concentrations of undesirable algae. Additional care must be taken so that they do not become mosquito breeding grounds for mosquitos.
- Activated sludge systems and variants: conventional activated sludge, batch sequence reactors, aerated lagoons with complete mixture, oxidation ditches. These systems are more common in large cities because they are more compact and produce good quality effluents. They are more complex to design, build and operate and the oxygenation necessary for degradation of organic matter occurs by artificial aeration, which consumes much energy. They can be designed for biological removal of both phosphorus and nitrogen.
- Anaerobic systems: septic tanks, Imhoff tanks, anaerobic filters, UASB reactors, and expanded or fluid anaerobic reactors. In general, they need an additional treatment step to reduce the load of solids and improve the oxygenation of their effluents. They have been widely used as pre-treatment units for lagoons, biological filters, and activated sludge because they reduce much of the organic load without the need for aeration, resulting in an economy of electric power.
- Fixed-bed aerobic systems: bio-filters, bio-disks, aerated bio-filters. Conceptually simpler than activated sludge, they are usually used as post-treatment for anaerobic systems. These systems present high BOD removal rates and the possibility of nitrogen removal. However, they have high implementing costs.

Aerobic biological processes are more effective in removing BOD than anaerobic processes, which can scarcely treat effluents alone in order to meet the Brazilian environmental legislation standards. Thus, anaerobic processes present as a disadvantage the need for an additional step in order to purify the generated effluent. On the other hand, anaerobic processes generate less sludge and present lower investment and operational costs.

The chemical treatment consists in adding chemicals, such as aluminium sulfate, to remove colloidal particles. The chemical treatments are associated with biological and physical processes for greater efficiency, and may result in a significant increase in operational costs. Final purification may be an interesting alternative should high quality effluent production be necessary.

Natural soil discharge processes, such as soil infiltration, runoff and built wetlands, are still incipient in the country, but offer important qualities to be considered. When properly designed and operated, it is possible to obtain good quality effluents without high concentration of algae, and these processes have the possibility of removing nutrients. This option may require a large implantation area and attention must be paid to the limitations of the soil and water table and the risk of insect proliferation.





2.4 | ASSESSMENT OF THE CURRENT SITUATION

The overview of Brazil's urban sewage treatment services may be divided into the following groups: 43% have collected and treated sewage and 12% use individual solutions, that is, 55% of the Brazilian urban population may be considered as supplied with appropriate services considering the PLANSAB concepts; 18% have their sewage collected but not treated, which may be considered as precarious services; and 27% do not have access to collection or treatment, that is, they receive no sewage service at all.

The total sewage load generated in the Brazilian cities that reaches the water bodies is called the remaining load. In order to estimate the remaining load the loads balance was used, which consists on the division of the generated sewage considering its different forwarding options, such as: collection (with or without treatment), individual solution (septic tanks) and open air discharge or precarious solution (no collection and discharge into a pit latrine).

Out of the 9.1 BOD tons generated by the country's urban sewage on a daily basis 5.6 thousand tons are collected and do not flow in the open air (61%) Part of the collected amount (1.7 thousand t BOD/day) is not submitted to any kind of treatment, while about 3.9 thousand tons are forwarded for collective treatment, where part of the organic load (BOD) is removed in the STPs with different efficiency levels.

With regard to the part that is not collected (2.5 thousand t BOD/day), about 1.1 thousand tons are forwarded to septic tanks and the remaining 2.4 thousand tons are discharged to the open air or forwarded to precarious sewage solutions (including the organic load from rudimentar cesspits or pit latrine).

Urban area stream
Shutterstock Image Bank

LOAD BALANCE METHODOLOGY

The distribution of the parcels considered in the load balance was based on the concepts set out in the National Basic Plan - PLANSAB, which groups the municipalities into three service groups: (i) appropriate services and (iii) no services.

The PLANSAB classifies as "appropriate treatment "that furnished by septic tank (it is assumed that the "septic tank "appropriate treatment" is that carried out in the post-treatment or final discharge unit, properly designed and constructed') or by a sewage collection network followed by treatment. The situations considered as "precarious service" means that the service is offered in an unsatisfactory manner, potentially compromising human health and the quality of the environment. Finally, the parcel that does not fit into any of these categories is considered as "no service" (collection or treatment).

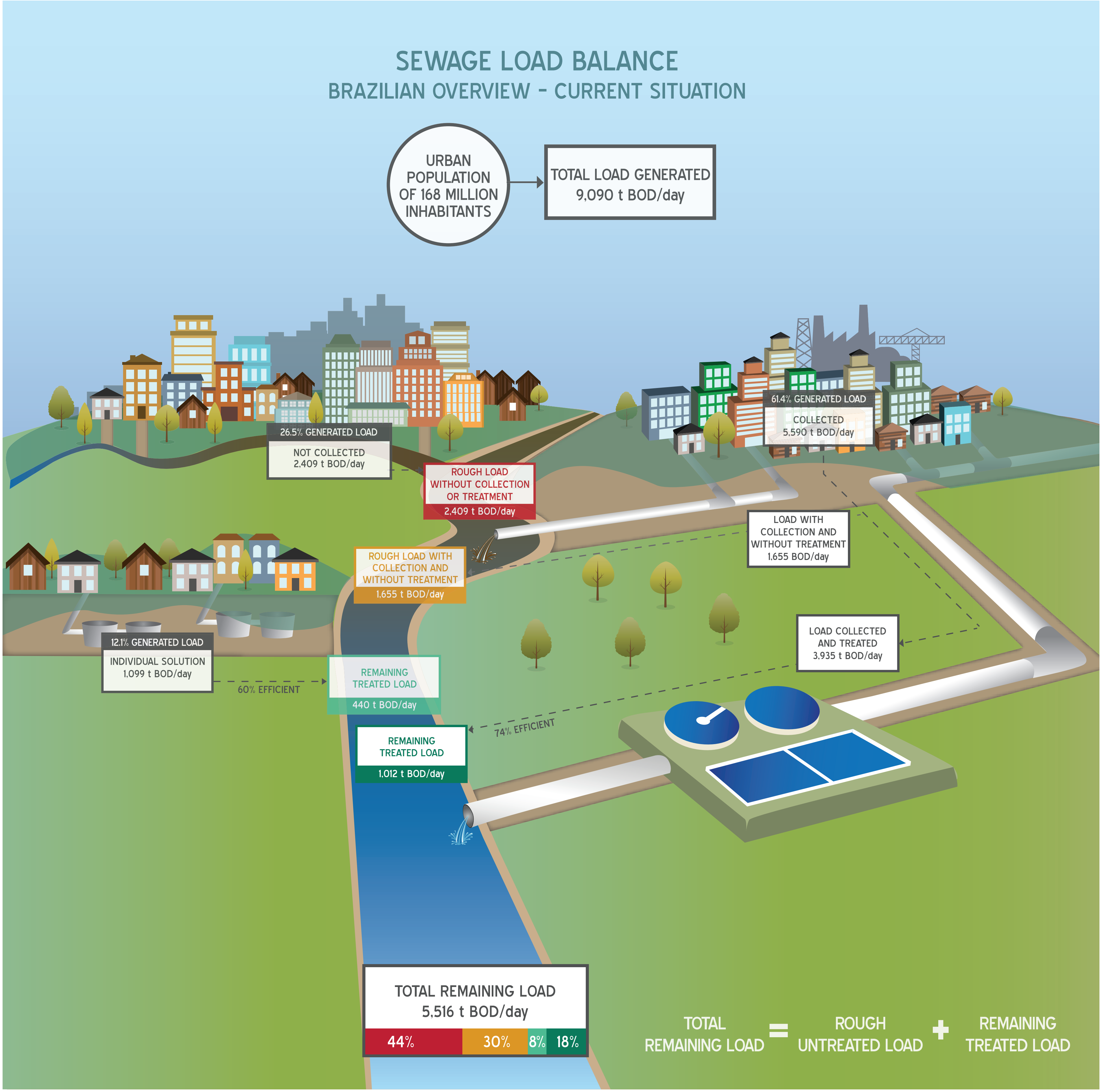
The estimation of each organic load parcel associated to sewage (expressed in the form of BOD) was the object of the methodology that used urban population data, sewage coverage, removal efficiency of treatment processes employed and population supplied by an individual solution (septic tanks). This methodology was applied for the urban centers of the 5,570 Brazilian municipalities, always using the best information available for each sewage system, prioritizing primary data (directly obtained from
the municipal sewage service providers).

BOD rebates were considered for portions of the organic loads of sewage with collection and treatment and those sent to septic tanks, recognized in PLANSAB as "adequate care." For theremaining parcels no reductions were applied, considering the methodological difficulty of any reliable estimate for the reduction to be applied to the organic loads of sewage destined for rudimentary cesspools, discharge on the ground or rainwater discharges before effectively reaching the water bodies.

In order to calculate the reduction and the respective remaining load, for the estimate of the BOD stemming from collected and treated sewage, the STPs efficiency was used and considered for each municipality where the urban population is supplied with this service. For the population supplied by an individual solution (septic tanks with appropriate operation) a 60% organic load removal was considered.

TOTAL LOAD GENERATED	DISTRIBUTION OF THE LOAD GENERATED		REMAINING LOAD*	
9,098 t BOD/day	WITH COLLECTION 5,590 BOD/day (61%)	WITH COLLECTION AND TREATMENT 3,935 t BOD/day (43%)	1,012 t BOD/day (18%)	5,516 t BOD/day
		WITH COLLECTION AND WITHOUT TREATMENT 1,655 t BOD/day (18%)	1,655 t BOD/day (30%)	
	WITHOUT COLLECTION 3,508 BOD/day (39%)	INDIVIDUAL SOLUTION 1,099 t BOD/day (12%)	440 t BOD/day (8%)	
		WITHOUT COLLECTION OR TREATMENT 2,409 t BOD/day (27%)	2.409 t BOD/day (44%)	

* La carga remaneciente consideró la disminución de las parcelas removidas en el tratamiento y en las soluciones individuales.


SEWAGE LOAD BALANCE
BRAZILIAN OVERVIEW - CURRENT SITUATION
URBAN POPULATION OF 168 MILLION INHABITANTS
TOTAL LOAD GENERATED 9,090 t BOD/day
26.5% GENERATED LOAD
NOT COLLECTED 2,409 t BOD/day
ROUGH LOAD WITHOUT COLLECTION OR TREATMENT
2,409 t BOD/day
61.4% GENERATED LOAD
COLLECTED 5,590 t BOD/day
LOAD WITH COLLECTION AND WITHOUT TREATMENT 1,655 BOD/day
ROUGH LOAD WITH COLLECTION AND WITHOUT TREATMENT
1,655 t BOD/day
12.1% GENERATED LOAD
INDIVIDUAL SOLUTION 1,099 t BOD/day
60% EFFICIENT
REMAINING TREATED LOAD
440 t BOD/day
LOAD COLLECTED AND TREATED 3,935 t BOD/day
74% EFFICIENT
REMAINING TREATED LOAD
1,012 t BOD/day
TOTAL REMAINING LOAD
5,516 t BOD/day
44% 30% 8% 18%
TOTAL REMAINING LOAD = ROUGH UNTREATED LOAD + REMAINING TREATED LOAD

When evaluating the remaining loads, discounting the parts removed in collective treatment and in individual solutions, we may infer an association with urban concentration, as well as observe the impact of the existing sewage treatment infrastructure in the reduction of sewage load with a potential of reaching receiving bodies.

Taking into account the sum of the remaining sewage loads across the country, with the calculations based on the existing collection and treatment infrastructure, and its respective efficiency level, it is estimated that over 5.5 thousand tons of BOD/day may reach water bodies.

Due to the population and sanitation infrastructure variations between the Brazilian geographic regions, great differences are observed in the amount of the loads generated and in the distribution of sewage treatment all of which is reflected in the remaining load total.

The southeastern region accounts for about 45% of the organic load generated (4.2 thousand t BOD/day). However, if on the one hand it concentrates the largest amount of load generated, on the other hand it has the largest amount of load collected and treated in STPs, and these services reach over half of its inhabitants. It is worth noting that, in spite of this, the southeastern region has a significant portion of sewage collected with no treatment (29%) or with neither collection nor treatment (13%).

On the opposite side, the North Region is responsible for the smallest amount of generated load (684 t BOD/day) but it also has the lowest percentage of load submitted to treatment processes (collective or individual). This means that about 67% of the total load generated in the region receives no treatment whatsoever. The organic load portion that does not receive any treatment at all is also significant. In the Northeast parcel discharged without any treatment is significant, more than 50%.

The amount of organic loads forwarded to septic tanks in the South Region is also noteworthy treated (only 2% of the load generated in the region is estimated as collected but not treated). It should be noted, however, that the two regions also have significant service deficits, with 35% and 37% of the sewage not receiving any treatment in the southern and midwestern regions, respectively.

In the southeastern region, the most populous, a remaining load of one thousand tons BOD/day is estimated for the 2,3 thousand tons of BOD/day despite presenting better sewage collection and treatment coverage if compared to the other regions.

This number represents a significant load of just over half of the total load generated in its cities and over 40% of the total remaining load in the country.

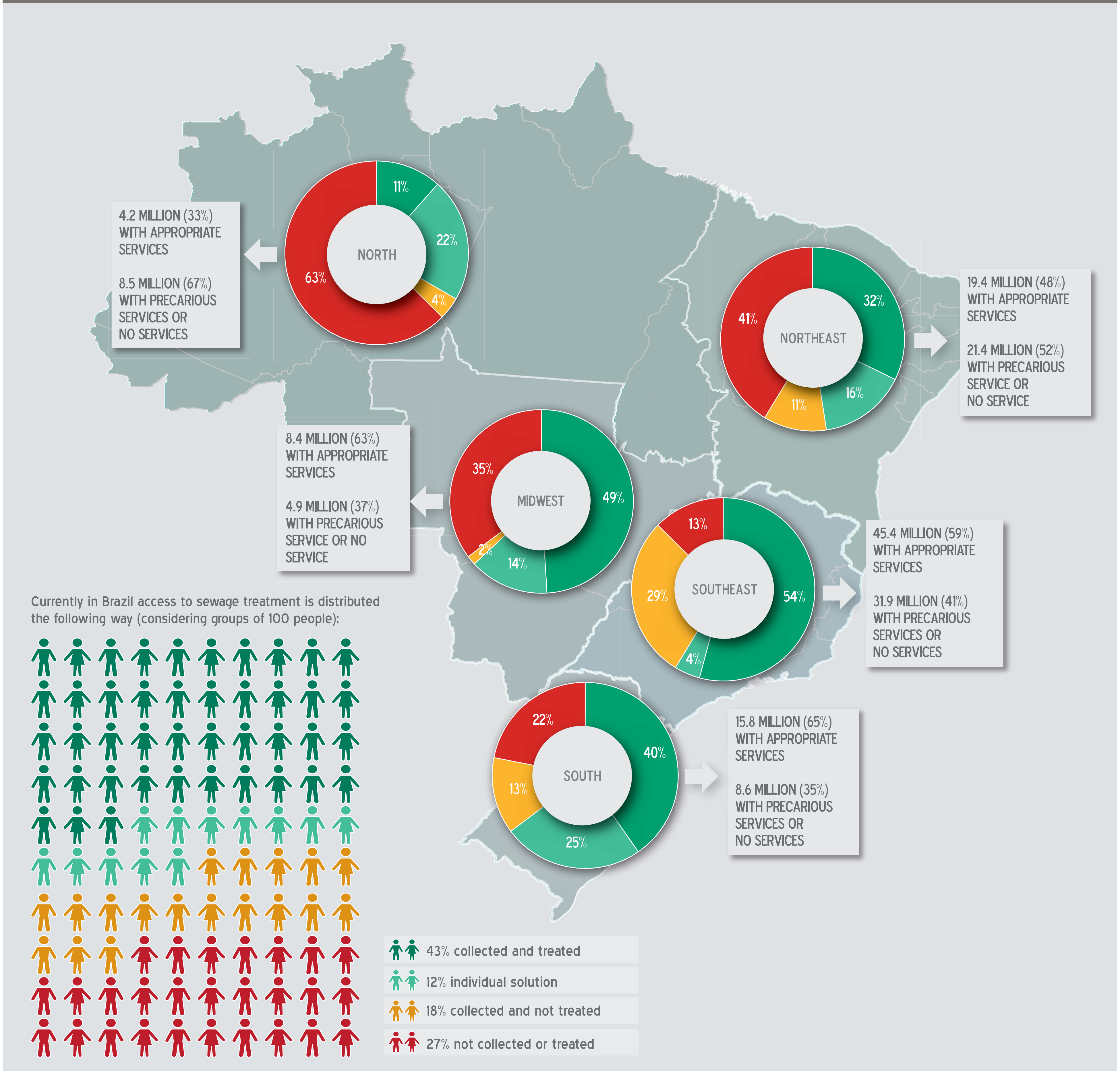
In turn, the northern and northeastern regions indicate remaining load values that are closer to its generated loads (79% and 73% respectively) due to the low rates of appropriate sanitary services for its populations.

DISTRIBUTION OF THE ORGANIC LOAD GENERATED IN BRAZIL BY GEOGRAPHIC REGION

GEOGRAPHIC REGION	TOTAL LOAD (t BOD/day)	DISTRIBUTION OF THE LOAD GENERATED (t BOD/day)				REMAINING LOAD* (t BOD/day)
		COLLECTED AND TREATED	INDIVIDUAL SOLUTION	COLLECTED AND UNTREATED	NOT COLLECTED AND NOT TREATED	
NORTH	684	79	149	27	429	541
NORTHEAST	2,204	711	338	245	910	1,602
SOUTHEAST	4,174	2,261	189	1,195	528	2,290
SOUTH	1,319	532	322	176	289	707
MIDWEST	717	352	101	12	253	376
BRAZIL	9,098	3,935	1,099	1,655	2,409	5,516

* The remaining load considered the reduction of the parcels removed in the treatment and in the individual solutions.

SEWAGE COLLECTION AND TREATMENT OVERVIEW



The 100 most populous cities in Brazil are responsible for about 2.2 thousand BOD/day of the country's remaining load (about 40% of the total), considering that half this load comes from 15 cities with urban populations over 1 million inhabitants each. For comparison purposes, about 5 thousand municipalities with urban populations inferior to 50 thousand inhabitants, represent 90% of the Brazilian cities, are responsible for a remaining load of about 1.9 BOD/day.

The vast majority of Brazilian cities (about 3.9 thousand cities) have organic load removal levels below 30%, out of which over 3.7 thousand have no collective sewage treatment system. At the other end, only 118 cities are currently able to remove over 80% of BOD.

In all the geographic regions there is also a predominance of cities with low levels of organic load removal. The southeastern region is an exception in terms of cities with organic load removal of over 60%: over 500 urban centers.

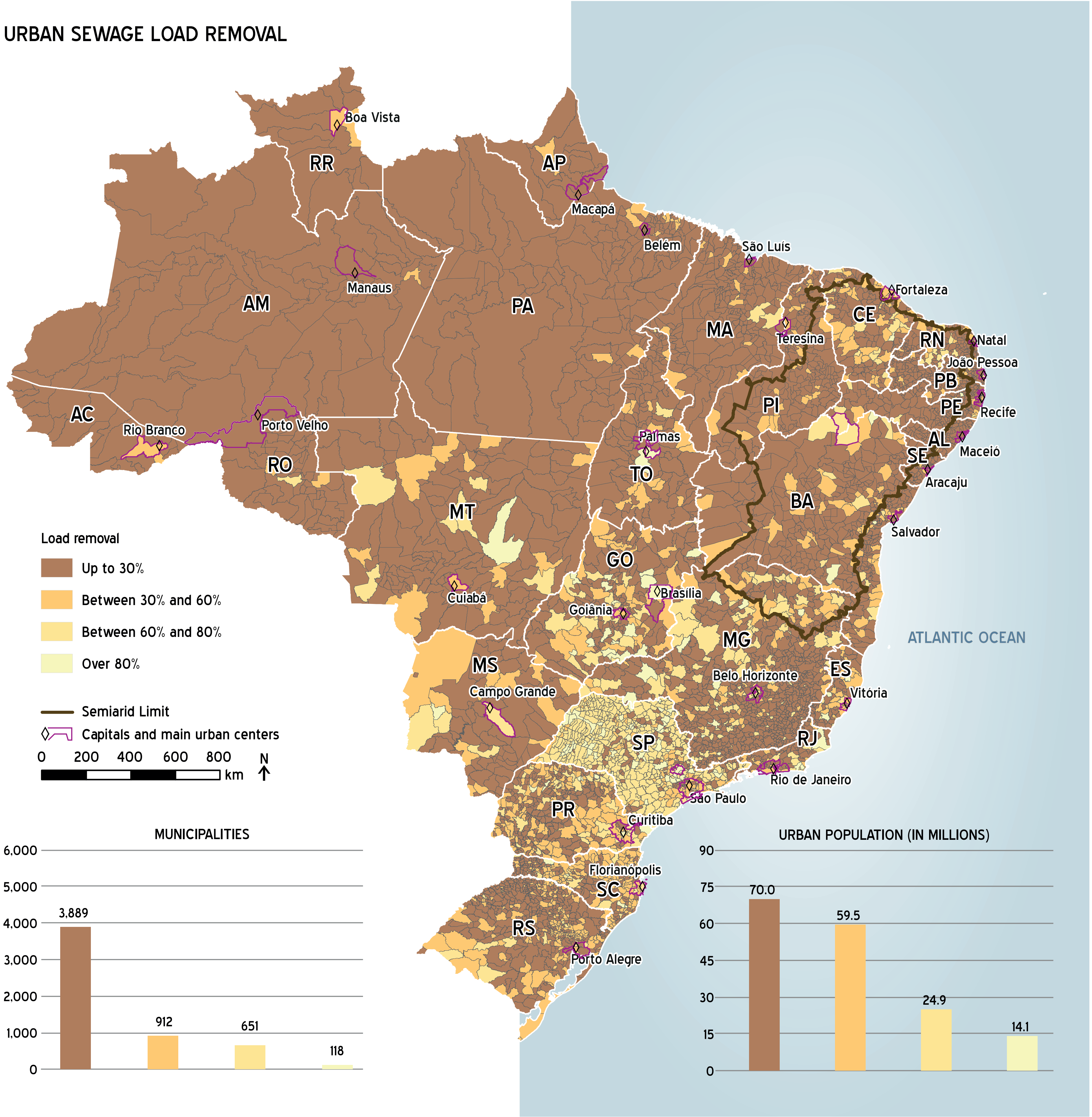
In the state of São Paulo, 461 of the 645 cities (over 70%) present organic load removal levels above 60%. Out of these, 61 remove over 80% of the BOD total generated.

In the Federal Units (FUs) it is verified that excepting the Federal District and the states of São Paulo and Paraná, all other FUs have organic load removal rates below 50%. The Federal District has an appropriate sewage treatment infrastructure and it is the only FU in which the removal of the generated load is higher than 60%, for it removes 82% of the generated load.

DISTRIBUTION OF ORGANIC LOAD IN BRAZIL BY STATE AND GEOGRAPHIC REGION

GEOGRAPHIC REGION	FEDERATION UNION	URBAN POPULATION (in thous. inhab..)	GENERATED LOAD (t BOD/day)	COLLECTED LOAD		CARGA NO RECOLECTADA		REMAINING LOAD (t BOD/day)	PARCEL OF LOAD REMOVED
				Treated (t BOD/day)	Untrated (t BOD/day)	Individual Solution (t BOD/day)	Untreated (t BOD/day)		
NORTH	Acre	562.8	30.4	10.2	0.6	3.9	15.7	19,9	35%
	Amapá	658.8	35.6	2.4	0.2	6.0	27.0	30,0	15%
	Amazonas	3,014.2	162.8	30.6	6.0	32.3	94.0	128,0	21%
	Pará	5,611.0	303.0	12.3	15.1	76.6	199.0	248,5	18%
	Rondônia	1,277.3	69.0	2.5	3.6	13.6	49.3	59,0	14%
	Roraima	374.1	20.2	3.0	0.8	6.8	9.7	13,9	31%
	Tocantins	1,169.2	63.1	18.3	0.8	9.9	34.1	41,3	35%
	TOTAL	**12,667.4**	**684.1**	**79.3**	**27.1**	**149.1**	**428.8**	**540,6**	**21%**
NORTHEAST	Alagoas	2,426.3	131.0	21.7	12.0	16.1	81.2	112,6	14%
	Bahia	10,865.0	586.7	298.4	72.2	33.0	183.1	451,8	23%
	Ceará	6,569.3	354.7	141.0	14.0	108.2	91.4	197,4	44%
	Maranhão	4,283.4	231.3	9.1	30.0	51.4	140.8	193,5	16%
	Paraíba	2,956.4	159.6	68.1	25.9	11.0	54.7	102,9	36%
	Pernambuco	7,383.6	398.7	107.5	70.2	45.1	175.9	293,9	26%
	Piauí	2,096.9	113.2	11.4	2.7	32.2	67.0	85,1	25%
	Rio Grande do Norte	2,619.7	141.5	34.6	8.6	31.3	66.9	98,4	30%
	Sergipe	1,616.8	87.2	18.9	9.4	10.0	49.1	65,9	25%
	TOTAL	**40,817.4**	**2,203.9**	**710.7**	**245.0**	**338.3**	**910.1**	**1.601,5**	**27%**
SOUTHEAST	Espírito Santo	3,136.5	169.4	69.5	33.1	7.7	59.2	105,4	38%
	Minas Gerais	17,705.0	956.1	418.1	403.9	23.6	110.5	612,0	36%
	Rio de Janeiro	15,922.1	859.8	363.2	262.7	75.9	158.0	587,5	32%
	São Paulo	40,521.4	2,188.2	1,410.4	495.0	82.6	200.2	985,6	55%
	TOTAL	**77,285.0**	**4,173.5**	**2,261.2**	**1,194.7**	**189.8**	**527.9**	**2.290,5**	**45%**
SOUTH	Paraná	9,397.5	507.5	325.0	5.6	57.3	119.4	219,3	57%
	Rio Grande do Sul	9,477.2	511.8	134.2	144.2	122.9	110.4	331,0	35%
	Santa Catarina	5,557.4	300.1	72.8	26.1	141.9	59.3	156,3	48%
	TOTAL	**24,432.1**	**1,319.4**	**532.0**	**175.9**	**322.1**	**289.1**	**706,6**	**46%**
MIDWEST	Distrito Federal	2,694.3	145.5	120.9	0.0	12.0	12.5	26,7	82%
	Goiás	5,801.9	313.3	149.9	7.9	41.0	114.5	184,8	41%
	Mato Grosso	2,617.2	141.3	31.8	3.0	29.5	77.0	98,0	31%
	Mato Grosso do Sul	2,170.4	117.2	49.4	0.9	17.9	48.9	66,8	43%
	TOTAL	**13,283.8**	**717.3**	**352.0**	**11.8**	**100.4**	**252.9**	**376,3**	**48%**
BRAZIL		**168,485.7**	**9,098.2**	**3,935.2**	**1,654.5**	**1,099.7**	**2,408.8**	**5.515,5**	**39%**

URBAN SEWAGE LOAD REMOVAL



Knowing the portion of organic load removed allows for a good overview of the efforts already made in sewage treatment. However, it is crucial not to lose sight of the remaining pollutant load regarding its potential impacts in water bodies and human health, considering that in more populous cities, even with high removal rates, the remaining load may be significant.

Of the country's hydrographic regions, the Paraná HR has the largest urban population and the greatest number of municipalities, including 6 large urban centers. It is the region with the highest treatment levels in Brazil, and the removal of organic load is of over 60% in over 500 cities, serving a population of over 22 million people. However, it still produces highest amount of remaining load with potential to impact water bodies in the country.

LThe Paraná HR is followed by the Southeast Atlantic and Eastern Northeast Atlantic HRs in respect to remaining load. These are regions that are highly populated and have a great number of municipalities with low organic load removal capacity, including the Paraíba do Sul river basin in the Southeast Atlantic HR and coastal basins in the Eastern Northeast Atlantic HR.

In the Amazon, Tocantins-Araguaia and Western Northeast Atlantic HRs, there predominate populations with an extremely low organic load removal (up to 30%). The existence of winding rivers, especially in the first two regions, can lead to the belief that the sewage will eventually be diluted by their waters. However, this vision is inadequate once the absence of proper sewage treatment in these municipalities has the potential of impacting urban canals and rivers and affects the local situation of public health.

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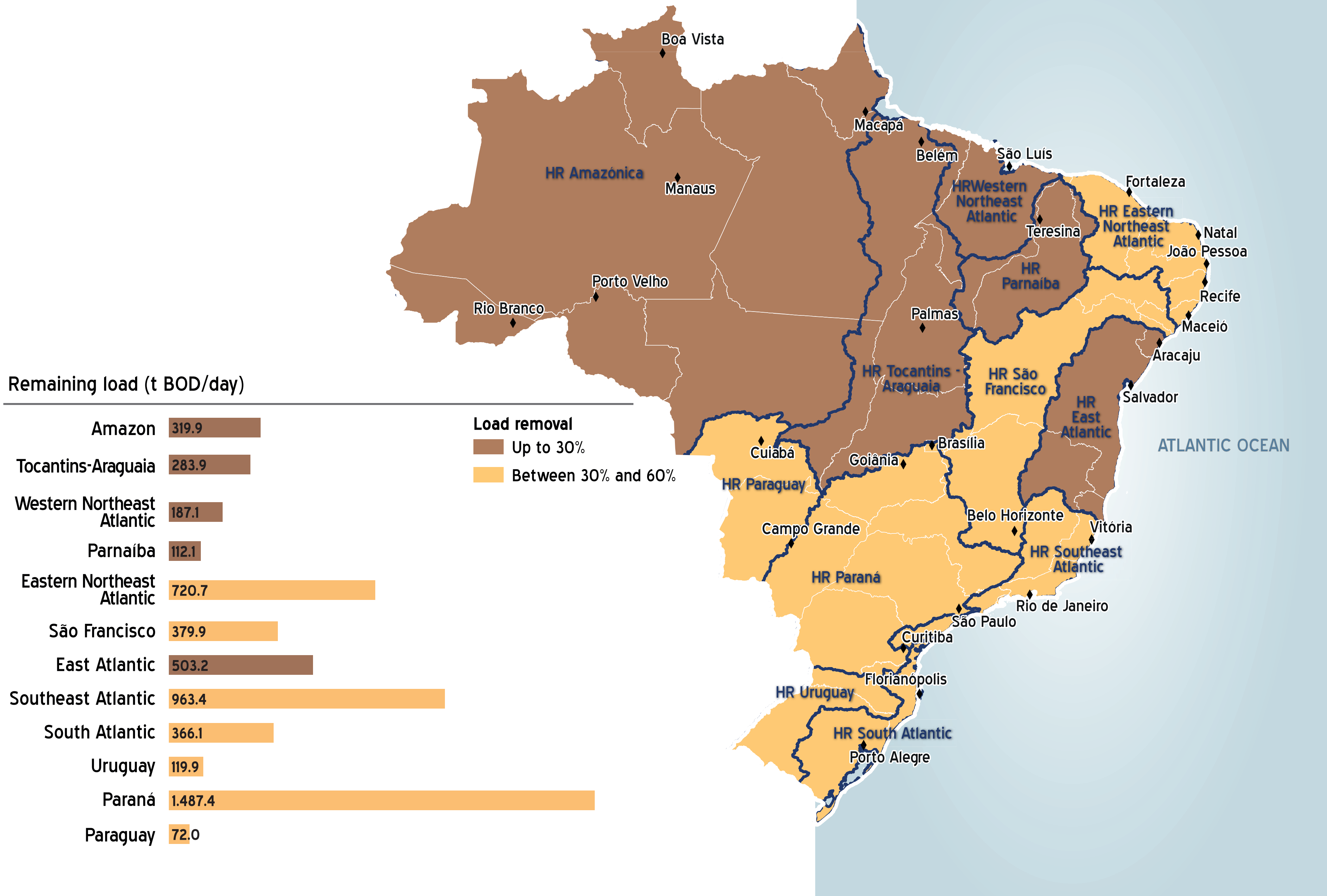
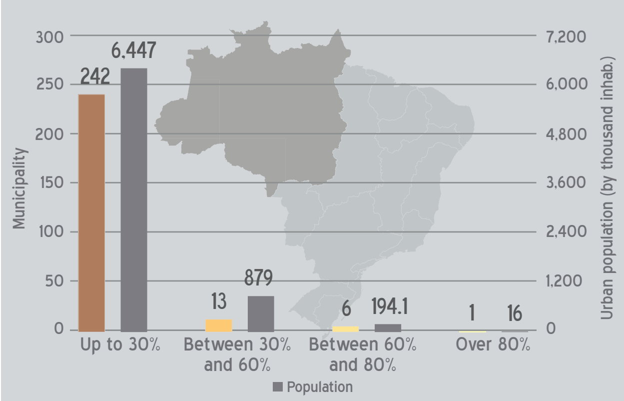
REMOCIÓN DE CARGA POR REGIÓN HIDROGRÁFICA

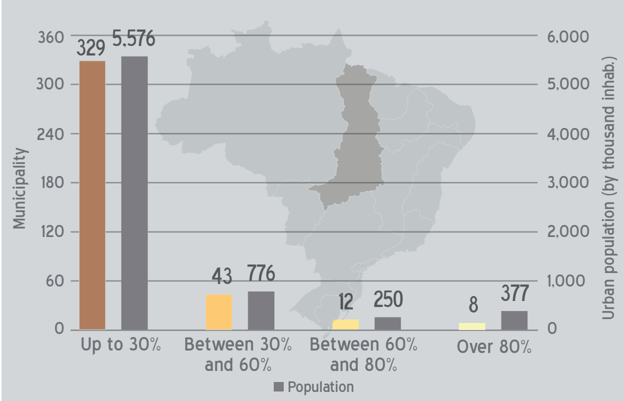


ORGANIC LOAD REMOVAL CLASSES BY HYDROGRAPHIC REGION

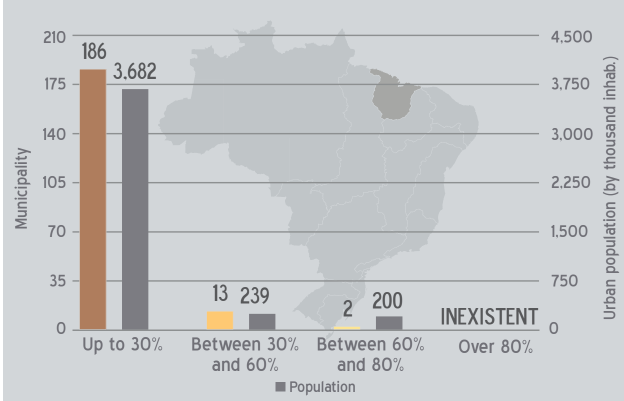
AMAZON HR



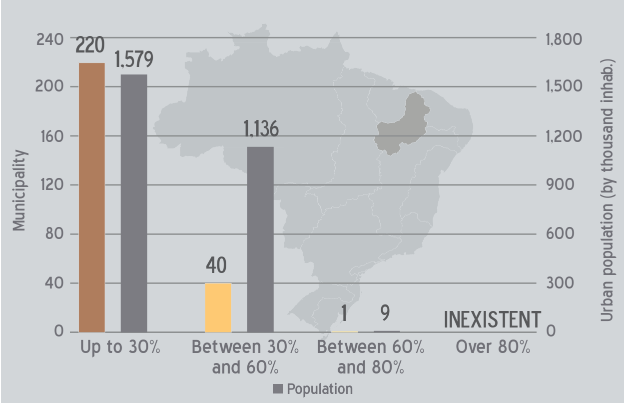
TOCANTINS-ARAGUAIA HR



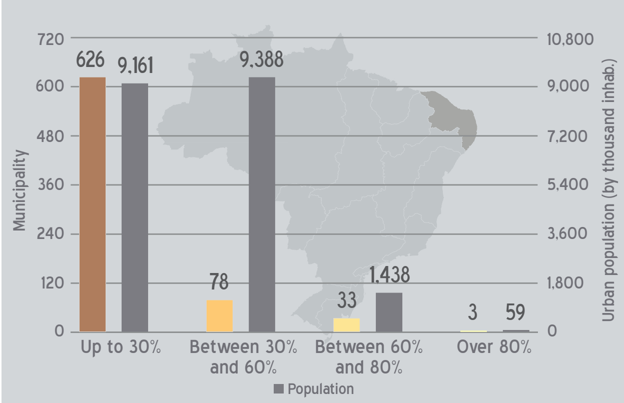
WESTERN NORTHEAST ATLANTIC HR



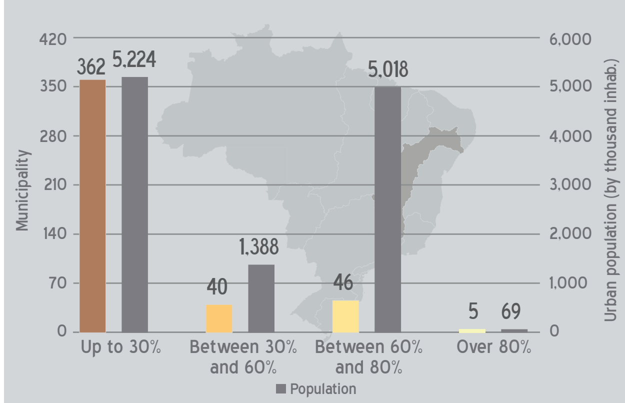
PARNAÍBA HR



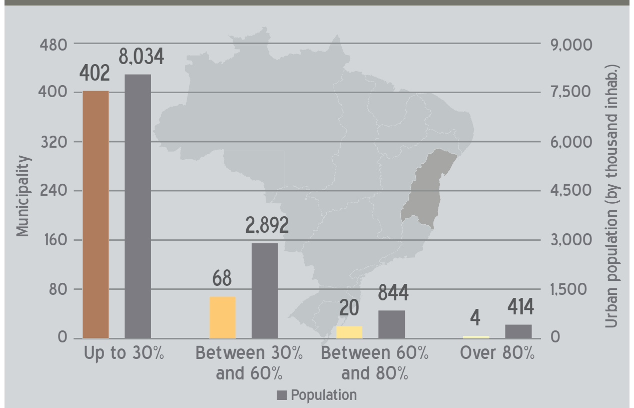
EASTERN NORTHEAST ATLANTIC HR



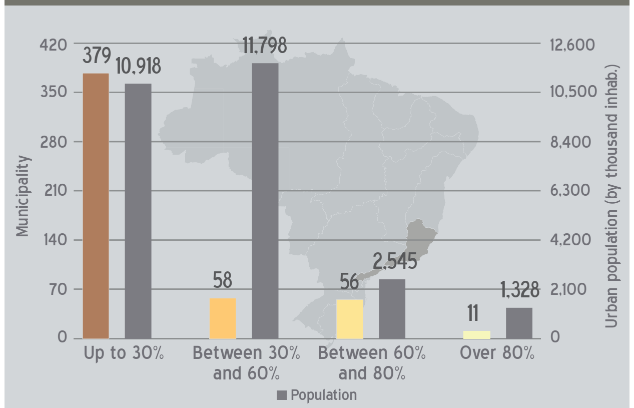
RH SÃO FRANCISCO



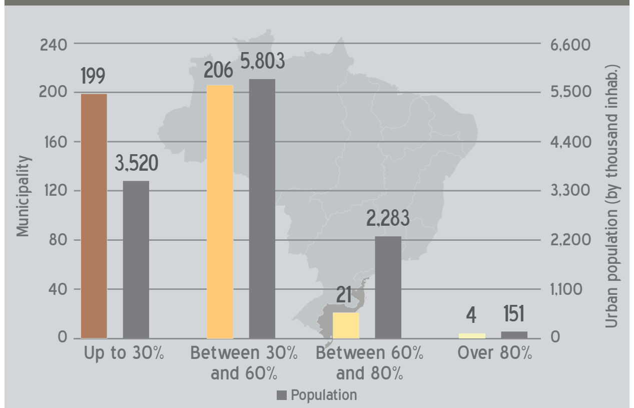
RH ATLÁNTICO ESTE



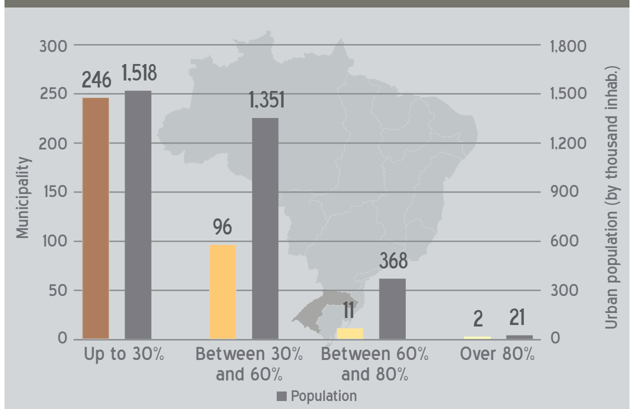
RH ATLÁNTICO SURESTE



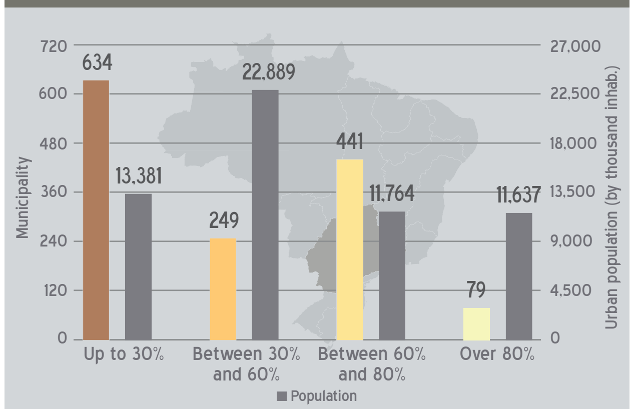
RH ATLÁNTICO SUL



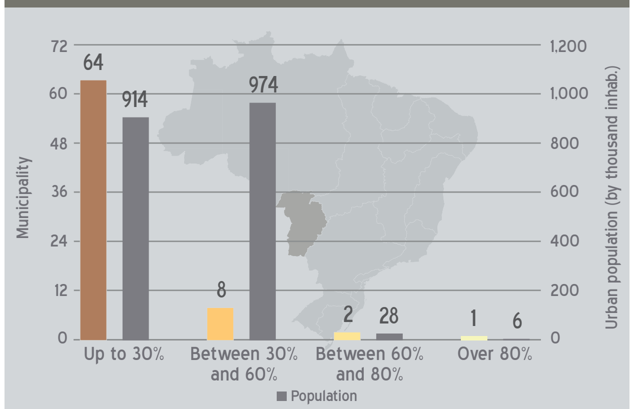
RH URUGUAY



RH PARANÁ



RH PARAGUAY



2.5 | RESULTS BY MUNICIPALITY

In order to have a graphic representation of the existent and proposed Sewage Treatment Systems for all urban centers covered in the study, standardized diagrams were prepared and are available in the ANA website (www.ana.gov.br) and the National Water Resources Information System SNIRH (www.snirh.gov.br).

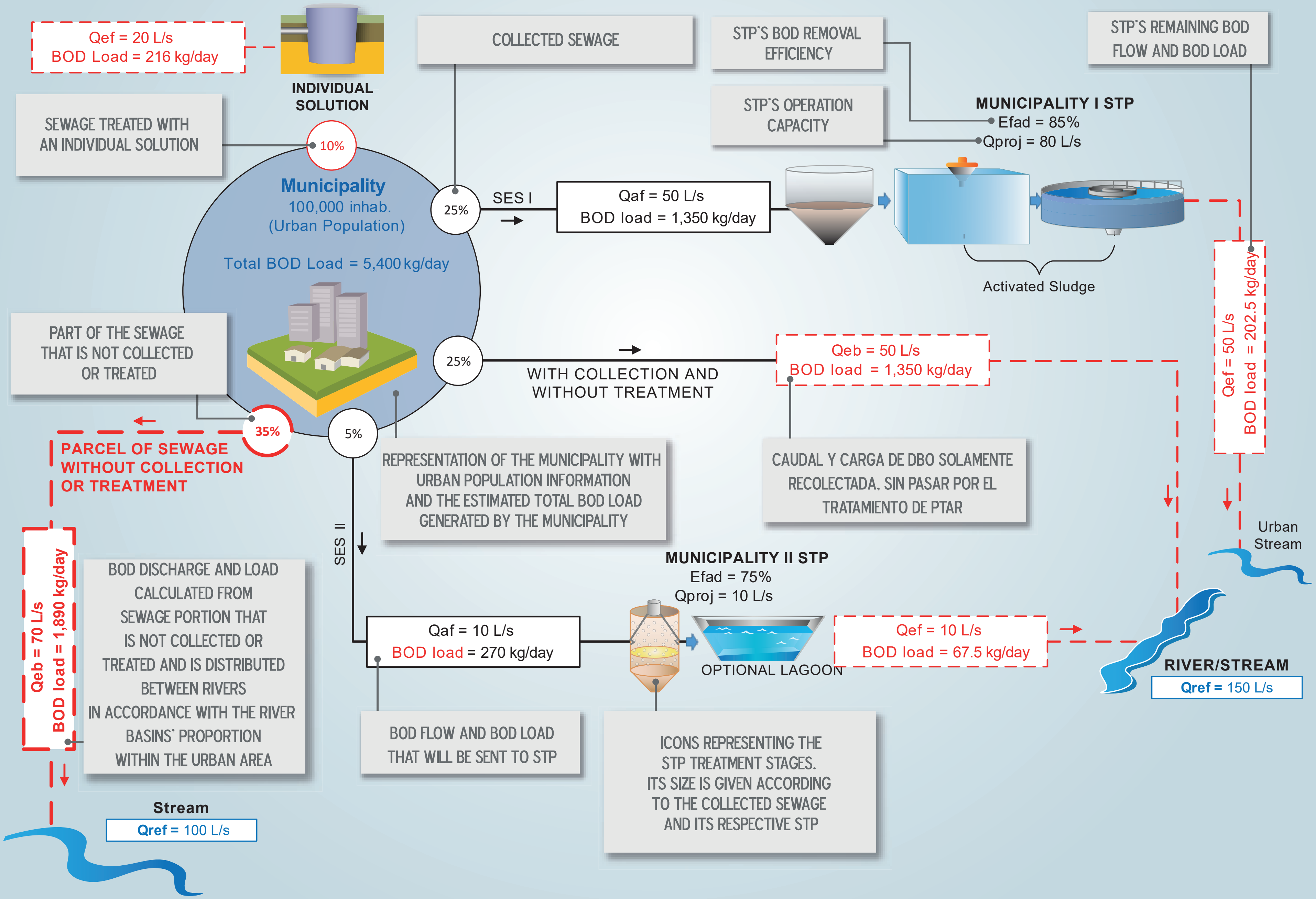
In the diagrams all of the sewage portions are identified: collected and treated, collected and untreated, supplied by individual solution with septic tank and no treatment whatsoever.

In this context, the stages of the treatment process for the liquid phase of the effluents are represented. Finally, the receiving bodies of raw and/or remaining loads are represented. When the discharge coordinates were not informed, the final effluent destination adopted was the receiving body with the highest flow in the city.

In the studies, the total flow and BOD load generated by the city were considered in order to identify the adequacy of the STP's operational capacity, as well as the capacity of self-purification of the water bodies.

GRAPHIC REPRESENTATION OF THE GENERATION, COLLECTION, TREATMENT AND FINAL DISPOSAL OF SEWAGE LOADS IN BRAZILIAN CITIES

For each of the **5,570 municipalities** in Brazil, a graphic representation of the current sewage treatment system conditions



Caption

Qaf: affluent discharge	Qeb: raw sewage discharge	STP: Sewage Treatment Plant
Qef: effluent discharge	Qref: Reference discharge	BOD: Biochemical Oxygen Demand
Qproj: project discharge	Efad: efficiency adopted (project, operation or literature)	STS: Sewage Treatment System

3 | THE WATER RESOURCES SITUATION

3.1 | EFFECTS OF SEWAGE ON WATER QUALITY

3.2 | ASSESSMENT OF THE SEWAGE DILUTION CAPACITY

3.1 | EFFECTS OF SEWAGE ON WATER QUALITY

Sewage discharge into water bodies without proper treatment has resulted in the worsening of water quality, mainly close to urban areas, which can impact the population's health and even make its downstream use impossible, especially for human supply.

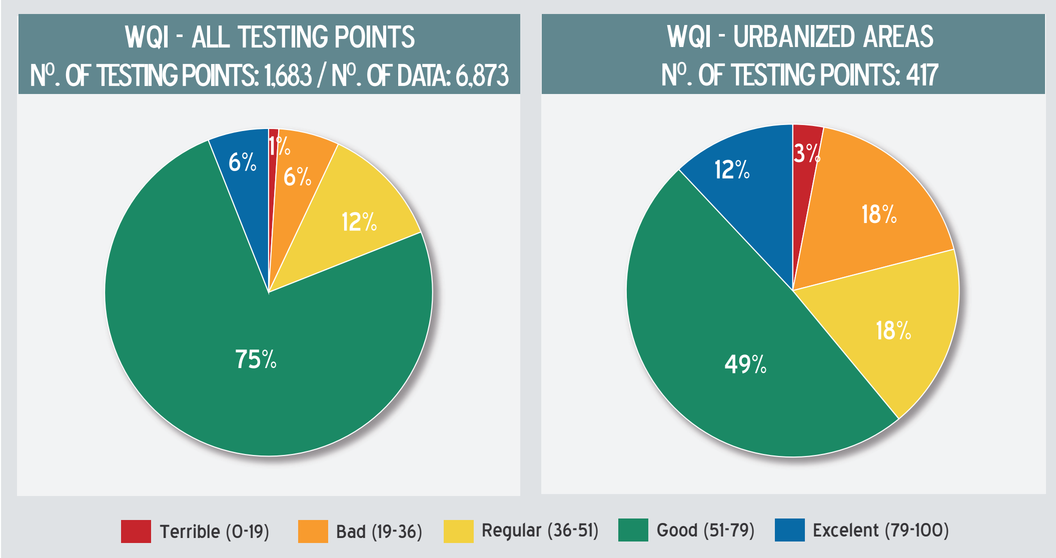
The 2015 Water Resources Report showed that 21% of the monitoring points located in water bodies near urban areas revealed a bad or terrible Water Quality Index - WQI, while for the rest of the monitored points bad or terrible results were at about 7%.

This supports the perception that many water quality problems, especially those related to the concentration of organic matter and nutrients, are concentrated near large urban areas and are due to untreated sewage discharge.
Sewage treatment and collection may prevent impacts on public health and water resources but that does not mean that ascertaining the dilution capacity of the water bodies becomes unnecessary. It is still necessary to align the dilution capacity of the water bodies with the required water quality for different uses. The water bodies classification framework according to their preponderant uses, an instrument provided for in the National Water Resources Policy - PNRH, is the main guide for this assessment.

In order to quantify the impact of urban sewage discharge into water bodies, considering the current classification, a methodology was employed with the support of mathematical modeling of water quality. The loads considered in the modeling were obtained from the detailing sewage collection and treatment systems of the cities.

The modeling's results reflect the ability of the water bodies to receive the urban sewage discharges from each city without compromising its water class in each river stretch. The analysis was carried out considering the effluents' cumulative effect on the basins, so as to include the influence of upstream distcharges on the dilution capacity of river stretches located downstream.

In addition to BOD, phosphorus and nitrogen were evaluated in future predictions, as a way to identify groups of cities and/or river basins that require special attention regarding the removal of these nutrients. The phosphorus verification was carried out focusing on the influence of the affluent loads on lakes and reservoirs, aiming to control the eutrophication issue. In the case of nitrogen, the evaluation focused on the potential contamination of downstream springs.



Source: Current Situation of Water Resources - 2015, ANA

WATER BODY CLASSIFICATION FRAMEWORK

This instrument aims to ensure water quality compatible with the most demanding uses for which it is intended and to reduce the costs of fighting pollution through permanent preventive actions. The parameters and limits for water body classification according to their preponderant uses (water classes) are set out in resolution CONAMA No. 357/2005, and are supplemented and amended in CONAMA Resolution No. 430/2011 regarding the conditions and standards for effluent discharge.

Fresh water has, in short, the following uses:

- **Special class:** preservation of the natural balance between aquatic communities in conservation units of integral protection, human supply after simple disinfection and other uses for classes 1 to 4;
- **Class 1:** protection of aquatic communities on Indigenous land, supply for human consumption with simplified treatment, irrigation of raw vegetables / fruit growing close to the ground and other uses for classes 2 to 4;
- **Class 2:** protection of aquatic communities, supply for human consumption after con-ventional treatment, irrigation of vegetables, fruit plants and gardens and parks, primary contact recreation, aquaculture, fishing and other uses for classes 3 and 4;
- **Class 3:** supply for human consumption after conventional or advanced treatment, irrigation of tree crops, cereal and fodder crops, secondary contact recreation, amateur fishing and other class 4 uses;
- **Class 4:** navigation and landscape harmony.

WATER QUALITY MODELLING

The modelling used for water body assessment used as a basis:

- ANA multi-scale hydrography divided into stretches and sub-basins, with information on their flow and area;
- Reservoir database developed by ANA information about flow, volume, area and residence time;
- *ATLAS Brazil: Urban Water Supply* surface withdrawal database;
- Sewage treatment plant database developed from field visits and contacts with service providers;
- Urban area polygons defined based on the 2013 IBGE Constructed Environmental Areas database, complemented and refined through consultation to the following pieces of research: (I) urbanized areas - IBGE, 2005: large urban concentrations, cities above 100,000 inhabitants and coastal cities; (ii) Census Sectors - IBGE, 2010; and, (iii) manual refinement, with the help of the *Google Earth* tool.

Urban areas were superimposed on the hydrography and its respective sub-basins for the distribution of the remaining sewage loads associated with the respective water bodies. In this way, it became possible to identify the portions associated with each river stretch, providing subsidies for the evaluation of its impact by simulating water quality parameters, both for the current situation and for the year 2035.

BOD parameter:
The BOD evaluation process was structured with the aim of calculating the concentration of the parameter at the end of each river stretch with a $Q_{95\%}$ reference flow.

A cumulative upstream to downstream load analysis scheme was used in the modeling, differencing between lentic and lotic environments. The per capita contribution used was 54 g BOD/day. The concentration decrease in water bodies was accounted for by the analytical solution of first order decay:

$$C = C_0 e^{-k_d t}$$

where:
C is the BOD concentration (mg/l) over time t;
C_0 is the initial BOD concentration (mg/L);
t is the time (day);
kd is the decay coefficient (day^{-1}).

Three values for the k_d coefficient were considered:

Characteristics	Value of k_d (d^{-1})
Lotic environments with upstream concentrations <= 5 mg BOD/L	0.15
Lotic environments with upstream concentrations > 5 mg BOD/L	0.25
Lentic environments	0.033

The resulting BOD concentration in each stretch was compared to the limits set in the water classes and used as a reference for estimating the required treatment efficiencies.

Total Phosphorus Parameter:
The phosphorus evaluation process was structured to provide the resulting concentrations in lakes or reservoirs only for the year 2035. It took into account loads from cities located in the contribution areas for each lake or reservoir, using a per capta contribution for 1g P/inhab.day. The lake or reservoir was treated as a well-mixed reactor and the concentration was calculated by the following equation:

$$C = \frac{L.10^3}{V.\left(\frac{1}{t} + \frac{2}{\sqrt{t}}\right)}$$

where:
C is the phosphorus concentration (mg/L) in the reservoir;
L is the phosphorus load (kg/year) inflow to the reservoir;
V is the reservoir volume (m^3); and,
t is the reservoir residence time (year).

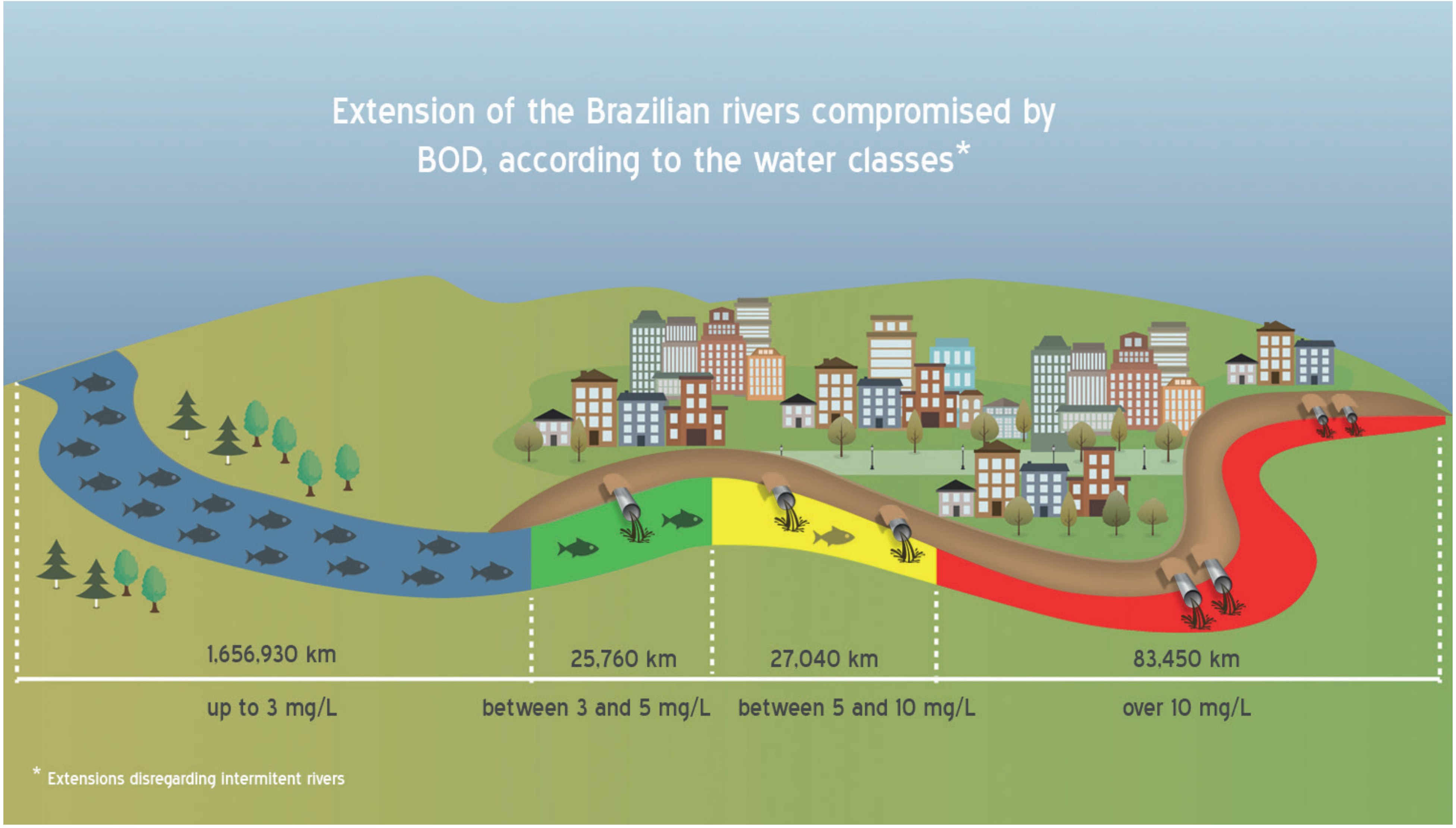
The estimate of the inflow load to the lake or reservoir was carried out from the flow and concentration in the immediately upstream stretch for the analyzed unit. The upstream concentration was obtained the same way as the BOD concentration, considering a decay coeficient of 0.01 day^{-1} for Phosporus.

The results were assessed in relation to the impact on the reservoirs' trophic level, compairing the estimated load value to a limit load (calculated in relation to the 0.025 mg P/L concentration considered as a limit reference value for eutrophication).

Total Nitrogen Parameter:
The Nitrogen evaluation was based on a conservative approach using the sum generated by the population of cities located upstream of the respective withdrawal point, cumulatively and without decreases, considering a per capta contribution of 8 g N/inhab.day.

The resulting concentration was calculated for the reference flow in the river stretch where the evaluated withdrawal was located. The results over 10 mg N/L were highlighted as stretches that may not be safe for public supply.

Note:
Despite being an important an important public health indicator, the thermotolerant coliform parameter was not modeled, considering that the result would not alter the treatment type required. Its efficient removal requires a 100% collection and a disinfection process.



Considering the $Q_{95\%}$ and the limits established for BOD in the different water classes foreseen in CONAMA Resolution No. 357/2005, it is estimated that, out of the total waters assessed in the current situation, about 4.5% (83,450 km) have organic matter concentrations that are equivalent to the limits established for class 4, which significantly compromises the possibilities of use for these waters. The compromised stretches are located close to the more concentrated urban areas or in stretches base for with very reduced dilution capacity.

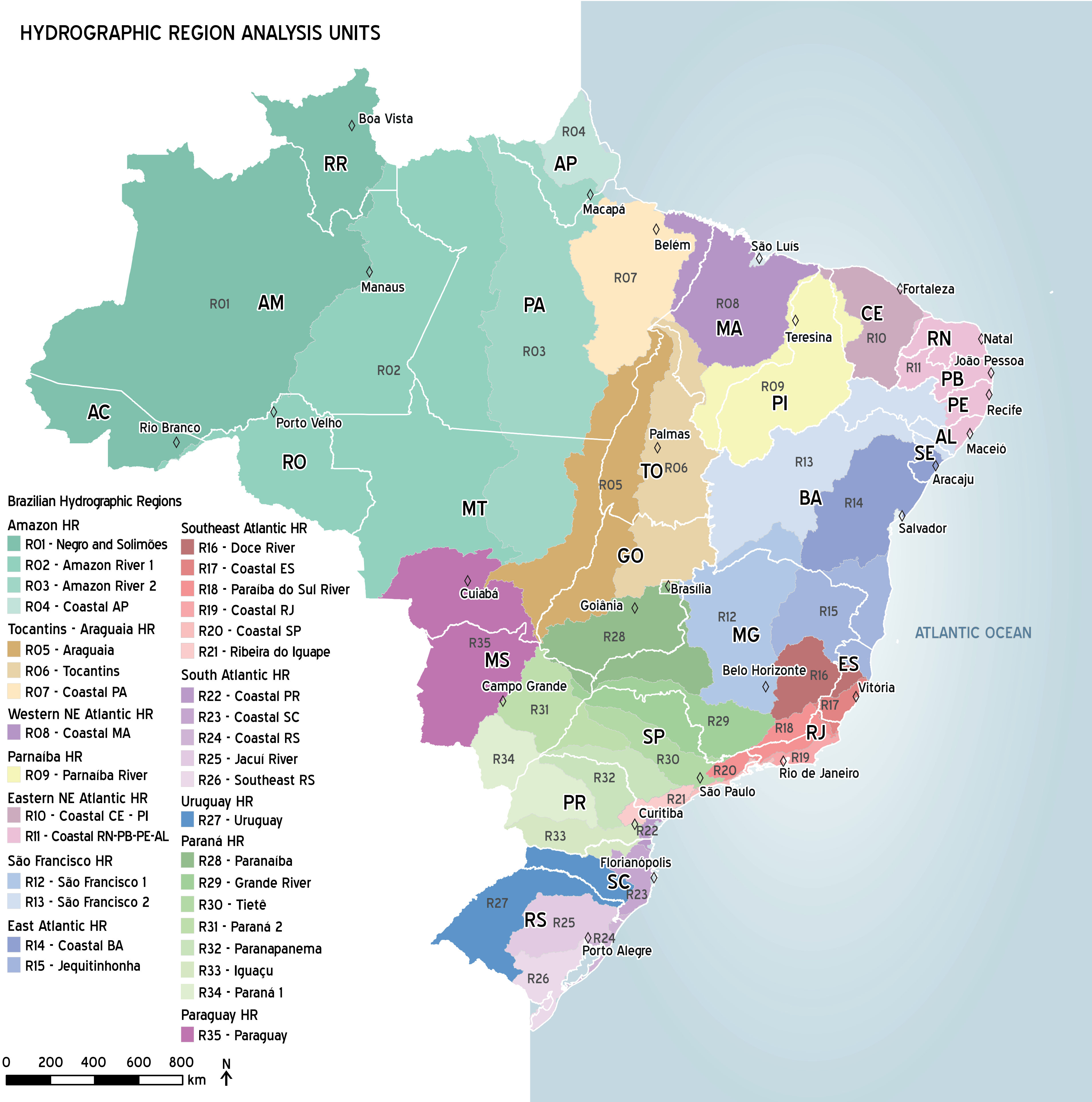
The base for calculation used in the mathematical modeling was orga-nized into 35 Hydrographic Region Analysis Units - HRAU, structured from 12 Brazilian Hydrographical Regions - HRs defined by the National Council of Water Resources - CNRH.

These units were defined for two main purposes: (i) facilitating modeling through the HRs subdivision into smaller units; and (ii) reproducing states and strategic units used by ANA in the planning of water resources.

It is possible to identify in the analysis a great number of river stretches that are compromised, especially in the semiarid region in the HRAUs with higher population concentrations, especially in the eastern part of the country.

On the other hand, the lowest number of compromised stretches occurs in the Amazon Hydrographic Region, which focuses 53% of the discharge available in Brazil and only 13 million inhabitants (7% of the Brazilian population. By comparison, the southeast region concentrates a population 6 times larger than the northern region and only 4% of the country's water availability. This unequal distribution directly affects the quality of the water bodies.

HYDROGRAPHIC REGION ANALYSIS UNITS



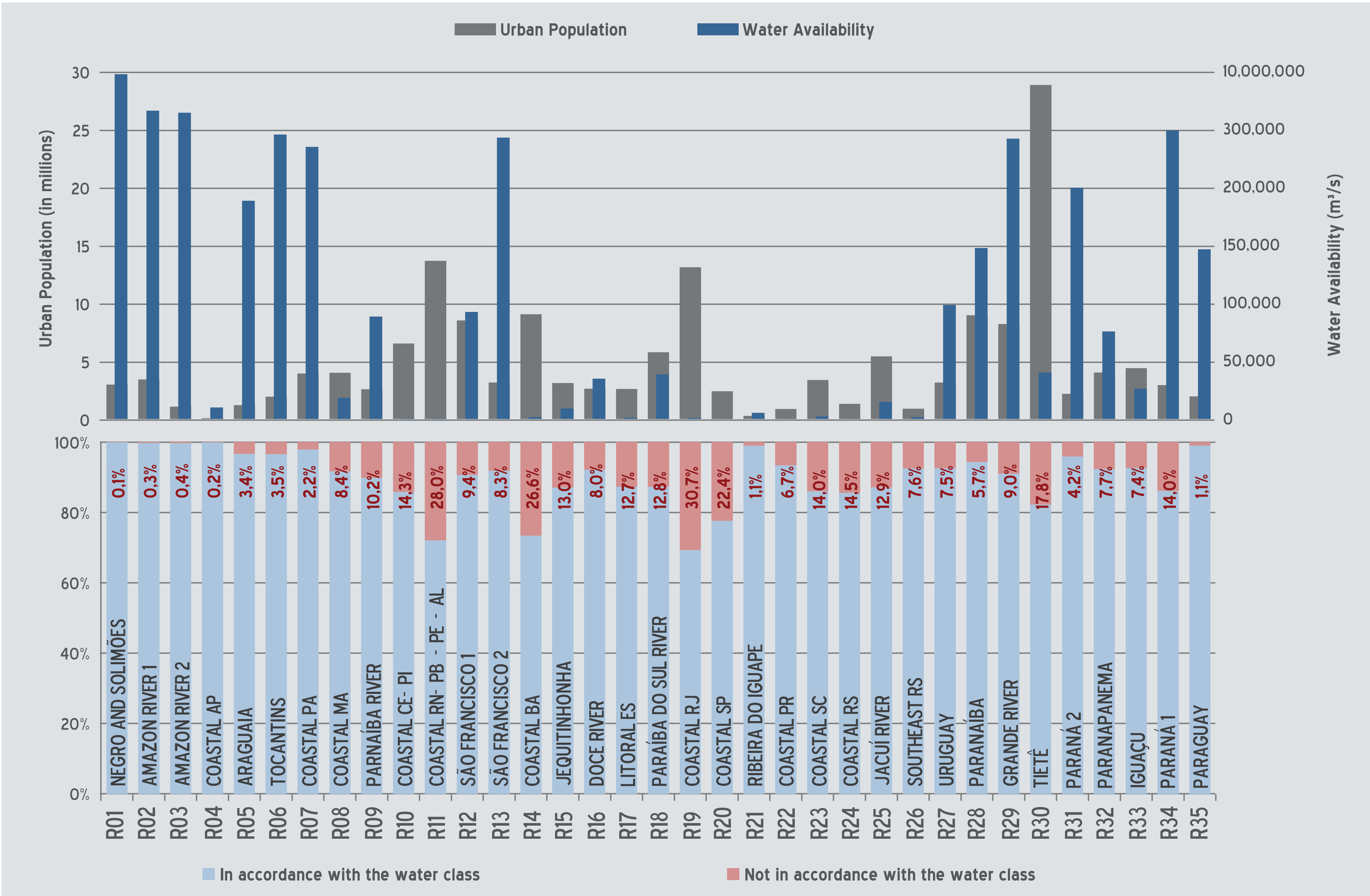
Among the analysis units the one that proportionally has the highest compromised river stretch extension percentage is the one that includes the Rio de Janeiro Coast (R19): 30.7% of the water bodies extension. 19 out of the 21 cities composing the state capital's metropolitan region are located in this region, covering almost 12 million Brazilian citizens. The HRAU's remaining sewage organic load is of almost 70% of the load generated by its population, which demonstrated that low level of BOD removal from the effluent that may reach water bodies and impact in their water quality.

The Tietê River HRAU (R30) is the one that covers the biggest urban population, about 29 million inhabitants. The compromised receiving bodies in the HRAU (17.8% of the assessed water bodies extension) are mostly located close to the São Paulo and Campinas Metropolitan Regions, where the receiving bodies flow is insufficient to receive the load generated by the large urban concentration. The R20 unit, also in the state of São Paulo, is also noteworthy, this 22.4% of its water bodies are currently compromised. It is less populated than the Tietê River, but with a high population density. It is worth noting that the state of São Paulo has a classification framework that encompasses, as a rule, less restrictive classes in the river stretches under the influence of effluents from main urban centers.

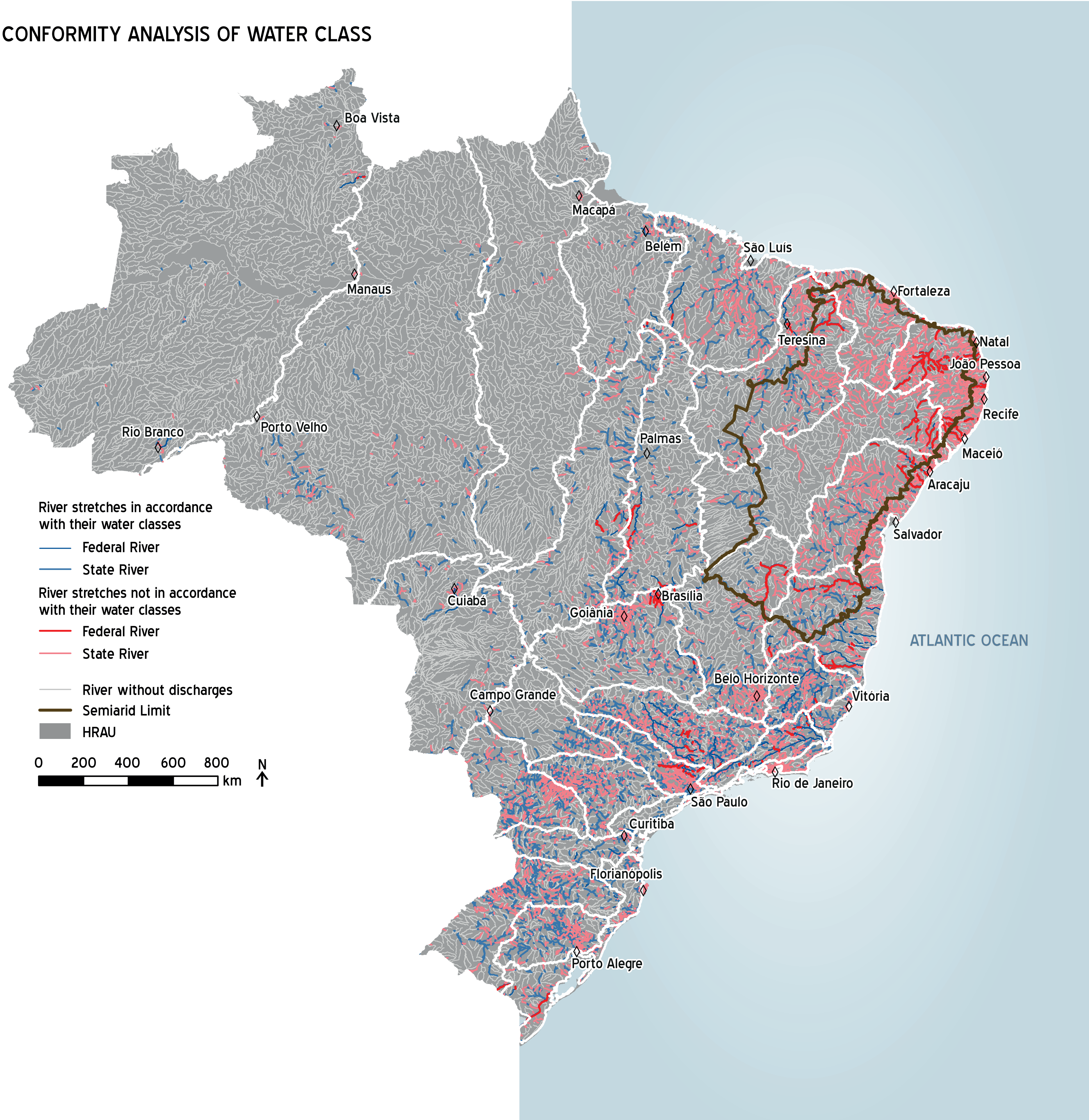
In addition to the already mentioned HRAU, a large number of compromised coastal basins were also observed in the Northeast region and headwater areas with large urban agglomerations.

The water quality modeling results showed, in general terms, that about 6% of the measured river stretches' extent are above the organic load concentration allowed for its class. Out of these regions, 90% are of state domain, that is, water resources whose management is the responsibility of the federation units.

The main urban populations are not located in the HRAUs with the most water availability, which results in challenges to be faced in order to solve the sanitation issue in Brazil and its impact in the receiving bodies.



CONFORMITY ANALYSIS OF WATER CLASS



3.2 | CAPACITY ASSESSMENT OF SEWAGE DILUTION

In addition to understanding the impact of sewage on the receiving bodies, which is the result of water availability and water quality requirements, it was important to define an indicator that synthesized the dilution capacity of sewage in relation to the population of the cities, so as to support sewage planning and treatment.

The relationship between water availability and the urban population residing in each receiving body's contribution area was used to categorize the main receiving body for each urban center in relation to its potential to dilute domestic sewage.

The water availability, considered for the purposes of the study, refers to the drought flows with a permanence of 95% (Q_{95}%). For discharges downstream of reservoirs, the flow considered was the minimum flow or, in its absence, the regular fow.

In the distribution of dilution capacity categories, the receiving bodies' dilution capacity ranges were evaluated in relation to the potential of meeting the freshwater classes, foreseen by CONAMA Resolution Nº. 357/2005, and the removal of organic load applied to the total generated by the respective urban population in the contribution area for each river stretch evaluated.

DILUTION CAPACITY OF THE RECEIVING BODIES CONSIDERING THE WATER CLASSES

DILUTION CAPACITY	WATER AVAILABILITY / URBAN POPULATION (L/inhab.day)		DESCRIPTION
	LOWER LIMIT	UPPER LIMIT	
Unlimited	Not applicable		Possibility of discharge in the sea
Excellent	> 11,000		There are no problems for diluting wastewater
Good	4,500	11,000	Can meet class 2 with removal of up to 60% of the organic load
Regular	2,000	4,500	Can meet class 2 with 60% to 80% organic load removal
Bad	300	2,000	Can meet class 2 with 90% to 97% organic load removal or Class 3 with 90% organic load removal
Terrible	< 300		Can meet class 4
Zero	Not applicable		Ephemeral or intermittent receiving water body without dilution flow

SPECIAL DILUTION CONDITIONS

From a Water Resources standpoint, the extreme situations that may be observed related to the possibility of diluting sewage discharges are: the inexistence of flow in the water body during long periods of time in the year, or an infinitely greater flow than the nutrient load discharged.

The first case may occur, for example, in the semiarid region, where many of its rivers are intermittent and the weirs are the solution found to store water for nobler uses, such as human supply, and water for overcoming drought periods, in addition to having the function of regulating the flow of the region's water bodies.

At these sites, depending on the scarcity of water for dilution, more complex solutions may be necessary, such as the using of more efficient processes for the removal of pathogens (alternative to reduce risks to the use of downstream water) or sewage disposal (alternative for nutrient load removal upstream of the weirs).

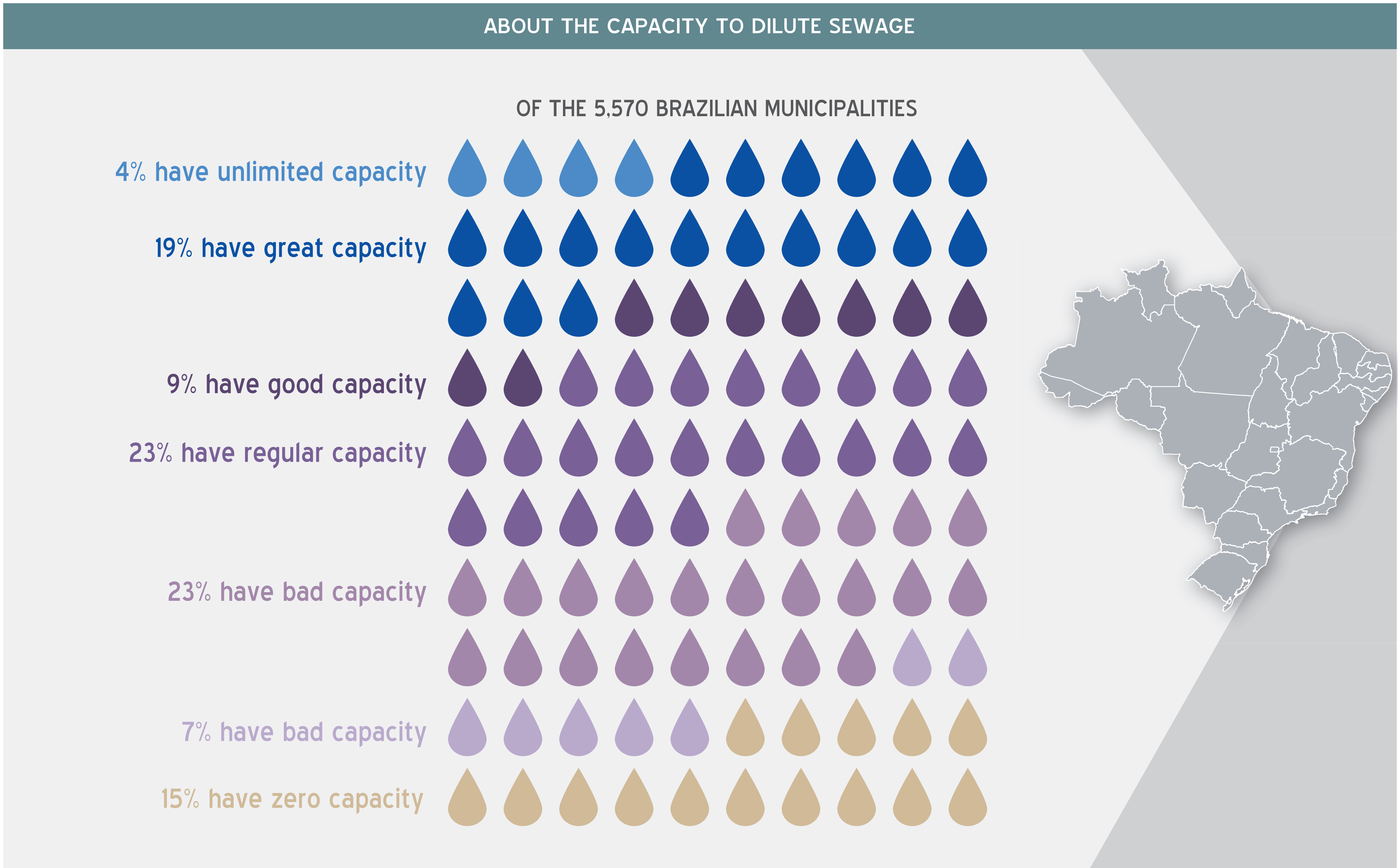
At the other extreme, we may find coastal cities, that have the alternative of using the ocean for the final sewage discharge, but require special attention when it comes to the understanding the local water environment dynamic wastewater discharge modalities, always focusing on the environmental demands.

The classification presented, given seven dilution capacity categories, was applied to the Brazilian urban centers considering the receiving water body responsible for diluting the greater parcel of sewage load in the cities that have a sewage system. In the absence of a sewage system, the receiving body with the highest water availability in the urban area or in its surrounding areas was used.

Over half of the Brazilian municipalities have receiving bodies with great, good or regular dilution capacity, that is, they have enough flow to dilute the sanitary wastewater in the urban centers and are able to meet class 1 or 2 standards of classification after appropriate sewage treatment. However, in population terms, they correspond to about 20% of the urban population in the country, indicating that the solution for small cities may demand simplified systems for the treatment and final disposal of sewage.

About 2,500 urban centers are characterized by water bodies with bad, terrible or inexistent dilution capacity, that is, they do not have receiving bodies that are able to dilute the wastewater, even after treatment, without resulting in water quality only compatible with class 3 or class 4. They are municipalities whose urban centers are located in headwaters or regions with very low rainfall indexes, such as the Brazilian semiarid region, or they are located in great urban concentrations. For these municipalities the treatment and final disposal solutions may demand more sophisticated arrangements such as the using of advanced treatment technologies and/or receiving bodies that are farther away. In both cases, investments are significant.

The 254 urban centers located in the coastal region that currently discharge their wastewater into the sea or have this as a potential alternative for the discharging of treated wastewater are categorized as “unlimited dilution capacity”. Some big cities are part of this category, such as Rio de Janeiro and Salvador, which represent an urban population of over 40 million people.



With the exception of the Northeast region, in the other geographic regions there is a preponderance of cities close to water bodies of great, good or regular dilution capacity. However, in terms of population, this situation only occurs in the northern region.

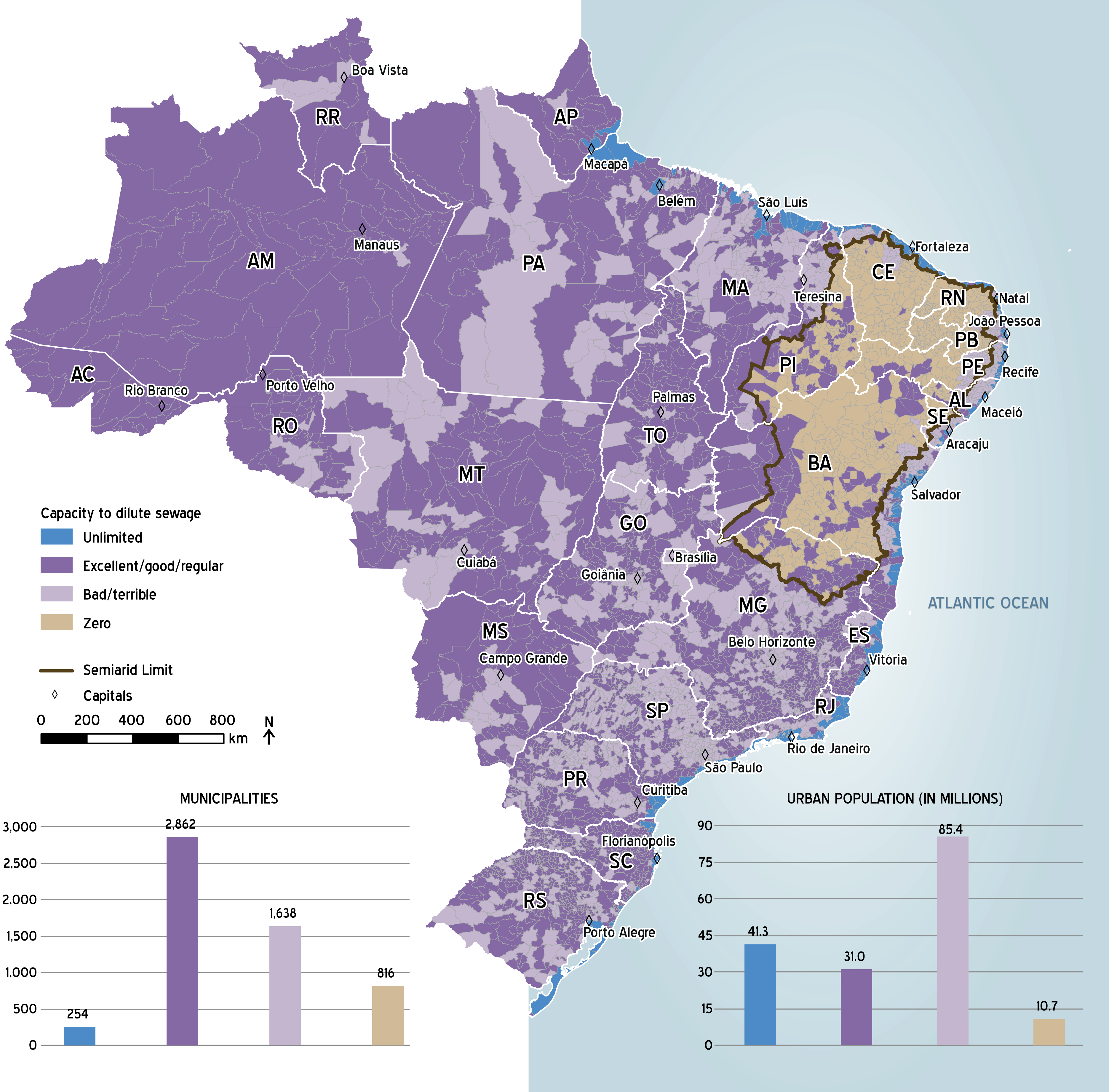
In the southeastern, southern and midwestern regions the largest population is found in cities whose receiving bodies have bad or terrible dilution capacity. In the southeastern region, where the largest urban agglomerations of the country are located, almost 50 million people are close to receiving bodies with low dilution capacity (about 60% of its urban population).

In the northeast of the country, since much of its area is located in the semiarid region, almost 800 cities do not possess water bodies with enough flow to dilute sewage. There are over 10 million people in these cities, and about 25% of the urban population in this region. Still in relation to population distribution, over 17 million people in the Northeast region are in coastal cities, which are some of the most important cities in the region and that, therefore, have the sea as a possible final destinantion possibility for wastewater.

ABOUT THE CAPACITY TO DILUTE SEWAGE

GEOGRAPHIC REGION	FEDERATION UNIT	UNLIMITED		EXCELLENT/GOOD/REGULAR		BAD/TERRIBLE		ZERO	
		Municipalities	Population (in thous. inhab.)	Municipalities	Population (in thous. inhab.)	Municipalities	Population (in thous. inhab.)	Municipalities	Population (in thous. inhab.)
NORTH	Acre	-	0	22	562.8	-	-	-	-
	Amapá	1	418.6	14	237.4	1	2.8	-	-
	Amazonas	-	0	61	2,999.2	1	15.0	-	-
	Pará	9	2,043.7	92	1,784.7	43	1,782.5	-	-
	Rondônia	-	0	41	1,028.3	11	249.0	-	-
	Roraima	-	0	11	52.9	4	321.2	-	-
	Tocantins	-	0	117	508.8	22	660.5	-	-
	TOTAL	**10**	**2,462.3**	**358**	**7,174.1**	**82**	**3,031.0**	**-**	**-**
NORTHEAST	Alagoas	16	1,198.1	12	113.6	47	703.1	27	411.6
	Bahia	27	4,201.4	108	1,617.1	88	1,664.6	194	3,381.9
	Ceará	22	3,700.7	6	68.8	22	333.2	134	2,466.5
	Maranhão	22	1,317.9	84	1,280.0	111	1,685.4	-	-
	Paraíba	10	1,089.5	6	57.5	63	547.7	144	1,261.7
	Pernambuco	18	3,745.7	7	85.5	96	2,409.1	64	1,143.4
	Piauí	4	163.9	87	363.7	60	1,206.3	73	362.9
	Rio Grande do Norte	21	1,247.4	3	9.7	19	248.1	124	1,114.5
	Sergipe	6	775.0	9	64.0	42	631.4	18	146.4
	TOTAL	**146**	**17,439.6**	**322**	**3,659.9**	**548**	**9,428.9**	**778**	**10,288.9**
SOUTHEAST	Espírito Santo	12	2,151.9	49	773.2	17	211.5	-	-
	Minas Gerais	0	0	579	4,935.4	236	12,321.2	38	448.4
	Rio de Janeiro	30	13,093.9	33	805.6	29	2,022.5	-	-
	São Paulo	16	2,005.4	311	3,719.7	318	34,796.3	-	-
	TOTAL	**58**	**17,251.2**	**972**	**10,233.9**	**600**	**49,351.5**	**38**	**448.4**
SOUTH	Paraná	6	240	244	2,047.2	149	7,110.3	-	-
	Rio Grande do Sul	14	2,080	387	2,635.7	96	4,761.5	-	-
	Santa Catarina	20	1,833.4	242	2,289.8	33	1,434.1	-	-
	TOTAL	**40**	**4,153.4**	**873**	**6,972.7**	**278**	**13,305.9**	**-**	**-**
MIDWEST	Federal District	-	-	-	-	1	2,694.3	-	-
	Goiás	-	-	169	1,189.1	77	4,612.9	-	-
	Mato Grosso	-	-	108	1,008.4	33	1,608.9	-	-
	Mato Grosso do Sul	-	-	60	809.4	19	1,361.0	-	-
	TOTAL	**-**	**-**	**337**	**3,006.9**	**130**	**10,277.1**	**-**	**-**
BRAZIL		**254**	**41,306.5**	**2,862**	**31,047.5**	**1,638**	**85,394.4**	**816**	**10,737.3**

ASSESMENT OF THE CAPACITY TO DILUTE SEWAGE



The analysis of each city's situation regarding its receiving water bodies, reinforces the attention that must be given to the water quality assessment in high population density areas, and in the semiarid region, because these are the most critical regions and which may require more complex solutions to comply with regulatory requirements.

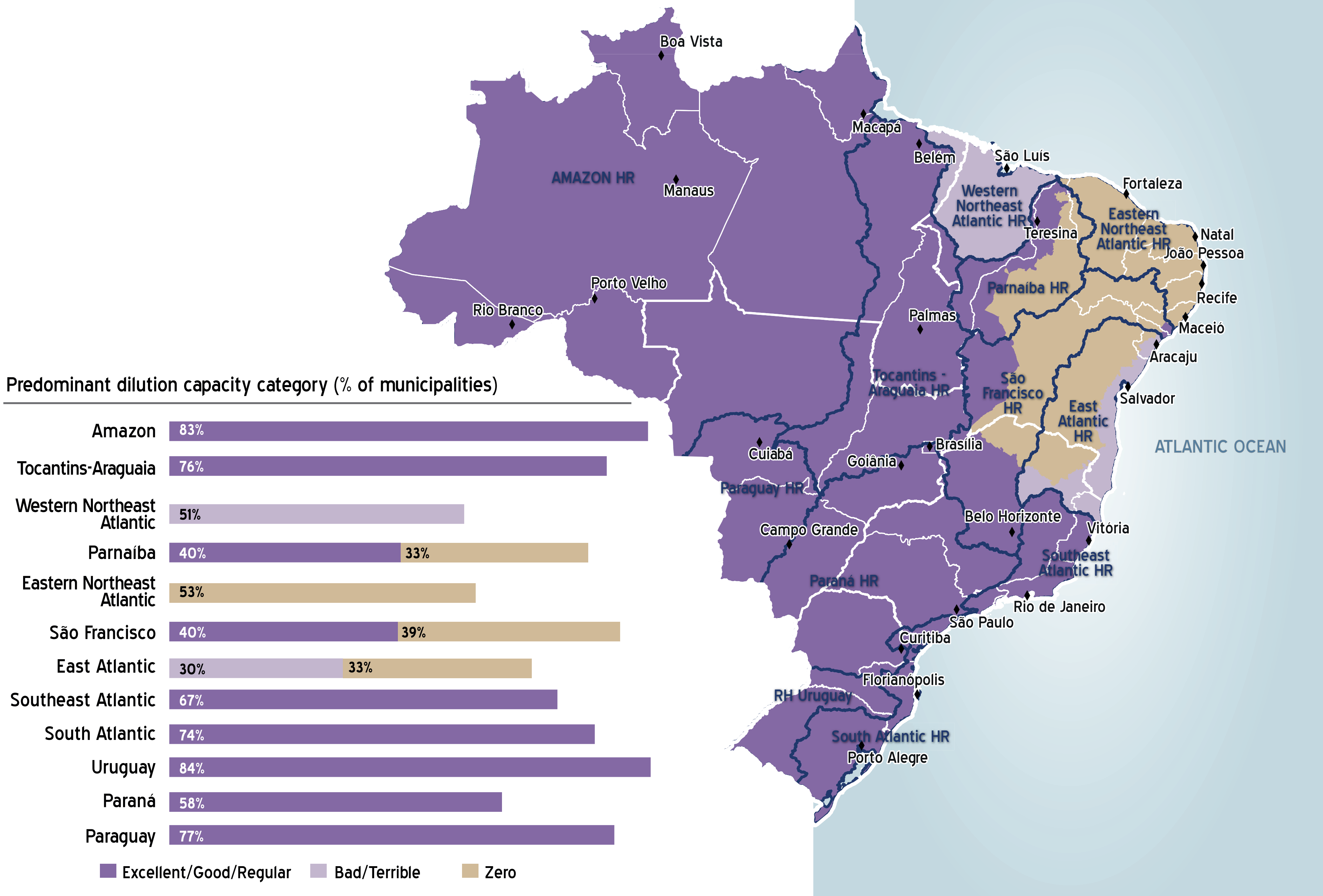
In addition to the critical situation of many municipalities located in the semiarid region, with zero flow for the dilution of treated wastewater, the states of Minas Gerais and São Paulo also need to be highlighted, since they have the largest number of municipalities and population contingent near water bodies with bad or terrible dilution capacity.

When observing the Hydrographic regions, the Paraná HR stands out with the largest number of municipalities and largest population with a bad/terrible dilution flow. In other words, it is HR that shows the highest need for advanced sewage treatment (efficiency over 80%) or complementary solutions to improve the condition of its water resources.

At the other extreme, we have the Amazon HR with high water availability and most of its municipalities requiring only conventional sewage treatment to keep their rivers in Class 2 classification.

The Parnaíba, the Eastern Northeast Atlantic, the São Francisco and the East Atlantic HRs have the fact that they have municipalities with zero or poor water availability in common since they are all located in the semiarid region. These municipalities require sewage treatment with high pathogen removal or with disposal in the soil, since the treated effluent will in many cases be the only available water for downstream use.

ASSESMENT OF THE CAPACITY TO DILUTE SEWAGE BY HYDROGRAFIC REGION



SEWAGE DILUTION CAPACITY BY HYDROGRAPHIC REGION

4 | SEWAGE TREATMENT PLANNING AND INVESTMENTS

4.1 | EVALUATION AND DEFINITION OF THE REQUIRED TREATMENT

4.2 | COLLECTION AND TREATMENT COSTS

4.1 | EVALUATION AND DEFINITION OF THE REQUIRED TREATMENT

The wastewater analysis of the water bodies was also designed with the 2035 horizon and based on the projected urban population and on the premise of universalization of sewage systems. The coverage level for the collection and treatment with the horizon of 2035 was considered equal to or over 90%, and are complemented by individual solutions (septic tanks). In turn, the same individual solution indexes currently observed in the municipalities were used for the future projection, except if they are higher than 10%.

The urban population and respecting remaining organic load projections (expressed in BOD) were used in this future impact analysis of sewage discharge into water resources.

The water quality modeling, considering the interaction between the discharges from all cities and using the hydrographic basin as an analysis unit, provided subsidies for the definition of the required efficiencies, based on the water class limits established by CONAMA Resolution no. 357/2005.

BOD removal was then determined as necessary for each existing or planned STP from the model, organized by conventional (60 to 80% efficiency) or advanced (above 80%) processes. Treatments with less than 60% efficiency were not considered, even when the receiving body had high water availability, although this flexibility is foreseen in resolution CONAMA No. 430/2011. Additionally, the analysis was expanded by considering the potential negative effects of phosphorus and nitrogen loads.

The BOD modeling results, which considered the cumulative effect of upstream sewage loads, were confronted with the solution required in each city when individually analyzed, without the influence of the other discharges. When differences were identified between the model and individual analysis results with respect to requiring an increase in the mandatory efficiency, municipalities were characterized by the need for a joint solution. However, the required efficiencies identified from water quality modeling were maintained as the solution adopted for cost estimates.

In cases where the maximum efficiency of organic load removal was not sufficient to meet the legal limitations, the municipalities were characterized by the need for complementary solutions, such as the discharge to land or re-use of the effluent. A significant part of the municipalities of the Brazilian semiarid region are in this situation, considering the intermittent flow in a great part of the receiving bodies.

Since these municipalities are regarded as extreme cases in need of complementary solutions, this group of municipalities has been separately characterized.

As a product of this analysis, these municipalities were organized according to the types of effluent treatment and final solutions for destination, as follows:

- **Type 1 (Conventional Treatment Solution):** a municipality whose main receiving body has enough water capacity to dilute the sewage, with BOD concentrations within the Class 2 limits with minimum treatment (removal between 60% and 80%).
- **Type 2 (solution with advanced treatment):** a municipality whose main receiving body requires high BOD removal (greater than 80%) to fit the Class 2 requirements. This occurs in municipalities with receiving bodies that have low sewage dilution capacity, where the BOD removal solution chosen is adequate.
- **Type 3 (Semiarid solution):** a municipality whose main receiving body is intermittent or ephemeral and is located in the Brazilian semiarid region. In addition to the BOD removal requirements, it is important to consider the possibility of reusing the treated effluent and/or prioritizing treatment processes resulting in high removal of pathogenic microorganisms. Due to water scarcity, effluents can be converted by the population into alternative sources of water and thus pose a risk to public health.

  Therefore, health concerns lead to the search for solutions with greater removal of pathogens. Another option for municipalities located in the Semiarid is the discharge effluents into the soil (groundwater or surface).
- **Type 4 (Joint Solution):** a municipality whose main receiving body is impacted by upstream sewage discharges which hamper the body's receiving capacity and make downstream discharges impossible. In this case, the levels of sewage treatment adopted in each municipality require a broader discussion, including between the municipalities concerned, in order to reach a joint solution considering their different institutional and financial capacities.
- **Type 5 (Complementary Solution):** a municipality whose main receiving body lacks dilution capacity because of the difference between the water availability and organic load discharged. A typical example of this is the case where the municipalities are in headwater regions. Additional solutions are necessary, such as: assigning a new receiving body or effluent treatment of wastewater discharge into the soil, among other solutions.

Concerning reuse, the Ministry of Cities in partnership with ANA, the Ministry of Integration, and the Ministry of the Environment, are conducting a specific project aimed at proposing an action plan for the institution of a policy to reuse sanitary effluents treated in Brazil. Some of the project stages are: raising the reuse potential, stressing difficulties and implementation potential; defining of quality standards for water reuse; evaluation of available technologies; discussion of institutional aspects; and proposing funding models and/or tax incentives.

MAIN REGIONS OF INTEREST FOR WATER RESOURCE MANAGEMENT

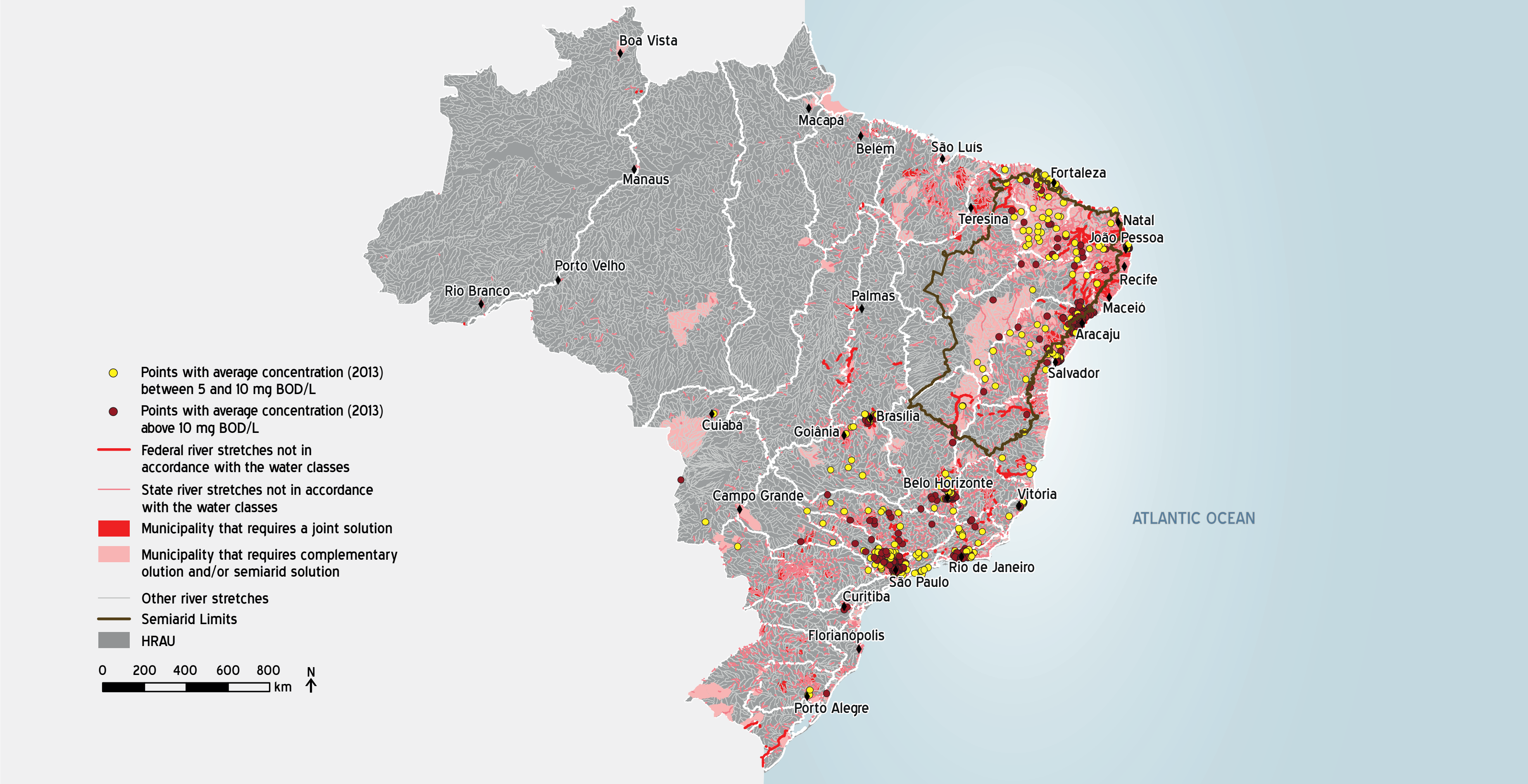
One of the objectives of the National Water Resources Policy is the integrated and rational use of water resources for sustainable development. In the case of sewage treatment, rational use occurs by discharging treated sewage that is compatible with the dilution capacity of the receiving body and with the main use for that water body.

During the definition of the treatment solution types, municipality groups that share the same hydrographic basins and that demand a joint solution were identified, these basins are of special interest for Water Resource Management. Among the basins with these characteristics some with historic action by The National Water Resources Management System - SINGREH integrating agencies, such as the Tietê river basins, including PCJ basins (São Paulo and Campinas region), Sinos (in the state of Rio Grande do Sul), Alto Iguaçu (on the state of Paraná), Paraíba do Sul (on the border between the states of São Paulo, Minas Gerais and Rio de Janeiro), Velha (in the state of Minas Gerais), Descoberto (on the outskirts of the Federal District), Meia Ponte (in the state of Goiás), and Ipojuca (in the state of Pernambuco), among others.

In addition to sewage treatment solutions for these municipal basins, it is also relevant to discuss solutions for the municipalities located in river headwater regions (that require a complementary solution because of the discrepancy between population and water availability) and solutions for basins located in the semiarid region, in this latter case due to the high occurrence of intermitent rivers and weirs.

Based on crossing data of river stretches conformity with the water classes (2013), the BOD monitoring data (2013) and the complexity of sewage treatment required for the necessary BOD removal (2035), it is possible to identify a significant occurrence of high BOD value and river stretches that are not in accordance with the classes. Such facts occur in the municipalities where the sewage treatment solutions foreseen in the *Sewage ATLAS* are more complex. This verification reinforces the importance of sewage treatment for the quality of Brazilian surface water.

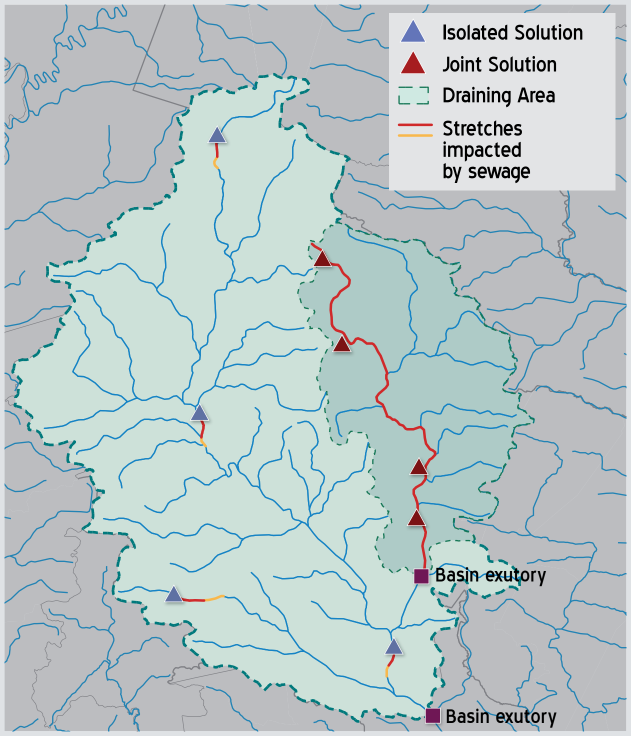
SEWAGE IMPACT ON WATER BODIES AND THE COMPLEXITIES OF TREATMENT SOLUTIONS



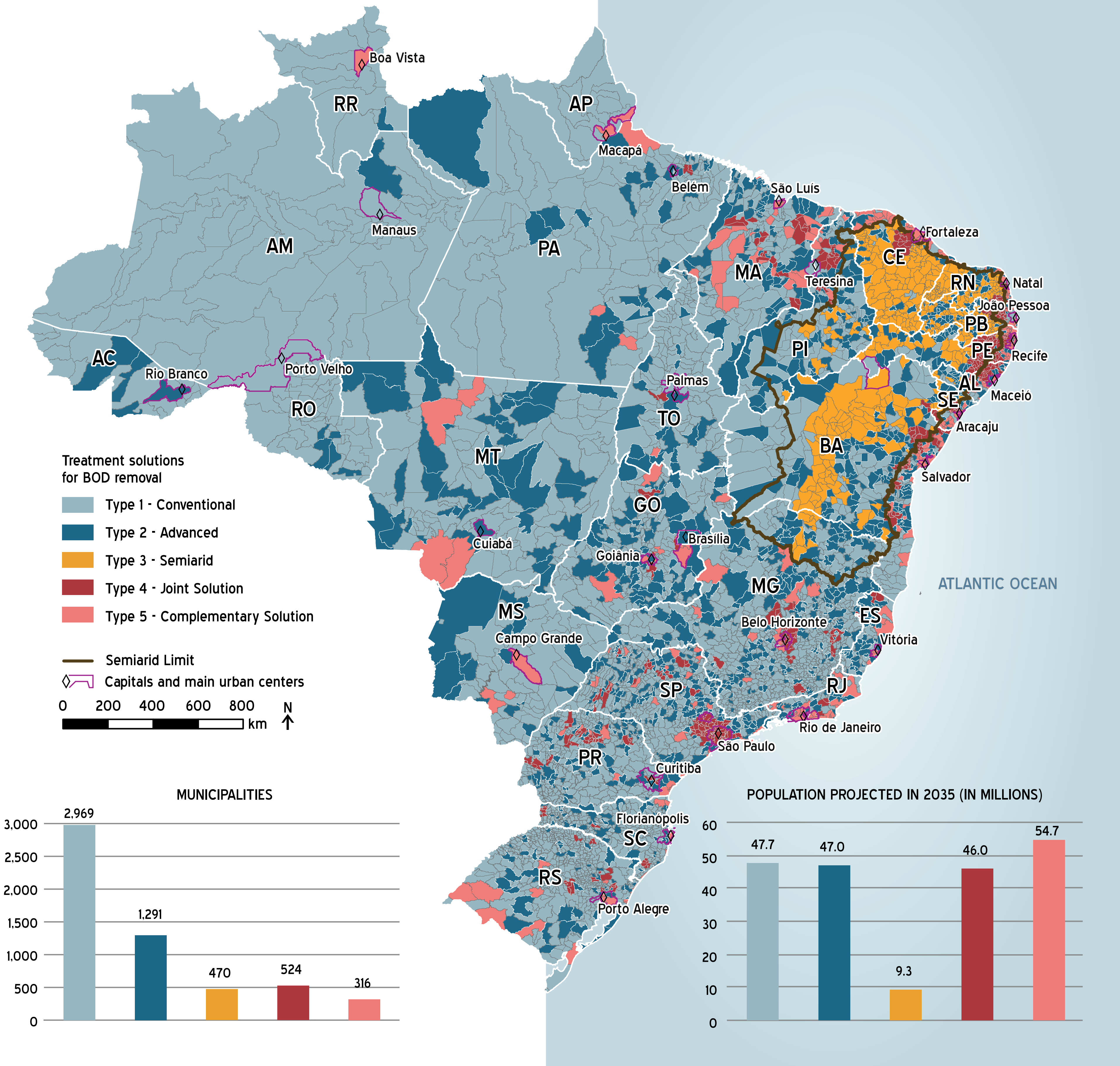
TREATMENT COMPLEXITY CONSIDERING BOD REMOVAL

Does the receiving body have a dilution capacity superior to 2,000 L/inhab./day?

- YES → **TYPE 1 - CONVENTIONAL:** Treatment compatible with the receiving body's class, considering the minimum requirements provided for CONAMA's resolutions No. 430/2011 (60% - 80%)
- NO → **Is it an intermittent or ephemeral river?**
  - YES → **TYPE 3 - SEMIARID:** Treatment with a good efficiency in removal of micro-organisms and to verify the possibility of reuse.
  - NO → **Is the municipality impacted by sewage discharges from other municipalities?**
    - YES → **TYPE 4 - JOINT SOLUTION:** Negociation to define treatment solutions covering the municipalities concerned
    - NO → **Is it enough to increase the efficiency of the treatment in order to attend the class requirements?**
      - YES → **TYPE 2 - ADVANCED:** Adoption of treatment modality of high BOD removal. (removal > 80%)
      - NO → **TYPE 5 - COMPLEMENTARY SOLUTION:** Search for additional solutions. E.g., a new receiving body, change of river class, soil discharge, reuse, or submarine emissary.



TREATMENT COMPLEXITY CONSIDERING BOD REMOVAL



The existence of a downstream reservoir of domestic sewage discharges requires the assessment as to whether treatment technologies that remove phosphorus are necessary. The total phosphorus simulations were carried out for the horizon of 2035, considering a database produced by ANA for 854 lakes and reservoirs distributed throughout the country. Phosphorus is an important element in the eutrophication of these water bodies in temperate climate regions and its excessive concentration unbalances the growth of algae with negative consequences for water quality.

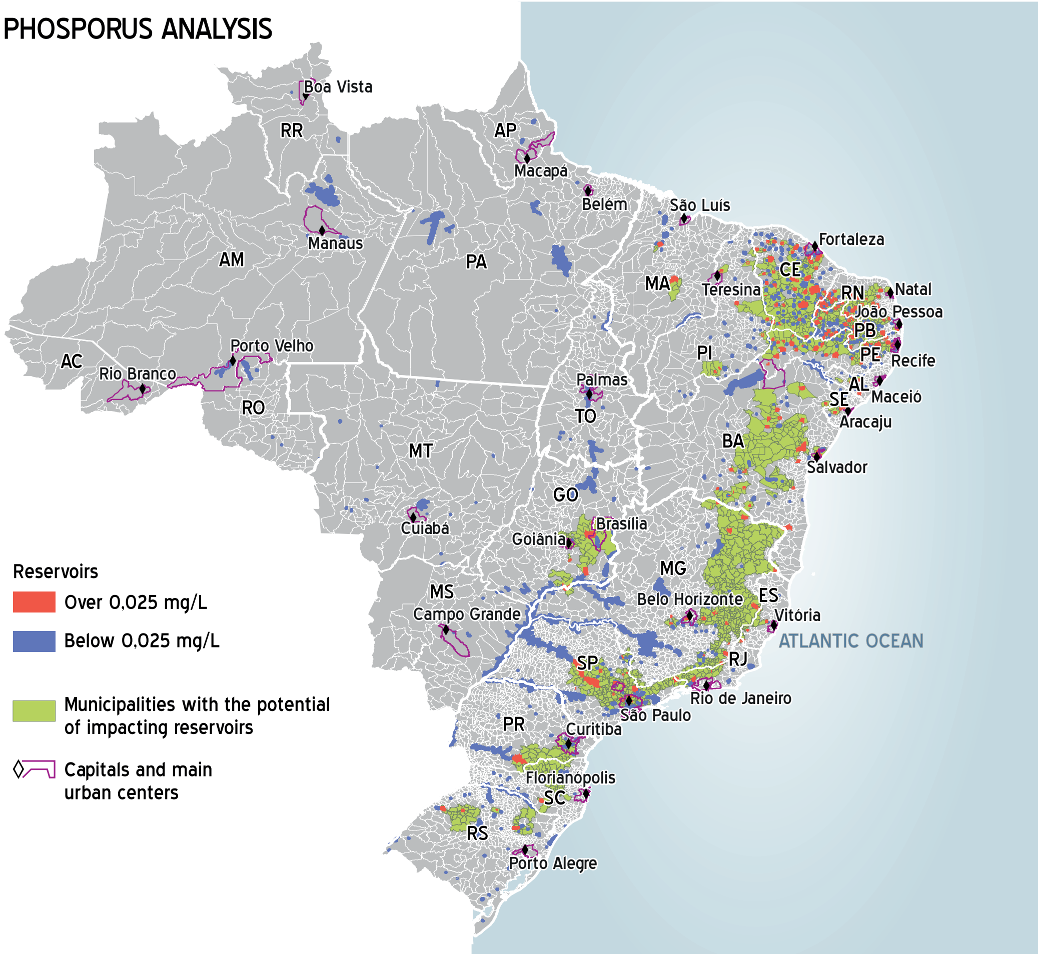
About 71% of the assessed lakes and reservoirs had phosphorus concentrations below 0.025 mg P/L, indicating in these cases, a low potential impact of the phosphorus load from the urban sewage discharge. In the remaining 250 lakes and reservoirs, the concentrations obtained were above this limit. The municipalities located in the contribution area of each reservoir in this group, which is responsible for the phosphorus supply, have been identified. For these municipalities the need for assessing the necessity of joint solutions for the removal of the phosphorus load was pointed out. Sewage treatment processes used to remove phosphorus (biological or chemical) generally require higher implementation costs and greater operational technical capacity. It is therefore appropriate to have negotiations between the municipalities that are in this situation, so that each one can contribute to the overall solution.

In the total nitrogen simulations carried out for the 2035 horizon, the focus was on the protection of withdrawal for public supply, using the information contained in the Brazil ATLAS: Urban Water Supply. The existence of downstream withdrawal requires research to define the need for the use of treatment processes including biological nitrification and denitrification, with a view to reducing the concentration of nitrates in waters for public supply. In addition to the issue related to the unwanted presence of nitrate in water intended for public supply, nitrogen and phosphorus are essential nutrients for algae growth and, in high concentrations, can lead to the eutrophication of water bodies.

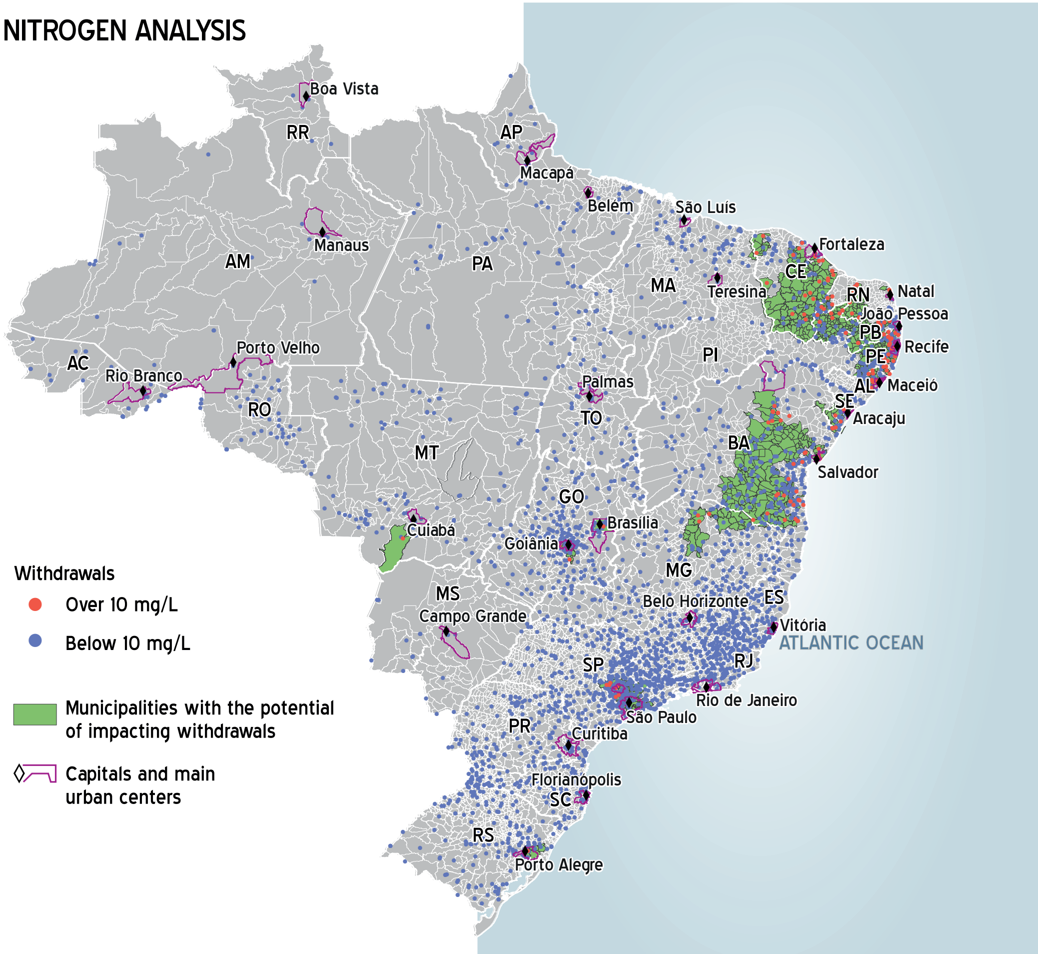
Of the 3,277 withdrawal points assessed, the results showed 5% nitrogen concentrations above the potability standard, i.e. above 10 mg N/L. The municipalities whose discharges contribute to downstream withdrawals that exceed the nitrogen concentration limit were also identified. The need for joint solutions to remove this nutrient was indicated for these municipalities.

Based on the current condition of the three parameters analyzed by the *Sewage ATLAS* (BOD, phosphorus and nitrogen), the municipalities were classified according to the required efficiency of BOD removal and the need for attention regarding the removal of phosphorus and nitrogen. This classification was based on the search for solutions that allow the improving of water quality and, consequently, guarantee the other downstream uses, considering the dilution capacity of the receiving bodies and the potential impact of the discharges on the basins where they occur.

PHOSPORUS ANALYSIS



NITROGEN ANALYSIS



A great number of municipalities in the Northeast region require more complex solution for treating sewage. This is due to the semiarid region's characteristics, with predominance of rivers with low or zero dilution capacity and many weirs. At the opposite end are the municipalities in the northern region, where the great majority of the receiving bodies have high dilution capacities and consequently require less complex treatment processes.

The southeastern region has the second largest concentration of municipalities that require more complex solutions. Many municipalities demand integrated analysis to search for global solutions for sewage treatment related problems. In general, this solution is often needed in densely populated areas, such as capitals and their surrounding areas.

In the southern and midwestern regions, less complex treatment solutions are more common, except for municipalities located in the headwater regions or with greater concentrations of population.

SEWAGE TREATMENT COMPEXITY

GEOGRAPHIC REGION	FEDERATION UNIT	LESS COMPLEX		MORE COMPLEX								COMPLEMENTARY ANALYSIS OF THE NUTRIENTS*			
		TYPE 1 - CONVENTIONAL		TYPE 2 - ADVANCED		TYPE 3 - SEMIARID		TYPE 4 - JOINT SOLUTION		TYPE 5 - COMPLEMENTARY SOLUTION		FOCUS ON PHOSPHORUS		FOCUS ON NITROGEN	
		Municipalities	Population (thous. inhab.)	Municipalities	Population (thous. inhab.)	Municipalities	Population (thous. inhab.)	Municipalities	Population (thous inhab.)	Municipalities	Population (thous. inhab.)	Municipalities	Population (thous. inhab.)	Municipalities	Population (thous. inhab.)
NORTH	Acre	18	339.8	4	476.6	-	-	-	-	-	-	-	-	-	-
	Amapá	15	348.0	-	0.0	-	-	-	-	1	599.0	-	-	-	-
	Amazonas	61	4,077.8	1	20.7	-	-	-	-	-	-	-	-	-	-
	Pará	107	4,211.3	32	2,559.8	-	-	2	220.9	3	148.2	-	-	-	-
	Rondônia	47	1,585.0	5	109.6	-	-	-	-	-	0.0	-	-	-	-
	Roraima	13	107.9	1	6.1	-	-	-	-	1	413.6	-	-	-	-
	Tocantins	116	853.6	20	592.6	-	-	2	61.8	1	7.7	-	-	-	-
	TOTAL	**377**	**11,523.4**	**63**	**3,765.4**	**-**	**-**	**4**	**282.7**	**6**	**1,168.5**	**-**	**-**	**-**	**-**
NORTHEAST	Alagoas	12	176.2	37	560.1	10	348.8	33	533.6	10	1,348.1	8	121.4	33	1,745.3
	Bahia	124	2,545.3	123	2,821.4	95	2,300.1	46	681.1	29	4,758.6	117	6,410.5	186	7,900.8
	Ceará	10	156.0	19	464.9	116	2,817.3	10	208.5	29	4,687.4	103	2,611.3	115	2,744.3
	Maranhão	92	2,050.2	77	1,066.3	0	0.0	21	322.2	27	2,060.6	5	175.0	0	0.0
	Paraíba	9	224.0	63	318.0	86	1,275.1	50	467.6	15	1,302.7	150	1,758.6	170	1,865.5
	Pernambuco	8	470.2	39	893.7	31	714.1	73	2,422.3	34	4,327.4	73	1,763.0	85	2,667.5
	Piauí	95	1.509.0	84	442.8	15	236.6	22	197.4	8	96.5	16	164.2	1	3.7
	Rio Grande do Norte	6	345.7	35	259.7	97	1,282.6	14	117.4	15	1,285.9	83	1,693.8	68	571.0
	Sergipe	11	160.4	21	148.9	9	154.6	15	278.7	19	1,378.4	5	215.6	20	441.5
	TOTAL	**367**	**7,637.0**	**498**	**6,975.8**	**459**	**9,129.2**	**284**	**5,228.8**	**186**	**21,245.6**	**560**	**14,913.4**	**678**	**17,939.6**
SOUTHEAST	Espírito Santo	28	604.7	39	2,187.8	-	-	4	40.3	7	1,328.2	11	183.3	-	-
	Minas Gerais	580	7,113.5	204	5,207.3	11	174.6	44	6,087.1	14	1,891.9	286	6,334.3	33	764.9
	Rio de Janeiro	35	1,167.2	28	1,681.4	-	-	4	300.1	25	14,986.8	27	1,712.5	-	-
	São Paulo	351	5,501.9	166	8,428.5	-	-	103	29,537.7	25	4,536.3	193	35,347.5	81	28,482.2
	TOTAL	**994**	**14,387.3**	**437**	**17,505.0**	**11**	**174.6**	**155**	**35,965.2**	**71**	**22,743.2**	**517**	**43,577.6**	**114**	**29,247.1**
SOUTH	Paraná	275	3,751.6	74	4,542.9	-	-	40	2,128.9	10	1,140.8	37	4,094.8	-	-
	Rio Grande do Sul	405	3,405.5	54	2,285.1	-	-	20	1,135.9	18	3,694.1	37	1,457.8	8	2,893.3
	Santa Catarina	230	2,732.1	46	2,821.6	-	-	12	405.6	7	1,464.5	38	698.0	-	-
	TOTAL	**910**	**9,889.2**	**174**	**9,649.6**	**-**	**-**	**72**	**3,670.4**	**35**	**6,299.4**	**112**	**6,250.6**	**8**	**2,893.3**
MIDWEST	Federal District	0	0,0	1	3,860.0	-	-	-	-	0	0.0	1	3,860.0	1	3,860.0
	Goiás	162	1,317.3	64	3,353.3	-	-	9	858.0	11	1,922.4	44	4,660.4	8	2,650.3
	Mato Grosso	98	1,752.8	39	1,458.7	-	-	-	-	4	201.7	-	-	1	24.8
	Mato Grosso do Sul	61	1,233.3	15	468.4	-	-	-	-	3	1,148.0	-	-	-	-
	TOTAL	**321**	**4,303.4**	**119**	**9,140.4**	**-**	**-**	**9**	**858.0**	**18**	**3,272.1**	**45**	**8,520.4**	**10**	**6,535.1**
BRAZIL		**2,969**	**47,740.3**	**1,291**	**47,036.2**	**470**	**9,303.8**	**524**	**46,005.1**	**316**	**54,728.8**	**1,234**	**73,262.0**	**810**	**56,615.1**

* Municipios y población ya contempladas en las tipologías anteriores.

4.2 | COLLECTION AND TREATMENT COSTS

In order to contribute to the solving of the problems related to discharge of urban sewage into water bodies in an articulated manner, the *Sewage ATLAS* verified alternatives for the 5,570 Brazilian cities, which range from the expansion of treatment efficiencies in existing systems when necessary to propose solutions for cities that do not currently have access to sewage treatment.

The specific case of each city or region was considered for these alternatives as well as the current classes of the receiving bodies. In addition, the universalization of the services was always considered for the 2035 horizon and the treatments were proposed with a minimum 60% organic matter removal efficiency, even when the river had enough flow to dilute the wastewater without treatment.

Based on the identification of the required removal efficiencies and the municipalities that impact withdrawal and reservoirs, sewage collection and treatment curves were calculated to estimate the financial resources needed to universalize the sewage treatment services. It should be noted that the estimate of the value required for the universalization of sewage treatment services did not consider costs associated with the following aspects:

- Construction and maintenance of septic tanks, used in individual solutions;
- Replacement of old collecting networks that cannot be used in new sewage treatment systems or replacement of mixed or unit collecting systems with complete separation systems;
- Suitability of the treatment for combined sewage (rainwater and wastewater);
- Recovery and/or processing of by-products such as sludge and biogas.

The cost analyses both for collection and treatment, involved the surveying of existing projects to obtain curves that provided the average cost per inhabitant for the desired service.

In the case of treatment, one selected the most representative technical alternatives for each removal class adopted by the *Sewage ATLAS* and used in the cost estimate for each municipality. It is noted, however, that there are several types of treatment available for the same removal efficiency and that the choice of the process to be used must be compatible with the reality of the location.

For municipalities that require a joint sewage treatment solution, the costs adopted referred to the treatment efficiency required according to the water quality modeling results, considering the upstream to downstream logic, but without taking into account what would be the best possible arrangement found after the discussion between the basin's municipalities.

The collection costs estimation representsa more complex approximation in relation to all variables that influence the determination of an average per capita cost. Factors such as population concentration, topography, type of soil and average number of persons per household can have a substantial influence on the cost of implementing a sewage collection network. Due to the diversity observed throughout Brazil, these factors show several regional variations. The results obtained should be treated with caution since the *Sewage ATLAS* is a planning instrument.

COMPLEMENTARY ACTIONS

Some actions did not consider the calculation of the necessary costs for universalizing sanitary sewage treatment services in Brazil:

- **Construction and maintenance of septic tanks:** the use of septic tanks is a good solution in places where the implementation of collection networks is not feasible. Should this system (septic tank and biological filters or pit latrines) be properly implemented and operated, it will generate effluents of a quality compatible with those produced by STP secondary treatment processes. For this reason, this type of solution is therefore considered appropriate. The treatment plants analyzed or proposed by the *Sewage ATLAS* have enough capacity to treat sewage from the cleaning of septic tanks. However, the cost of building and maintaining these tanks was not considered.

- **Replacement of old collection networks or replacement of mixed collecting systems:** many cities have old collection networks or mixed systems that may be used in a strategy of gradual transformation of the current situation into the ideal situation. The cost of the removal, including the construction of a new collection network, was not considered in the *Sewage ATLAS*.

- **Combined sewage treatment:** algunas Some cities have mixed systems (rainwater and sewage in the same pipeline) whose combined sewage can be treated as an intermediate solution until the construction of the complete separation system. The necessary adjustments to the treatment process for such cases were not accounted for in the present document.

- **Exploitation and/or processing of by-products:** el recovery of by-products such as slime and biogas, contributes to the environmental and economic sustainability of sewage treatment plants. The technological costs for the recovery and/or processing of by-products has not been addressed, for these costs depend on a more unit specific assessment. The final discharge of sludges stemming from sewage treatment must be effected carefully and must contemplate the potential contamination risk to the environment.

COST CURVES

The cost and budget evaluation of the interventions proposed in the *Sewage ATLAS* was carried out for all components of the sewage system. The existing costs of projects considered are the ones updated by the National Construction Cost Index - INCC (2015) and regionalized for collection and transport by the National Systems of Civil Construction Costs and Indexes - SINAPI.

Sewage collection and transport costs:

Based on the implementing costs for collecting networks, sewage pumping stations, discharge lines and interceptors, simulations were carried out for various city ports, with a proportional population increase considering their specific sizes. The purpose of the simulation was to calculate an average cost per capita for sewage collection and transport, to permit projection of cost curves.

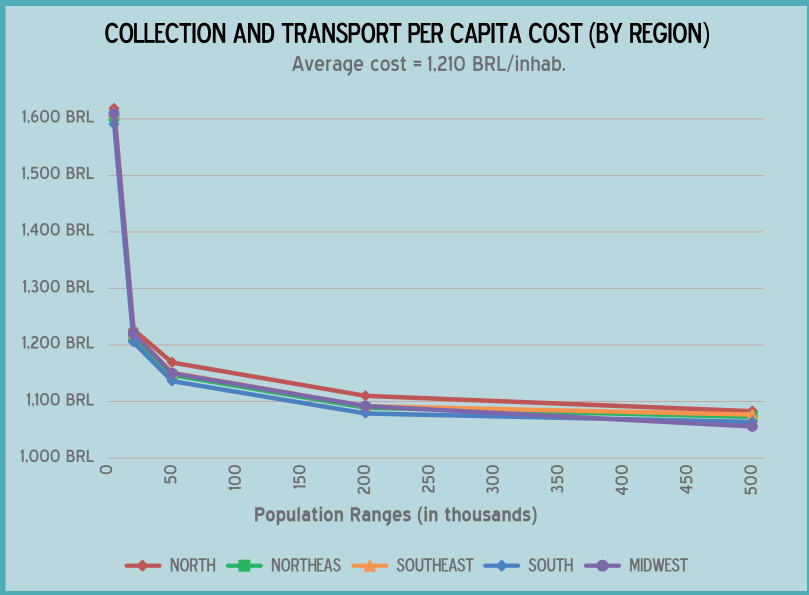
Sewage Treatment Solution Costs:

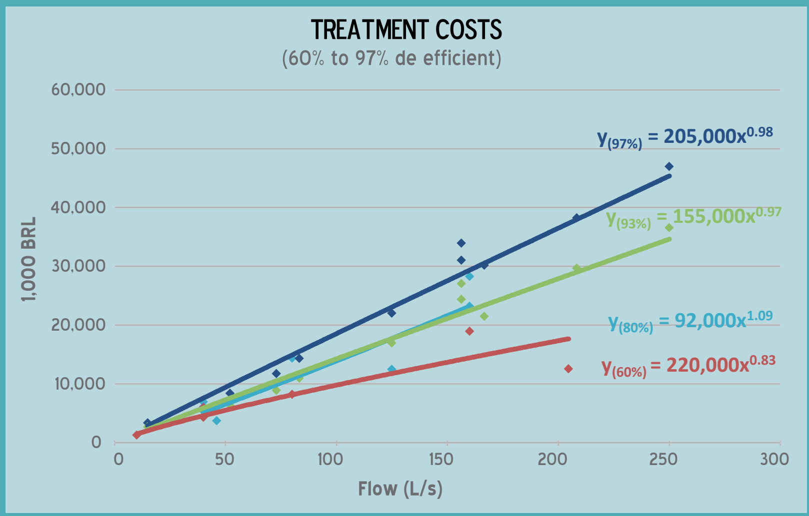
The methodology for the determination of treatment plant costs considered four treatment processes with different BOD removal efficiencies. For each treatment process a cost curve was presented and adopted based on the efficiency required to meet the limits of the receiving bodies.

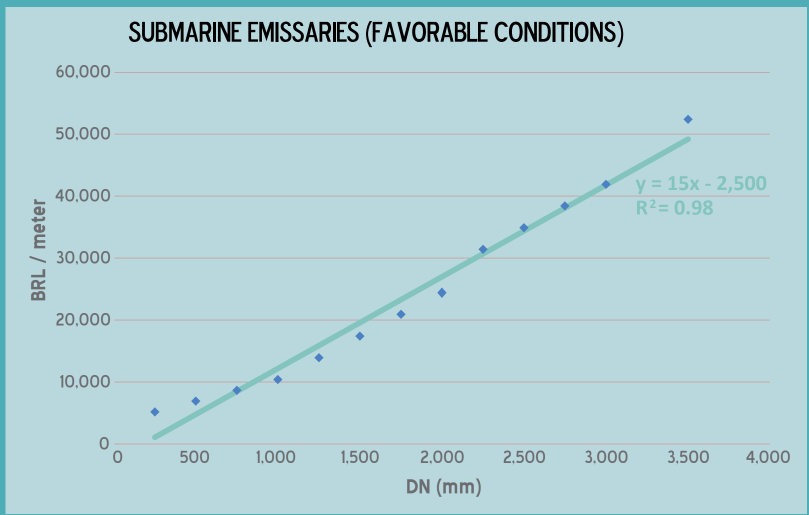
When the required solutions involved processes with high efficiency of organic load removal, alternative costs that took into account the discharging of treated sewage into downstream regions or into another receiving body were further assessed. In such cases, the implementation costs were calculated for transporting the treated sewage to the alternative discharge location, besides calculating costs of the new removal efficiency. As a result, the less costly solution was selected.

Costs of submarine emissaries:

For coastal municipalities, whose rivers did not have enough water availability for the dilution of sewage discharged, the implementing of submarine emission was considered as a solution, preceded by efficient treatment to remove organic loads between 60% and 80%.In order to determine the costs of these emissions, the costs present in the literature have been updated, taking into account normal tide conditions (wave amplitudes, depths and surf zone).







CAPITALES Y PRINCIPALES AGLOMERACIONES URBANAS

Almost all the main urban areas need adjustments, adjustments in their sewage treatment systems.

The 57.4 billion BRL foreseen for these regions (about 38% of the country's total investments will benefit 182 urban centers, where almost half of the Brazilian urban population (46%) lives. Of the total resources foreseen for sewage treatment interventions in these urban centers, over 80% (47.5 billion BRL) are associated with municipalities with services provided by state companies.

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The universalization of urban sewage collection amounts to 29 billion BRL in these regions. The 18.5 billion BRL investment foreseen for improving or implementing sewage treatment plants requires a minimum efficiency of 80% BOD removal in 146 of the 182 municipalities.

SEMIARID REGION

The sewage treatment resources foreseen for the Brazilian semiarid region's municipalities total 15 billion BRL (about 10% of the total foreseen for the country), focusing on the states of Bahia and Ceará, which account for more than half of this amount.

In the semiarid region, 470 municipalities with intermittent or ephemeral receiving bodies have been identified and, although the cost estimates considered only processes based on BOD removal with 80% efficiency, it is important that for the design of STPs processes with high pathogen removal rates and soil discharge or effluent reuse possibilities are evaluated.

The municipalities that receive services from state companies cover 70% (10.5 billion BRL) of the investments planned for the semiarid region. Another 3.1 billion BRL is associated with municipalities with an urban population of less than 50,000 inhabitants and without the delegation of this service.

The investment amounts necessary to universalize sewage treatment services in Brazil for the planning horizon of 2035, was estimated at around 149.5 billion BRL. The sewage treatment investment estimates contained in the PLANSAB for the period 2014-2033 amounted to 181.9 billion BRL, of which 47,6 million BRL (26.2% of the total) referred to the expansion of hydro-sanitary facilities and the replacement of the sewage collection systems or sewage treatment plants. These costs are not included in the Sewage ATLAS estimates. Considering this, the PLANSAB expected value results amount to 134.3 billion BRL.

Out of all the investments estimated by the *Sewage ATLAS*, the investments destined for sew-age collection represented more than twice the amount foreseen for treatment. Similar values are found in the PLANSAB, the amount destined for the expansion of collection and interception systems has been estimated at 102,1 billions of BRL. The PLANSAB also foresees 30.8 billion BRL for the replacement of the sewage collection network.

The work for the implementation of the collection network is a step that requires higher initial investment and the Brazilian reality corroborates the high values presented, considering less than 50% of the population of 3,301 municipalities has access to a sewage collection network.

The value estimated for sewage treatment in the *Sewage ATLAS* was 47.6 billion BRL, while in PLANSAB the estimated amount was 32.3 billion BRL. Even with the additional cost foreseen in the PLANSAB for replacing the sewage treatment system at 5.3 billion BRL, the higher value es-timated by the *Sewage ATLAS* is justified by the analysis of the dilution capacity of receiving bodies, the accumulation of loads in the upstream basins and, consequently, the detailing of the treatment efficiencies required in each municipal seat.

Most of the estimated investments are for the northeastern region, where about 70% of the investments represent the implementing collection networks. The states of Pernambuco, Bahia and Ceará represent together 56% of the resources estimated for the region.

In the southeastern region the estimated value represents about 29% of the Brazilian total. Almost 7 billion BRLcorrespond to the four capitals, over 15% of the total for the region. 612 cities with large urban concentrations in the region require sewage treatment with load efficiency removal of over 80% and demand 30.1 billion BRL of the total of 43.5 BRL estimated.

The southern region represented the third largest amount estimated. Collection network interventions represented 71% of this value, distributed in similar amounts between the three states in the region. 940 cities in the region demand solutions with load removal efficiency below 80%.

The states of Amazonas and Pará represent 67% of the investments estimated for the northern region. The capitals, Manaus and Belém, represent, together, over a third of the necessary investment for both states (4.2 billion BRL). About 14.8 billion BRL were foreseen for cities where the solution requires up to 80% removal of BOD load.

The state of Goiás corresponds to the largest investment volume provided for the midwestern region, 44% of the total. Urban centers with less than 80% BOD load removal necessity are predominant in the region. However, these cities represent only 31% of the investments (5.4 billion BRL for 328 municipalities).

INVESTMENT REQUIRED IN BRAZIL BY STATE AND BY GEOGRAPHIC REGION

GEOGRAPHIC REGION	FEDERATION UNIT	NUMBER OF MUNICIPALITIES	URBAN POPULATION (in thous. inhab.)	REQUIRED INVESTMENT (in billions of BRL)		
				Collection	Treatment	Total
NORTH	Acre	22	562.8	697	144	841
	Amapá	16	658.8	904	232	1,136
	Amazonas	62	3,014.2	3,390	916	4,306
	Pará	144	5,611.0	6,804	1,798	8,602
	Rondônia	52	1,277.3	1,706	367	2,073
	Roraima	15	374.1	517	59	577
	Tocantins	139	1,169.2	1,328	275	1,603
	TOTAL	**450**	**12,667.4**	**15,346**	**3,792**	**19,138**
NORTHEAST	Alagoas	102	2,426.3	2,355	761	3,116
	Bahia	417	10,865.0	6,760	2,836	9,596
	Ceará	184	6,569.3	5,676	2,545	8,221
	Maranhão	217	4,283.4	4,947	1,724	6,671
	Paraiba	223	2,956.4	1,920	987	2,907
	Pernambuco	185	7,383.6	6,116	3,774	9,890
	Piauí	224	2,096.9	2,484	542	3,027
	Rio Grande do Norte	167	2,619.7	2,650	1,096	3,745
	Sergipe	75	1,616.8	1,647	926	2,573
	TOTAL	**1,794**	**40,817.4**	**34,555**	**15,191**	**49,746**
SOUTHEAST	Espírito Santo	78	3,136.5	2,215	1,008	3,222
	Minas Gerais	853	17,705.0	5,370	4,177	9,547
	Rio de Janeiro	92	15,922.1	5,729	5,455	11,185
	São Paulo	645	40,521.4	11,497	8,031	19,528
	TOTAL	**1,668**	**77,285.0**	**24,811**	**18,671**	**43,482**
SOUTH	Paraná	399	9,397.5	5,221	2,021	7,242
	Rio Grande do Sul	497	9,477.2	5,517	2,784	8,301
	Santa Catarina	295	5,557.4	5,847	1,794	7,641
	TOTAL	**1,191**	**24,432.1**	**16,584**	**6,599**	**23,183**
MIDWEST	Federal District	1	2,694.3	1,305	398	1,702
	Goiás	246	5,801.9	4,447	1,744	6,191
	Mato Grosso	141	2,617.2	2,908	757	3,665
	Mato Grosso do Sul	79	2,170.4	1,905	484	2,389
	TOTAL	**467**	**13,283.8**	**10,565**	**3,383**	**13,947**
BRAZIL		5,570	168,485.7	101,862	47,635	149,496

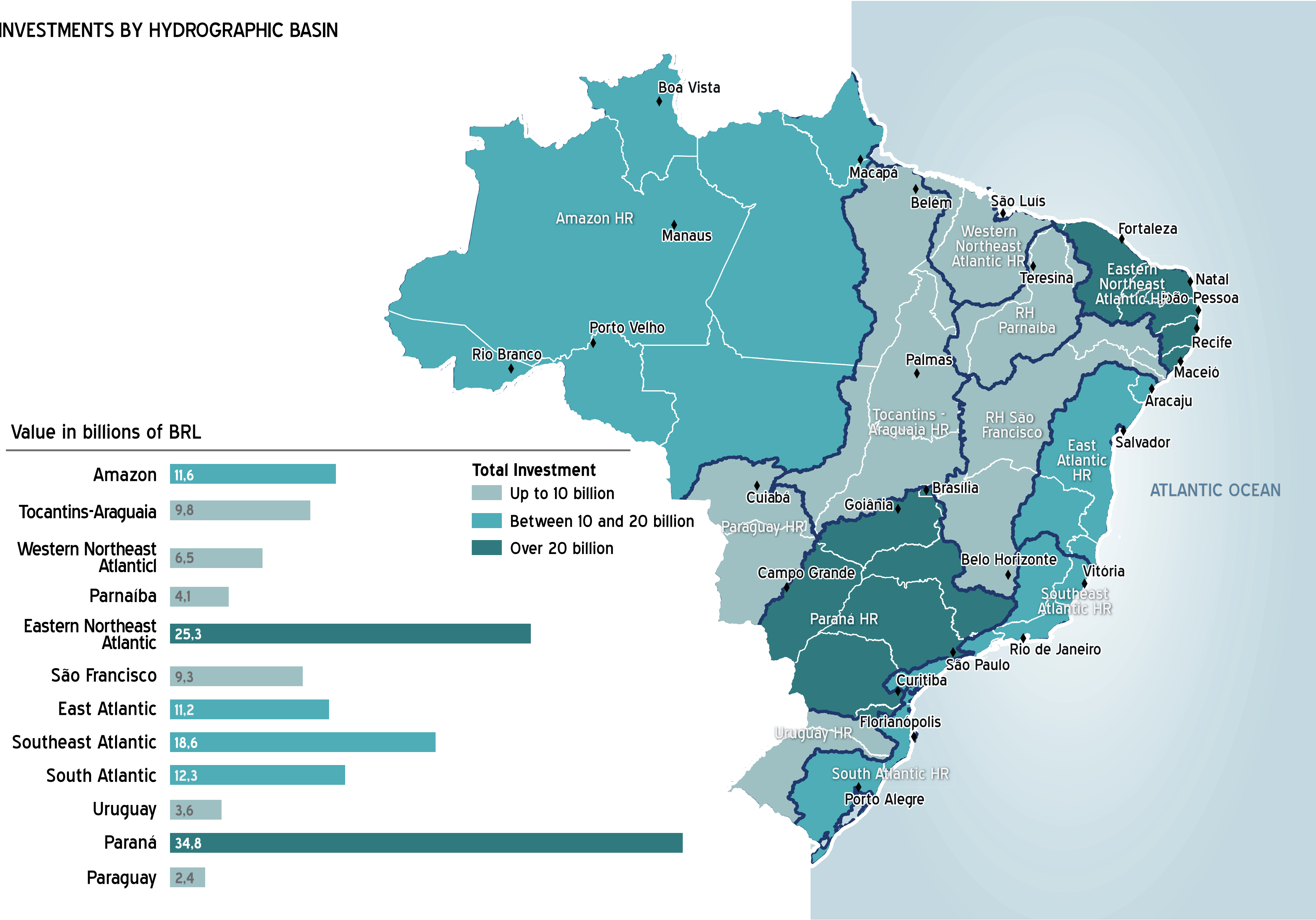
In the hydrographic regions, the largest investments required are in the Paraná HR (about 23% of the total). In spite of the higher level of the sewage collection and treatment services in this region, it is also densely populated and the coverage indexes are insufficient to achieve the load removal necessary to meet the receiving bodies' dilution capacity limits.

In this river basin, the estimated investments for sewage treatment considering processes of greater complexity (efficiency greater than 80%) represent 77.9% of the total estimated. This high percentage results from the largest capital and urban agglomerations in the country. The East Atlantic and Southeast Atlantic regions have similar characteristics.

The Eastern Northeast Atlantic HR is the second highest investment area required. In this hydrographic region, intermittent river stretches and cities with poor or inexistent services of collection and sewage treatment services predominate. In spite of the estimated costs pointing to higher investments in processes with efficiencies between 60 and 80%, it is essential to prioritize solutions compatible with the reality of the semiarid region.

At the opposite end, the Paraguay HR is the one that requires the least amount of investment, because it has a small population and good dilution capacity in the receiving bodies. Similar situations are found in the Amazon HR and the Tocantins-Araguaia HR. However, the estimated investments are high in these regions because they are predominantly made up of cities with poor or inexistent services of sewage collection and treatment.

INVESTMENTS BY HYDROGRAPHIC BASIN

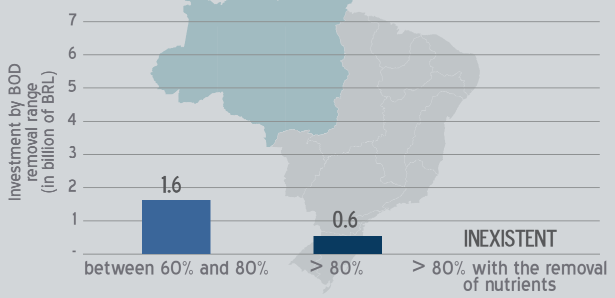


TOTAL INVESTMENT IN BRAZIL 149.5 BILLION

AMAZON HR

Total Investment: 11.6 billion BRL
Investment in Collection: 9.4 billion BRL

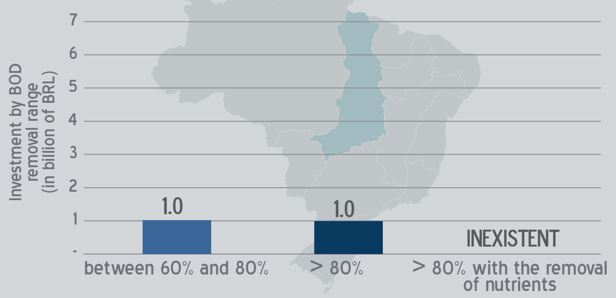
INVESTMENT IN TREATMENT: 2.2 BILLION BRL



TOCANTINS - ARAGUAIA HR

Total Investment: 9.8 billion BRL
Investment in Collection: 7.8 billion BRL

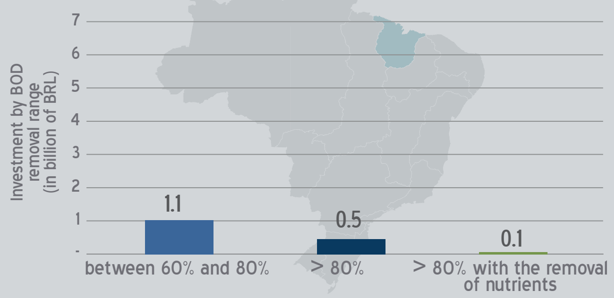
INVESTMENT IN TREATMENT: 2 BILLION BRL



WESTERN NORTHEAST ATLANTIC HR

Total Investment: 6.5 billion BRL
Investment in Collection: 4.8 billion BRL

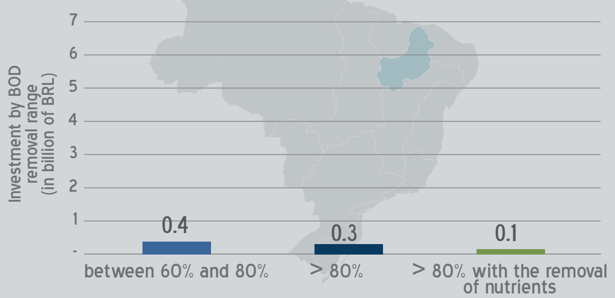
INVESTMENT IN TREATMENT: 1.7 BILLION BRL



PARNAÍBA HR

Total Investment: 4.1 billion BRL
Investment in Collection: 3.3 billion BRL

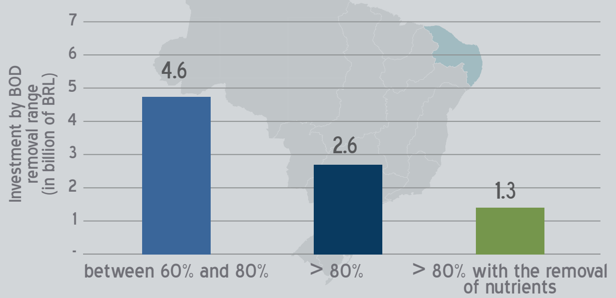
INVESTMENT IN TREATMENT: 0.8 BILLION BRL



EASTERN NORTHEAST ATLANTIC HR

Total Investment: 25.3 billion BRL
Investment in Collection: 16.8 billion BRL

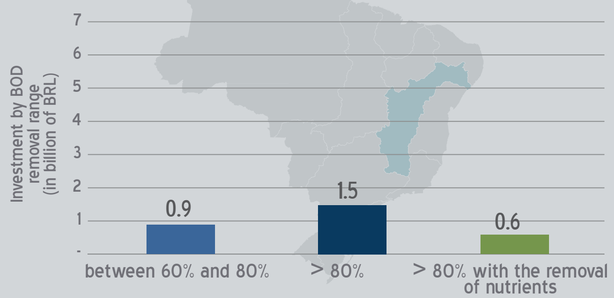
INVESTMENT IN TREATMENT: 8.5 BILLION BRL



SÃO FRANCISCO HR

Total Investment: 9.3 billion BRL
Investment in Collection: 6.3 billion BRL

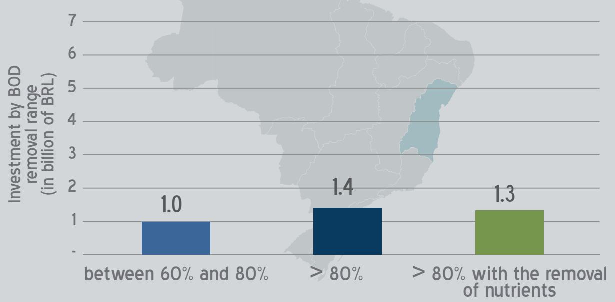
INVESTMENT IN TREATMENT: 3 BILLION BRL



EAST ATLANTIC HR

Total Investment: 11.2 billion BRL
Investment in Collection: 7.5 billion BRL

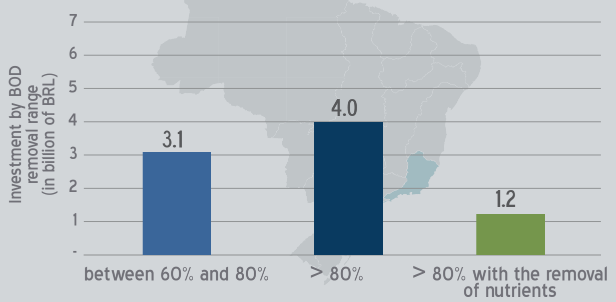
INVESTMENT IN TREATMENT: 3.7 BILLION BRL



SOUTHEAST ALTANTIC

Total Investment: 18.6 billion BRL
Investment in Collection: 10.3 billion BRL

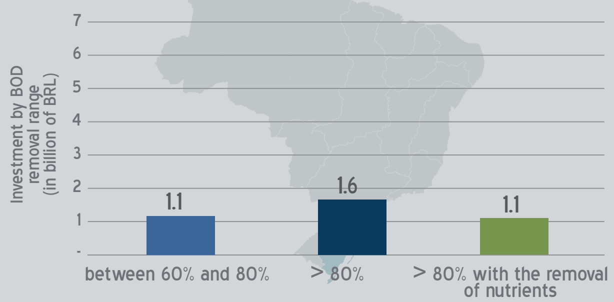
INVESTMENT IN TREATMENT: 8.3 BILLION BRL



SOUTH ATLANTIC

Total Investment: 12.3 billion BRL
Investment in Collection: 8.5 billion BRL

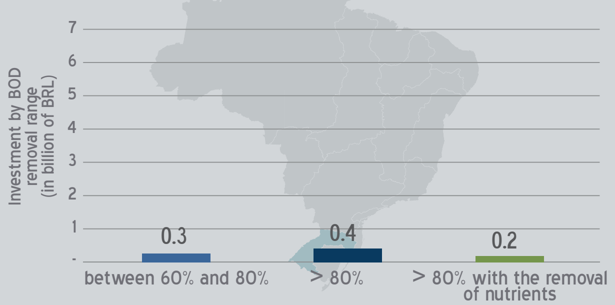
INVESTMENT IN TREATMENT: 3.8 BILLION BRL



URUGUAY HR

Total Investment: 3.6 billion BRL
Investment in Collection: 2.7 billion BRL

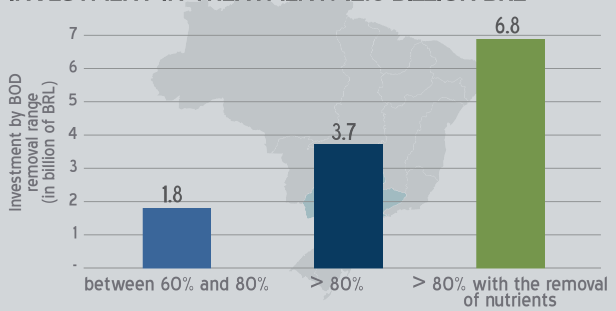
INVESTMENT IN TREATMENT: 0.9 BILLION BRL



PARANÁ HR

Total Investment: 34.8 billion BRL
Investment in Collection: 22.5 billion BRL

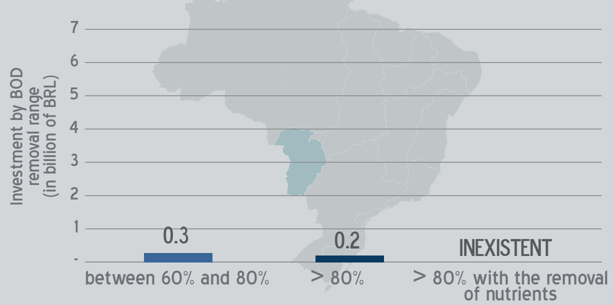
INVESTMENT IN TREATMENT: 12.3 BILLION BRL

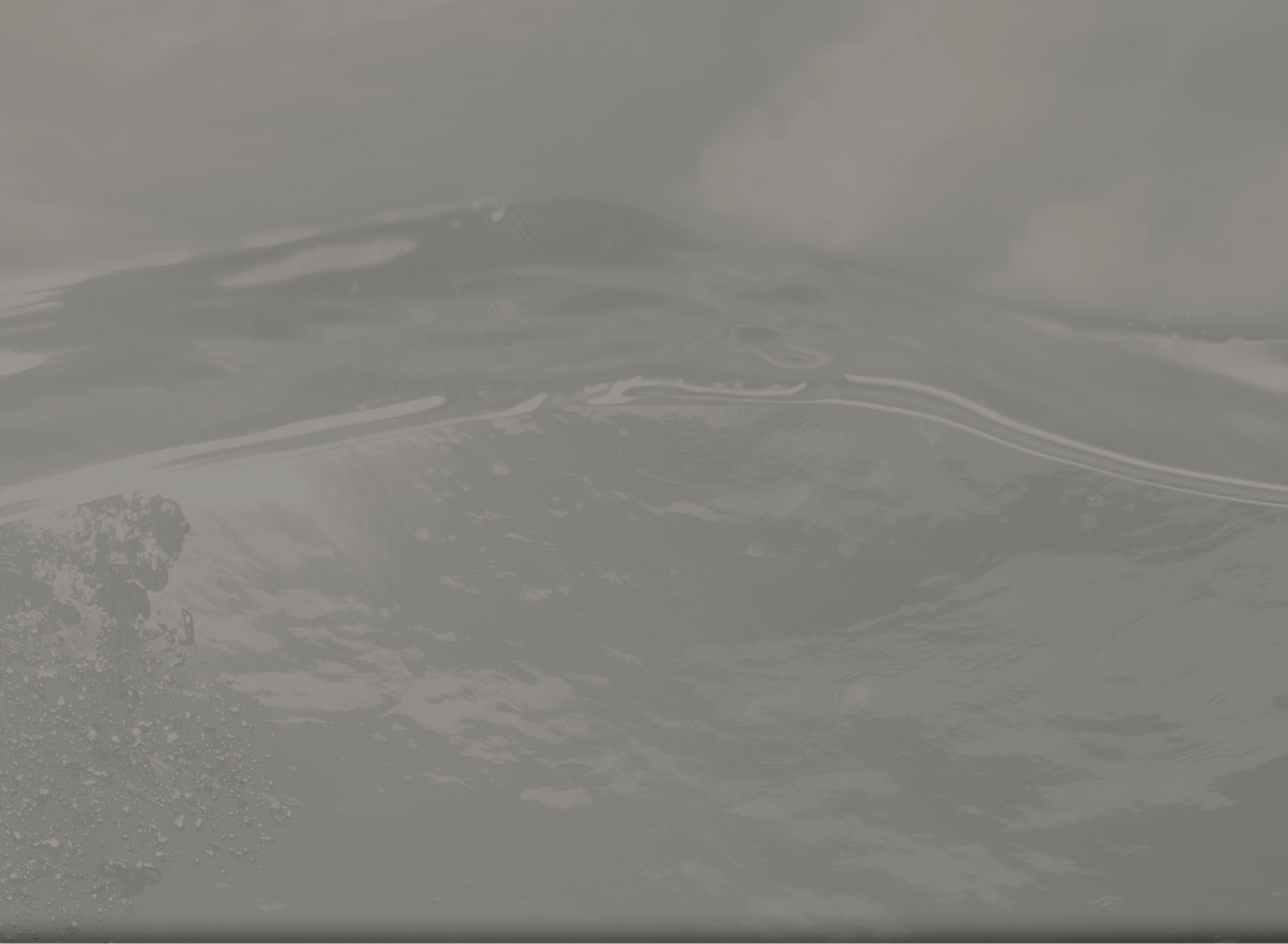


PARAGUAY RH

Total Investment: 2.4 billion BRL
Investment in Collection: 1.9 billion BRL

INVESTMENT IN TREATMENT: 0.5 BILLION BRL





5 | IMPLEMENTATION STRATEGY AND RECOMMENDATIONS

5.1 | INSTITUTIONAL ASSESSMENT OF THE PROVISION OF SEWAGE TREATMENT SERVICES

5.2 | IMPLEMENTATION STRATEGY

5.3 | CONCLUSIONS AND RECOMMENDATIONS

5.1 | INSTITUTIONAL ASSESSMENT OF THE PROVISION OF SEWAGE TREATMENT SERVICES

The institutional organization and provision of sanitation infrastructure became historically relevant in the 60s and 70s. At that time, the National Sanitation Plan - PLANASA, supported by the then National Housing Bank – BN- and FGTS resources, set targets for providing water to 70% and sewage treatment systems to 30% of Brazil's urban population.

Government programs and actions, such as the Sanitation Sector Modernization Project - PMSS (1992) and the Growth Acceleration Program - PAC (since 2007) have directed actions and allocated resources for reducing sewage treatment deficits. However, the country remained distant from the desired universalization of services.

More recently, PLANSAB (2014) defined a substantive set of macro-guidelines, strategies, goals and investments, becoming one of the main technical and political references for the sector.

If, on the one hand, this set of efforts stresses the importance of the contribution and continuity of the investments in sewage services, on the other hand it exposes the need to consider other strategic aspects in order to achieve the universalization of these services.

In addition to financial resources, the political-institutional advances, as well as operational, technological and management regulation and modernization are also fundamental to consistent progress in the provision of quality services of sewage collection and treatment and in an effective improvement of the country's sanitary and environmental conditions.

It is necessary to consider a set of legal, administrative, political, economic, social, environmental and technical variables in order to adequately chose solutions that take into account regional peculiarities, the ability to dilute pollution loads in the water bodies, the technical and economic feasibility and especially the institutional framework for the provision of services in the Brazilian municipalities. Ignoring this set of aspects may impair the effectiveness of the investments and the expected results.

It is with this integrated approach that the *Sewage ATLAS* proposes ways to address the problems and impacts related to sewage treatment through an institutional evaluation of the provision of sanitary sewage services.

The institutional framework for the provision of sewage treatment services in Brazil reveals that little more than half of the municipalities have delegated these services to a state or private company or to a municipal autoarchy, in which 89% of the Brazilian urban population is encompassed. The other municipalities do not count with an institutionalized sewage service provider.

Even though most of these providers have been operational for a long time, there is a considerable universe of agencies and entities with insufficient structure, a lack of resources or even even without regulatory, political-administrative and financial support, and even of mechanisms supporting actions and investments in the sector.

These issues define the institutional situation of the service providers that, in turn, conditions their capacity and determines the rythm of implementation for the proposed solutions and investments. Considering these conditions, the *Sewage ATLAS* established the following categories:

- **Group A – Consolidated Institutional Situation:** this group includes the most structured municipalities, with institutionalized sanitation services, generally good administrative and financial conditions, good material, human and organizational resources and good technical and operational conditions, resulting in an offering of good quality services. From the history of thieir achievements and by their demonstrating less difficulty in the implementation of actions and investments the *Sewage ATLAS* considered that its proposals would be more feasible for this group.
- **Group B – Intermediate institutional situation:** it includes municipalities that have service providers with reasonable institutional conditions, but that require adjustments in their technical and operational management capacity, administrative structuring and improvement in their economic and financial situations. Therefore, investments in this group must be accompanied by institutional de-velopment actions.
- **Group C – Basic Institutional Situation:** this corresponds to the group of municipalities under less favorable institutional conditions: without an institutionalized service provider or with a poorly structured provider and with a low operational or financial capacity. They usually demonstrate a history of insufficient investment and low or zero capacity to implement plans, projects and works for sewage collection and treatment, factors that make it difficult to overcome prob-lems and improve existing deficits.

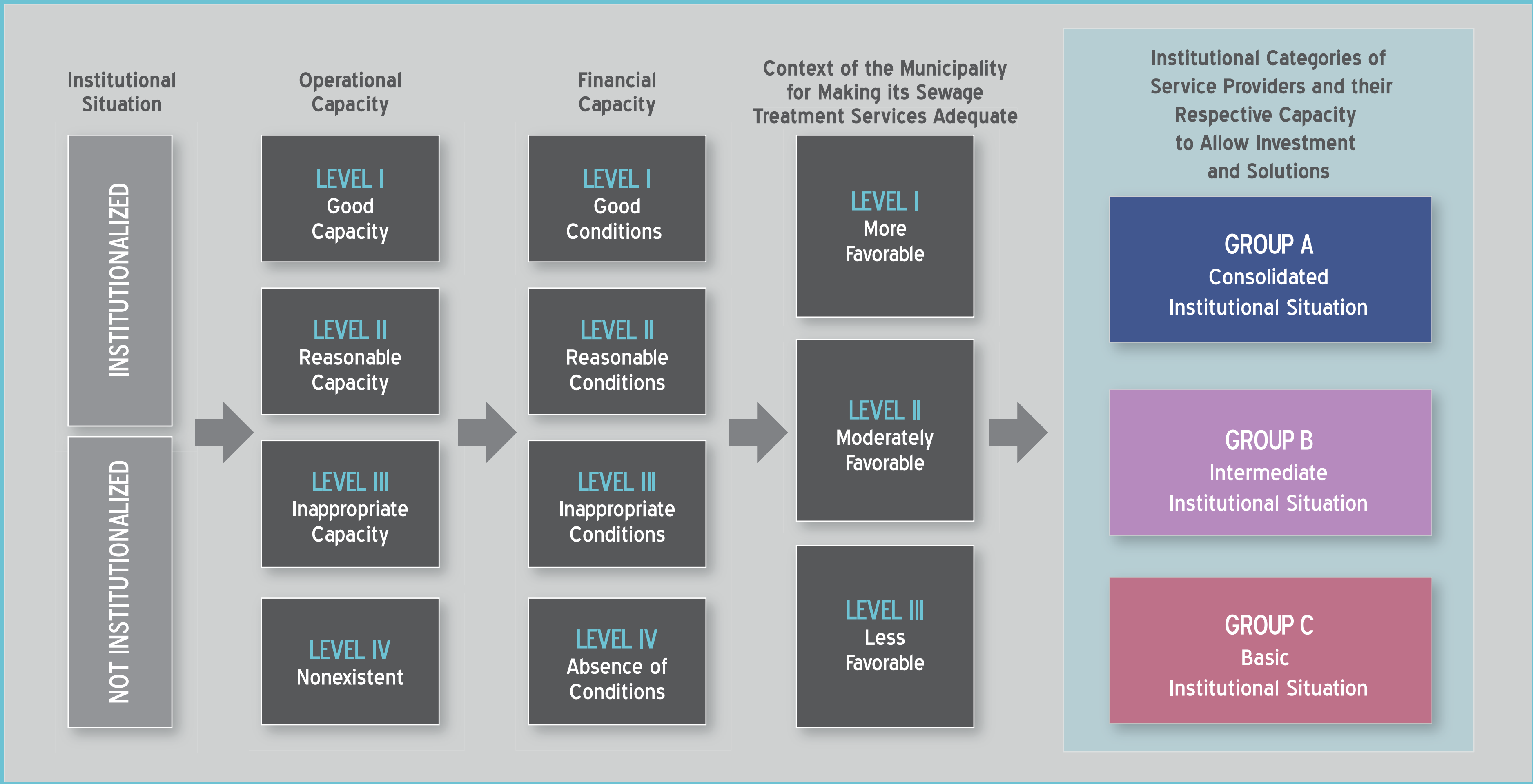
METHODOLOGY FOR ASSESSING THE INSTITUTIONAL SITUATION

In order to assess the institutional conditions of the basic service providers (ABDIB), trade unions and labor associations were consulted, and relevant information was collected and analyzed regarding legal and regulatory arrangements for the creation of the entities and organizations; their physical, administrative and organizational structures and the situation of water supply and sewage treatment services; commercial, fiscal and partrimony aspects (when available); instituttional representativeness (as for example, activity
in collegiate forums, councils, committees etc.); technical and financial capaci-ty; existent debts; among other aspects.

The data was obtained through direct consultation with the sewage service providers, as well as from secondary sources, including the National Sanitation Information System - SNIS, IBGE, agencies in the sector (the Association of Basic Sanitation Companies - AESBE, the Brazilian Association of Private Concessionaires of Public Services of Water and Sewage - ABCON, the National Association of Municipal Sanitation Services – ASSEMAE and the Brazilian Association of Infrastructure and Basic Industries ABDIB), unions, and class associations among others.

Based on the extensive set of information obtained, 4 main criteria were selected, which could express the institutional situation and the capacity to enable solutions and investments, which are: (i) institution-al status; (ii) operational capacity; (iii) financial capacity; and (iv) context of the municipality for adaquating the sewage services (if necessary).

The combination of these 4 criteria generated multiple institutional typologies, which were organized into three groups: - A Consolidated Institutional Situation; B - Intermediate Institutional Situation and C - Basic Institutional Situation, as illustrated below.

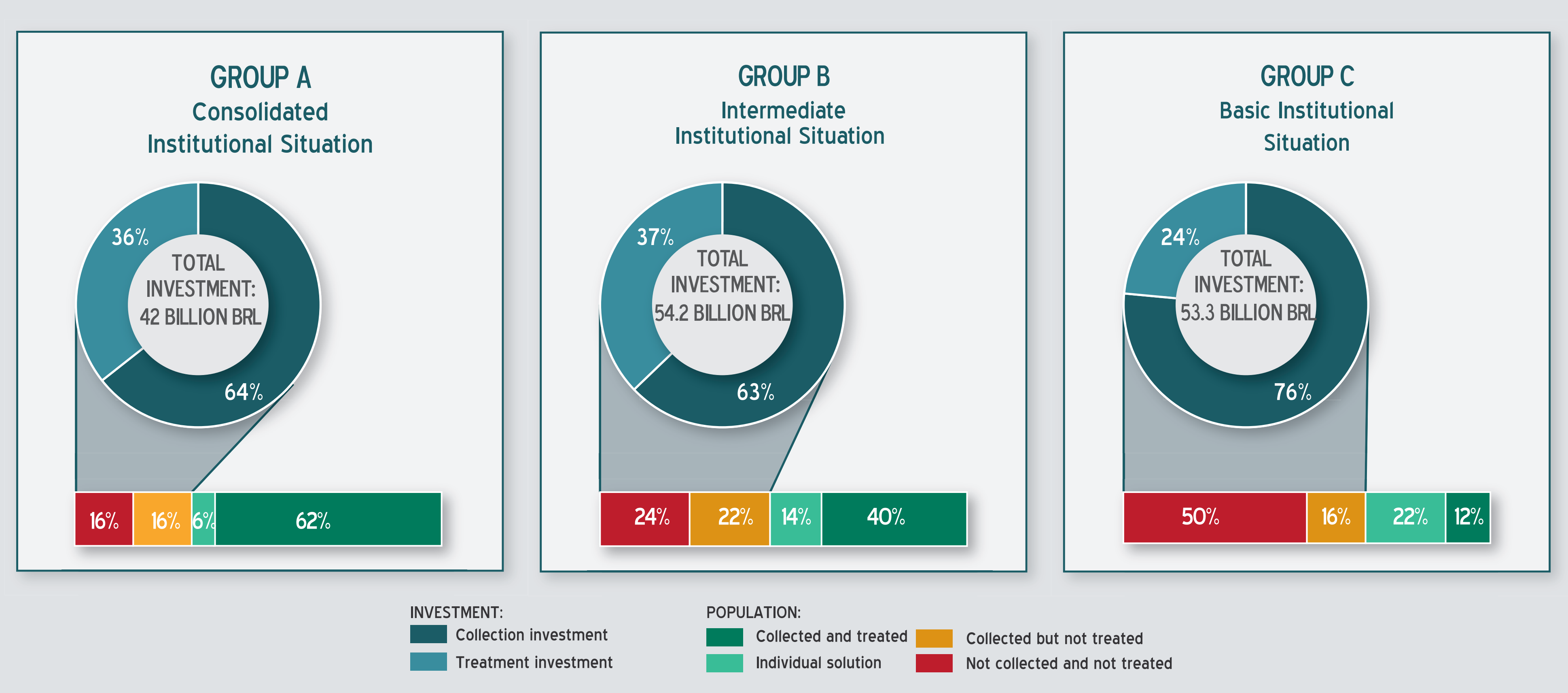


The group of municipalities with a consolidated institutional situation is home to the largest population and includes 80 cities in the metropolitan regions, with 6 of them having over 1 million inhabitants. In addition to the Federal District, these municipalities are located, predominantly in the states of Bahia, Minas Gerais, São Paulo and Paraná. Group A presents the best service rates, with 79% sewage collection coverage and 62% collective treatment but, even so, great investments are still necessary. In order to meet all demands in the 2035 horizon, 42 billion BRL in investments are necessary, out of which 27 billion BRL are destined for sewage collection and 15 billion BRL to its treatment.

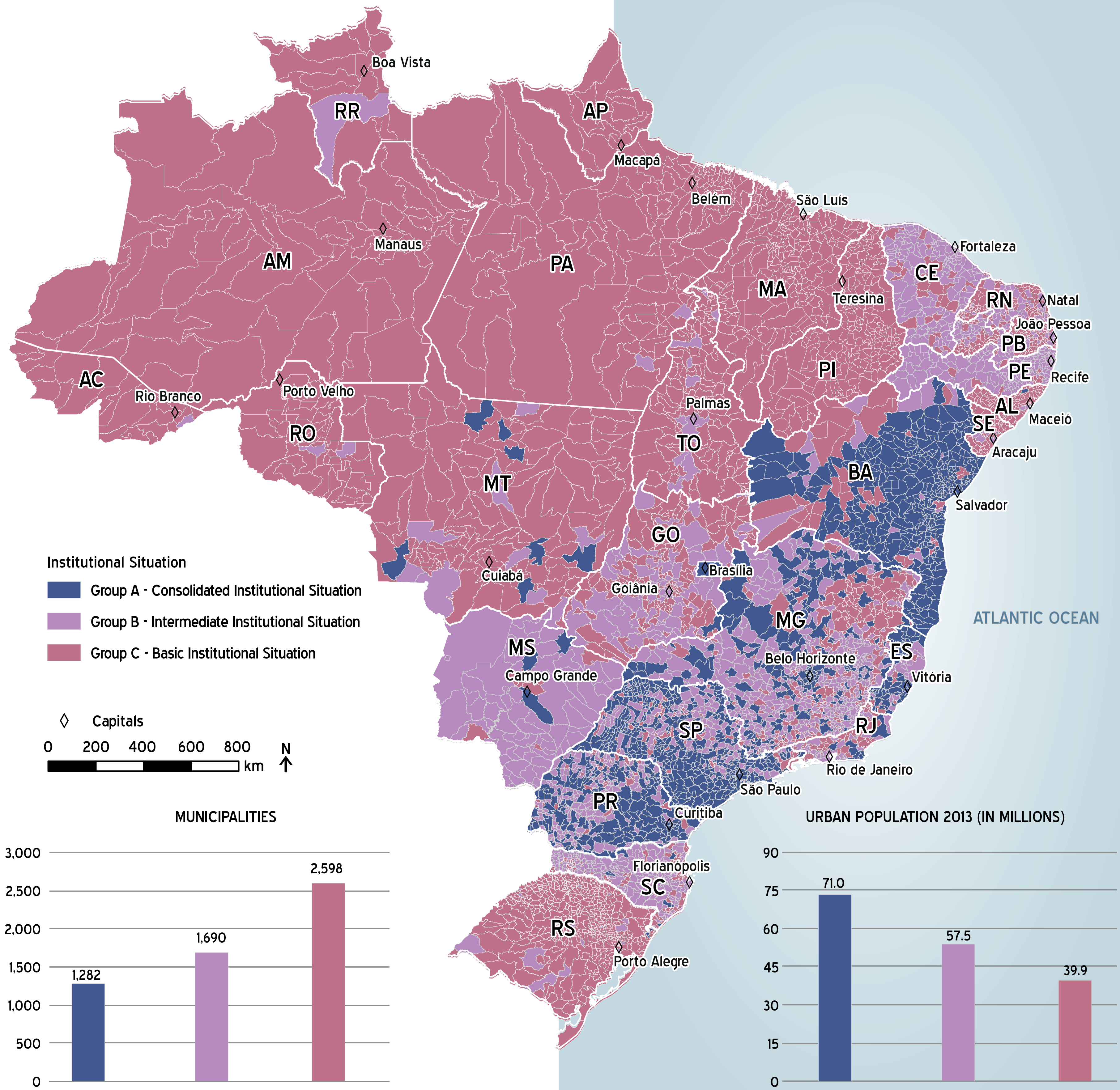
The group of municipalities with intermediate institutional status concentrates a considerable number of cities located in metropolitan regions (65 municipalities) although most of the municipalities are small (1,239 with less than 20,000 inhabitants). In this group, about 62% of the population has access to sewage collection and 40% has access to collective treatment, levels that are very close to the Brazilian average. 52.2 billion BRL in investment are foreseen for this group of municipalities; 34.1 billion BRL are destined to collection and 20.1 billion BRL to sewage treatment. The Group B municipalities are more widespread throughout the country if compared to the other groups, and the Group B municipalities are located in the northeastern (Ceará, Rio Grande do Norte, Paraíba, Pernambuco), southern, southeastern and midwestern regions.

The group of municipalities possessing a Basic Institutional Situation corresponds to the largest number of municipalities (47% of all the group), and 37 of these municipalities are in metropolitan regions. As was expected, a large part of this group (86%) is represented by small municipalities with a population of less than 20.000 inhabitants. In terms of population, however, these municipalities represent the lowest number of inhabitants (39.9 million inhabitants). It is also in this group that we can find the highest demands due to the lowest coverage indexes, with service provision rates of 28% for sewage collection and only 12% for sewage treatment. Because of these characteristics, this group presented the largest amounts of sewage collection investment (40.7 billion BRL). This is not reflected in the amount estimated for sewage treatment since these municipalities predominantly demand more simplified solutions considering the availability of water resources sufficient for dilution of the effluents. From a spatial point of view, the municipalities in this group are more concentrated in the Northern region, and mainly in the states of Mato Grosso, Maranhão, Piauí, Tocantins, Rio Grande do Sul and to the north of Minas Gerais.

TOTAL INVESTMENT AND COLLECTION AND TREATMENT RATES BY INSTITUTIONAL SITUATION



SEWAGE SERVICES PROVISION INSTITUTIONAL SITUATION



5.2 | IMPLEMENTATION STRATEGY

The division by hydrographic basin, associating sewage treatment with a systemic vision of water resources is the approach of the Sewage ATLAS and reflects the partnership between ANA and SNS/MCities in addition to several other stakeholders who are involved in the sewage treatment and water management theme.

The technical discussions held during the preparation of this study highlighted the perception that even though the sewage collection and treatment solutions are dimensioned in accordance with the water resources management principle, investing resources in municipalities without the necessary institutional capacities may not achieve the desired results. There are several examples in the country of sewage systems that were abandoned or are unfinished due to these types of problems.

Therefore, the goal was establishing a strategy that would consider the institutional diversity in the provision of sewage treatment services in Brazil, as well as the complexity of the required solutions, focusing on the sewage services universalization and the mitigation of negative impacts on water resources.

As a part of that strategy, the following steps were defined:

i. Structuring of the provider (only for municipalities with a Basic Institutional Situation – Group C): proposed as a stage prior to the implementation of any other action. Regardless of the model chosen by the municipality, it is fundamental that the municipality can count on an institutionalized service provider with a clear definition of tasks and with enough structure to elaborate or at least evaluate the sewage treatment solution for the municipality.

ii. Institutional development (municipalities with basic and intermediate institutional situation - Groups B and C): an important stage to leverage the service providers' operational and financial capacity. This action, which is foreseen in the PLANSAB, is necessary to ensure the improvement in the quality of the services provided and guarantee the continuity of the operation of the sewage treatment system.

iii. Investments in works (all municipalities -Groups A, B and C): provision of financial resources necessary for the execution of sew-age collection and treatment systems, which must be conditioned to the institutional capacity of the service providers.

As mentioned in the previous stages, the institutional capacity is a necessary aspect for the effectiveness of sewage collection and treatment works. The establishing of management goals associated with physical indicators is also an important step in the programing of investments.

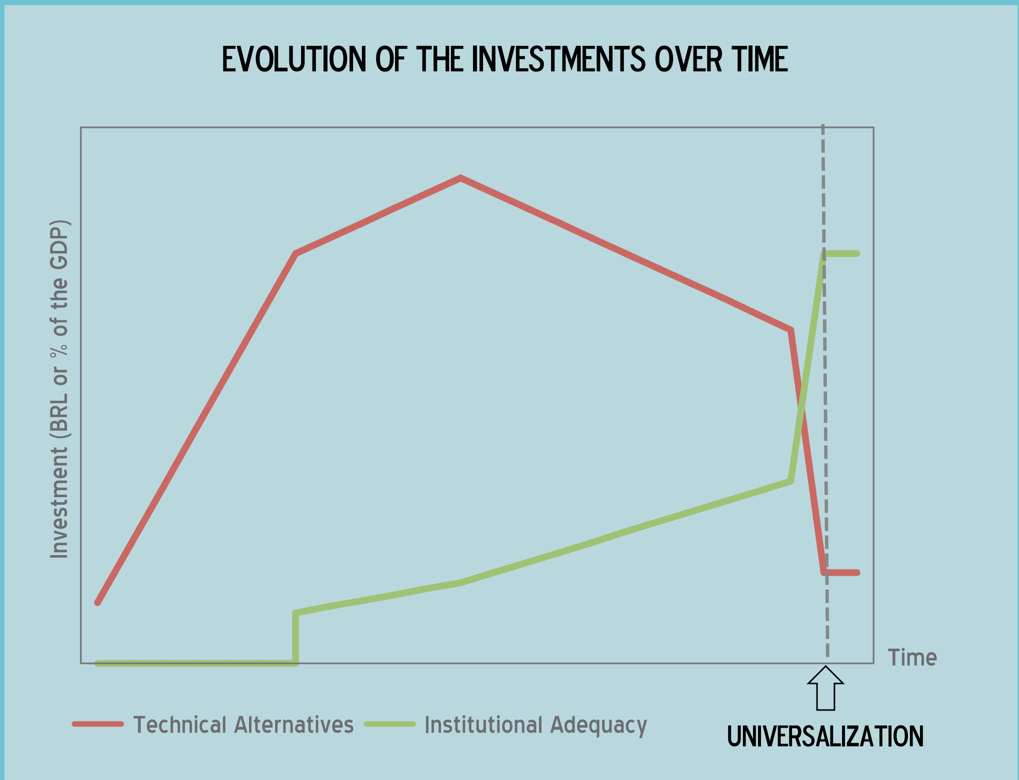
THE IMPORTANCE OF INSTITUTIONAL ADEQUACY ACCORDING TO PLANSAB

PLANSAB characterizes the proper balance between the structural and structuring measures denominated in the *Sewage ATLAS* for institutional development and investment in sewage collection and treatment works as the central premise of the planned investments.

The PLANSAB also argues that structural measures are important until the universalization of the sewage treatment services is possible, but that these measures need to occur with the strengthening of structuring measures to support them in the long term.

After the universalization of the services is complete, technical alternatives would then be necessary, mainly for the replacement of obsolete systems or adaptation of systems to new Sanitary and Environmental Quality Standards.

The support for public management of sewage treatment services aims to create sustainable conditions for adequate population access, including the qualification of social participation and its control over the services.



Source: Adapted from PLANSAB.

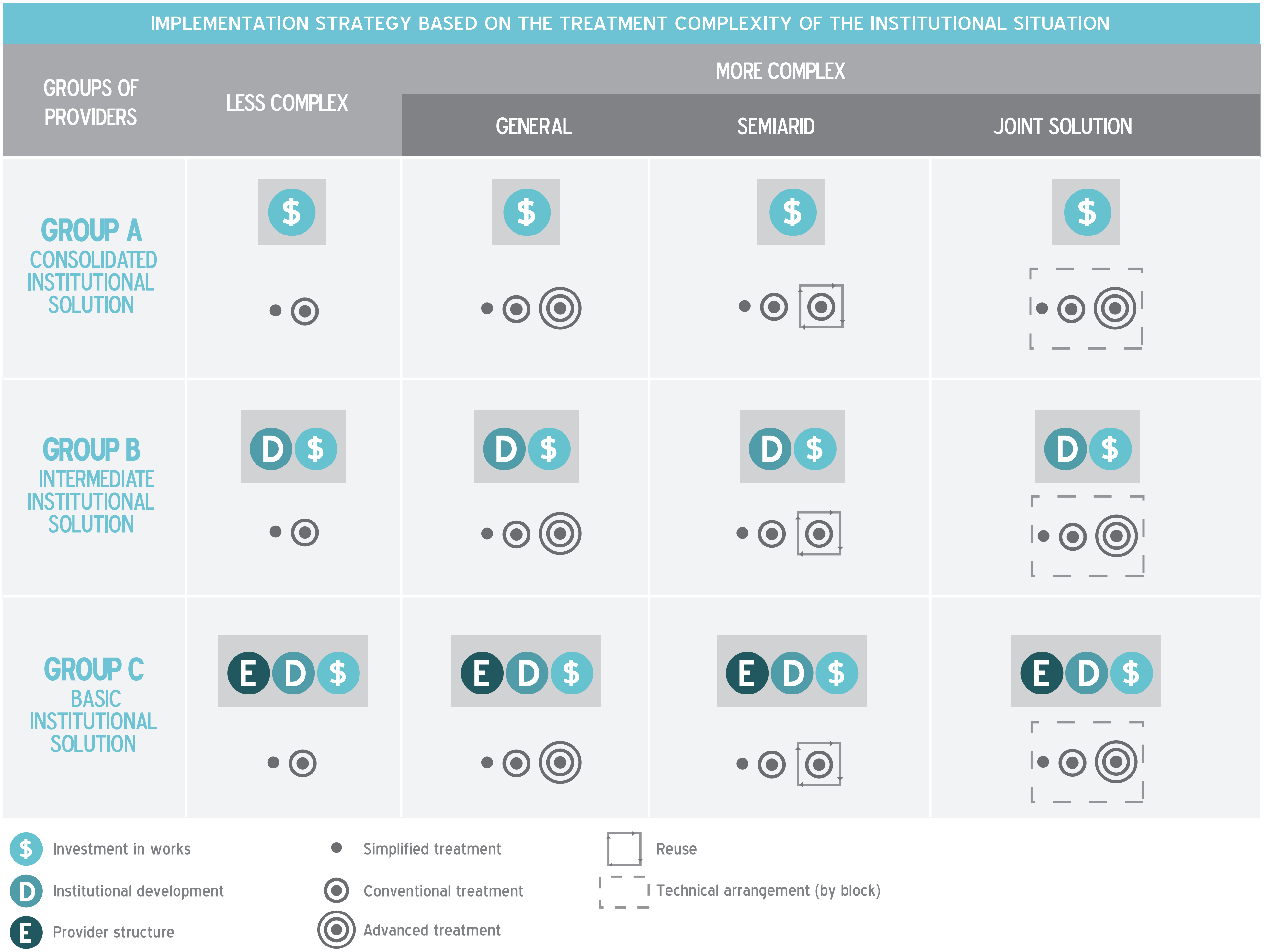
In addition to the above-mentioned steps, the proposed strategy envisages the possibility of implementing the sewage treatment solutions and associated investments in a gradual manner, respecting the removal efficiencies necessary to meet the requirements of the receiving bodies.

This gradual approach, considering the establishment of progressive targets in line with Sanitation and Water Resources Policies, should be observed in the Basic Sanitation Municipal Plans and in the Hydrographic Basin Plans.

For less complex sewage treatment solutions, progress may be limited to the gradual extension of the areas to be dealt with e.g. in accordance with the sewage basins in the municipalities.

For more complex solutions the possibility of implementing complementary treatment processes by stages is also considered if the technology permits. These processes would be necessary to achieve higher efficiencies of load removal associated with the final targets of water quality.

Other particularities may be considered, such as the choice of reusing the treated effluent for non-drinkable purposes or the discussion of a treatment solution involving several municipalities belonging to a single basin.



Based on the strategy presented, with an integrated analysis of the institutional situation and the treatment complexity, it can be inferred that, in general, municipalities with a consolidated or intermediate institutional situation are predominantly in regions with low sewage dilution capacity. Therefore, they tend to require more complex treatment and, in many cases, the discussing of a joint or complementary solution between municipalities in the same basin.

On the other hand, most municipalities that demand structuring and institutional development are in regions with high water availability and that can reach universalization through conventional treatment.

In the tendency context of the sewage treatment efforts made in Brazil, it is expected that the municipalities with consolidated institutional situations will be the first ones to achieve the universalization of this service. This effort amounts to a removal of 1,105 tons of BOD/day and an estimated investment of 42.0 billion BRL.

It is then expected that municipalities with intermediate institutional status will acquire the institutional development necessary to leverage and manage financial resources on the order of 54 billion BRL for the construction and maintenance of sewage systems that remove 1,197 tons of BOD/day.

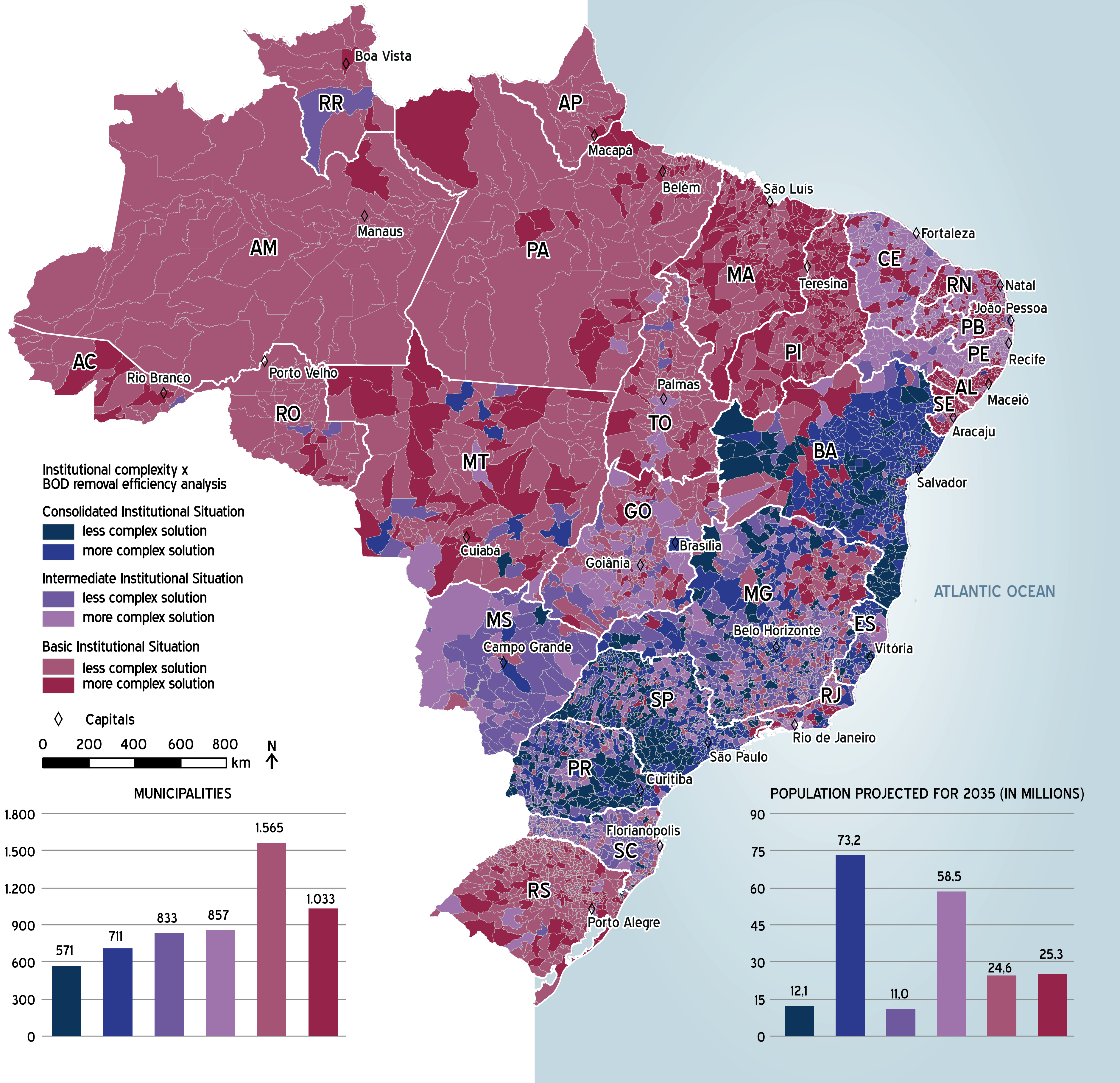
Lastly, according to the ttendency context, we would have the municipalities with a basic institutional situation, which still need to define a service provider and/or supply it with operational and financial capacity to manage the respective sewage treatment systems. These municipalities would achieve the universalization of sanitary sewage through the removal of 1,298 tons of BOD/day with an investment of 53.3 billion BRL. It is emphasized that in addition to the financial resources, this group also requires a structuring effort to be undertaken by these municipalities, including deciding on appropriate models for the different municipalities in order to meet the universalization targets.

In terms of the water quality results of the receiving bodies, one emphasizes the investment for more complex situations that consequently have a greater impact on water resources, regardless of the institutional situation (Groups A, B, and C). Such situations occur in an equivalent number of municipalities (2,601), but demand investments 2.5 times greater (107.7 billion BRL). In addition to the environmental benefits, it is important to stress that advances in sewage treatment universalization are critical because of their positive public health effects, regardless of the strategy adopted.

COMPLEXITY OF TREATMENT AND INSTITUTIONAL SITUATION

INSTITUTIONAL SITUATION	COMPLEXITY OF THE TREATMENT REQUIREMENT (BOD REMOVAL) 2035	GENERAL DATA 2035	LOAD TO BE REMOVED FOR UNIVERSALIZATION 2035 (BOD T/DAY)	INVESTMENT NECESSARY 2035 (BRL)
GROUP A CONSOLIDATED	Less complex (between 60 and 80%)	571 municipalities Population 12.1 millions inhabitants (2035) Average municipal population: 21.191 inhab	145	6.8 billion
	More complex (above 80%, joint or complementary solution)	711 municipalities Population 73.2 millions inhabitants (2035) Average municipal population: 102.953 inhab	960	35.2 billion
GROUP B INTERMEDIATE	Less complex (between 60 and 80%)	833 municipalities Population 11.0 millions inhabitants (2035) Average municipal population: 13.205 inhab	249	8.4 billion
	More complex (above 80%, joint or complementary solution)	857 municipalities Population 58.5 millions inhabitants (2035) Average municipal population: 68.261 inhab	948	45.8 billion
GROUP C BASIC	Less complex (between 60 and 80%)	1.565 municipalities Population 24.6 millions inhabitants (2035) Average municipal population: 15.719 inhab	652	26.6 billion
	More complex (above 80%, joint or complementary solution)	1.033 municipalities Population 25.3 millions inhabitants (2035) Average municipal population: 24.492 inhab	646	26.7 billion

TREATMENT COMPLEXITY AND INSTITUTIONAL SITUATION OF THE MUNICIPALITIES



5.3 | CONCLUSIONS AND RECOMMENDATIONS

The *Sewage ATLAS* is the result of a joint work, developed under ANA's Coordination and in partnership with SNSA/MCities and with the collaboration of federal, state and municipal institutions from all over Brazil. This study considers the point of view of water resources management, collecting and presenting information, diagnoses and solutions for all of 5,570 urban centers in Brazil. The work was based on the assessment of the sewage collection and treatment situation in these cities, and the impact of effluent discharges into water bodies, with a systemic vision divided by hydrographic basins. The proposals for solutions were prepared for the 2035 horizon, focusing on the protection of Water Resources, their sustainable use for the purification of urban effluents and the rationalization of investments.

The first challenge in covering all Brazilian municipalities was to obtain the information that would support impact assessments of the sewage discharge. This information was obtained through visits to 472 autonomous municipal organizations (SAAE or similar) or private bodies, responsible for the provision of the sewage treatment services, in addition to technical meetings with the 25 state companies that operate in the country. Municipalities with populations of over 50,000 inhabitants that did not count on a service provider were also visited. In 2013, this universe reached 157.7 million inhabitants, which represents about 90% of the Brazilian urban population.

The assessment of the current situation of sewage systems and their respective receiving bodies stressed the relevance of this pollutant load in compromising the quality of water resources, especially near large urban centers and areas with low water availability, and highlighted the following aspects:

- 55% of the Brazilian population has access to appropriate sewage treatment services in accordance with PLANSAB concepts (individual solution or sewage collection and treatment services). However, only 39% of all organic load generated in Brazil is removed, resulting in 5.5 thousand BOD t/day that can reach the receiving bodies.

- There is a predominance of low levels of organic load removal in urban centers (about 3.9 thousand cities have BOD removal levels below 30%) and, consequently, the situation is similar in the FUs total levels. Only the Federal District, São Paulo and Paraná FUs remove over 50% of the organic load generated in their territory.

- In addition to the significant deficit existing in sewage collection and treatment, only 1/3 of the identified sewage treatment plants use processes with BOD removal of over 80%, these plants are concentrated in the southeast region.

- The high organic load stemming from treated and untreated sewage being discharged into the receiving bodies, implies a great occurrence of river stretches with water quality compatible with water classes 3 or 4 (BOD concentrations higher than 5 mg/L), totaling about 110 thousand kilometers of watercourses, notably in the eastern part of the country. Thus, 57% of the Brazilian population lives in municipalities that do not possess a sufficient flow for the dilution of the organic load without resorting to more efficient treatment processes or resulting in a water quality condition that is only compatible with the water uses foreseen in water Classes 3 or 4.

- The worst dilution conditions are close to large urban centers and in the semiarid region, where the ratio between population and water availability in the receiving bodies is generally unfavourable. In the semiarid region, the situation requires additional attention, in view of the high occurrence of intermittent or ephemeral rivers and the high number of dams used for human supply, which are also potential final destinations for sewage organic load resulting from rainwater washing over the soil..

The evaluation of the sewage services deficit and its impacts on the water bodies, seeks solutions to meet water quality requirements to ensure the multiple uses of water resources, supported the elaboration of a strategic approach complemented by cost estimates, having as its main aspects:

- The great heterogeneity in water availability in Brazil's water bodies demands equally diverse solutions for the removal of polluting loads. In addition to the adoption of more advanced treatment processes for municipalities whose recipient bodies have less favourable dilution capacities, differentiated approaches with greater involvement of the water supply sector may be necessary in areas of critical water quality. These municipalities are the semiarid region, headwater areas and, especially, highly populated regions in the same basin.

- The water quality modeling results , wich were corroborated by the water quality monitoring dat, a underscore the relevance of sewage treatment actions in these critical areas. It is also desirable to involve the water sector in the discussions about implementation of solutions, especially in the more densely populated regions that already have Basin Committees established, such as those for the rivers: Sinos,Tietê, Velhas, Paraíba do Sul, Doce, Meia Ponte, Piracicaba, Capivari and Jundiaí (PCJ basins), Mogi-Guaçu, among others.

- The analysis of the need for phosphorus and nitrogen removal for 2035 showed that 29% of the reservoirs have phosphorus concentrations above the target (up to 0.025 mg/L), and 5% present nitrogen concentrations that surpass the potability standard (up to 10 mg/L). These are indicated as municipalities that need to pay attention not only to sewage treatment, but also to nutrient removal.

- The investments necessary for universalizing the sewage treatment services in Brazil by the year 2035 are estimated at 149.5 billion BRL, of which the northeastern and southeastern regions are the ones that require the largest investments, either due to their low coverage levels and high prevalence of intermittent or ephemeral rivers (the case of the Northeast) or due to the large number of urban centers (the case of the southeastern region). Out of the total investment in the country, 44% was planned for implementation in 840 municipalities requiring a joint or complementary solution. The population associated with these municipalities amounts to over 100 million inhabit-ants.

- The investments in sewage collection and treatment estimated in the Sewage ATLAS do not consider costs associated with the construction and maintenance of the septic tanks, the replacement of old collection networks or the replacement of mixed collection systems, combined sewage treatment and/or the recovery/ or processing of by-products, such as sludge and biogas. The sewage treatment and collection investments estimated in the PLANSAB for the 2014-2033 period amount to 181.9 billion BRL, and incorporate actions to expand hydroelectric facilities, the replacement of sewage collection and interception systems and replacement of sewage treatment networks.

In addition to diagnosing the services, the PLANSAB, as a federal instrument for sanitation planning in Brazil, also provides guidelines, targets, and instruments that should be used to achieve these targets. In view of the importance of all PLANSAB aspects, it is worth noting that PLANSAB is concerned with strengthening the institutional, regulatory and implementation capacity and the management ability of sewage service providers, factors which are certainly among the main obstacles to the achieving of interventions in all regions of the country.

Based on these results and on the technical discussions held during all the study, PLANSAB's evident concerns were reinforced that the sewage collection and treatment actions may not have the desired effect should the financial contribution be offered without the necessary institutional competence installed and without considering the specific characteristics of the required solutions in view of the dilution capacity of the receiving bodies.

All these points considered, the assumptions adopted in the *Sewage ATLAS* were used to define an implementation strategy, reckoning with the institutional diversity existing in the provision of sewage services in the country and the sewage treatment solutions required. This strategy should guide the planning, regulation, financing and decision-making processes within SINGREH and the sanitation sector and is also aligned with efforts to meet the access targets for sanitation and water quality improvement set forth in the Sustainable Development Goals of the 2030 Agenda of the UN member countries.

In this context, the following recommendations are presented, grouped into three dimensions: (i) the political-strategic dimension; (ii) the organizational dimension (management and provision of sewage treatment services); and (iii) the operational dimension.

Political-strategic dimension:

- One of the main challenges that needs to be addressed in the political-strategic dimension includes a wide-ranging discussion about the reorganization of the water sector, whose activities are currently carried out in a dispersed manner and by multiple actors (Ministry of Cities/SNSA, Ministry of Planning, Ministry of the Environment/ SRH/ANA, Ministry of Health/FUNASA, Ministry of National Integration, Ministry of Social Welfare, Caixa, BNDES, Ministry of Defense and Codevasf among others). Although the control of the sanitation policy is the responsibility of the Ministry of Cities and the coordination of the implementation of the National Policy on Water Resources is the responsibility of ANA, for the implementation strategy suggested in the *Sewage ATLAS* to actually guide the actions and investments in sewage treatment at the federal level, an inter-ministerial instance is critical to ensure the coordination between all the agents involved and their decision-making rationale.
- With regard to planning, the *Sewage ATLAS* offers a detailed sewage treatment situation by municipality, considering regional and river basin arrangements. The *Sewage ATLAS* should be taken as a complementary instrument to the PLANSAB, supporting its revisions and guiding actions to promote the universalization and quality of services and the allocation of financial resources.
- The *Sewage ATLAS* also establishes a technical reference for studies, diagnoses and prognoses that will integrate the municipal and micro-regional sanitation plans and the water resources plans (national, state and river basin) and constitutes the starting point and baseline for the sewage treatment topic.
- Some of the technical alternatives indicated still lack guidelines for their application, which will be carried out through the elaboration of technical and normative references among others. This is the case, for example, of the strategy of effluent reuse, which currently relies on an action plan proposal that aims to institute a specific policy in Brazil, and is currently ongoing within the framework of the Interaguas program.
- The establishment of progressive targets in line with the Sanitation and Water Resources Policies and in accordance with the strategy drawn up in the *Sewage ATLAS* must be observed in the municipal sanitation plans, river basin plans and water classes proposals. These goals contemplate the gradual implementation of sewage solutions and associated investments, respecting the removal efficiencies necessary to meet the requirements applicable to the receiving bodies and water classes for different uses.
- Efforts are also important to improve the regulation processes and mechanisms in the sanitation sector, as well as the legal framework for issuing grants of water

and environmental licenses. These processes consider the integrated analysis carried out in the Sewage ATLAS, and take into account the river basin division, the country's institutional diversity and the required sewage treatment solutions. This analysis highlights the need for a uniform approach for defining gradual actions, standardizing the progressive expansion goals, and the quality of the services with the quality targets of the water bodies. Moreover, decisions that do not depend on the domain of the water body must be assumed and agreed on by the regulatory and environmental organizations and controlling entities.

Organizational dimension:

- In this dimension issues prevail relating to the organization of service providers, where gaps have been verified in the institutional management and operational arrangements in effect. Thus, the *Sewage ATLAS* database and results, combined with other instruments, can support the discussion of more appropriate institutional models for the provision of sanitary sewage services, considering the technical aspects that the data base raised, as well as the wide diversity of the country's municipalities with regard to their technical, financial and human resources capabilities.

- This organization of the sewage services provision, which includes institutionalizing management and institutional development actions, is fundamental to ensure the effectiveness of the investments in works estimated in the *Sewage ATLAS* and, when necessary, can be used as a condition for the application of public resource.

Operational dimension:

- Within the operational dimension, emphasis is given to the operation of the sewage treatment systems, especially to ensure the efficiency of sewage treatment plants. Thus, experiences such as that of the River Basin Cleanup Program - PRODES, created and maintained by ANA since 2001, can serve as a model, presenting options for the monitoring of sanitation activities (sewage collection and treatment) and not only the physical execution (construction of an STP), in addition to the focus on mitigating the impacts on water resources.

- The PRODES and other actions of this nature, because of their potential contribution to operational improvement and ensuring effectiveness in the removal of polluting loads, should give priority to the most critical basins with lowest water quality and which require more complex treatment solutions, as pointed out in the Sewage ATLAS.

- It is also important that treatment efficiency indicators be permanently incorporated in the setting of targets and in monitoring the implementation of actions, so that the evaluation metric is not only based on the execution of works and the evolution of the coverage of sewage services, but also on the operational efficiency of the STPs and on the improvement of the water quality of the receiving bodies.

In addition to the recommendations mentioned, there are also some important reservations to be addressed and which are not included in the dimensions treated above:

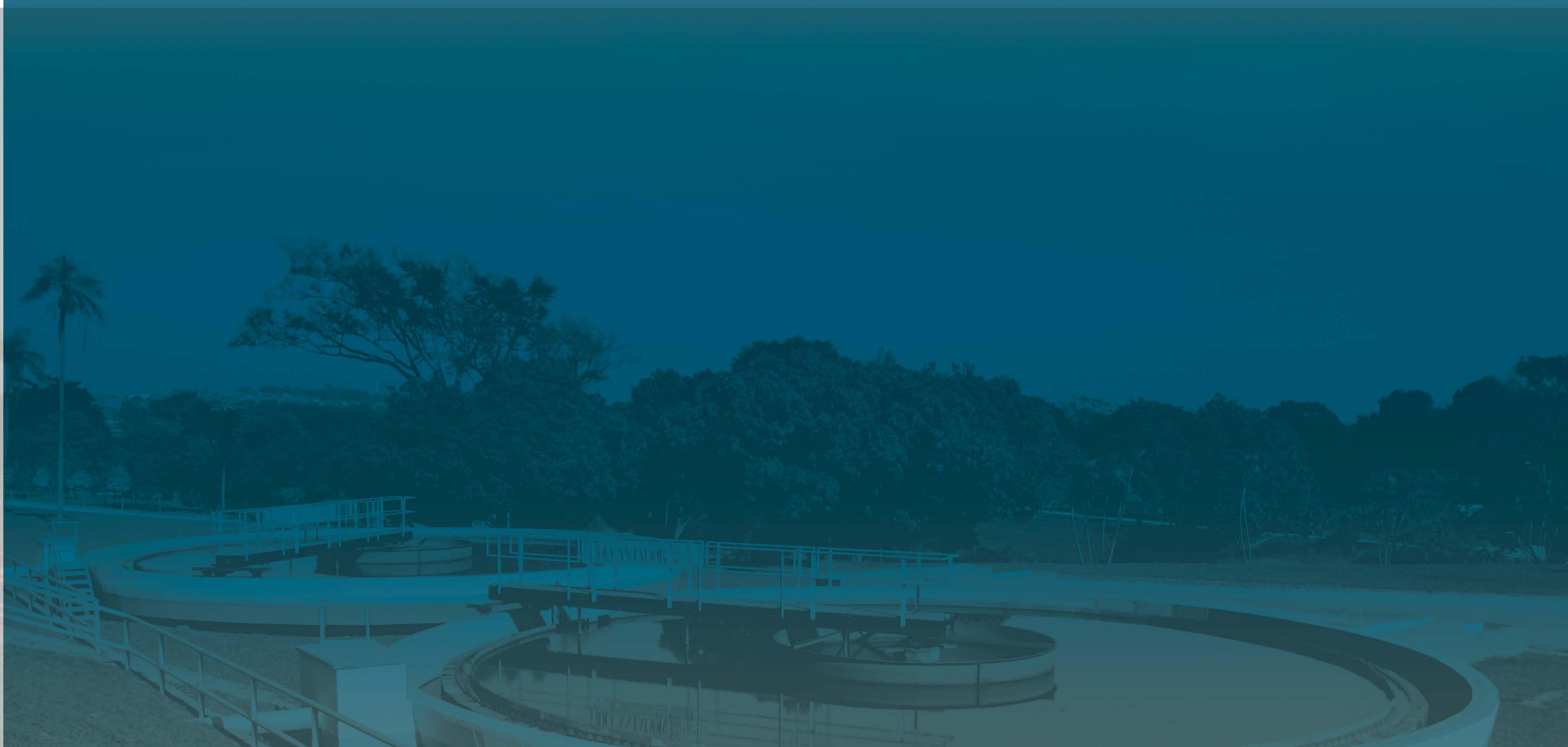
- In relation to the option to prioritize joint collection and treatment systems as a solution, as indicated in the *Sewage ATLAS*, it should be remembered that septic tanks can also be considered appropriate solutions, provided they are properly executed and operated. Some studies even point out that under certain conditions septic tanks are a more economical alternative when compared to collection systems. However, it is essential that progress be made in regulating this solution, by clearly defining the responsibilities for maintenance and final disposal of residues, and by establishing guidelines for their use as a public policy alternative to universalize sewage treatment services.

- With regard to the use of the *Sewage ATLAS* as a decision-making tool, it is important to clarify that the technical alternatives that compose this document are not sewage collection and treatment projects for municipalities, but an indication of possible solutions considering the required efficiencies when evaluating the receiving bodies in specific geographical areas. Although it includes proposals based on robust information for this planning scale, the designing of sewage treatment projects requires more detailed information. Many other variables such as availability and cost of land, and the topography among other matters should be considered, as well as taking a closer look at the available technologies and their suitability to the local realities.

The publication of this Executive Summary at the same time as the dissemination of the *Sewage ATLAS* results available on ANA's website (www.ana.gov.br) provides society with a wide range of information on all Brazilian cities. This represents a valuable contribution to national, regional or local planning and decision-making. It is, therefore, important that this information be continuously updated, so that the analyses carried out and the planning proposed can be improved and monitored, by accompanying the progress and any new challenges.

Lastly, it is expected that the Sewage ATLAS will strengthen water resources and sanitation planning and management, by motivating the establishment of partnerships and enhanced intergovernmental cooperation, committed to the necessary sanitation investments to improve the country's health, environmental and urban conditions.



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