MASTER THESIS

Development of a classification instrument to allocate federal funding available for sanitation improvement in the cities under fifty thousand people in Ceará, Brazil.

August 2018

Daniel Pereira Garcia

ID: S2030209

Supervisors:

1. Dr. Kris Lulofs
2. Dr. Luewton Lemos

MASTER OF ENVIRONMENTAL AND ENERGY MANAGEMENT PROGRAM

UNIVERSITY OF TWENTE

ACADEMIC YEAR 2017/2018

Abstract

The objective of this study is the development of an instrument for classification and ranking of sanitation systems of municipalities in the State of Ceará in Brazil. Such an instrument improves the allocation of resources over municipalities that applied for funding to the Brazilian National Health Foundation. The research thus focuses upon the sanitary conditions in the Municipalities of the State of Ceará in Brazil. The concept sanitation refers to the collection, disposal and treatment of wastewater and solid waste as well as supply of potable water and urban drainage. The current approach adopted by The Brazilian National Health Foundation uses the 'Municipal Human Development Index' as instrument to prioritize which municipality will firstly receive budget. Unfortunately, this index does not account for technical parameters and performances of sanitation systems.

This study started with literature review into the state of affairs in Brazil, the State of Ceará in Brazil and municipalities and elaborating literature with regard to core concepts and approached to classify and rank sanitation systems.

The methodology used to develop a classification instrument consists of three major steps: study of situation, data analysis and research validation.

The *study of situation* aims at gathering knowledge on how reports define the sanitation systems and extract the variables into a data matrix. The Brazilian National Health Foundation provided ten diagnosis reports to enable this work package.

Data analysis is instrumental to pushing the needed classifications in a two-step approach: macro classification (overall view of the systems) and micro classification (detailed assessment of the sanitation systems). Both classifications are the basis for the development of the instrument.

Research validation refers to crossing-reference techniques used to evaluate whether the instrument is valid. Upon the complete creation of the classification instrument, testing was done, first applying it on the same ten municipalities. Once completed, a comparison between the current practice using the Human Development Index and the outputted raking from the instrument is done. Moreover, through this testing, the study is capable to collect data on what is measured as strengths and weaknesses and provide a range of recommendations to improve reporting techniques as well as to betterment of the classification instrument.

Keywords: Sanitary conditions, National Health Foundation, Human Development Index, variable, and classification instrument.

ACKNOWLEDGEMENTS

I would first like to thank my thesis advisors Dr. Kris Lulofs and Dr. Luewton Lemos from the Environmental and Energy Management programme at the University of Twente. The door to Prof. Dr. Lemos office was always open and I could always reach Prof. Dr. Lulofs through skype whenever I ran into a trouble spot or had a question about my research. They consistently permitted this study to be my own work, but guided me in the right direction whenever they thought it was necessary.

I would also like to thank the Brazilian National Health Foundation who contributed tremendously to this work in providing all the archived data. Without its participation and input, the research could not have been successfully completed.

Finally, I must express my very deep gratitude to my parents for having provided me with unfailing support and continuous encouragement throughout this year of study and through the process of researching and writing this thesis. I could not have done it without their presence in my life and this accomplishment would not have been possible.

My most sincere thank you to all of you

Daniel Pereira Garcia

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLES

1 CHAPTER 1 INTRODUCTION

1.1 Background

Recent studies suggests that although there is evidence of surface-based storm drainage systems in early Babylonian and Mesopotamian Empires in Iraq (ca. 4000–2500 BC), it is not until after 3000 BC that evidence is found of the well organized and operated sewer and drainage systems of the Minoans and Harappans in Crete and the Indus valley, respectively (de Feo et al., 2014). The Minoans and Indus valley civilizations originally, and the Hellenes and Romans thereafter, are considered pioneers in developing basic sewerage and drainage technologies, with emphasis on sanitation in the urban environment (de Feo et al., 2014).

Recently, there is a growing body of literature that recognises the importance of well stablished sanitation systems for the development of societies. According to the United Nations, the benefits of having access to an improved drinking water source can only be fully realized when there is also access to improved sanitation and adherence to good hygiene practices. Beyond the immediate, obvious advantages of people being hydrated and healthier, access to water, sanitation and hygiene – known collectively as WASH – has profound wider socio-economic impacts, particularly for women and girls.

The UN arguments that WASH being the subject of dedicated targets within the Sustainable Development Goal (SDG 6) is testament to its fundamental role in public health and therefore in the future of sustainable development. Indeed, access to safe water and sanitation are human rights, as recognized in 2010 by the United Nations General Assembly.

However, though human rights in the 21st century, 2.1 billion people still lack access to safely managed drinking water services (WHO/UNICEF 2017), 4.5 billion people lack safely managed sanitation services (WHO/UNICEF 2017), and 340,000 children under five die every year from diarrhoeal diseases. (WHO/UNICEF 2015).

It is the broadly accepted that for universal fulfilment of these basic human rights, the world needs to have the right systems in places, these are according to the UN: well-resourced, capable institutions delivering services and changing behaviour in resilient and appropriate ways

1.1.1 Focus of the research

The research focus on the sanitary conditions in Brazil with a broader view of the country’s situation and then narrowing it down to the municipalities under fifty thousand inhabitants in the state of Ceara, Brazil.

Contextualizing the country’s current conditions, numbers released by the Brazilian National Water Agency in 2017 have shown that 81% of Brazilian municipalities discharged at least half of the sewage they produce directly into water bodies without any treatment. More than 110 thousand kilometres of water bodies in the country with quality compromised by the launch of untreated effluents. The agency also released that nearly 90% of Brazilian municipalities treated less than 60% of sewage and 70% of the municipalities did not even have a wastewater treatment plant.

For the state of Ceará, the situation is worse. Only 20% of Ceará's cities have a municipal sanitation plan, according to a study released by the institute Trata Brasil. Based on the study, despite the low rate considered, Ceará has the second best performance in the Northeast. Sergipe has the highest index in the region (43%); and

Piauí, the lowest (4%). In the country, the average is 30% of municipalities with the plan to universalize basic sanitation.

1.1.2 The legal framework

The water, sanitation and hygiene sector in the country is guided by a national plan (2013 - 2033) and by a set of laws.

The law 11.445 / 2007 – Federal law for Basic Sanitation addresses the set of public drinking water supply services; collection, treatment and final disposal of sanitary sewers; drainage and management of urban rainwater, as well as urban cleaning and solid waste management. This law establishes national guidelines for basic sanitation and set goals to be met until 2033 such as to universalize the collection and treatment of sewage throughout the country.

In addition to the law the plan prioritizes the elimination of open defecation, the achievement of universal access to safely managed water and the attainment of at least 92% access to safely managed sanitation (Brazil Overview: Water, sanitation and hygiene, 2017). Still, according to the plan, expanding access to Water Supply and Sanitation Hygiene (WASH) includes substantial reduction of regional and local inequalities

The Legal framework for sanitation in Brazil can be summarized as it follows:

I. The public consortia law enacted in 2005 that establishes general rules about agreements among members of the Brazilian federation.
II. The federal law enacted in 2007.
III. The national plan published in 2013, which establishes national goals to the sector and estimates necessary investments.
IV. The Investments Partnerships Program (PPI) law enacted in 2016, which stimulates public-private partnerships and privatization of state-owned enterprises.

For the elaboration of the Municipal Sanitation Plans a document named Term of Reference is used as guidelines. According to the Brazilian National Health Foundation, the purpose of this Term of Reference (TR) is to establish standards, criteria, key procedures and provide information that allows the normalization of proposals for the application of budgetary resources and through the conclusion of an agreement, for the elaboration of Municipal Plans of Basic Sanitation (PMSB).

The content of the Term of Reference is inserted in the context of the following laws

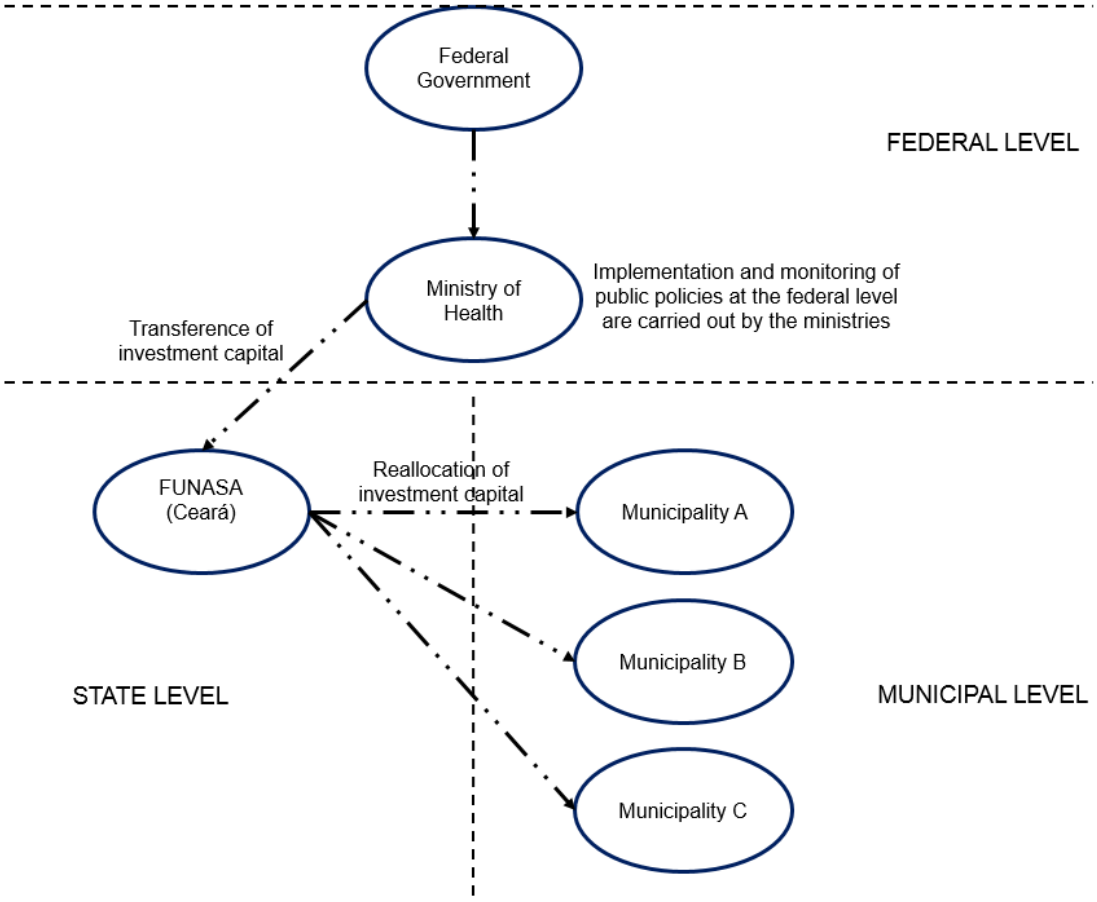
I. Law No. 11,445, of January 5 of 2007, which defines the national guidelines and establishes the Federal Basic Sanitation Policy, and of its Regulatory Decree No. 7,217, of June 21, 2010;
II. Law No. 12,305, of December 2, August 2010, which establishes the National Policy on Solid Waste, and its Decree Regulation No. 7,404, of December 23, 2010;
III. Law 10,257 of July 10 2001, which establishes the Town Statute.

1.1.3 The actors involved in sanitation for cities under fifty thousand inhabitants

By Law, municipalities are responsible for water supply and sanitation services: they are in charge of municipal planning, service provision, organisation, regulation and controls, as well as of defining tariffs and preventing abuse of dominant position. The Law provides provisions on delegation of these responsibilities and the associated conditions: municipalities can decide to delegate their responsibilities for regulation, monitoring and service provision to states or to public consortia under public or private law. When service provision is regionalised, comprising several municipalities, it allows service provision to be provided by delegation to another public body or a company.(Government of India, 2017)

Figure 1 illustrates a simple representation of how the federal resources in Brazil is distributed. As mentioned, we are focusing in cities under fifty thousand inhabitants and on sanitary condition and for that reason is the Brazilian National Health Foundation the organization responsible for manage this linkage.

Figure 1 Decision making structure



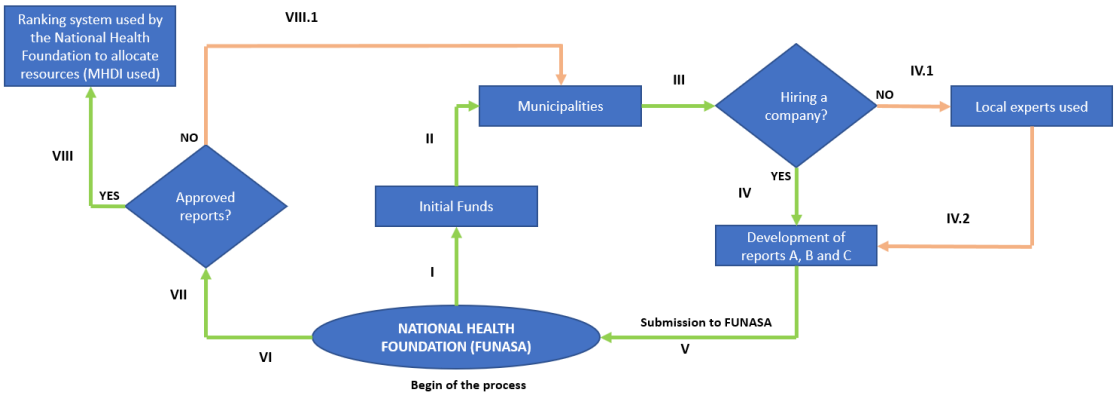
Source: Author's work

The connection between state level and municipal level to develop the Municipal sanitation Plans works as following: there is first the initial budget provided by the Brazilian National Health foundation to develop a list of required reports from which a diagnosis report is one of them. The initial funding is made available through covenant

where the municipality can hire specialized experts to assist in the elaboration of the initial reports.

For the release of a second budget, a specialized committee must approve the reports submitted in order to proceed to the elaboration of the Municipal Sanitation Plan. In this phase, the National Health Foundation assess all the reports and if they are according to the Term of Reference, the foundation releases the budget to the elaboration of the remaining reports. The National Health Foundation releases the funding based on the approval of the submitted reports and select who will receive the second budget ranking them based on Municipal Human Development Index.

Figure 2 Decision making map



Source: Author's work

The Diagram of figure 2 illustrates in details the decision-making process between the National Health Foundation and the municipalities when allocating the budget to sanitation improvement and development of remaining reports according to the Term of Reference.

1.1.4 Ministries and the Ministry of Health

The ministries are part of the administrative leadership. They are directly subordinated to the President of the Republic, assisting in the exercise of the Executive Power. They have the technical, financial and administrative autonomy to execute the actions in their areas of competence. It is also up to them to establish strategies, guidelines and priorities in the application of public resources, as well as to create standards, monitor and evaluate federal programs (Government of Brazil, 2009).

The Ministry of Health is the Federal Executive Branch responsible for the organization and elaboration of plans and public policies aimed at the promotion, prevention and health care of Brazilians. It is the function of the Ministry to have conditions for the protection and recovery of the population's health, reducing diseases, controlling endemic and parasitic diseases, and improving health surveillance, thus giving Brazilian citizens a better quality of life (Ministry of Health, 2017).

1.1.5 The Brazilian National Health Foundation

The Brazilian National Health Foundation (FUNASA), executive body of the Ministry of Health, is one of the institutions within the Federal Government responsible for promoting social inclusion through sanitary actions in order to prevent and control diseases. It is also the institutions responsible for formulate and implement actions that promote public health related to what is established in the National Subsystem of Environmental Health Surveillance. The organization act on the areas of Public Health Engineering and Environmental Health (Funasa, 2017).

In the area of Public Health Engineering, FUNASA has the oldest and continuous experience in sanitation actions in the country and operates based on sanitary, epidemiological, environmental and social indicators (Funasa, 2017). FUNASA provides technical and/or financial support in the fight against, control and reduction of infant mortality and the incidence of waterborne diseases or caused by the lack of basic and environmental sanitation (Funasa, 2017). The investments aim to intervene in the environment, in the infrastructure of the municipalities of up to 50 thousand inhabitants, and in the living conditions of vulnerable populations (Funasa, 2017).

It aims to by 2030, become a national and international benchmark in sanitation and environmental health actions, contributing to the goals of universal sanitation in Brazil.

1.1.6 The Municipal plans and diagnosis reports

Municipalities must adopt plans for water supply and sanitation. Plans provide the diagnostic of the situation, the targets to be attained and their timing; the actions, programmes and projects for implementation and their subsequent evaluation. As from 2017, the non-adoption of the water supply and sanitation plan implies no access to federal funding of sanitation infrastructure, either through grants or in the form of loans from federal financial institutions (Governance of drinking water and sanitation infrastructure in Brazil, 2017).

Beyond the existence of water supply and sanitation plans, the allocation of federal resources is also subject to the existence of a consultative consumer body, the good performance of the operator and efficient and effective services over the lifetime of works. Resources are allocated on the basis of priorities aiming at supporting municipalities that lack resources to sustain the services without external support (Governance of drinking water and sanitation infrastructure in Brazil, 2017). By Law, it is prohibited to grant federal resources to basic public sanitation services not provided by an (public) entity or body of the Federation as defined in Brazil's Constitution. For integrated economic development regions, regional water supply and sanitation plans are articulated with states and municipalities. (Governance of drinking water and sanitation infrastructure in Brazil, 2017)

1.1.7 The relationship among actors

The Ministry of Health with its financial and administrative autonomy is responsible for allocating investment capital from the government to each state. Within each state, there are organizations to make use of the budget accordingly. For example, FUNASA is responsible for allocating federal resources (for sanitation improvement) to municipalities up to fifty thousand inhabitants. As presented in the Figure 1.

Additionally, so that the municipalities can receive the budget, each municipality has to go through the process illustrated in figure 2.

However, the capital from the government is received by FUNASA and re-allocated to the municipalities using Municipal Human Development Index (MHDI) as criteria to prioritize - amongst the approved municipal plans- who is to firstly receive the budget, and this ranking process is the problem

1.2 Problem statement

As mentioned in the background, the Brazilian National Health Foundation is responsible for allocating federal resources to municipalities. In order to provide such service, it uses Municipal Human Development Index (MHDI) as criteria to prioritize - amongst the approved municipalities - who will firstly receive the capital

Although HDI is a strong indicator for human development, it can be controversial in a country with very big social differences like Brazil. The index considers three dimensions: life expectancy at birth, mean years of schooling and expected years of schooling and Gross National Income per capita. However, it does not consider the specificities of sanitary conditions such as techniques and technologies used in sanitation infrastructure nor the level of infrastructure between cities. There is thus a need to develop a classification instrument that measures sanitation quality to assist FUNASA in the allocation of financial resources.

1.3 Research objective

The objective of this research is to develop a classification instrument that measures sanitation quality offered to cities up to fifty thousand people, in order to assist the National Health Foundation during the allocation of financial resources for sanitation improvement.

1.4 Main research questions

How to classify the levels of sanitation systems in cities under fifty thousand inhabitants in Ceará, Brazil to determine which municipality needs to receive federal funds first?

1.4.1 Research questions

I. What are the current guidelines that classify the minimum quality of sanitation systems?
II. What are the variables to consider in the classification of drinking water systems, wastewater systems, drainage systems and solid waste for the development of the classification instrument?
III. What indicators can be used to assess the quality of sanitation systems for the development of the classification instrument?
IV. Is a classification instrument for sanitation infrastructure valid?
V. What are the strengths and weaknesses of the classification instrument?
VI. What are the major priorities for cities under fifty thousand inhabitants in Ceará regarding sanitation.

1.5 Answering the research questions

The research questions are gradually answered through chapters 2 up to chapter 6 throughout the development of the study. However, chapter 7 explicitly answers them indivually.

The minimum sanitation standards are defined by using variables indicators found in the international community standards for sanitation as shown in section 2.3. The variables considered in the classification of wastewater and drinking water systems as well as in drainage systems and solid waste management are defined in two main instances. Through reviewing past literature developed on the topic and by developing the classification instrument in chapters 4 and 5 using the diagnosis reports as basis for data.

Once all relevant sanitation parameters are drawn from the reports and literature, the relevant ones are used for the classification instrument. Further we explore – in section 6.2 - the validity and reliability of the instrument by comparing the ranking from using MHDI and using the classification instrument developed in the research. To assess reliability, section 6.3 evaluates strengths and weaknesses pointing the upsides and the pitfalls of using such tool to classify the level of sanitation infrastructure in a given municipality.

Ultimately, we present - in section 7.6 - a list with the major priorities regarding sanitation in the state of Ceará in terms of infrastructure based on the reports, past literature and by using the classification instrument.

1.6 The layout of the research

Research layout by chapter	
1. Introduction	Defining the focus, object and objective of the research and contextualizing the problem
2. Literature Review	Starting answering the research questions and assessing past literature and methods that may assist the development of the classification instrument
3. Research framework and methodology	Defining the layout of the research in terms of the steps taken and explaining the methods and procedures used to gather and assess data collected.
4. Study of situation	This section is mainly focused on the data that can be acquired by assessing the diagnosis reports provided by the Brazilian National Health Foundation. In other words: understanding the current situation found in the cities based on the reports.
5. Data analysis	The analysis is the section where the data from the previous section is analysed using the method defined in Research framework and methodology.
6. Development of the classification instrument	This section is the last section that still have data analysis, now evaluating the results found by using the instrument. This section also comprehend the validation of the research, analysis of strength and weaknesses.
7. Findings: answering the research questions	This section summarize all the findings of the study addressing each research questions separately.
8. Recommendation	The section provide insight on – based on strength and weaknesses – what can be done to improve the classification instrument and how to better data on the reports.
9. Conclusion	This section summarizes the findings of the research providing the answer for the main research question and what was achieved by the study.

Source: Author's work

2 CHAPTER 2 LITERATURE REVIEW

The literature review presents relevant information that has already been developed to classify sanitation systems. Among those, there are ranking systems, index and classification methods with indicators of performance. It also provides several definitions for sanitation including the one used by the Brazilian National Health Foundation and defines the current sanitary condition in Brazil.

2.1 Definitions and modes of sanitation

There are many definitions for the term sanitation, with the majority of them being related to drainage and storm water, drinking water and wastewater systems. The definitions found in the literature review provide enough information to determine the scope of sanitation sought-after in this research.

The Brazilian National Health Foundation definition

The Brazilian National Health Foundation defines Environmental Sanitation as a set of socioeconomic actions that aim to reach environmental salubrity through the supply of potable water as well as collection, disposal and treatment of solid, liquid and gas waste. It also promotes sanitary discipline for the usage of soil, urban drainage and

control of transmissible diseases targeting to protect and improve urban and rural life conditions.

The United States Environmental Protect Agency definition

The US Environmental Protection Agency (EPA) defines sanitation as control of physical factors in the human environment that could harm development, health, or survival.

The water supply and collaborative Council definition

The Water Supply and Sanitation Collaborative Council defines sanitation as the collection, transport, treatment and disposal or reuse of human excreta, domestic wastewater and solid waste, and associated hygiene promotion

The United Nations definition

The United Nations defines sanitation as access to, and use of, excreta and wastewater facilities and services that ensure privacy and dignity, ensuring a clean and healthy living environment for all. “Facilities and Services" should include the ‘collection, transport, treatment and disposal of human excreta, domestic wastewater and solid waste and associated hygiene promotion’ to the extent demanded by the particular environment conditions.

The World Health Organization definition

The United Nations defines sanitation as access to, and use of, excreta and wastewater facilities and services that ensure privacy and dignity, ensuring a clean and healthy living environment for all. “Facilities and Services" should include the ‘collection, transport, treatment and disposal of human excreta, domestic wastewater and solid waste and associated hygiene promotion’ to the extent demanded by the particular environment conditions.

The Unesco-IHE and CWSR definition

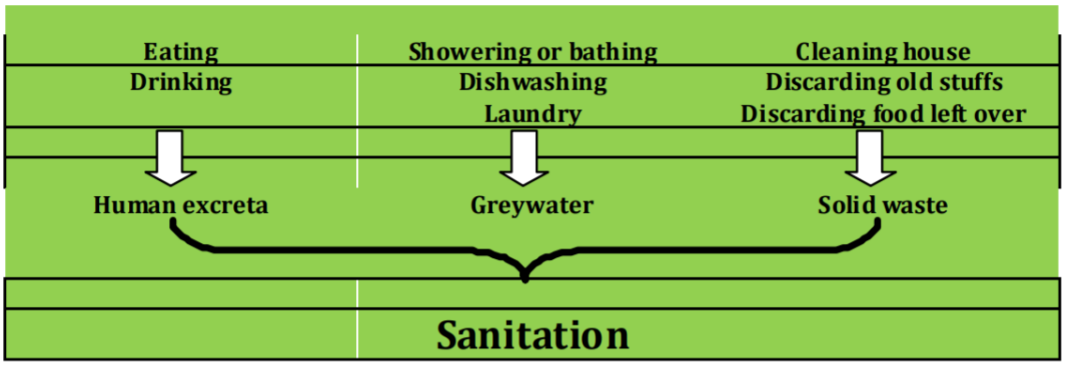
The Unesco-IHE and CWSR (Centre for Water and Sanitation Research) says that sanitation refers to:

I. The safe management of human excreta and greywater
II. The principles and practices relating to the collection, removal, or disposal of human excreta, refuse and waste water.
III. The provision of facilities and services for the safe disposal of human excreta, maintenance of hygienic conditions, through services such as garbage collection and wastewater disposal.

2.1.1 Modes of Sanitation

The figure 2 represents the scope of sanitation as defined by Unesco_IHE and CWSR, separating the sources into human excreta, greywater and solid waste.

Figure 3 Scope of sanitation as defined by Unesco_IHE



Source: Unesco IHE and CWSR.

The classification used by Unesco IHE and CWSR are threefold as presented in table 1.

I. Earth and water based

Table 1 Sources of sanitation

Waterborne or wet	Non-waterborne or wet
Full flush or cistern flush (water comes from the cistern)	Urine diverting dry toilet (UDDT)
Pour flush (use of bucket to throw water for flushing purpose)	Dry toilet (sit or squat pan)
Low flush toilet (flushing mechanism release small quantity of water)	VIP toilet
Aqua privy	Vault toilet

Source: Unesco IHE and CWSR.

II. Place of the treatment unit

- Onsite treatment before disposal - the treatment of human excreta occur where or close to the source of generation
- Off-site - human excreta is removed from the site where it was generated and treated elsewhere

III. Context of use

- Individual facility
- Shared facility

The work of Eawag Sandec, (2008) uses a similar approach separating sanitation systems into waterless systems and water based systems as seen in the figure 3. The figure 3 shows the classification of sanitation systems within each category as defined by Tilley, (2008).

Figure 4 Classification of sanitation systems

Waterless systems		Water based systems	
System 1:	Single Pit System	System 3:	Pour Flush with Urine Diversion
System 2:	Waterless Alternating Double Pits	System 5:	Decentralised Blackwater Treatment
		System 6:	(Semi-) Centralised Blackwater Treatment
System 4:	Waterless Urine Diversion	System 6:	Sewerage with (Semi-) Centralised Treamtent
		System 8:	Sewerage with (semi-) centralized treatment

Source: Tilley, (2008).

Another classification is the one used by Joint Monitoring Programme (JMP). The JMP is the official United Nations branch responsible for monitoring progress towards the sixth Sustainable Development Goal (SDG6) since 2016. Its classification considers the existence of improved and unimproved sanitation facilities. An improved sanitation facility being defined as one that hygienically separates human excreta from human contact and an unimproved sanitation facility as one ranging from simple but protected pit latrines to flush toilets with a sewerage connection.

A more in-depth look breaks down these concepts into detail as seen below.

Improved sanitation usually related to the following facilities

I. Connection to a public sewer
II. Connection to a septic system
III. Pour-flush latrine
IV. Simple pit latrine
V. Ventilated improved pit latrine

Unimproved sanitation usually related to these facilities

I. Public or shared latrine
II. Open pit latrine
III. Bucket latrine

The facilities here defined as improved or unimproved are in accordance with the criteria used by the United Nations.

The work of Hutton & Haller, 2004, classify unimproved and improved sanitation facilities according to the Global Water Supply and Sanitation 2000 Report. The table 2 show their specificities.

Table 2 Unimproved and Improved sanitation facilites

Intervention	Improved	Unimproved *
Water supply	• House connection • Standpost/pipe • Borehole • Protected spring or well • Collected rain water • Water disinfected at the point-of-use	• Unprotected well • Unprotected spring • Vendor-provided water • Bottled water • Water provided by tanker truck
Sanitation	• Sewer connection • Septic tank • Pour-flush • Simple pit latrine • Ventilated Improved Pit-latrine	• Service or bucket latrines • Public latrines • Latrines with an open pit

* Due to being either unsafe or costly

Source: Global Water Supply and Sanitation 2000 Report

2.2 Importance of sanitation

In nineteenth-century Europe and North America, diarrhoea, cholera, and typhoid spread through poor sanitation was the leading cause of childhood illness and death; today, such deaths are rare in these regions (UN water, international year of Sanitation, 2008). In developing countries, however, they are all too common, and recent research suggests that poor sanitation and hygiene are either the chief or the underlying cause in over half of the annual child deaths (UN water, international year of Sanitation, 2008).

Compelling, evidence based analysis shows that hygiene and sanitation are among the most cost effective public health interventions to reduce childhood mortality. Access to a toilet alone can reduce child diarrhoeal deaths by over 30 percent and handwashing by more than 40 percent (UN water, international year of Sanitation, 2008).

According to the Unesco-IHE and CWSR (Centre for Water and Sanitation Research) sanitation is needed to:

Protect and promote health by:

I. Keeping disease carrying waste and insects away from people, toilets and homes
II. Break the spread of diseases
III. Prevent spreading of waterborne diseases
IV. Improve the health and quality of life

Protect the environment against pollution by:

I. Keeping disease carrying waste and insects away from the environment

II. Prevent environmental pollution (air, soil and emission)
III. Prevent contamination of water resources (surface and ground water)

2.2.1 Economic value of sanitation

The Swiss Tropical Institute, in a report (Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level) commissioned by the WHO, delineated significant economic benefits to the world, and predominantly to the developing world, if the Millennium Development Goals (MDG) and World Summit on Sustainable Development goals are met. It estimates that the economic benefits would range from US$ 3 to US$ 34 per US$ 1 invested, depending on the region and reductions in exposure to contaminated drinking water, such as through household-level disinfection, would lead to an overall benefit ranging from US$ 5 to US$ 60 per US$ 1 invested.

2.2.2 Financial incentives for investment in sanitation

The following data is based on the report from Vandor & Emiliano, 2018. L.E.K Consulting, a report that assess in-depth the sanitary conditions in Brazil.

I. According to the World Health Organization (WHO), for each dollar invested in sanitation, $4.3 is saved in health costs.
II. Workers in areas with access to sanitation are up to 4% more productive than those without proper facilities.
III. Real estate value is up to 13% higher in areas with access to water and sewage systems.

Tourism loses approximately $3 billion a year due to the lack of sanitation infrastructure and its impact on the environment.

2.3 International community standards for sanitation: minimum standards for sanitation systems

The Minimum Standards in Water, Sanitation and Hygiene Promotion are a practical expression of the principles and rights embodied in the Humanitarian Charter because it is concerned with the most basic needs for sustaining the lives and dignity of those affected by calamity or conflict, as reflected in the body of international human rights, humanitarian and refugee law (Sphere, 2004).

The right to water is recognised in international legal instruments and provides for sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses (Sphere, 2004). Moreover, an adequate amount of safe drinking water is necessary to prevent death from dehydration, to reduce the risk of water-related disease and to provide for consumption, cooking, and personal and domestic hygienic requirements. The right to water cannot be separated from other human rights such as the right to health, the right to housing and the right to adequate food and as such, it is part of the guarantees necessary to human survival.

The following standards (from section 2.3.1. to 2.3.7.) are taken from the Sphere, 2004 report on The Minimum Standards in Water, Sanitation and Hygiene Promotion and adapted to the reality of Brazil. The elimination and/or adaptation of an indicator is based on the assumption that Brazil does not live in a refugee or disaster condition.

2.3.1 Water supply standard: access and quantity

Access to sufficient water quantity for basic needs. In other words, all people must have safe and equitable access to a sufficient quantity of water for drinking, cooking and personal and domestic hygiene. Moreover, public water points should be close enough to households to guarantee the use of the minimum water requirement. The indicators to assess the compliment with these standards are as seen below:

I. Average water use for drinking, cooking and personal hygiene in any household is at least 15 litres per person per day
II. The maximum distance from any household to the nearest water point is 500 metres.
III. Queuing time at a water source is no more than 15 minutes
IV. It takes no more than three minutes to fill a 20-litre container.
V. Water sources and systems are maintained such that appropriate quantities of water are available consistently or on a regular basis.

2.3.2 Water supply standard: quality

Water is palatable, and of sufficient quality to be drunk and used for personal and domestic hygiene without causing significant risk to health. The indicators to assess the compliment with these standards are as seen below:

I. There are no faecal coliforms per 100ml at the point of delivery
II. People drink water from a protected or treated source in preference to other readily available water sources
III. For piped water supplies, or for all water supplies at times of risk or presence of diarrhoea epidemic, water is treated with a disinfectant so that there is a free chlorine residual at the tap of 0.5mg per litre and turbidity is below 5 Nephelometric Turbidity Unit (NTU)

2.3.3 Water supply standard: water use facilities and goods

People must have adequate facilities and supplies to collect, store and use sufficient quantities of water for drinking, cooking and personal hygiene, and to ensure that drinking water remains safe until it is consumed. The indicators to assess the compliment with this standards are as seen below:

I. Each household has at least two clean water collecting containers of 10-20 litres, plus enough clean water storage containers to ensure there is always water in the household
II. Water collection and storage containers have narrow necks and/or covers, or other safe means of storage, drawing and handling, and are demonstrably used
III. There is at least 250g of soap available for personal hygiene per person per month. Where communal bathing facilities are necessary, there are sufficient bathing cubicles available, with separate cubicles for males and females, and they are used appropriately and equitably

IV. Where communal laundry facilities are necessary, there is at least one washing basin per 100 people, and private laundering areas are available for women to wash and dry undergarments and sanitary cloths.
V. The participation of all vulnerable groups is actively encouraged in the siting and construction of bathing facilities and/or the production and distribution of soap, and/or the use and promotion of suitable alternatives

2.3.4 Excreta disposal standard: access to, and numbers of, toilets

People must have adequate numbers of toilets, sufficiently close to their dwellings, to allow them rapid, safe and acceptable access at all times of the day and night. The indicators to assess the compliment with these standards are as seen below:

I. A maximum of 20 people use each toilet
II. Use of toilets is arranged by household(s) and/or segregated by sex
III. Separate toilets for women and men are available in public places (markets, distribution centres, health centres, etc.)
IV. Shared or public toilets are cleaned and maintained in such a way that they are used by all intended users
V. Toilets are no more than 50 metres from dwellings
VI. Toilets are used in the most hygienic way and children's faeces are disposed of immediately and hygienically

2.3.5 Excreta disposal standard: design, construction and use of toiles

Toilets are sited, designed, constructed and maintained in such a way as to be comfortable, hygienic and safe to use. The indicators to assess the compliment with these standards are as seen below:

I. Toilets are designed, built and located to have the following features:
   a. They are designed in such a way that they can be used by all sections of the population, including children, older people, pregnant women and physically and mentally disabled people.
   b. They are sited in such a way as to minimise threats to users, especially women and girls, throughout the day and night.
   c. They are sufficiently easy to keep clean to invite use and do not present a health hazard;
   d. They provide a degree of privacy in line with the norms of the users; – they allow for the disposal of women's sanitary protection, or provide women with the necessary privacy for washing and drying sanitary protection cloths
   e. They minimise fly and mosquito breeding.
II. All toilets constructed that use water for flushing and/or a hygienic seal have an adequate and regular supply of water.
III. Pit latrines and soakaways (for most soils) are at least 30 metres from any groundwater source and the bottom of any latrine is at least 1.5 metres above

the water table. Drainage or spillage from defecation systems must not run towards any surface water source or shallow groundwater source.

IV. People wash their hands after defecation and before eating and food preparation

V. People are provided with tools and materials for constructing, maintaining and cleaning their own toilets if appropriate.

2.3.6 Solid waste management: collection and disposal

People must have an environment that is acceptably uncontaminated by solid waste, including medical waste, and have the means to dispose of their domestic waste conveniently and effectively. The indicators to assess the compliment with these standards are as seen below:

I. People from the affected population are involved in the design and implementation of the solid waste programme.

II. Household waste is put in containers daily for regular collection, burnt or buried in a specified refuse pit.

III. All households have access to a refuse container and/or are no more than 100 metres from a communal refuse pit.

IV. At least one 100-litre refuse container is available per 10 families, where domestic refuse is not buried on-site.

V. Refuse is removed from the settlement before it becomes a nuisance or a health risk

VI. Medical wastes are separated and disposed of separately and there is a correctly designed, constructed and operated pit, or incinerator with a deep ash pit, within the boundaries of each health facility

VII. There are no contaminated or dangerous medical wastes (needles, glass, dressings, drugs, etc.) at any time in living areas or public

VIII. There are clearly marked and appropriately fenced refuse pits, bins or specified areas at public places, such as markets and slaughtering areas, with a regular collection system in place

IX. Final disposal of solid waste is carried out in such a place and in such a way as to avoid creating health and environmental problems for the local and affected populations

2.3.7 Drainage standards: drainage works

People must have an environment in which the health and other risks posed by water erosion and standing water, including storm water, floodwater, domestic wastewater and wastewater from medical facilities, are minimised. The indicators to assess the compliment with these standards are as seen below:

I. Areas around dwellings and water points are kept free of standing wastewater, and storm water drains are kept clear

II. Shelters, paths and water and sanitation facilities are not flooded or eroded by water.

III. Water point drainage is well planned, built and maintained. This includes drainage from washing and bathing areas as well as water collection points
IV. Drainage waters do not pollute existing surface or groundwater sources or cause erosion
V. Sufficient numbers of appropriate tools are provided for small drainage works and maintenance where necessary

As seen above, the standards and their respective indicators provide in fact the minimum requirements to an acceptable sanitary condition therefore these indicators and standards may be adapted to fit within the classification instrument that measures sanitation quality. The mentioned indicators provides the research with the most basic sanitary conditions thus creating the boundary/limit of what can be considered the minimum necessity: a base line.

2.4 Ranking for sanitation

This section of the literature review seeks to provide the methods already used to classify and then rank a given city, region or country according to its level of sanitation. It also aims to find indicators used to define sanitation infrastructure in terms of efficiency, improvement and quality.

2.4.1 The Environmental Performance Index approach

The current methodology used by the Environmental Performance Index, measures two indicators: access to drinking water and access to sanitation. Access to drinking water measures the proportion of a country's total population with access to an "improved drinking water source" as a main source of drinking water.

According to the World Health Organization, an improved drinking water is defined as a facility or delivery point that protects water from external contamination—particularly faecal contamination.

1. Piped water into a dwelling, plot, or yard;
2. Public tap or standpipe;
3. Tube well or borehole;
4. Protected spring;
5. Rainwater collection.

Access to Sanitation measures the percentage of a country's population that has access to an improved source of sanitation. "Improved" sanitation sources being defined as:

I. Connection to a public sewer;
II. Connection to a septic system;
III. pour-flush latrine;
IV. simple pit latrine;
V. Ventilated pit latrine.

Based on the criteria used by the Environmental Performance Index, the system is considered "improved" if it hygienically separates human excreta from human contact and is not public, meaning that it can be neither private nor shared.

The Method itself

The EPI method starts by transforming raw datasets to standardized, comparable performance indicators, which, requires standardizing raw values based on population, gross domestic product, or other denominators that makes data comparable amongst countries. The method may involve the application of statistical transformations like inversions or logarithmic transformations used to analyse large amounts of raw data.

The transformed data is used to calculate performance indicators. The EPI indicators use a “proximity-to-target” methodology, which assesses how close a particular country is to an identified policy target (Environmental Performance Index, 2018). Primarily international or national policy goals or established scientific thresholds define that target, a high performance benchmark. For example, the benchmarks for protected areas are determined through international policy targets established by the Convention on Biological Diversity (CBD) (Environmental Performance Index, 2018).

Scores are then converted to a scale of 0 to 100 by simple arithmetic calculation, with 0 being the farthest from the target (worst observed value) and 100 being closest to the target (best observed value). See Figure 4. In this way, scores convey similar meaning across indicators, policy issues, and the overall EPI (Environmental Performance Index, 2018).

Figure 5 Scale used by the Environmental Performance Index

Source: Environmental Performance Index, 2018

Each indicator is weighted within each policy issue to create a single policy issue score. These weightings are generally set according to the quality of the underlying dataset, as well as the relevance or fit of the indicator to assess the policy issue (Environmental Performance Index, 2018). If the underlying global data for a particular indicator is less reliable or relevant than others in the policy issue, it will be weighted less heavily (Environmental Performance Index, 2018).

For example, the trends in carbon intensity indicators in the Climate and Energy category are weighted according to which indicator is more pertinent based on a country’s economic development and policy obligations with respect to climate change mitigation (Environmental Performance Index, 2018).

Although the methodology applied by the EPI englobes a scope involving several indicators (including the indicator for water and sanitation as mentioned above) it does provide an analytical framework on how a data set can be ranked.

2.4.2 The institute Trata Brasil approach

Another study developed by Oliveira, Scazufca, & Arouca, 2012, in the Institute Trata Brazil, created comprehensive methodology comparing the 100 biggest cities using data from the Brazilian National System for Sanitation Information. The work groups the variables into level of coverage, coverage improvement and level of efficiency. See the table 3 for reference.

Table 3 Grouping method of Institute Trata Brazil

Group	Indicator	Explanation
level of coverage	Total water	Urban and rural population covered by water supply
	Urban water	Urban population covered by water supply
	Total collection	Urban and rural population covered by sewage collection
	Urban collection	Urban population covered by sewage collection
	treatment	Volume of sewage treated in relation to the volume of water consumed, controlled by the collection indices
Coverage improvement	Investment	Percentage of municipal bills invested in the system
	New water connections/lacking connections	Percentage used of the number of missing connections for universalization of water service
	New sewage connection/lacking connection	Percentage of the number of missing connections to universalization of sewage service
Level of efficiency	Distribution losses	Water consumed as a percentage of the water produced
	billing losses	Intake water as a percentage of the water produced
	Evolution on billing losses	Evolution of municipal revenue losses
	Evolution on distribution losses	Evolution of losses in the distribution in the municipalities

Source: (Oliveira et al., 2012)

The methodology of Oliveira C.S. considers the use of a score for each of the indicators. Scores can range from zero to ten and are called Partial Scores (PS). The Ranking is composed by the sum of the Final Scores (FS) of each of the indicators, which consists of the weighting of the Partial Scores (PS). For most indicators, the logic is to calculate the grades according to the largest existing score (directly proportional note). For example, if the highest score of for instance 100 municipalities is 100% and Municipality A has 90% coverage therefore it will receive 9. For some specific indicators, a very large variation may occur in the municipalities data, which means that there are only very high or very low scores for these indicators.

The study standardized to identify these cases through observation of the mean and standard deviation of the indicator. If the standard deviation were greater than the mean (coefficient of variation greater than one) for a given indicator, the following criterion was proposed: if a municipality has an indicator twice the average, it receives grade 10; otherwise, the note is calculated by dividing the indicator by the average and multiplying the result by 5. This avoids distortions in municipal bills. A

Although this method used by Institute Trata Brazil was successfully applied for these indicators, this study may change the approach to correct large deviations based on our own data.

2.4.3 National Sanitation Information System approach

The SNIS is the largest and most important information system in the sanitation sector in Brazil, based on a database that contains information of an institutional, administrative, operational, managerial, economic-financial, accounting and quality on the provision of water services, sewage and solid urban waste management.

Among the objectives of the SNIS are:

I. Planning and execution of public policies;
II. Orientation of the application of resources;
III. Knowledge and evaluation of the sanitation sector;
IV. Evaluation of service performance;
V. Improvement of management;
VI. Guidance of regulatory and supervisory activities;
VII. Exercise of social control.

In addition, the consolidation of the SNIS since 1995 allows the use of its indicators as a benchmark for comparison and as a guide for measuring the performance of service delivery.

The SNIS is currently divided into two components:

I. Water and sewage (SNIS-AE)
II. Solid waste (SNIS-RS).

The information of the SNIS is collected annually and comes from service providers or municipal agencies in charge of the management of the services, being the database totally public and available free of charge in the site www.snis.gov.br.

The SNIS methodology considers a typology of service providers based on three basic characteristics:

I. The scope of its performance (differentiating providers by the quantity and complexity of service delivery systems, both physical and political / institutional systems and spatial / geographical systems);
II. The legal-administrative nature (differentiating the providers from the point of view of the legal and administrative formality to which they are submitted in all dimensions of their performance); and
III. The types of sanitation services that are offered to users (water, water and sewage, sewage, municipal solid waste).

Finally, the operational indicators the SNIS uses for water and sewage (SNIS-AE) are listed below and are dived in water operational indicators, sewage operational indicators, indicators about quality, Solid waste collection indictors and Selective solid waste collection indicators. All the indictor can be found at the SNIS website: http://www.snis.gov.br

Water operational indicator

- Total water service index
- Index of urban water service
- Density of water savings per connection
- Share of residential water savings in total water savings
- Macro-index
- Hydrometric index
- Micro average index for the volume made available
- Micro consumption measurement index
- Water fluoridation index
- Water consumption index
- Volume of water provided by economy
- Average water consumption per economy
- Economy micro measured consumption
- Consumption of water billed by economy
- Average consumption per Capita of water
- Index of electricity consumption in water supply systems
- Extension of the water network per connection
- Water billing index
- Index of loss of revenue Index of loss of distribution
- Gross index of linear losses
- Loss per connection rate

I. Sewage operational indicators

- Index of total sewage service referred to municipalities served with water Index of urban sewage service referred to municipalities served with water Index of urban sewage service referred to municipalities served with sewage
- Sewage collection index

- Sewage treatment index
- Treated sewage index referring to water consumed
- Extension of sewage network per connection
- Index of electricity consumption in sewage systems
- Economies affected by outages

II. Indicators about quality

- Average duration of downtime
- Savings hit by flashes
- Intermittent average duration
- Average length of sewer overflow repairs
- Sewage extravasation by network extension
- Average duration of services performed
- Sample Quantity Conformity Index - Residual Chlorine
- Incidence of non-standard residual chlorine analyses
- Sample quantity compliance rate - Turbidity
- Incidence of non-standard turbidity analyses
- Sample Quantity Compliance Index - Total Coliforms Incidence of total non-standard coliform analyses

III. Solid waste collection indictors

- Rate of coverage of the Residential Waste (RW) collection in relation to the total population
- Rate of coverage of the RW collection in relation to the urban population
- Rate of direct collection coverage RW relative to the urban population
- Collection outsourcing fee
- Average collector and driver productivity
- Rate of drivers and collectors per urban inhabitant Massa: RW + Public Waste (PW) collected per capita in relation to the urban population
- RDA mass collected per capita in relation to the total population served
- Collective cost of collection
- Incidence of cost of collection in total cost of management
- Incidence of employment of the collection of total employees in the
- Relationship: RW quantity collected by Pref. per total amount [RW + PW]
- Ratio: quantities collected from PW by RW
- Mass [RW + PW] collected per capita in relation to the total population served Mass of RW per capita / year in relation to pop. urban

IV. Selective solid waste collection indicators

- Coverage rate of col. Door-to-door selectivity in relation to urban population
- Recovery rate of recyclables in relation to the amount of RW and PW Mass recovered per capita Ratio between selective collection and RW quantities Paper / cardboard incidence on total recovered material
- Incidence of plastics on total recovered material
- Incidence of metals on total recovered material
- Incidence of glasses on total recovered material
- Incidence of '' others '' on total recovered material

- Mass per capita collected via selective collection

There are more indicators for water and sewage (SNIS-AE) and for Solid waste (SNIS-RS), however, for the purpose of this research, the mentioned ones are the most relevant.

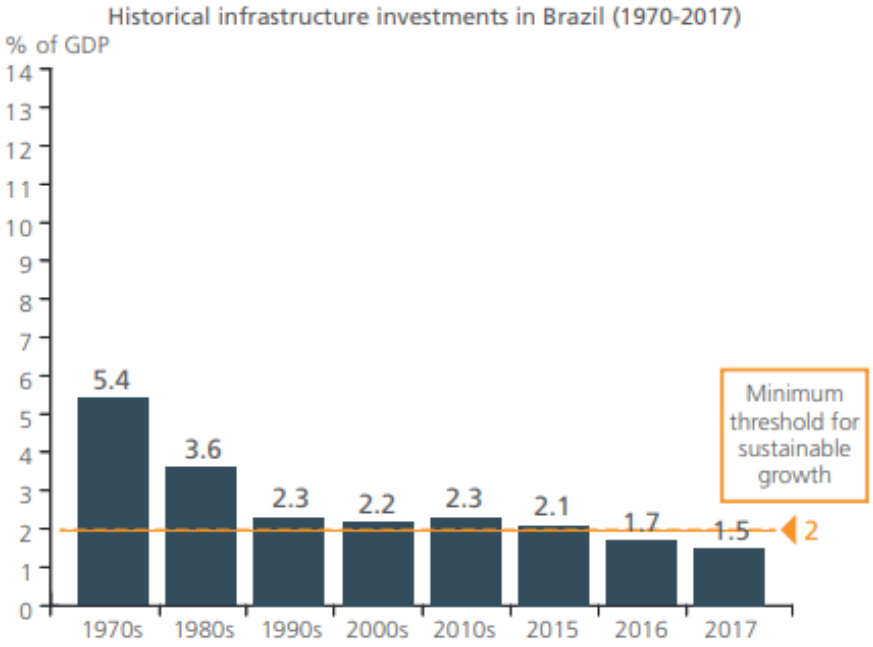
2.5 Brazil in the world scenario of sanitation

This section is based on the UN reports on SDGs (Brazil Overview: Water, sanitation and hygiene, 2017) based on the Brazilian National Water Agency website and reports and some additional report on sanitation infrastructure in Brazil.

2.5.1 Current situation

According to Vandor & Emiliano, 2018 from the L.E.K Consulting, in the last decades, Brazil has reduced its level of investment in the country's overall infrastructure below the annual threshold of 2%, which is considered the minimum for sustaining healthy economic growth. The state of affairs worsened by the economic recession that hit Brazil in 2015- 2016, which made Brazil's level of investment in infrastructure decrease below that of other developing nations. Figure 6 shows Brazil's historical investments in infrastructure.

Figure 6 Brazil's historical investments in infrastructure.



Source: Vandor & Emiliano, 2018. L.E.K analysis

Still based on the Vandor & Emiliano, 2018. L.E.K Consulting report, the sanitation sector accounts for less than 10% of investment in infrastructure in Brazil. Despite the central government's ambition to provide universal sanitation in 2015, only 83.3% of the population had access to treated water; sewage collection was even lower, reaching only 50.3% of the population. Brazil's sanitary situation in 2015 was already concerning. The table 4 shows the conditions of the five main regions in the country.

Table 4 Sewage collection and water distribution in Brazil

Region	Sewage collection (%)	Water distribution (%)
North	8.7	56.9
Northeast	24.7	73.4
Central-West	49.6	89.6
Southeast	77.2	91.3
South	41.0	89.4
National Average	**50.3**	**83.3**

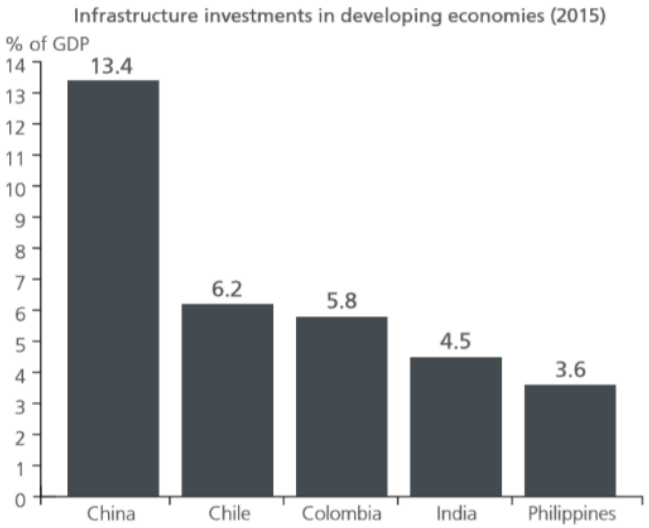
Source: Author's work (Data analysis from Vandor & Emiliano, 2018

In addition, numbers of the "Sewage Atlas - Watershed Clean-up", released by the Agência Nacional de Águas in 2017 (ANA in Portuguese) show that 81% of Brazilian municipalities discharge at least half of the sewage they produce directly into watercourses - that is, without any treatment. There are already more than 110 thousand km of watercourses in the country with quality compromised by the launch of untreated effluents. To regulate the sewage situation in the 5,570 Brazilian cities, with collection and treatment of effluents, would cost R$ 150 billion and would take at least 15 years, according to the same study.

Another clipping of data collected by ANA shows that nearly 90% of Brazilian municipalities treat less than 60% of sewage and 70% of the municipalities do not even have a sewage treatment plant.

2.5.2 Brazil in the world scenario

It is possible to see the gap of infrastructure development by comparing Brazil with other developing economies such as China, Chile, Colombia, India and The Philippines. The figure 6 clearly elucidates this scenario.



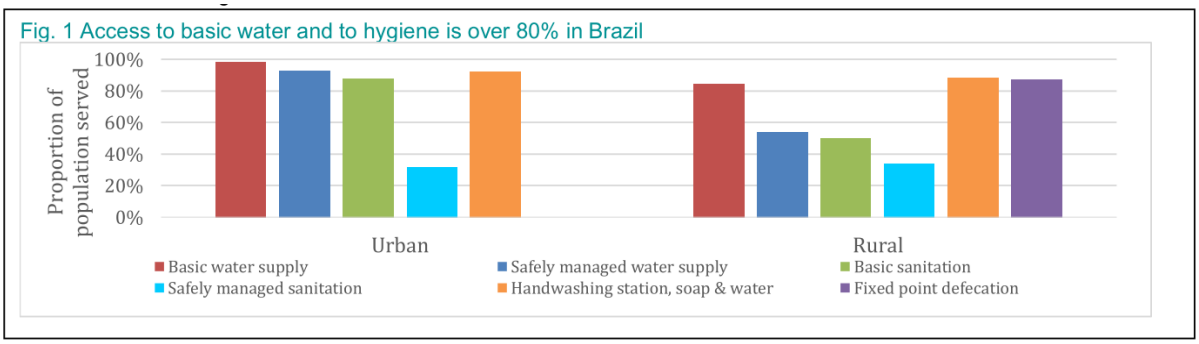
Source: Vandor & Emiliano, 2018

2.5.3 Overview of the Brazilian vision and targets for the SDGs

The water, sanitation and hygiene sector in Brazil is guided by a national plan (2013 - 2033) and by a federal law enacted in 2007 (Brazil Overview: Water, sanitation and hygiene, 2017). The plan prioritizes the elimination of open defecation, the achievement of universal access to safely managed water and the attainment of at least 92% access to safely managed sanitation (Brazil Overview: Water, sanitation and hygiene, 2017). Moreover, the national sanitation plan, expanding access to WASH includes decreasing difference at regional and local level. These goals are essentially in agreement with the SDGs. The federal law, in turn, sets the main policies to the sector, main roles and planning and social participation guidelines concerning water supply and sanitation.

In 2015, Brazil achieved the MDG targets for water and sanitation. These targets were halving, by 2015, the proportion of population without sustainable access to safe drinking water and basic sanitation. The main challenges are lack of services or poor quality services for the poor in urban and in rural areas in general, for the North and Northeast regions of Brazil where deficits are higher than the national average, and for a considerable number of small cities, under 50,000 habitants (Brazil Overview: Water, sanitation and hygiene, 2017). The coverage and quality of services are expressively inferior among these areas of the country. The figure 7 represent the access to basic water and to hygiene in Brazil in 2017.

Figure 7 Access to basic water and to hygiene



Source: Brazil Overview: Water, sanitation and hygiene, 2017

The critical bottlenecks to overcome lack of coverage and low quality service include:

I. Weak sector governance and integrity in many municipalities;
II. Heavy reliance on public financing;
III. Insufficient social participation and commitment.

If these barriers are not overcame, progress will remain slow and the national goals and the SDGs are likely not to be attained.

2.5.4 Review of the sector

Brazil is improving the foundations of a well-functioning sector. These foundations include four very important legal instruments in the federal level as mentioned before.

I. The public consortia law enacted in 2005 that establishes general rules about agreements among members of the Brazilian federation.

II. The federal law enacted in 2007.
III. The national plan published in 2013 which establishes national goals to the sector and estimates necessary investments.
IV. The Investments Partnerships Program (PPI) law enacted in 2016 which stimulates public-private partnerships and privatization of state-owned enterprises.

Additionally, the federal government increased the inflow of financial resources to the sector since 2007. This expansion was done by greater amounts of financial transfers from the national budget to the subnational entities and also by authorizations given by the national government to these entities and to the private sector to acquire more low cost loans. As a result, capital investments were leveraged nationwide in the past 10 years. All this has helped to clarify the vision for achieving the national goals and the SDGs. Nonetheless, there are gaps that still need to be better addressed in a number of building blocks.

2.5.5 Policy and strategy

According to Brazil Overview: Water, sanitation and hygiene, 2017, the Brazilian Government are focusing on strategies to increase access to WASH in poor urban areas and in informal settlements, which require more improvement, such as added integration with other infrastructure betterments in these areas. In addition, a clear strategy to increase WASH capital expenditures is essential to help eliminate the financing gap. Among policy issues, social participation and commitment to help achieving the goals should be expanded and social capacity should be improved.

2.5.6 The ways to solve the challenges on sanitation in Brazil

Based on the report of Vandor & Emiliano, 2018. L.E.K Consulting, some barriers and promising solutions to improve sanitary conditions in Brazil are presented in the table 5.

Table 5 Barriers and promising solution: sanitary conditions in Brazil

Barriers	Promising solutions
Government and private sector cannot work collaboratively together	Re-structure the regulatory framework so that the decision- and rule-making are not in the hands of each municipality.
Business model of the sector	Evolve the current model to a collaborative concept with multiple cooperation among stakeholders.
Lack of a feasible mechanism to attract capital	Design a mechanism that is legally viable and able to attract investors for the development of technical and financial studies by the municipalities responsible for the bidding process.

Rare or no social empowerment	Apply societal pressure by developing social capacity in society and making the population more aware of the problem.

Source: Vandor & Emiliano, 2018. L.E.K Consulting.

The table simple states some concerning points that are much more focused on governance issues rather than technical problems. Moreover, even though that is the current situation in the country, it is important to state that the objective of this research will provide assistance to the decision-making process based on technical standards and not exclusively on governance.

2.5.7 Sector financing

Regarding capital, maintenance and operating costs, there still is heavy reliance on public budgets to finance them. This dependency is often seen in rural areas, in small cities where service provision lacks of economies of scale, in poor urban areas which are burdensome to be reached, and in cases which the service providers have inadequate governance and/or are not properly regulated.

2.5.8 Planning, monitoring and reviewing

Sanitation services are provided by states or municipalities, and include water supply, sewage treatment, urban wastewater disposal and urban waste, all of which are regulated by the National Sanitation Policy (Law No. 11,445 / 2007).

However, even though the service of management, including planning, expansion, regulation, provision, supervision and social control of services are listed in the policy with instruments for its execution, there are not -until now- any institutions responsible for carrying the task.

2.5.9 Collaborative behaviours

The federal government has been the most important driver due to its laws that contain main policies and strategies regarding roles of the public sector and the private sector, public procurements, federative agreements and public-private partnerships. In addition, the federal government continuously acts as a major source and provider of financial and technical resources to the sector.

3 CHAPTER 3 RESEARCH FRAMEWORK AND METHODOLOGY

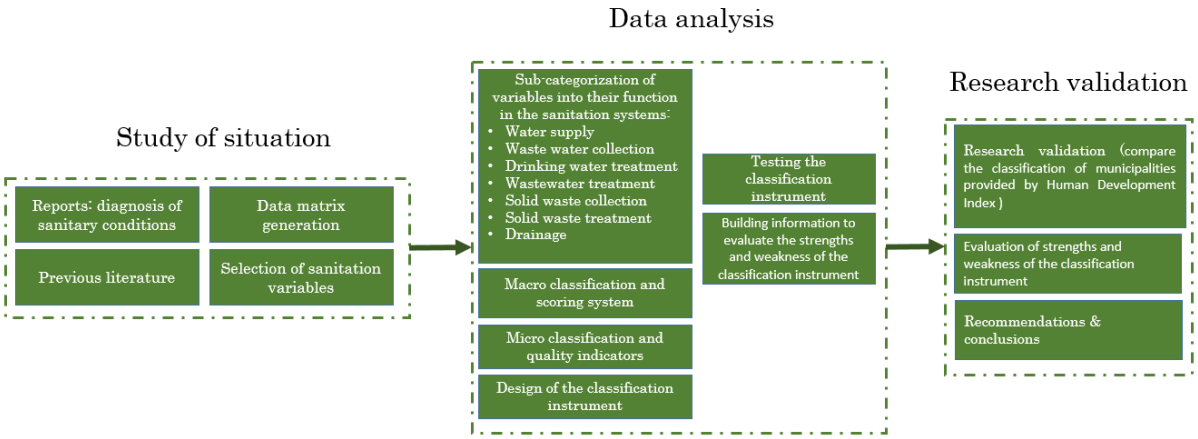
As seen in the literature review many researchers have utilized a set of variables and indicators to measure and classify sanitation infrastructures. Therefore, as the objective of this research is to develop a classification instrument and a ranking of sanitation systems, the methods employed are used to extract and assess variables and indicators presented in the diagnosis reports of sanitary condition. These reports are the main source for data input and they are provided by the Brazilian National Health Foundation.

The research is developed in three major steps: study of the situation, data analysis and research validation. On step-one, the intent is to develop an understanding of the current situation in the Municipalities in the State of Ceará, Brazil. During this phase, the research uses only data from the reports of diagnosis of sanitary conditions provided by the Brazilian National Health Foundation. From the reports, the research generates a data matrix with the most relevant variables that could be found using a simple methodology explained in section 3.1.4.1. The variables considered for the data matrix and for the classification instrument are explained in sections 4.3 to 4.6.

In the second step, all the data selected in the first step is analysed following a clear path. Firstly classifying the variables into a category according to their function. Then developing a scoring system for each variable under this classification. In the research, this first classification is denominated as macro classification because it only provides a general view of the systems that are in place. Next, another scoring system is developed for what the research calls micro classification. The micro classification uses quality indicators to define the state of some of the systems presented in the macro classification. Finally, with the analysis carried out, the classification instrument is designed and tested in the municipalities whose reports were the base of data for the research. Through the carrying out of the tests, the research builds the necessary information on the use of the classification instrument in order to assess its strengths and weakness.

On research validation, the aim is to compare the classification of municipalities provided by Municipal Human Development Index (current approach used by FUNASA) with the classification provided by the instrument. Through this validation process, the research can assess if the classification tool solves the problem stated in the research. Finally, based on the data built during testing, the research presents the strengths, weakness and recommendations to better use the classification instrument.

Figure 8 Research framework



Source: Author's work

3.1 Research methodology

The research methodology aims to specify the procedures and techniques used to identify, select, process, and analyse the data acquired. The methodology allows the research to evaluate its overall validity and reliability and permits a third party to replicate and/or take it further.

3.1.1 Research strategy

This research used archival research strategy with quantitative and qualitative analysis. The study extracts data from original archival records (Diagnosis of Sanitary Conditions reports), which in this case are provided by the Brazilian National Health Foundation.

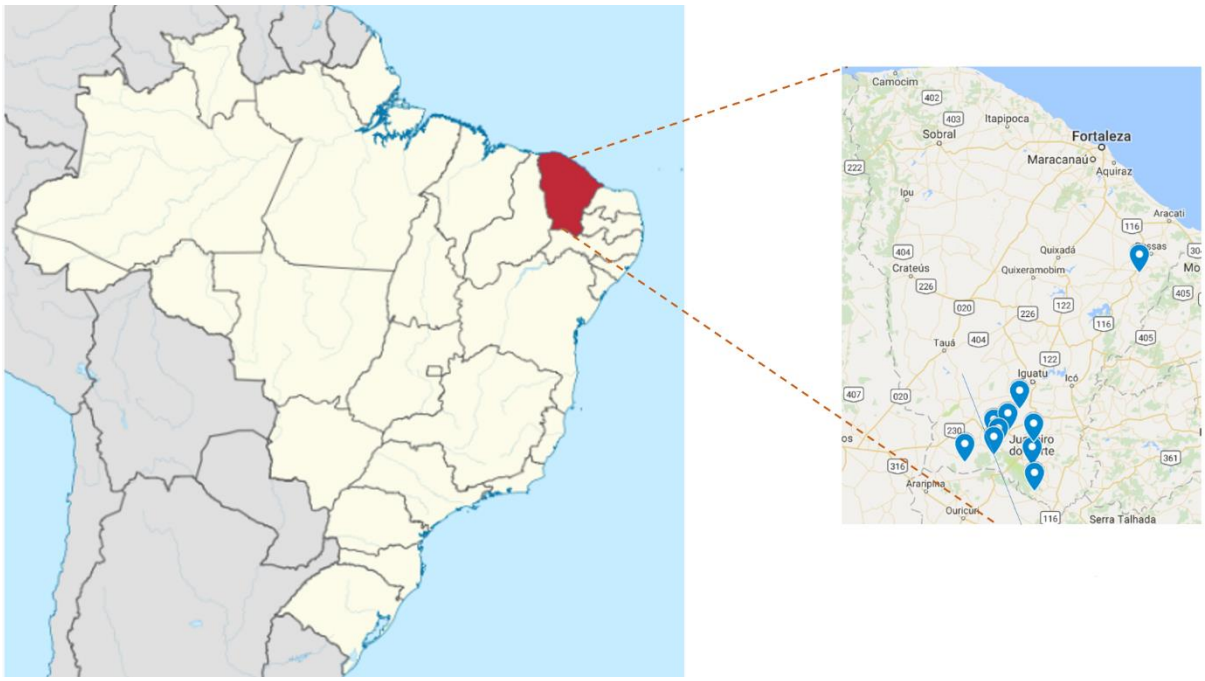
3.1.2 Samples

The research has assessed 10 diagnosis of sanitary condition reports provided by the Brazilian National Health foundation. The reports provide insights on the sanitary condition on 10 municipalities in the state of Ceará in Brazil. The municipalities assessed were: Altaneira, Araripe, Barbalha, Caririaçu, Carius, Faria brito, Jardim, Limeiro do norte, Nova Olinda and Santana do Cariri. See figure 8 for reference.

3.1.3 Location

Figure 8 shows the map locating - in Brazil - the state of Ceará and it pinpoint the municipalities.

Figure 9 Samples' location



Source: Google maps and Wikipedia

3.1.4 Procedures

The following section outline and explain the methods used in each part of the research.

3.1.4.1 Procedures used to generate de data matrix

Often the reports assessed have a logical structuring however, since there is a chance that different companies are working for different municipalities, the reports do not always present the same structuring nor the same depth in content. For that reason, locating where one might find the necessary information regarding each variables is an impossible task.

Thus, attempting to facilitate this process of data mining, the research developed its own simple procedure to generate a data-matrix that follows a clear systematic.

I. Step-one: Gather all the reports from the municipalities in the State of Ceará provided by FUNASA.
II. Step-two: Read them all to create an overall idea on what basis the municipalities define their sanitary conditions: overview of the services and sanitary facilities.
III. Step-three: Understand the legal framework in the report. It means to comprehend the laws and regulations that govern the municipalities thus knowing their obligations.
IV. Step-four: Establishing – based on the several reports – the standards used to describe the sanitary conditions of the municipalities.
V. Step-five: List the variables found and highlight the place where they were found.
VI. Step-six: Select the variables that can be quantifiable and the put into a scale.

VII. Step-seven: Read the sections highlighted and extract the values (qualitative or quantitative).

3.1.4.2 Procedures used to develop the macro classification and scoring system

The macro classification is the classification of the variables in the data matrix according to their functions, those being: water supply, wastewater collection, drinking water treatment, solid waste collection, solid waste treatment and drainage. Once classified, each function has a set number of variables. These variables are assigned scores according to their level of coverage or their existence in the sanitation systems.

The macro classification uses the following approach:

I. Variables related to water supply are under water supply
II. Variables related to wastewater collection are under wastewater collection
III. Variables related to drinking water treatment are under drinking water treatment
IV. Variables that related to wastewater treatment are under wastewater treatment
V. Variables that related to solid waste collection are under solid waste collection
VI. Variables that related to solid waste treatment are under solid waste treatment
VII. Variables that related to drainage systems area under drainage.

Tables 12 through table 20 presents the scoring system used.

3.1.4.3 Procedures used to develop the micro classification and scoring system

The micro classification, designed to provide detailed information about some of the variables in macro classification, is developed by assessing the archived data. The reports are different from one another however; they quantify and qualify the variables in similar ways so that a set of indicators on sanitation quality can be drawn from them.

Due to the limited number of reports, there were not enough information on all the variables and so, the ones more frequently reported allowed us to develop a group of quality indicators that aims to represent in detail the conditions of the systems and services present in the 10 municipalities. The variables were: water distribution network, wastewater collection network, water treatment, receiving-body, wastewater pre-treatment, wastewater primary treatment, wastewater secondary treatment and solid waste final destination

Moreover, the indicators chosen for the micro classification are the ones that are well described in terms of quality of service or physical structure in the diagnosis reports and therefore their qualitative analysis can be put into a scale and a scoring approach can be used.

Table 6 defines the points giving to what is classified as insufficient, fair, acceptable, good and excellent.

Table 6 Explanation of the points given in the micro classification

Scale	Points	Definition of the status
Insufficient	1	Variable is not present or if it is, it does not work
Fair	2	Variable is present however its operation is below quality standards for the system in question
Acceptable	3	Variable is on the limit to be acceptable - enough functionality
Good	4	Variable is above the limit however still with some minor setbacks
Excellent	5	Smooth functioning of the variable

Source: Author's work

The scales and scores are given according to two points:

I. The described situation on the diagnosis reports to define the condition of the service or physical structure;
II. Photos taken of the physical structure;

Tables 21 through table 29 presents the scoring system used.

3.1.4.4 Procedures used to develop strengths and weaknesses evaluation

In order to assess the strength and weakness of the classification instrument its use is necessary. Consequently, through using the instrument in the 10 municipalities, the study can evaluate the weak and strong points of utilizing such classification tool. Tables 37 through table 39 presents the strengths and weakness evaluation.

3.1.4.5 Procedures used to validate the research

Using the United Nations Development programme of 2000, data on Municipal Human Development index (MHDI) for all the 10 municipalities are extracted and put into a table in crescent order of MHDI. This table is then compared to the ranking resulted through the application of the classification instrument on the same 10 municipalities.

3.1.5 Data limitations

The research initially intended to extract data from 100 approved municipal sanitation plans from and from 100 diagnosis reports from 100 different cities to generate a data-matrix. However, once in touch with the Brazilian National Health Foundation, external circumstances made it impossible to obtain all reports.

The external circumstances were:

I. The engineer providing the reports had access to a limited number of reports
II. The time required to get more reports would cause delay in the research due to time constraints

Therefore, from the original number of reports, only 10 diagnosis of sanitary condition reports were actually used as data source. It is important to notice that, although the initial idea was to use Municipal Sanitation Plans, their absence did not cause problems. Since Municipal Sanitation Plans describe what is the desired future situation and the diagnosis reports focus on the current sanitary condition, using diagnosis reports still allowed for the development of the classification instrument which is the objective of this study.

4 STUDY OF SITUATION

4.1 Data from the diagnosis reports of sanitation

The diagnosis reports aims to provide enough information about the sanitary condition of a given municipality and thus assist in the elaboration of the Municipal Plan of Basic Sanitation (PMSB) for the municipalities in Brazil.

In the reports there are subdivisions regarding the scope of sanitation and the responsibilities that the municipalities have on providing those services to their respective citizens. As already stated in the Literature Review (sub-section 2.1.1.), the scope of sanitation in Brazil and therefore in this research has a broad view encompassing four main areas: drinking water supply, wastewater systems, management of public cleaning services and solid waste; and drainage and storm water management.

Often these reports have a logical structure of content with two to four chapters focusing on the management of the services provided and service operations detailing their specificities. In addition, most reports divide the municipality area into districts and the main district as well as into rural and urban areas for each district. As a result, the detailing of the municipality's sanitary condition is presented for the rural and urban areas of each district.

The reports focus too on the legal framework at the Federal, State and Municipal level to elucidate municipalities' responsibilities towards providing sanitation services to its citizens. This legal framework specified in the reports are not used for the analysis since the goal of the research is concentrated in the technical side of sanitation, however, the research uses it – in some case – as a minimum standard that the municipalities have to meet.

4.2 Data matrix

The Data matrix created using the procedure mentioned in 3.1.4.1 is in **APPENDIX A.** The matrix is separated into drinking water supply, wastewater systems, management of public cleaning services and solid waste; and drainage and storm water management.

Although the diagnosis reports have large quantities of data, the lists presented in section 4.3 to 4.6 are the relevant variables considered for the classification of the sanitation systems in Ceará. They were selected because they were the most common variables in the analysed reports.

4.3 The variables to consider in the classification of drinking water systems

The variables considered in the classification of drinking water systems are listed below.

- Coverage of water supply in the Urban Area
- Coverage of water supply in the Rural Area
- Water supply from water fountains, cisterns, wells and other decentralized forms.
- Water supply from water truck
- Water quality

- Drinking water treatment
- Water distribution Network

The variables listed for drinking water system and its relevant participation in the report are explained in tables 7.

Table 7 Variables and scope of drinking water supply

Classification of drinking water supply	
Variables	**Scope**
Coverage of water supply in the Urban Area	Percentage of the population with access to drinking water in the Urban area. This variable indicates how many people has access to water regardless of origin.
Coverage of water supply in the Rural Area	Percentage of the population with access to drinking water in the rural area. This variable indicates how many people has access to water regardless of origin.
Water supply based on fountains, cisterns, wells or other decentralized forms	There are in the state of Ceará other sources of water supply such as water fountains, cisterns, wells or other decentralized forms. This is due to long dry periods and/or absence of a constant source of water supply.
Water supply from water truck	There are in some cities in the state the necessity of using water trucks to supply isolated communities and sometimes the urban area during dry periods.
Water quality	The municipalities to comply with water quality standards defined by the Ministry of Health. Act_518_2004 from the Brazilian Ministry of Health.
Drinking water treatment	This variable refers to the technologies and or techniques used to treat the water before reaching the consumption point.
Water distribution Network	The percentage of consumers that are connected to the water supply network.

Source: Author's work

4.4 The variables to consider in the classification of wastewater water systems

The variables considered in the classification of wastewater systems are listed below.

- Coverage of wastewater systems in the Urban Area
- Coverage of wastewater systems in the Rural Area
- Coverage of rudimentary tank or open wastewater

- Receiving body
- Use of septic tank
- Coverage of the wastewater collecting network
- Wastewater Pre-treatment
- Wastewater primary treatment
- Wastewater Secondary treatment

The variables listed for wastewater system and its relevant participation in the report are explained in table 8.

Table 8 Variables and scope of drinking water supply

Classification of wastewater systems	
Variables	**Scope**
Coverage of wastewater systems in the Urban Area	Percentage of the population with access to wastewater systems in the Urban area.
Coverage of wastewater systems in the Rural Area	Percentage of the population with access to wastewater systems in the rural area.
Coverage of rudimentary tank or open wastewater	This variable concerns the existence and use of rudimentary tank or open wastewater ways.
Capability of dissolution – Receiving-body	This concerns the existence and use of a receiver water body used to dissolve the effluent generated.
Use of septic tank	This variable concerns the existence and use of septic tank.
Coverage of the wastewater collecting network	The percentage of consumers that are connected to the wastewater systems network.
Wastewater pre-treatment	It concerns the existence of pre-treatment facilities.
Wastewater primary treatment	It concerns the existence of primary treatments given to the effluents.
Wastewater secondary treatment	It concerns the existence of primary treatments given to the effluents.

Source: Author's work

4.5 The variables to consider in the classification of classification of management of public cleaning services and solid waste

The variables considered in the classification of management of public cleaning services and solid waste are listed below.

- Coverage of solid waste collection
- Coverage of selective solid waste collection
- Solid waste storage
- Solid waste transportation
- Solid waste processing
- Solid waste final destination

The variables listed for management of public cleaning services and solid waste and its relevant participation in the report are explained in table 9.

Table 9 Variables and scope of management of public cleaning services and solid waste

Classification of management of public cleaning services and solid waste	
Variables	**Scope**
Coverage of solid waste collection	Percentage of the population with access collection of waste.
Coverage of solid waste selective collection	Percentage of the population with access selective collection of waste.
Solid waste storage	It concerns the existence of the storage techniques used to store the waste generated.
Solid waste transportation	It concerns the existence the transportation systems used to transport the waste generated.
Solid waste Processing	It concerns the existence the processing techniques used to process the waste generated.
Solid waste Final destination	It concerns the existence of the final destination given to the waste generated.

Source: Author's work

4.6 The variables to consider in the classification of drainage systems and storm water management

The variables considered in the classification of drainage systems and storm water management are listed below.

- Coverage of the superficial network
- Coverage of the underground network

The variables listed for drainage systems and storm water management and its relevant participation in the report are explained in table 10.

Table 10 management of drainage and storm water management

Classification of drainage and storm water management.	
Variables	**Scope**

Coverage of the superficial network	Percentage of the population connected to the superficial drainage network.
Coverage of the underground network	Percentage of the population connected to the underground drainage network.

Source: Author's work

Through the evaluation of the 10 diagnosis reports and based on the contact with the engineer in the Brazilian National Health Foundation the research concluded that although drainage systems and storm water management are relevant for basic sanitation, these services and structures are not present in the municipalities assessed.

5 DATA ANALYSIS

The analysis of the data follow is clear pathway classifying the variables into categories according to their function, which are listed below.

- Water supply
- Wastewater collection
- Drinking water treatment
- Wastewater treatment
- Solid waste collection
- Solid waste treatment
- Drainage

See section 3.1.4.2 for reference on the methodology.

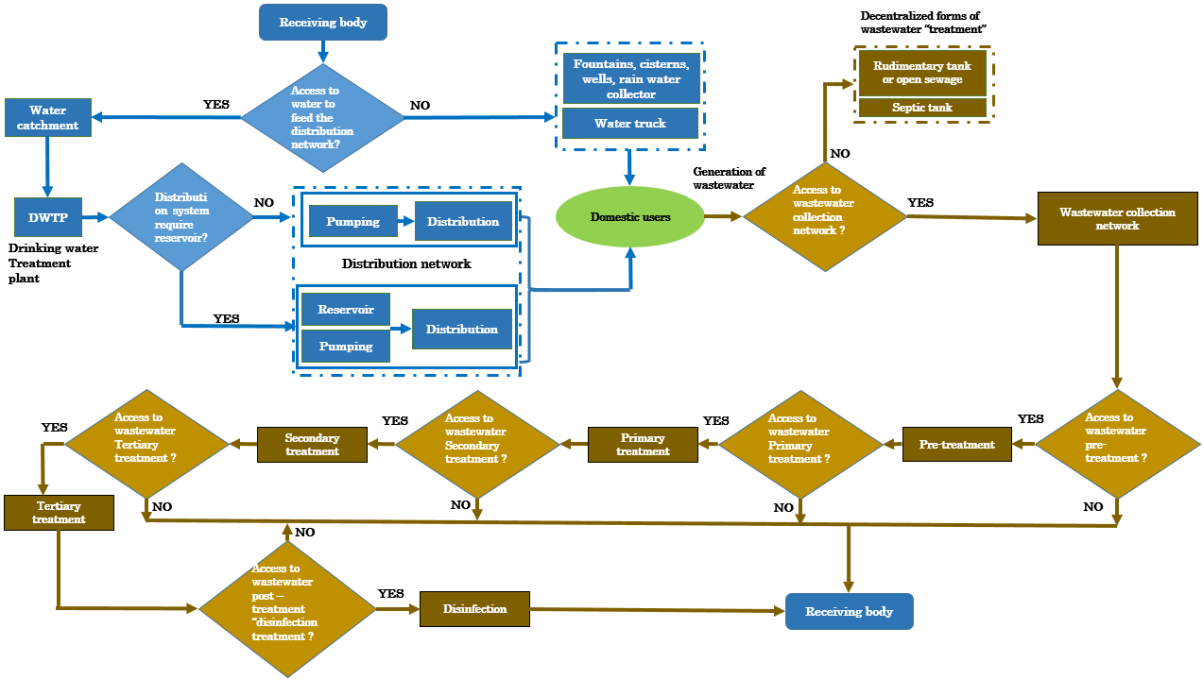
5.1 Classification of variables into a category according to their function

According to the diagnosis reports assessed, the municipalities present the following characteristics. Drinking water is supplied through water supply networks managed by public utilities that retrieve water from water sources (rainwater, groundwater or surface water) and pump it to households. In some cases, there is no connection to the water distribution network or no water availability forcing households to look for decentralized sources of water, which are water fountains, cisterns (usually supplied with a water truck) and water wells.

Once water is used for its purpose, wastewater is generated and it either follows the wastewater path towards the wastewater treatment plants (WWTP) or (in case the households are not connect to the wastewater collection network) it goes to a septic tank or in worse conditions it is stored in rudimentary tank or release at open sky with no treatment.

Figure 7 illustrates in details this reality in a dynamic way with a flow diagram.

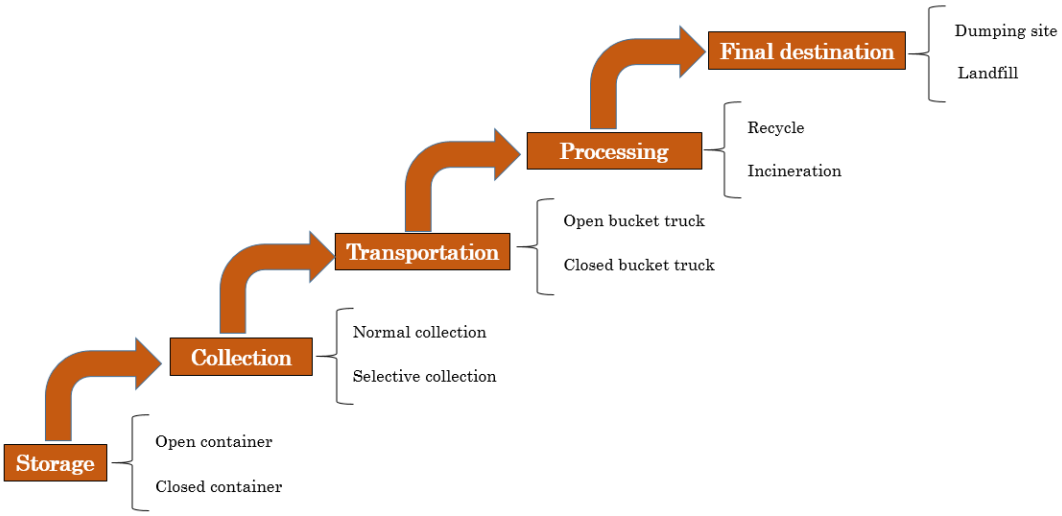
Figure 10 Drinking water and wastewater system relationship



Source: Author's work

In figure 10, storm water collection was not added because based on the reports analysed, there are no drainage systems in place apart from the natural drainage. Regarding solid waste (figure 11), all municipalities assessed follow the same processes: storage, collection, transportation, processing and final destination.

Figure 11 Solid waste steps



Source: Author's work

According to data from the State Environment Secretariat, citizens from the state of Ceará produce about nine thousand tons of waste daily. Most of this solid waste end up in dumping site.

On section 5.2, the variables from figure 10 and 11 are categorized according to their participation in the system.

5.2 Macro classification: a general view of the systems

As mentioned, the macro classification intends to provide a general view of the sanitation systems that are currently in place thus it classifies the variables mentioned in sections 4.3 to 4.6 into correspondent columns as seen in the table 11.

Table 11 Macro classification of variables

Macro classification of variables						
Water supply	**Wastewater collection**	**Drinking water treatment**	**Wastewater treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Coverage of water supply in the Urban Area	Coverage of wastewater systems in the Urban Area	Water quality	Receiving-body	Coverage of solid waste collection	Solid waste storage	Coverage of the superficial network
Coverage of water supply in the Rural Area	Coverage of wastewater systems in the Rural Area	Water treatment techniques and technologies	Wastewater pre-treatment	Coverage of selective solid waste collection	Solid waste transportation	Coverage of the underground network
Water supply based on fountains, cisterns, wells or other decentralized forms	Coverage of rudimentary tank or open sewage		Wastewater primary treatment		Solid waste processing	
Water supply from water truck	Use of septic tank		Wastewater secondary treatment		Solid waste final destination	
Water distribution Network	Coverage of the wastewater collecting network		Wastewater tertiary treatment			

Source: Author's work

Based on this classification a basic scoring system, concerning each variable is created. Table 12 through 19 shows the scoring system for water supply, wastewater collection, drinking water treatment, wastewater treatment, solid waste collection, solid waste treatment and drainage systems respectively

Table 11 focus on "water supply" and attributes range of scores to each of the variables under "water supply" presented in table 12.

Table 12 Scoring system for water supply

Water supply				
Coverage of water supply in the Urban Area (%)	Coverage of water supply in the Rural Area (%)	Water supply based on fountains, cisterns, wells or decentralized forms	Water supply from water truck	Water distribution Network (%)
0 - 20% (1 point)	0 - 20% (1 point)	Access 1 Point	Access 1 Point	0 - 20% (1 point)
21 - 40% (2 points)	21 - 40% (2 points)	No Access 0	No Access 0 Point	21 - 40% (2 points)
41 - 60% (3 points)	41 - 60% (3 points)	Not Required 2 Points	Not Required 2 Points	41 - 60% (3 points)
61 -80 % (4 points)	61 -80 % (4 points)			61 -80 % (4 points)
81 - 100% (5 points)	81 - 100% (5 points)			81 - 100% (5 points)

Source: Author's work

As seen in the table 12, the scoring systems for "coverage of water supply" and "water distribution network" are based on the idea that the higher the coverage area of water supply the higher the score. Regarding "water supply from decentralized forms" and "water truck" the scoring system is as the following: if the municipality have access, it receives one point, if it does not need to have decentralized forms to supply water it score 2 however, if it needs those decentralized structures and it has no access to it the score is 0.

Following up with the sanitation system in the figure 10, the table 13 presents the scoring system for wastewater collection.

Table 13 Scoring system for wastewater collection

Wastewater collection				
Coverage of sewage systems in the Urban Area	Coverage of sewage systems in the Rural Area	Coverage of rudimentary tank or open sewage (Points)	Use of septic tank	Coverage of the sewage collecting network
0 - 20% (1 point)	0 - 20% (1 point)	Existent 0	Access 1	0 - 20% (1 point)
21 - 40% (2 points)	21 - 40% (2 points)	Not required 1	No Access 0	21 - 40% (2 points)
41 - 60% (3 points)	41 - 60% (3 points)		Not Required 2	41 - 60% (3 points)
61 -80 % (4 points)	61 -80 % (4 points)			61 -80 % (4 points)
81 - 100% (5 points)	81 - 100% (5 points)			81 - 100% (5 points)

Source: Author's work

The scoring systems for "coverage of wastewater system" and "Coverage of the wastewater collecting network" is the same as used of "coverage of water supply" and "water distribution network" in table 12.

Regarding "coverage of rudimentary tank" or "open sewage" the scoring system is as the following: if the municipality have uses either rudimentary tanks or dispose its wastewater at open sky, it is assigned zero points. Conversely, if the city does not use these types decentralized forms as wastewater collection it scores one. Additionally, in regards to " Use of septic tanks" having access gives a score of one and not having access (but needing it) gives a score of zero. In addition, the municipalities that do not require the usage of septic tanks anymore are the ones where the wastewater

collection network is connected to all house holds and therefore this situation is given two points.

The next scoring systems concerns water quality and treatment . Table 14 shows the scoring system for water **quality and treatment**. The scoring system is based on the sampling plans stated in the Act_518_2004 from the Brazilian Ministry of Health.

Firstly, the municipalities or utilities who provide the service of water supply need to comply with the sampling plans stated in the Act_518_2004 from the Brazilian Ministry of Health. This sampling plans define numbers of samples required according to a defined parameter as well as state with what frequency such parameter have to be measured by the service provider. Table 14 refers to the sampling plans and whether the activity carried out or not.

Table 14 Sampling plans

Parameter	Water quality - Sampling plans
Ammonia	Activity carried out (1 point), if not (0 points)
Free residual Chlorine	Activity carried out (1 point), if not (0 points)
Colour	Activity carried out (1 point), if not (0 points)
Toughness	Activity carried out (1 point), if not (0 points)
Iron	Activity carried out (1 point), if not (0 points)
Manganese	Activity carried out (1 point), if not (0 points)
Sodium	Activity carried out (1 point), if not (0 points)
Taste	Activity carried out (1 point), if not (0 points)
Odour	Activity carried out (1 point), if not (0 points)
Total dissolved solids	Activity carried out (1 point), if not (0 points)
Turbidity	Activity carried out (1 point), if not (0 points)
pH	Activity carried out (1 point), if not (0 points)
Total coliforms	Activity carried out (1 point), if not (0 points)
Fluorine	Activity carried out (1 point), if not (0 points)

Source: Author's work

An additional remark is that, the articles 16 in the Act 518_2004 defines some other water quality parameters that also need to be tested to guarantee safe human consumption. However, these remaining tests were not considered due to its level of execution complexity or the lack of financial resources to carry out them. In other words, through the assessment of the reports is clear to see that the facilities and resources in those places are already scarce, which means if they are already having difficulties with the basic testing like pH and turbidity, they are not likely to have the resources to provide all the sampling prescribed in article 16.

This first stage of the scoring system for Drinking water quality is strict since not being able to carry out the mandatory activities may result in unreliable information regarding the water quality. Thus if the activity (number of samples and frequency of sampling) is correctly executed the parameter receives one point, if not, no points are assigned.

It is important to notice that these two sequential tables (14 and 15) have to work together since one can only assign scores to activities that were executed.

According to the Act_518_2004 from the Brazilian Ministry of Health, drinking water must comply with microbiological standards, inorganic and organic chemical standards, pesticide standards, Cyan-toxins standards and Radioactivity standards. Table 15 shows only the level of non-conformity that can be found in the diagnosis reports for the sampling mentioned in table 14.

Table 15 Scoring system for water treatment

Parameter	Water quality standards " Not conformity check"				
Ammonia	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Free residual Clorine	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Color	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Toughness	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Iron	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Manganese	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Sodor	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Taste	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Odor	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Total dissolved solids	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Turbidity	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
pH	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Total coliforms	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Fluorine	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)

Source: Author's work

The scoring system here is the opposite of those presented in table 11 for "Coverage of water supply". In this case, having less samples as non-conform will result in higher scores. It is important to notice that, the Brazilian Ministry of Health does define the minimum standards for each parameter as seen in Act_518_2004 from the Brazilian Ministry of Health. However, as assessed in the report, many municipalities do not comply with those standards and therefore such system is useful to assess which municipalities is disrespecting the minimum water quality standards.

Giving sequence to figure 10, table 16 demonstrates the scoring system for wastewater treatments. This scoring system goal is to provide a broad view of the systems in place in each municipality therefore it relies solely in the existence or not of the physical structure designated to carry out the activities expected with pre-treatment[1], primary treatment, secondary treatment and tertiary treatment.

Table 16 Scoring system for wastewater treatment

Wastewater treatment				
Receiving-body (Existence of receptor body)	Wastewater Pre-treatment	Wastewater primary treatment	Wastewater Secondary treatment	Wastewater Tertiary treatment
Existence 1 Point	Pre-treatment - Access 1 Point	Primary treatment - Access 1 Point	Secondary - Access 1 Point	Terciary treatment - Access 1 Point

[1] Pre-treatment in this case refers to the removal of big objects and particles. Solid waste that might come with the wastewater and others.

Non existence 0 point	Non existence 0 point	Non existence 0 point	Non existence 0 point	Non existence 0 point

Source: Author's work

Following, the scoring system for wastewater treatments grants one point to the municipalities that have access to the treatments and receiving- body and zero to the ones that have not yet built theirs. Although this scoring structure seems basic because it does not evaluate the efficiency or effectiveness of the treatment itself it is a stepping-stone. Furthermore, an in-depth look into the WWTP is part of section 5.3 where a detail assessment of the municipality's sanitation systems are produced. Tables 17 and 18 are designed to create a global view of the solid waste systems and services present in the municipalities. The scoring system for solid waste collection is also based on coverage hence using the same arrangement of table 12.

Table 17 scoring system for solid waste collection

Solid waste collection	
Coverage of solid waste collection	Coverage of selective solid waste collection
0 - 20% (1 point)	0 - 20% (1 point)
21 - 40% (2 points)	21 - 40% (2 points)
41 - 60% (3 points)	41 - 60% (3 points)
61 -80 % (4 points)	61 -80 % (4 points)
81 - 100% (5 points)	81 - 100% (5 points)

Source: Author's work

Alternatively, the scoring structure for solid waste treatment (table 18) consist whether or not there is the supply of the service of transportation and processing, and the existence of the facilities or physical structures responsible for solid waste storage and final destination.

Table 18 Scoring system for solid waste treatment

Solid waste treatment			
Solid waste storage	Solid waste transportation	Solid waste Processing	Solid waste final destination
Open container 0 point	Open bucket truck 0 point	Recycle 1 point	Dumping site 0 points
Close containers 1 point	Close bucket truck 1 point	Incineration for medical waste 1 point	Landfill 1 point

Source: Author's work

Finally, table 19 displays the scoring system for drainage systems. Although it is known – based on the assessment of the reports – that the municipalities do not have any type of drainage but natural, this scoring system is still important because it will eventually fit the expect future conditions.

Table 19 Scoring system for drainage systems

Drainage systems	
Coverage of the superficial network	Coverage of the underground network
x0 - 20% (1 point)	0 - 20% (1 point)
21 - 40% (2 points)	21 - 40% (2 points)
41 - 60% (3 points)	41 - 60% (3 points)

61 -80 % (4 points)	61 -80 % (4 points)
81 - 100% (5 points)	81 - 100% (5 points)

Source: Author's work

Table 20 Summary of the presented scoring system

Sub-categorization of variables – macro classification and scoring system							
Variables	Water supply	wastewater collection	Drinking water treatment	wastewater treatment	Solid waste collection	Solid waste treatment	Drainage
Score range	3 to 19	3 to 18	14 to 84	0 to 6	2 to 10	0 to 5	2 to 10
Total range	24 to 152						

Source: Author's work

5.3 Micro classification and quality indicators for sanitation systems

As a result of assessing the diagnosis reports the indicators chosen for the micro classification are the ones that are well describe in terms of quality of the service or physical structure and therefore their qualitative analysis can be put into a scale and a scoring approach can be used.

The method used to develop this section is presented in section 3.1.4.3.

Water distribution network

The micro classification for water distribution network (table 21) uses a number of indicators to classify the state of the system. To each indicator a range of weight is given where the highest weight represent the best condition of the system and the lowest weight represent the worst condition of the system. The exception to the rule are materials where a weight is given to each one of the found materials. Basically, asbestos is illegal by law, Iron is easily oxidized increasing iron concentration in drinking water and PVC is the most suitable.

Table 21 Water distribution network – micro classification and scoring system

Water distribution network		
Quality indicators (variable)	**Scale**	**Points**
Materials used for the pipeline	Iron (1), PVC (2), Asbestos (0)	0 to 2
Monitoring of continuity and pressure	insufficient, fair, acceptable, good and excellent	1 to 5
Contingency water pumps	non-existent or existent	0 or 1
State of conservation/ Maintenance of electrical boards	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of pump-motor assembly	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of reservoirs	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of pipe line	insufficient, fair, acceptable, good and excellent	1 to 5
Losses in the Water distribution Network (%)	0 to 20%, 21 to 40%, 41 to 60%, 61 to 80%, 81 to 100%	0.5 to 0.1

State of conservation/ Maintenance of Continuity and water pressure	insufficient, fair, acceptable, good and excellent	1 to 5

Source: Author's work

Wastewater collection network

Similarly, to water distribution network, the micro classification for wastewater distribution network (table 22) uses a set of indicators to classify the state of the system. The scoring is also the same with the exception of "leakage" where the scores are from 0.5 to 0.1: the best and the worst conditions respectively.

The weight of 0.5 to 0.1 are given because this indicator work on an opposite scale from the other ones.

Table 22 wastewater collection network – micro classification and scoring system

wastewater collection network		
Quality indicators (variable)	Scale	**Points**
Leakage	very low, low, medium, High and Vey high	0.5 to 0.1
State of conservation/ Maintenance of Canals	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of electrical boards	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of pump-motor assembly	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of pipe line	insufficient, fair, acceptable, good and excellent	1 to 5

Source: Author's work

Water treatment techniques and technology

Finally, the micro classification for "Drinking water treatment", "Receiving-body", "wastewater pre-treatment", "wastewater primary treatment", "wastewater secondary treatment" and "solid waste final destination" (tables 23 through table 28) all utilise indicators to classify the state of the system. For every indicator a range of weight is given where the highest weight characterise the best condition of the system and the lowest weight signify the worst.

Table 23 Drinking water treatment - micro classification and scoring system

Drinking water treatment		
Quality indicators (variable)	Scale	**Points**
State of conservation/ Maintenance of the DWTP	insufficient, fair, acceptable, good and excellent	1 to 5
Goal attainment with the treatment	insufficient, fair, acceptable, good and excellent	1 to 5

Source: Author's work

Table 24 Receiving-body's micro classification and scoring system

Receiving-body

Quality indicators (variable)	Scale	Points
	insufficient, fair, acceptable, good and excellent	1 to 5
Provide conditions in the receiving-body so that its quality fits within the standards of receiving-bodies	insufficient, fair, acceptable, good and excellent	1 to 5
Receiving-body's dissolution capacity	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of the receiving-body and surroundings	insufficient, fair, acceptable, good and excellent	1 to 5

Source: Author's work

Wastewater pre-treatment

Table 25 Pre-treatment - micro classification and scoring system

Wastewater pre-treatment		
Quality indicators (variable)	Scale	**Points**
State of conservation/ Maintenance of the WWTP	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of surroundings	insufficient, fair, acceptable, good and excellent	1 to 5
Goal attainment with the treatment	insufficient, fair, acceptable, good and excellent	1 to 5

Source: Author's work

Wastewater primary treatment

Table 26 Primary treatment - micro classification and scoring system

Primary treatment		
Quality indicators (variable)	Scale	**Points**
State of conservation/ Maintenance of the WWTP	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of surroundings	insufficient, fair, acceptable, good and excellent	1 to 5
Goal attainment with the treatment	insufficient, fair, acceptable, good and excellent	1 to 5

Source: Author's work

Wastewater secondary treatment

Table 27 Secondary - micro classification and scoring system

Secondary treatment		
Quality indicators (variable)	Scale	**Points**
State of conservation/ Maintenance of the WWTP	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of surroundings	insufficient, fair, acceptable, good and excellent	1 to 5
Goal attainment with the treatment	insufficient, fair, acceptable, good and excellent	1 to 5

Source: Author's work

Sold waste final destination

Table 28 Solid waste final destination – micro classification and scoring system

Solid waste final destination		
Quality indicators (variable)	Scale	**Points**
State of conservation/ Maintenance of the dumping site	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of the Landfill	insufficient, fair, acceptable, good and excellent	1 to 5

Source: Author's work

A summary of the scoring system developed for the micro classification is presented in the table 29.

Table 29 Summary of the scoring system for micro classification

Sub-categorization of variables - Micro classification							
Variables	Water supply	wastewater collection	Drinking water treatment	wastewater treatment	Solid waste collection	Solid waste treatment	Drainage
Score Range	6.5 to 33.1	4.5 to 20.1	2 to 10	16 to 80	Non-applicable	2 to 10	Non-applicable
Total Range	31 to 153.2						

Source: Author's work

5.4 Development of the classification instrument

The classification instrument has been gradually developed through sections 5.1 to 5.3 using the methods presented in chapter 3. Thus, ultimately the key of the classification instrument is the filling of table 30 where each variable (for macro and micro classification) can be assigned a final value and further assessed as an overall result.

Table 30 Summary: micro and micro classification's score ranges

Sub-categorization of variables - Macro classification							
Variables	Water supply	wastewater collection	Drinking water treatment	wastewater treatment	Solid waste collection	Solid waste treatment	Drainage
Score Range	3 to 19	3 to 18	0 to 84	0 to 6	2 to 10	0 to 5	2 to 10
Total Range	10 to 152						
Sub-categorization of variables - Micro classification							
Variables	Water supply	wastewater collection	Drinking water treatment	wastewater treatment	Solid waste collection	Solid waste treatment	Drainage
Score Range	6.5 to 33.1	4.5 to 20.1	2 to 10	16 to 80	Non-applicable	2 to 10	Non-applicable
Total Range	31 to 153.2						

Source: Author's work

6 DEVELOPMENT OF THE TOOL

Table 30 in section 5.4 is the representation of the output when using the instrument to classify the analysed municipalities. However, a complete picture of what the instrument looks like is presented **APPENDIX B**.

6.1 Application of the classification instrument in the 10 analysed municipalities

To find the instrument's strengths and weaknesses as well as to test its efficacy, the research test it with the 10 municipalities analysed. The results for each municipality is in **APPENDIX C**.

The overall results are in the tables below. Table 31 refers to the macro classification of the municipalities using the classification instrument.

Table 31 Macro classification results using the classification instrument

Macro classification								
Variables	Water supply	Sewage collection	drinking water treatment	wastewater treatment	Solid waste collection	Solid waste treatment	Drainage	Total
Altaneira	11	3	80	4	4	1	2	105
Araripe	15	4	84	3	6	0	2	114
Barbalha	12	6	84	4	5	2	2	115
Caririaçu	12	4	18	0	4	0	4	42
Carius	10	4	6	0	4	1	4	29
Faria brito	8	4	64	1	5	1	2	85
Jardim	10	7	0	1	6	1	2	27
Limeiro do norte	8	4	36	5	8	1	2	64
Nova olinda	11	6	84	1	4	1	4	111
Santana do Cariri	7	4	84	0	4	0	2	101
MAX	**19**	**18**	**84**	**6**	**10**	**5**	**10**	**152**

Source: Author's work

In order to have all the values classified under a common denominator, the results of each cell of each municipality is divided by the maximum possible value defined in table 30. By using this method the table displays the percentages of each variable for each municipality as seen in table 32.

Table 32 Macro classification - percentual results using the classification instrument

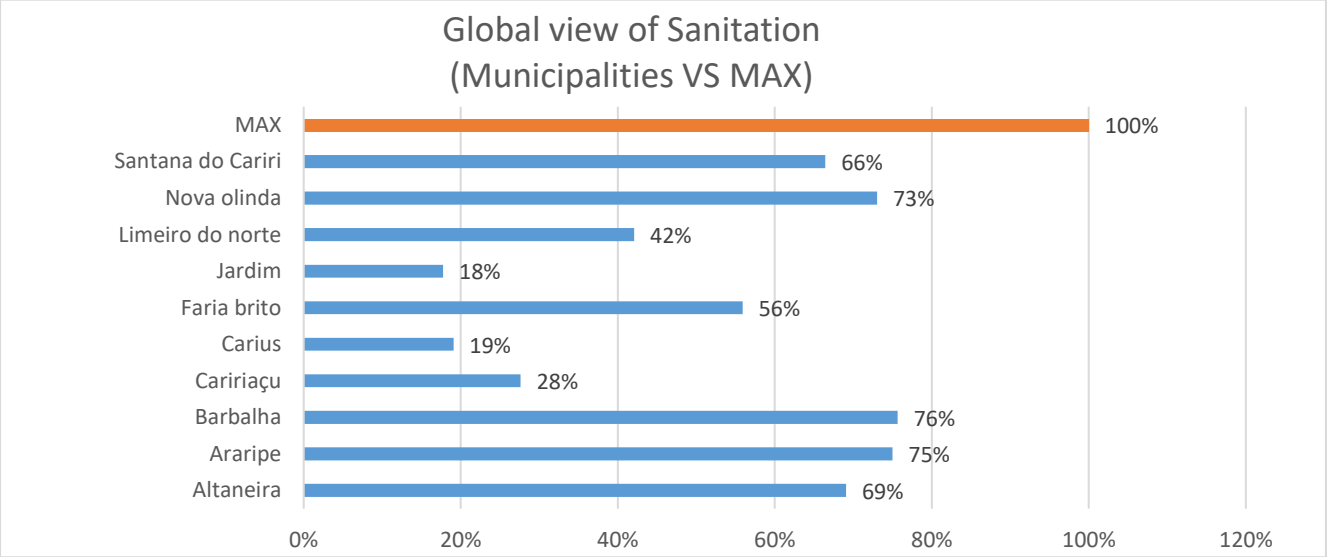
Macro classification – % values								
Variables	Water supply	Sewage collection	drinking water treatment	wastewater treatment	Solid waste collection	Solid waste treatment	Drainage	Total
Altaneira	58%	17%	95%	67%	40%	20%	20%	69%
Araripe	79%	22%	100%	50%	60%	0%	20%	75%
Barbalha	63%	33%	100%	67%	50%	40%	20%	76%
Caririaçu	63%	22%	21%	0%	40%	0%	40%	28%
Carius	53%	22%	7%	0%	40%	20%	40%	19%
Faria brito	42%	22%	76%	17%	50%	20%	20%	56%

Jardim	53%	39%	0%	17%	60%	20%	20%	18%
Limeiro do norte	42%	22%	43%	83%	80%	20%	20%	42%
Nova olinda	58%	33%	100%	17%	40%	20%	40%	73%
Santana do Cariri	37%	22%	100%	0%	40%	0%	20%	66%
MAX	100%	100%	100%	100%	100%	100%	100%	100%

Source: Author's work

With the data from table 32, it is possible to output a visual representation of the current sanitary situation for the analysed municipalities. The graph in figure 12 illustrates the comparison between these cities according to their sanitary condition.

Figure 12 General view of the systems in place: comparison amongst municipalities



Source: Author's work

The graph in figure 12 shows the scored result for each municipality for all of their sanitation systems defined under this study. However, the micro classification using quality indicator to assess some of those systems is still necessary. Thus, table 33 shows the results found using the micro classification section of the classification instrument in **appendix B**.

Table 33 Micro classification results using the classification instrument

Micro classification								
Variables	Water supply	Sewage collection	drinking water treatment	wastewater treatment	Solid waste collection	Solid waste treatment	Drainage	Total
Altaneira	6.4	4.5	5	25	NA	1	NA	41.9
Araripe	20*	14.3	5	9	NA	1	NA	29.3
Barbalha	18.3	14.4	7	22	NA	1	NA	62.7
Caririaçu	12*	0	2	0	NA	1	NA	3
Carius	26*	NA	2	NA	NA	2	NA	4
Faria brito	8.5	NA	3	3	NA	1	NA	15.5
Jardim	8*	0	NA	3	NA	1	NA	4

Limeiro do norte	19.3	12.4	3	30	NA	3	NA	67.7
Nova olinda	19.4	0	8	3	NA	3	NA	33.4
Santana do Cariri	13*	0	9	0	NA	1	NA	10
MAX	**33.5**	**20.5**	**10**	**80**	**NA**	**10**	**NA**	154

Source: Author's work

Equally to table 32, all the values are turned into percentages for each variables for each municipality as seen in table 34. The main distinction with the micro classification is the following:

I. For indicator with missing data (*) the research considered their result equals to zero
II. For indicator where it says NA (not applicable) the research considered their result equals to zero

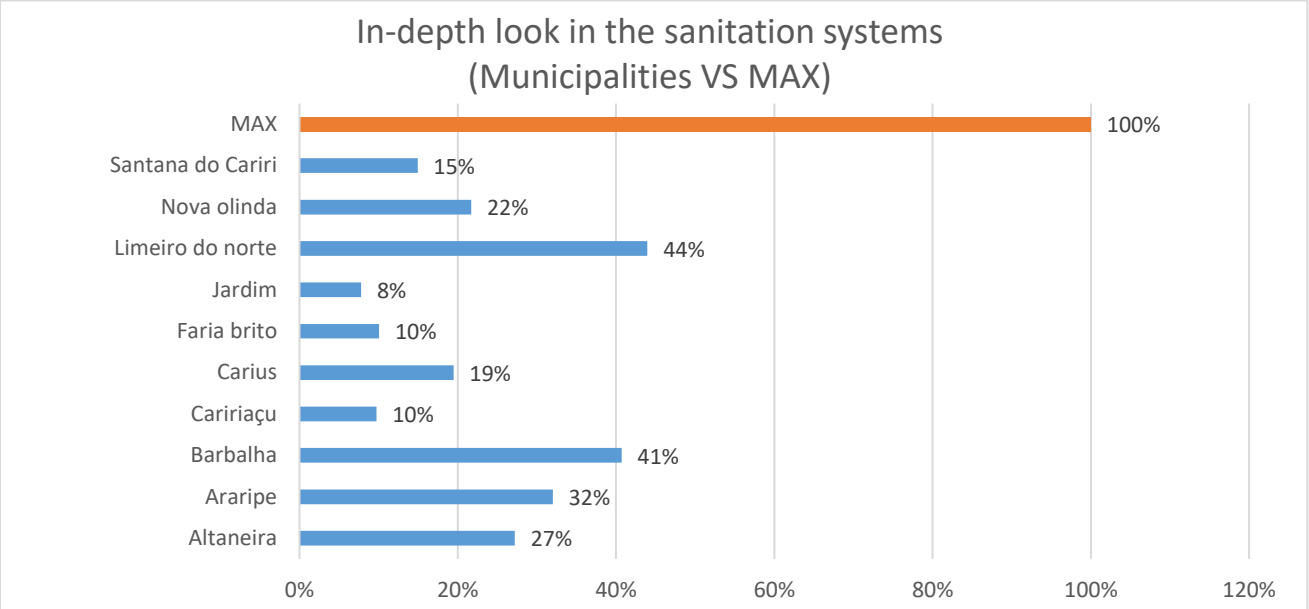
Table 34 Micro classification - percentual results using the classification instrument

Micro classification								
Variables	Water supply	Sewage collection	drinking water treatment	wastewater treatment	Solid waste collection	Solid waste treatment	Drainage	Total
Altaneira	19%	22%	50%	31%	0%	10%	0%	27%
Araripe	60%	70%	50%	11%	0%	10%	0%	32%
Barbalha	55%	70%	70%	28%	0%	10%	0%	41%
Caririaçu	36%	0%	20%	0%	0%	10%	0%	10%
Carius	78%	0%	20%	0%	0%	20%	0%	19%
Faria brito	25%	0%	30%	4%	0%	10%	0%	10%
Jardim	24%	0%	0%	4%	0%	10%	0%	8%
Limeiro do norte	58%	60%	30%	38%	0%	30%	0%	44%
Nova olinda	58%	0%	80%	4%	0%	30%	0%	22%
Santana do Cariri	39%	0%	90%	0%	0%	10%	0%	15%
MAX	1	1	1	1	0	1	0	100%

Source: Author's work

The graph in figure 13 illustrates the use of the micro classification approach in the sanitation systems existent.

Figure 13 In-depth view of the systems in place: comparison amongst municipalities



Source: Author's work

Since the classification instrument delivers both values under macro and micro classification, a total value can be output using arithmetical average of the values presented. Therefore, table 35 presents the resulted value for each municipality for each variable.

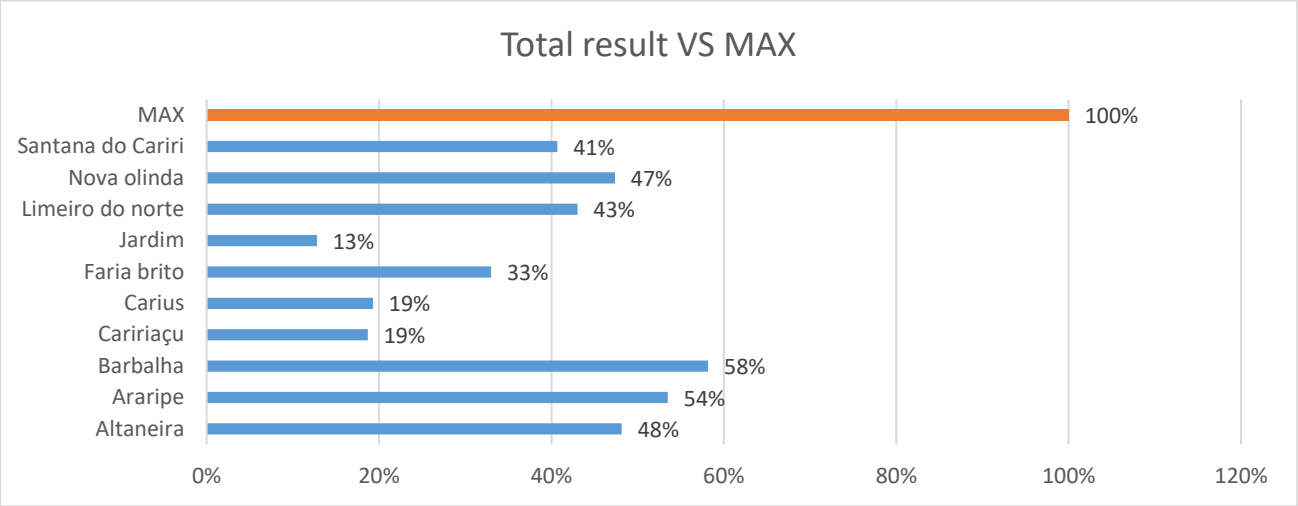
Table 35 Final results using the classification instrument: comparison amongst municipalities

Total								
Variables	Water supply	Sewage collection	drinking water treatment	wastewater treatment	Solid waste collection	Solid waste treatment	Drainage	Total
Altaneira	38%	19%	73%	49%	20%	15%	10%	48%
Araripe	69%	46%	75%	31%	30%	5%	10%	54%
Barbalha	59%	52%	85%	47%	25%	25%	10%	58%
Caririaçu	49%	11%	21%	0%	20%	5%	20%	19%
Carius	65%	11%	14%	0%	20%	20%	20%	19%
Faria brito	34%	11%	53%	10%	25%	15%	10%	33%
Jardim	38%	19%	0%	10%	30%	15%	10%	13%
Limeiro do norte	50%	41%	36%	60%	40%	25%	10%	43%
Nova olinda	58%	17%	90%	10%	20%	25%	20%	47%
Santana do Cariri	38%	11%	95%	0%	20%	5%	10%	41%
MAX	100%	100%	100%	100%	50%	100%	50%	100%

Source: Author's work

By using the total values in the last column, the graph in figure 14 is outputted with the possibility of ranking the cities based on the conditions of their sanitation systems which is the objective of this research.

Figure 14 Final results using the classification instrument: comparison amongst municipalities



Source: Author's work

As seen in the figure 14 the city in the best and worst sanitation condition are Barbalha and Jardim, respectively. Further, by using the data from the graph above the ranking of the cities using the classification instrument is presented in table 36.

6.2 Validation of the classification instrument

As stated in the problem statement of this research, the Brazilian National Health Foundation utilizes Human Development Index to rank the municipalities in terms of priorities to allocate the federal funding for sanitation improvements. However, Human Development Index is not the most accurate way to measure the sanitary condition of a given municipality hence the development of this classification instrument. And so, in order to validate the classification instrument the study compares the ranking provided by the classification instrument with the ranking (of the municipalities) using Human Development Index for the municipalities using the census carried out by the United National Development Programme in 2000, table 36.

Table 36 Classification instrument VS Human Development Index

Positioning	Ranking Municipalities(classification instrument)	Total	Positioning	Ranking Municipalities (HDI 2000)	Total
1st	Jardim	13%	1st	Altaneira	0.576
2nd	Caririaçu	19%	2nd	Araripe	0.584
3rd	Carius	19%	3rd	Caririaçu	0.591
4th	Farias brito	33%	4th	Farias brito	0.609
5th	Santana do Cariri	41%	5th	Santana do Cariri	0.609
6th	Limeiro do norte	43%	6th	Carius	0.63
7th	Nova olinda	47%	7th	Jardim	0.642
8th	Altaneira	48%	8th	Nova olinda	0.643
9th	Araripe	54%	9th	Barbalha	0.687
10th	Barbalha	58%	10th	Limeiro do norte	0.711

Source: Author's work

As seen in table 36, the only two municipalities that are in the same place in the ranking is Farias Brito and Santana do Cariri, 4th and 5th place of priority respectively. What is even more striking is if we look at the pattern by comparing the ranks allocated by our instrument with those of the HDI 2000 procedure in use 1-7; 2-3; 3-6; 4-4; 5-5; 6-10; 7-8; 8-1; 9-2 and 10-9. If one for instance would assume that only the first four municipalities are funded, the population-funded municipalities varies a lot.

6.3 Strengths and weaknesses analysis of the instrument

Based on the application of the classification instrument on the 10 analysed municipalities the research can present the tool's weaknesses and strengths. This approach intends find where the instrument could have been more precise and where it offers an accurate definition of the system. It also provides the basis to write the recommendations.

Table 37 Strengths and weaknesses of the instrument in the macro classification

Variable	Weaknesses	Strength
Coverage of water supply in the Urban Area	The ranges used in the scoring system is of 20 units and in some cases, it cannot be sufficient to build a concrete general idea of the coverage of water supply in the municipality.	For the urban area, the coverages are usually really high and therefore, municipalities with 80% or more of water supply coverage score the highest and therefore, even though they might not have 100% of citizens being supplied they fit into the category which means they are progressing to reach full coverage.
Coverage of water supply in the Rural Area	The coverage of water supply in rural areas are harder to measure. Most times the rural districts have citizens pumping their own water from wells and when they are connect to some network, this network is not register as a provider nor as public utility and therefore the coverage of that given area does not enter the global calculation. A good example of this situation is the SISAR (Integrated Rural Sanitation System). Additionally, most of the municipalities analysed are below 20% and therefore with the range of 20 units it is difficult to see which one has a better water supply situation for the rural area.	It provides enough information to understand the system.
Water supply based on fountains, cisterns, wells or other decentralized forms	The reports do not provide enough quantitative data of coverage when using these technologies and it is therefore difficult to calculate how many people are still with no access to water whatsoever.	The reports state the usage of this option thus creating a picture of the water necessities and conditions of the municipalities.
Water supply from water truck		
Coverage of water distribution Network	The ranges used in the scoring system is of 20 units and in some cases it cannot be sufficient to build a concrete general idea of the coverage of water supply in the municipality	Municipalities with 60, 80% or more connected to the water distribution network score the highest and therefore, even though they might not have 100% of citizens connected, they fit into the category, which means they are progressing to reach full coverage. Moreover, in some cases, the rural area represent a good percentage of the population contingency and because decentralized forms of water supply in those areas are more present, a municipality having scored above 4 is likely to have a consistent water supply situation.
Coverage of wastewater systems in the Urban Area	The ranges used in the scoring system is of 20 units and in some cases, it cannot be sufficient to build a concrete general idea of the coverage of water supply in the municipality.	Municipalities with 80% or more with some service of wastewater systems the highest and therefore, even though they might not have 100% of citizens benefiting from the service, they are progressing to reach full coverage.
Coverage of wastewater systems in the Rural Area	The coverage of wastewater systems in rural areas are hard to measure. Often these locations are using decentralized forms of wastewater collection. Most municipalities in rural areas have no access to wastewater systems and when they do, it is through non-registered services hence not included in the final calculations.	It provides enough information to understand the system
Coverage of rudimentary tank or open sewage	The reports do not provide enough quantitative data of coverage when using these technologies.	The reports state the usage of this option thus creating a picture of the conditions of the municipalities regarding wastewater.
Use of septic tank		

Source: Author's work

Table 38 Strengths and weaknesses of the instrument in the macro classification

Variable	Weaknesses	Strength
Coverage of the wastewater collecting network	As in "coverage of water supply" the ranges used in the scoring system is of 20 units that might not be sufficient to build a concrete general idea of the coverage of the wastewater collection network in the municipality.	Municipalities with 60, 80% or more connected to the wastewater collection network score the highest and therefore, even though they might not have 100% of citizens connected, they fit into the category, which means they are progressing to reach full coverage. In other words, municipality having scored 4 and above are likely to have a consistent wastewater collection situation.
Water quality	It does not use all the mandatory testing because it would not be real to say that all municipalities have the financial and technical resource to carry out such procedures.	Although a reduce version of the mandatory parameters is considered ,the tool does assess the real conditions of the municipalities when stating their incapability to provide all the mandatory procedure written in the Act_ 518_2004 Ministry of Health.
Water treatment	Water treatment is linked to the water quality variable which means that without the minimum of 14 points to water quality, there is no way to safely assess if the treatment is enough or not.	By using the percentage of samples that are not in conformity with the legislation, the instrument allows a comparison between municipalities regarding their ability to treat water, which can be enough to help FUNASA assessing which city is in worse conditions.
Receiving-body	It does not assess efficiency of the system	It provides an initial visualization of the sanitary condition of the municipality regarding wastewater treatments.
Wastewater pre-treatment		
Wastewater primary treatment		
Wastewater secondary treatment		
Wastewater tertiary treatment		
Coverage of solid waste collection	The ranges used in the scoring system is of 20 units and in some cases, it cannot be sufficient to build a concrete general idea of the coverage of solid waste collection in the municipality.	Municipalities with 80% or more with some service of wastewater systems the highest and therefore, even though they might not have 100% of citizens benefiting from the service, they are progressing to reach full coverage.
Coverage of selective solid waste collection	Most municipalities have no selective collection of solid waste, and the one that do have, have considerably low levels of it. Thus, the 20 unit-rage in the scoring system is not well fit for this variable.	It provides enough initial idea of the system.
Solid waste storage	Not applicable	The steps of solid waste from storage to final destination and its sub-division were enough to create general view of what is available in the municipalities and what is still required.
Solid waste transportation		
Solid waste processing		
Solid waste final destination		
Coverage of the superficial network	Because no municipality has any actual coverage of drainage systems, or if it has it is too low, the 20 unit-range attributes 1 point to a very poor system.	Municipalities with 80% or more (which is not the case for the cities analysed) with some service of drainage systems score the highest and therefore, even though they might not have 100% of citizens benefiting from the service, they are progressing to reach full coverage.
Coverage of the underground network		

Source: Author's work

The following strengths and weaknesses analysis concerns the micro classification. A common weakness in the micro classification is the usage of the scale from insufficient to excellent to describe the condition of the system. This scale (though well explained in table 6) is subject to interpretation and therefore it can be hard to assign the right

value to define the system. Such situation can jeopardize comparison among different municipalities, since different people analyse different reports to extract the necessary data.

Table 39 shows the strengths and weaknesses found when using the micro classification.

Table 39 Strengths and weaknesses for the micro classification

Variable	Weaknesses	Strength
Coverage of water distribution Network	The point of concern regarding this variable is about the materials used in the pipes. As mentioned in the table, the pipes are made of Iron, Asbestos or PVC. However, the reports do not provide concrete information of how much of each the system has and when scoring the system the tool suggests considering the worse situation (asbestos) as majority. In some cases that can cause large errors.	All variables in the scale of insufficient to excellent assist on the creation of an accurate scenario of how is the condition of the water distribution network connecting the citizens. It is important to remember that it classifies the percentage mentioned in the macro classification.
Coverage of the wastewater collection network	Percentage of superficial and underground leakage is not measured.	All variables in the scale of insufficient to excellent assist on the creation of an accurate scenario of how is the condition of the wastewater collection network. It is important to remember that it classifies the percentage mentioned in the macro classification.
Water treatment	It does not consider additional tests for the goal attainment. In other words, because in the macro classification not all parameter were considered the goal attainment here is incomplete according to the Act_ 58_2004 Ministry of Health.	This variable concerns the state of the facility carrying out the activity as well as if the non-conformities are solved with the treatment: goal attainment.
Receiving-body		
Wastewater pre-treatment	It does not consider the level of efficiency of the treatment.	It provides enough information to understand what is the condition of each phase of the wastewater treatment plants.
Wastewater primary treatment		
Wastewater secondary treatment		
Solid waste final destination	It does not assess illegal activities in the areas such as burning solid waste or illegal workers entering the facilities to get scrap materials. Moreover, it does not score time of operation	It provides concrete information about the conditions of dumping sites and landfills.

Source: Author's work

7 FINDINGS: ANSWERING RESEARCH QUESTIONS

Chapter 7 is intended to present the findings of this study answering the research questions individually. In some cases, when the question was answered in a separate chapter or more information is necessary, the specific section is provided for reference.

7.1 What are the current guidelines that classify the minimum quality of sanitation systems?

The current guidelines used as minimum standards to qualify sanitation systems are the ones taken from the work of Sphere,2004 mentioned in sections 2.3.1 to 2.3.7. the variables accounted in the study were:

- Water supply standard: access and quantity
- Water supply standard: quality
- Water supply standard: water use facilities and goods
- Excreta disposal standard: access to, and numbers of, toilets
- Excreta disposal standard: design, construction and use of toiles
- Solid waste management: collection and disposal
- Drainage standards: drainage works

For each variable, a group of indicators are used to assess whether that standards are met. Please go back to section 2.3 for reference on the indicators used to qualify what is minimum standard for each of the mentioned variables

7.2 What are the variables to consider in the classification of drinking water systems, wastewater systems, drainage systems and solid waste for the development of the classification instrument?

Although the literature review has presented several variables that could be used to classify these sanitation systems, to the purpose of developing the classification instrument, only the variables extracted from the diagnosis reports were considered. Those were:

For drinking water systems

- Coverage of water supply in the Urban Area
- Coverage of water supply in the Rural Area
- Water supply from water fountains, cisterns, wells and other decentralized forms.
- Water supply from water truck
- Water quality
- Drinking water treatment

For wastewater systems

- Water distribution Network
- Coverage of wastewater systems in the Urban Area
- Coverage of wastewater systems in the Rural Area
- Coverage of rudimentary tank or open wastewater
- Receiving body
- Use of septic tank
- Coverage of the wastewater collecting network
- Wastewater Pre-treatment
- Wastewater primary treatment
- Wastewater Secondary treatment

For solid waste

- Coverage of solid waste collection
- Coverage of selective solid waste collection
- Solid waste storage
- Solid waste transportation
- Solid waste processing
- Solid waste final destination

Drainage systems

- Coverage of the superficial network
- Coverage of the underground network

Some variables reported in the literature review are then later presented as recommendations to the improvement of the classification instrument.

7.3 What indicators can be used to assess the quality of sanitation systems for the development of the classification instrument?

Quality indicators are used for the micro classification in section 5.3. These indictors were:

For water supply

- Materials used for the pipeline
- Monitoring of continuity and pressure
- Contingency water pumps
- State of conservation/ Maintenance of electrical boards
- State of conservation/ Maintenance of pump-motor assembly
- State of conservation/ Maintenance of reservoirs
- State of conservation/ Maintenance of pipe line
- Losses in the Water distribution Network
- State of conservation/ Maintenance of Continuity and water pressure

For waste water collection network

- Leakage
- State of conservation/ Maintenance of Canals
- State of conservation/ Maintenance of electrical boards
- State of conservation/ Maintenance of pump-motor assembly
- State of conservation/ Maintenance of pipe line

For water treatment techniques and technology

- State of conservation/ Maintenance of the Drinking water treatment plant
- Goal attainment with the treatment

For receiving-body

- Meet the effluent discharge standards in the receiving-body

- Provide conditions in the receiving-body so that its quality fits within the standards of receiving-bodies
- Receiving-body's dissolution capacity
- State of conservation/ Maintenance of the receiving-body and surroundings

For wastewater pre-treatment, primary treatment and secondary treatment

- State of conservation/ Maintenance of the wastewater treatment plant
- State of conservation/ Maintenance of surroundings
- Goal attainment with the treatment

For solid waste final destination

- State of conservation/ Maintenance of the dumping site
- State of conservation/ Maintenance of the Landfill

For the betterment of the classification instrument, several indicators cited in the literature review are recommended. See Chapter 8 for reference.

7.4 Is the classification instrument for sanitation infrastructure valid?

Section 6.2 explores the validity of the classification instrument developed. It does so by comparing Municipal Human Development index (MHDI) from the United Nations Development Programme with the ranking established by using the instrument (table 36). The results suggests that the instrument is valid for the following reasons:

- It outputs a different ranking from MHDI
- It suggests percentage levels of sanitation development already reached by each municipality assessed.
- It considered variables and indicators taken from diagnosis reports
- And more important, It solves the problem addressed in this study

7.5 What are the strengths and weaknesses of the classification instrument?

Strengths and weaknesses are assessed in section 6.3 and since the analysis are long and thorough, the study recommends referring back to section.

7.6 What are the major sanitation priorities for cities under fifty thousand inhabitants in Ceará regarding sanitation?

Through the usage of the classification instrument, by having assessed the diagnosis reports and based on the literature review this study comes out with a list of the major sanitation priorities in the cities under fifty thousand people in the state of Ceará in Brazil.

I. Municipalities do not comply with the minimum standards regarding water quality, mostly due to financial problems and technical capability.
II. Wastewater is disposed in open areas, either due to superficial leakages or due to the inexistence of basic treatment.

III. Municipality often do not present a study on the capacity for the receiving body to dilute the effluent.
IV. Most of the analysed wastewater treatment plants are not operating accordingly. They are badly conserved and maintained.
V. The rural districts in the municipalities receive drinking water (usually) through the service of a non-registered party and therefore quality cannot be assured nor enforced.
VI. Investments in wastewater are still too focused in the main district pushing the rural areas to go for decentralized forms of wastewater treatment, which – usually because of lack of resources or knowledge – end up being rudimentary tanks or the disposal at open areas.
VII. Investment in drinking water systems are too focused in the main district and so the rural areas need water wells, water fountains and water trucks to have their drinking water. This situation decreases quality of life and it is an impediment on prosperity.
VIII. There is no operational drainage systems apart from what the report calls “natural drainage”.
IX. Selective collection of solid waste is inexistent in all municipalities and when there is mention of it, they are refereeing to “poor citizens” that due to its financial condition have to look for scrap metals and other materials to sell. Usually they “work” in dumping sites or going around the city’s storage units.
X. There is lack of awareness from citizens on how to store solid waste
XI. Considerable amount of trucks that carry solid waste are not designed to do so.

8 RECOMMENDATIONS

The recommendations given below regards the utilization of the classification instrument and the diagnosis reports analysed. The research present recommendations based on weaknesses and strengths assessed.

Table 40 Recommendations for the betterment of the classification instrument

Variable	**Recommendations**
Coverage of water supply in the Urban Area	More often than not, diagnosis reports have some similar governmental sources of information regarding coverage of services once those are done - in its majority - by companies with access to governmental data. These information have their own scale of coverage which can be used in the instrument to better fit the reality of the area of evaluation.
Coverage of water supply in the Rural Area	To better use the instrument, accurate inputs should be made and in order to do so, coverage of service in the rural area should be better measured and presented in the reports. If possible, use geo-processing tools to pinpoint what type of water technology is being used to deliver drinking water to the rural households.
Water supply based on fountains, cisterns, wells or other decentralized forms	Decentralized forms of water supply play a significant role in the analysed cities in Ceará however, the coverage of these services or facilities are not measured. The research recommend that the data scan of the situation to better represent the reality of the cities regarding how many people are still with no access to drinking water.
Water supply from water truck	
Coverage of water distribution Network	The recommendation for the coverage of water distribution network is the same given to coverage of water supply. One exception is the number of illegal connection in the water distribution network which should be measured to provide more accurate inputs about the quality of the water distributed.
Coverage of wastewater systems in the Urban Area	
Coverage of wastewater systems in the Rural Area	There is not much information about not registered services or facilities concerning decentralized wastewater systems. Therefore, the research recommend to scan the area and provide concrete data on the matter to better use the instrument.
Coverage of rudimentary tank or open sewage	
Use of septic tank	
Coverage of the wastewater collecting network	The recommendation for the coverage of wastewater collection network is the same given to coverage of water supply in the urban area.
Water quality	The research recommend that all municipalities - when sending the diagnosis reports - send together a history of the data and sampling for water potability like is expected with the 518_2014. With the additional information, the instrument can improve its assessment on water quality and provide more accurate information.
Water treatment	
Receiving-body	The diagnosis reports provide vague information about the treatments itself and how effective their operation are. Therefore it is suggested that a thorough investigation on the WWTP effectiveness on treating the effluent. In addition, the receiving-body (usually a river) in most reports are neglected regarding their situation up-stream and down-stream and about it capacity dissolute the effluent. Parameter that should be better presented in the report so that they can be incorporated in the tool to provide a more accurate output regarding the sanitary situation of the municipalities.
Wastewater pre-treatment	
Wastewater primary treatment	
Wastewater secondary treatment	
Wastewater tertiary treatment	
Coverage of solid waste collection	The research recommend a more in-depth look into the situation of the collection and disposal of solid waste as the research did not go really deep onto assess all the variables related to the management of solid waste and public cleaning services.
Coverage of selective solid waste collection	Recommendation is the same given to coverage of water supply in the urban area.
Solid waste storage	As from 2021, disposing solid waste in dumping sites will be an illegal activity and therefore it is necessary to update the instrument to this condition.
Solid waste transportation	
Solid waste processing	
Solid waste final destination	
Coverage of the superficial network	Recommendation is the same given to coverage of water supply in the urban area. In cases where no coverage is a reality, a value of 0 should be inserted in the instrument.
Coverage of the underground network	

Source: Author's work

The classification instrument produces an acceptable result as presented in table 36 however, its accuracy and scope can be expanded to analyse more complex sanitation systems in bigger municipalities but also to show more detailed sanitation services and structures.

To expand the range of operation of the classification tool the research recommend adding some indicators used by the Institute trata Brazil mentioned in section 2.4.2. and used by the National Sanitation Information System mentioned in section 2.4.3. The ones from the Institute Trata Brazil are:

I. Coverage improvement
- Investment
- New water connections/lacking connections
- New sewage connection/lacking connection

II. Level of efficiency.
- Billing losses
- Evolution on billing losses
- Evolution on distribution losses

The indicators from the National Sanitation Information Systems are:

Water operational indicator

- Total water service index
- Index of urban water service
- Density of water savings per connection
- Share of residential water savings in total water savings
- Hydrometric index
- Micro average index for the volume made available
- Micro consumption measurement index
- Water consumption index
- Volume of water provided by economy
- Average water consumption per economy
- Economy micro measured consumption
- Average consumption per Capita of water
- Index of electricity consumption in water supply systems
- Water billing index

Sewage operational indicators

- Sewage collection index
- Sewage treatment index
- Treated sewage index referring to water consumed
- Index of electricity consumption in sewage systems
- Economies affected by outages

Indicators on quality

- Average duration of downtime

- Intermittent average duration
- Average length of sewer overflow repairs
- Sewage extravasation by network extension
- Average duration of services performed

Solid waste collection indictors

- Average collector and driver productivity
- Rate of drivers and collectors per urban inhabitant Massa: Residential Waste (RW) + Public Waste (PW) collected per capita in relation to the urban population
- RDA mass collected per capita in relation to the total population served
- Ratio: quantities collected from PW by RW
- Mass (RW + PW) collected per capita in relation to the total population served Mass of RW per capita / year in relation to urban population

Selective solid waste collection indicators

- Recovery rate of recyclables in relation to the amount of RW and PW
- Mass recovered per capita Ratio between selective collection and RW quantities Paper / cardboard incidence on total recovered material
- Incidence of plastics on total recovered material
- Incidence of metals on total recovered material
- Incidence of glasses on total recovered material
- Incidence of '' others '' on total recovered material
- Mass per capita collected via selective collection

In addition, as most of the reports do not detailed wastewater and drinking systems for the rural districts the research suggest (to increase specificities in the classification instrument) the utilization of the indicators used in the Environmental Performance Index (EPI) in section 2.4.1. These are:

I. An improved drinking water is Piped water into a dwelling, plot, or yard;
   - Public tap or standpipe;
   - Tube well or borehole;
   - Protected spring;
   - Rainwater collection.

II. Improved sanitation sources
   - Connection to a public sewer;
   - Connection to a septic system;
   - pour-flush latrine;
   - simple pit latrine;
   - Ventilated pit latrine.

By using the indicator from the Institute Trata Brazil, National Sanitation Information Systems and the ones from the EPI, the classification instrument can be used for larger cities with lager capacity to details thereby becoming a strong tool to assess the sanitation condition of a given municipality.

As for future view, the suggestion is to develop a software that combines geo-processing with the classification instrument developed by this research. This combined tool would allow for an interactive map outputting scores for the municipalities (similar to the ones in the classification instrument) and ranking them according to a selected function: water supply, wastewater collection, drinking water treatment, wastewater treatment, solid waste collection, solid waste treatment and drainage systems. Figure 15 illustrates how the research images this software's layout.

Figure 15 Software layout

Source: Author's work editing google maps

The hope is to – with this software – decision makers will have control and awareness of high risk and low risk areas and their sanitary conditions. As a result, through using the ranking system, they can more rapidly allocate financial resources for the improvement or construction of the required sanitation facilities or services.

Finally, the last remark concerns the term of reference used as based line for the elaboration of Municipal Sanitation Plans. The chapters 5.4.3 to 5.4.6 in the Term of Reference define the boundaries for the elaboration of the diagnosis reports. However, through assessing the existing reports we recommend that those chapters enforce better definitions for sanitation infrastructures using quantitative data to support the qualitative results often presented as sufficient. The additional quantitative data will allow for faster and more complete assessment of the municipalities' sanitary condition, easier data input in the classification instrument and ultimately assist on reducing decision-making time for budget allocation.

9 CONCLUSION

The objective of this study has been the development of an instrument for classification and ranking of sanitation systems of municipalities in the State of Ceará in Brazil. Such an instrument improves the allocation of resources over municipalities that applied for funding to the Brazilian National Health Foundation.

To reach such goals the study has had access to archived data provided by the Brazilian National Health Foundation focused in the State of Ceará, Brazil. The foundation has supplied 10 sanitation diagnosis reports from which - by following the research's methodology in chapter 3 - the study has been able to fashion the classification instrument. For the designing of the classification instrument, the study has considered the variables mentioned in section 4.3 to 4.6. These variables were the basis for the development of what the research called macro classification and micro classification designed to offer an overall and detailed view of the sanitation systems respectively.

Once the classification instrument was completed, the research set out to carry testing using the same ten samples. Upon completion, a comparison between the current practice using the Human Development Index and the outputted raking from the instrument has been established. This crossing-reference technique has been used to assess if the instrument was valid.

Moreover, through testing the instrument against the ten samples, the study has been able to gather data on what was considered strengths and weaknesses (tables 37 to 39) and thus it has provided a range of recommendations (section 6.5) to both improving reporting techniques and the classification instrument itself

The results of this study has indicated that there is still much research to be done in the matter. The fashioning of this classification instrument has started paving the way to the creation of a robust and complete software. Several variables and indicators could still be added to the instrument, which would make it more accurate and broader.

Although the study has only laid the ground for future researches, the insight gained from this work may be of assistance to the Brazilian National Health Foundation in future budget allocations.

Besides, the main weakness of this study was the paucity of data in the reports and scarcity of reports itself, which may have affected the reliability of the classification instrument. Notwithstanding these limitations, the study has suggested that the state of Ceará has many technical problems regarding its sanitation infrastructure (as listed in section 6.4) and it may not reach the Brazilian National Sanitation Plan - designed to have until 2033 - universal sanitation for the country.

REFERENCE

[1] Agência Nacional de Águas. (2017). *Atlas de Esgotos: Despoluição de Bacias Hidrográficas*.

[2] America, N. (2008). Sanitation is vital for human health. *World Health*.

[3] Brazil Overview : Water , sanitation and hygiene. (n.d.) (pp. 1–4).

[4] Buchanan, J. R. (2015). Wastewater Basics 101.

[5] de Feo, G., Antoniou, G., Fardin, H. F., El-Gohary, F., Zheng, X. Y., Reklaityte, I., … Angelakis, A. N. (2014). The historical development of sewers worldwide. *Sustainability (Switzerland)*, *6*(6), 3936–3974. https://doi.org/10.3390/su6063936

[6] Eawag Sandec. (2008). Sanitation Systems & Technologies. *Training*, 1–64.

[7] Government of India. (2017). Ministry of Drinking Water and Sanitation, (November), 1–61.

[8] Hutton, G., & Haller, L. (2004). Evaluation of the Costs and Benefits of Water and Sanitation Improvements at the Global Level. *World Health Organization*, 1–87. https://doi.org/10.2166/wh.2007.008

[9] Oliveira, G., Scazufca, P., & Arouca, L. F. A. F. (2012). Ranking do Saneamento - Instituto Trata Brasil, 86. Retrieved from http://www.tratabrasil.org.br/datafiles/estudos/ranking/relatorio-completo-2014.pdf%5Cnhttp://www.tratabrasil.org.br/ranking-do-saneamento

[10] Sphere. (2004). Chapter 2 : Minimum Standards in Water Supply , Sanitation and Hygiene. *The Sphere Handbook*, 350.

[11] Vandor, P., & Emiliano, E. (2018). What Must Be Done to Improve Brazil ' s Water and Sewage Infrastructure ?, *XX*(18), 4.

[12]

[13] United Nations water,Global Issues, Water. Retrieved from http://www.un.org/en/se*ctions/issues-depth/water/, accessed on 17 March 2018*.

[14] Sustainable Development, water and sanitation. Retrieved from http://www.un.org/sustainabledevelopment/water-and-sanitation/, accessed on 17 March 2018

[15] Sustainable Development Goals, Brazil Retrieved from http://sanitationandwaterforall.org/wp-ontent/uploads/download-manager-files/2017%20Brazil%20Overview_final.pdf, accessed on 17 March 2018.

[16] Global data on drinking water, sanitation and hygiene (WASH), Retrieved from https://washdata.org/, accessed on 17 March 2018.

[17] Gravetter FJ, Wallnau LB. 5th ed. Belmont: Wadsworth – Thomson Learning; 2000. Statistics for the behavioral sciences.

[18] Glossary on the Human Right to Water and Sanitation. Retrieved from http://www.un.org/waterforlifedecade/pdf/hrw_glossary_eng.pdf, accessed on 17 Mar 2018.

[19] Heath topics, Sanitation. Retrieved from http://www.who.int/topics/sanitation/en/, accessed on 17 Mar 2018.

[20] Improved sanitation facilities (% of population with access) - Country Ranking. Retrieved from https://www.indexmundi.com/facts/indicators/SH.STA.ACSN/rankings, accessed on 17 Mar 2018.

[21] Government of Brazil, 2009. brasil.gov.br. Retrieved from http://www.brasil.gov.br/governo/2009/11/governo-federal-e-formado-por-ministerios-secretarias-e-orgaos-especiais last accessed on March 17, 2018

[22] Ministry of Health, 2017. Institutional. Retrieved from http://portalms.saude.gov.br/institucional/o-ministerio, last accessed on March 17, 2018

[23] Funasa, 2017. Competências. Retrieved from http://www.funasa.gov.br/web/guest/competencias, last accessed on March 19, 2018

[24] Ministry of Health publications, 2017. Act_518_2004. Retrieved fromhttp://bvsms.saude.gov.br/bvs/publicacoes/portaria_518_2004.pd, last accessed on March 19, 2018

[25] United Nations Development Programa, Municipal Human Development Index Brazil. Retrieved from https://web.archive.org/web/20101123025800/http://www.pnud.org.br/atlas/ranking/IDH-M%2091%2000%20Ranking%20decrescente%20(pelos%20dados%20de%202000).htm, last accessed on August 25, 2018

[26] Ministry of cities, 2018. National System on Information about sanitation , Retrieved from http://www.snis.gov.br/diagnostico-agua-e-esgotos, last accessed on July 19, 2018

[27] Ministry of cities, 2018. National System on Information about sanitation , Retrieved from http://www.snis.gov.br/coleta-de-dados-snis-residuos-solidos, last accessed on July 19, 2018

APPENDIX A DATA MATRIX

Municipalities	Drinking water supply						
variables	Coverage of water supply in the Rural Area (%)	Coverage of water supply in the Urban Area (%)	Water supply based on fountains, cisterns, wells or other decentralized forms(Yes/ No)	Water supply from water truck(yes/no))	Water quality indicators	Water distribution Network (Yes / No)	Water distribution network(%)
Altaneira	17.80%	89.40%	Yes (9%)	Yes	Non conformities: turbidity (12.5 to 62.5%), fluorite: 12.5% to 37.5%), Colour and Aluminium	Yes	60%
Araripe	90% (50 90)	89.20%	Yes (Not mentioned)	Yes	Non conformities: Turbidity: 10,6% Colour: 2,1% residual chlorine: 2,1% total Iron: 4,2% Fluorite: 3,7%	Yes	94.42%
Barbalha	4.50%	97.70%	Almost all of it (90 % - 100%)	No	Non conformity: turbidity, colour, residual chlorine, pH, Total coliforms, E.coli bacteria	yes	64%
Caririaçu	4.90%	95.40%	Not mentioned	No	Inconclusive data	Yes	86%
Carius	50% - 70%		Not mentioned	Not mentioned	Inconclusive data	Yes	89.1% main district
Faria brito	15.80%	76.60%	Yes (37.3%)	Not mentioned	Non conformities: Colour: 25% e 100% Turbidity: 100% Iron 37,5% e 100% Aluminium: 12,5% Fluorite: 100% das	Yes	Not mentioned
Jardim	0.00%	84.20%	Yes (19.9)	Not mentioned	Not mentioned	Yes	30%
Limeiro do norte	90%		Yes	Not mentioned	Non-conformity: Colour, residual chlorine and turbidity.	Yes	11%
Nova olinda	5.30%	98.90%	Yes (28%)	Yes	Non conformity: turbidity	Yes	11%
Santana do Cariri	0.00%	68.10%	Yes (46%)	Not mentioned main district)	Non conformities: Turbidity, residual chlorine, turbidity and iron	Yes	Not mentioned

Municipalities	Wastewater variables										
variables	Coverage of sewage systems in the Rural Area (%)	Coverage of sewage systems in the Urban Area (%)	Coverage of sewage systems in the Urban Area (%)	Use of septic tank (yes / No)	Open sewag e	Coverage of the sewage collecting network (%)	WWTP with pretreatme nt	WWTP with primary treatment	WWTP with secondary treatment	Existence of receptor body	WWTP with tertiary treatme nt
Altaneira	11.30%	17%	Yes	No	yes	20% main district	Not mentioned		Stabilization ponds (2 Facultative e 1 maturaion)	Yes	No
Araripe	0%	17.50%	Yes	No	Yes	6.13%	Yes	Gradeamen to e caixa de areia	Stabilization ponds (1 Facultative e 3 maturation)	No	No
Barbalha	0%	50%	Yes	Yes	Yes	8.50%	Yes	Not mentioned	Stabilization pondso (1 Facultative e 2 maturation)	Yes	No
Caririaçu	0%	0%	Yes	Yes	Yes	Not mentioned	No	No	No	No	No
Carius	0%	0%	Yes	Not mentioned	Yes	No	No	No	No	No	No
Faria brito	0%	0%	Yes	Yes	Yes	No	No	No	No	No	No
Jardim	0%	75.80%	Yes	Yes	Yes	0%	No	No	No	No	Yes
Limeiro do norte	10.90%		Yes	No	yes	12%	Yes	No	Stabilization ponds (1 Facultative e 1 maturation)	Yes	Yes
Nova olinda	0%	65%	Yes	Yes	Yes	65% main district	No	No	No	No	Yes
Santana do Cariri	0%	0%	Yes	Yes	yes	Not mentioned	No	No	No	No	Yes

Municipalities	Public cleaning services and solid waste					
Variables	Coverage of solid waste collection (%)	Coverage of selective solid waste collection	Final destiny (dumping ground)	Final destiny (Landfill)	Final destiny (recycle)	Final destiny (incineration)
Altaneira	77.50%	0%	yes	No	No	Health residues
Araripe	97%	0%	Yes	No	No	Not mentioned
Barbalha	71%	0%	Yes	No	No	Health residues
Caririaçu	54.20%	0%	Yes	No	No	No
Carius	Not mentioned	0%	Yes	No	No	No
Faria brito	66%	0%	Yes	No	No	No
Jardim	90% - 100%	0%	Yes	No	No	No
Limeiro do norte	97% for urban area	0%	Yes	No	No	Health residues
Nova olinda	50 - 70 %	0%	yes	No	No	Health residues
Santana do Cariri	54.7	0%	yes	No	No	No

Municipalities	Drainage Systems	
Variables	Coverage of the underground network (%)	Coverage of the superficial network (%)
Altaneira	0.00%	0.00%
Araripe	2.00%	18.00%
Barbalha	0.00%	75% main district
Caririaçu	0.00%	95% main district
Carius	0.00%	0.00%
Farias brito	0.00%	10%
Jardim	0.00%	0.00%
Limeiro do norte	0.00%	2% main district
Nova olinda	0.00%	78.44% main district
Santana do Cariri	0.00%	0.00%

APPENDIX B THE CLASSIFICTION INSTRUMENT

Scoring system – Macro classification

Name of the municipality: _____Date:_____

Water supply				
Coverage of water supply in the Urban Area (%)	Coverage of water supply in the Rural Area (%)	Water supply based on fountains, cisterns, wells or decentralized forms	Water supply from water truck	Water distribution Network (%)
0 - 20% (1 point)	0 - 20% (1 point)	Access 1 Point	Access 1 Point	0 - 20% (1 point)
21 - 40% (2 points)	21 - 40% (2 points)	No Access 0	No Access 0 Point	21 - 40% (2 points)
41 - 60% (3 points)	41 - 60% (3 points)	Not Required 2 Points	Not Required 2 Points	41 - 60% (3 points)
61 -80 % (4 points)	61 -80 % (4 points)			61 -80 % (4 points)
81 - 100% (5 points)	81 - 100% (5 points)			81 - 100% (5 points)
Sewage collection				
Coverage of sewage systems in the Urban Area	Coverage of sewage systems in the Rural Area	Coverage of rudimentary tank or open sewage (Points)	Use of septic tank	Coverage of the sewage collecting network
0 - 20% (1 point)	0 - 20% (1 point)	Existent 0	Access 1	0 - 20% (1 point)
21 - 40% (2 points)	21 - 40% (2 points)	Not required 1	No Access 0	21 - 40% (2 points)
41 - 60% (3 points)	41 - 60% (3 points)		Not Required 2	41 - 60% (3 points)
61 -80 % (4 points)	61 -80 % (4 points)			61 -80 % (4 points)
81 - 100% (5 points)	81 - 100% (5 points)			81 - 100% (5 points)

Parameter	Water quality - Sampling plans
Ammonia	Activity carried out (1 point), if not (0 points)
Free residual Clorine	Activity carried out (1 point), if not (0 points)
Color	Activity carried out (1 point), if not (0 points)
Toughness	Activity carried out (1 point), if not (0 points)
Iron	Activity carried out (1 point), if not (0 points)
Manganese	Activity carried out (1 point), if not (0 points)
Sodor	Activity carried out (1 point), if not (0 points)
Taste	Activity carried out (1 point), if not (0 points)
Odor	Activity carried out (1 point), if not (0 points)
Total dissolved solids	Activity carried out (1 point), if not (0 points)
Turbidity	Activity carried out (1 point), if not (0 points)
pH	Activity carried out (1 point), if not (0 points)
Total coliforms	Activity carried out (1 point), if not (0 points)
Fluorine	Activity carried out (1 point), if not (0 points)

Parameter	Water quality standards " Not conformity check"				
Ammonia	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Free residual Clorine	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Color	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Toughness	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)

Iron	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Manganese	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Sodor	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Taste	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Odor	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Total dissolved solids	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Turbidity	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
pH	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Total coliforms	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)
Fluorine	0 - 20% (5 points)	21 - 40% (4 points)	41 - 60% (3 points)	61 -80 % (2 points)	81 - 100% (1 points)

Wastewater treatment				
Existence of receiving body	**Wastewater Pre-treatment**	**Wastewater primary treatment**	**Wastewater Secondary treatment**	**Wastewater Tertiary treatment**
Existence 1 Point	Pre treatment - Access 1 Point	Primary treatment - Access 1 Point	Secondary - Access 1 Point	Terciary treatment - Access 1 Point
Non existence 0 point	Non existence 0 point	Non existence 0 point	Non existence 0 point	Non existence 0 point

Solid waste collection	
Coverage of solid waste collection	Coverage of selective solid waste collection
0 - 20% (1 point)	0 - 20% (1 point)
21 - 40% (2 points)	21 - 40% (2 points)
41 - 60% (3 points)	41 - 60% (3 points)
61 -80 % (4 points)	61 -80 % (4 points)
81 - 100% (5 points)	81 - 100% (5 points)

Solid waste treatment			
Solid waste storage	Solid waste transportation	Solid waste Processing	Solid waste final destination
Open container 0 point	Open bucket truck 0 point	Recycle 1	Dumping site 0
Close containers 1 point	Close bucket truck 1 point	Incineration for medical waste 1	Landfill 1

Drainage systems	
Coverage of the superficial network	Coverage of the underground network
x0 - 20% (1 point)	0 - 20% (1 point)
21 - 40% (2 points)	21 - 40% (2 points)
41 - 60% (3 points)	41 - 60% (3 points)
61 -80 % (4 points)	61 -80 % (4 points)
81 - 100% (5 points)	81 - 100% (5 points)

Scoring system – Micro classification

Water distribution network		
Quality indicators (variable)	**Scale**	**Points**
Materials used for the pipeline	Iron (1), PVC (2), Asbestos (0)	0 to 2
Monitoring of continuity and pressure	insufficient, fair, acceptable, good and excellent	1 to 5
Contingency water pumps	non-existent or existent	0 or 1
State of conservation/ Maintenance of electrical boards	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of pump-motor assembly	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of reservoirs	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of pipe line	insufficient, fair, acceptable, good and excellent	1 to 5
Losses in the Water distribution Network (%)	0 to 20%, 21 to 40%, 41 to 60%, 61 to 80%, 81 to 100%	0.5 to 0.1
State of conservation/ Maintenance of Continuity and water pressure	insufficient, fair, acceptable, good and excellent	1 to 5

wastewater collection network		
Quality indicators (variable)	Scale	**Points**
Leakage	very low, low, medium, High and Vey high	0.5 to 0.1
State of conservation/ Maintenance of Canals	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of electrical boards	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of pump-motor assembly	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of pipe line	insufficient, fair, acceptable, good and excellent	1 to 5

Drinking water treatment		
Quality indicators (variable)	Scale	**Points**
State of conservation/ Maintenance of the DWTP	insufficient, fair, acceptable, good and excellent	1 to 5
Goal attainment with the treatment	insufficient, fair, acceptable, good and excellent	1 to 5

Receiving-body		
Quality indicators (variable)	Scale	**Points**
Meet the effluent discharge standards in the receiving-body	insufficient, fair, acceptable, good and excellent	1 to 5
Provide conditions in the receiving-body so that its quality fits within the standards of receiving-bodies	insufficient, fair, acceptable, good and excellent	1 to 5
Receiving-body's dissolution capacity	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of the receiving-body and surroundings	insufficient, fair, acceptable, good and excellent	1 to 5

Wastewater pre-treatment		
Quality indicators (variable)	Scale	**Points**
State of conservation/ Maintenance of the WWTP	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of surroundings	insufficient, fair, acceptable, good and excellent	1 to 5
Goal attainment with the treatment	insufficient, fair, acceptable, good and excellent	1 to 5

Primary treatment		
Quality indicators (variable)	Scale	**Points**
State of conservation/ Maintenance of the WWTP	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of surroundings	insufficient, fair, acceptable, good and excellent	1 to 5
Goal attainment with the treatment	insufficient, fair, acceptable, good and excellent	1 to 5

Secondary treatment		
Quality indicators (variable)	Scale	**Points**
State of conservation/ Maintenance of the WWTP	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of surroundings	insufficient, fair, acceptable, good and excellent	1 to 5
Goal attainment with the treatment	insufficient, fair, acceptable, good and excellent	1 to 5

Solid waste final destination		
Quality indicators (variable)	Scale	**Points**
State of conservation/ Maintenance of the dumping site	insufficient, fair, acceptable, good and excellent	1 to 5
State of conservation/ Maintenance of the Landfill	insufficient, fair, acceptable, good and excellent	1 to 5

Overview of the scoring systems

Sub-categorization of variables - Macro classification							
Variables	**Water supply**	**wastewater collection**	**Drinking water treatment**	**wastewater treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	3 to 19	3 to 18	0 to 84	0 to 6	2 to 10	0 to 5	2 to 10
Total Range	10 to 152						
Sub-categorization of variables - Micro classification							
Variables	**Water supply**	**wastewater collection**	**Drinking water treatment**	**wastewater treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	6.5 to 33.1	4.5 to 20.1	2 to 10	16 to 80	Non-applicable	2 to 10	Non-applicable
Total Range	31 to 153.2						

Form for field engineer 1 of 2													
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste collection**	**Scores**	**Solid waste treatment**	**Scores**	**Drainage**	**Scores**
Coverage of water supply in the Urban Area		Coverage of sewage systems in the Urban Area		Water quality indicators		Receiving-body		Coverage of solid waste collection		Storage		Coverage of the superficial network	
Coverage of water supply in the Rural Area		Coverage of sewage systems in the Rural Area		Water treatment techniques and technologies		Pre-treatment		Coverage of selective solid waste collection		Transportation		Coverage of the underground network	
Water supply based on fountains, cisterns, wells or other decentralized forms		Coverage of rudimentary tank or open sewage				Primary treatment				Processing			
Water supply from water truck		Use of septic tank				Secondary treatment				Final destination			
Water distribution Network		Coverage of the sewage collecting network				Tertiary treatment							
						Post-treatment (disinfection)							
Total score	0	Total score	0	Total score	0	Total score	0	Total score	0	Total score	0	Total score	0

Form for field engineer 2 of 2									
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Sold waste**	**Scores**
Water distribution Network		Wastewater collection network		Water treatment		Receiving-body		Final destination	
						Pre-treatment			
						Primary treatment			
						Secondary treatment			
						Tertiary treatment			
Total score	0	Total score	0	Total score	0	Total score	0	Total score	0

Sub-categorization of variables - Macro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range							
Total Range							
Sub-categorization of variables - Micro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range							
Total Range							

Comments:

Municipality of Altaneira

APPENDIX C RESULTS FOR EACH MUNICIPALITY

Form for field engineer 1 of 2													
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste collection**	**Scores**	**Solid waste treatment**	**Scores**	**Drainage**	**Scores**
Coverage of water supply in the Urban Area	5	Coverage of sewage systems: Urban Area	1	Water quality indicators	14	Receiving-body	1	Coverage of solid waste collection	4	Storage	0	Coverage of the superficial network	1
Coverage of water supply in the Rural Area	1	Coverage of sewage systems: Rural Area	1	Water treatment	66	Pre-treatment	0	Coverage of selective solid waste collection	1	Transportation	0	Coverage of the underground network	1
Water supply based on fountains, cisterns, wells or other decentralized forms	1	Coverage of rudimentary tank or open sewage	0			Primary treatment	1			Processing	1		
Water supply from water truck	1	Use of septic tank	0			Secondary treatment	1			Final destination	0		
Water distribution Network	3	Coverage of the sewage collecting network	1			Tertiary treatment	0						
						Post-treatment	0						
Total score	11	Total score	3	Total score	80	Total score	4	Total score	4	Total score	1	Total score	2

Municipality of Altaneira

Form for field engineer 2 of 2									
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste**	**Scores**
Water distribution Network	6.4	Wastewater collection network	4.5	Water treatment techniques and technologies	5	Receiving-body	4	Final destination	1
						Pre-treatment	7		
						Primary treatment	7		
						Secondary treatment	7		
						Tertiary treatment	NA		
Total score	6.4	Total score	4.5	Total score	5	Total score	25	Total score	1

Sub-categorization of variables - Macro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	11	3	80	4	4	1	2
Total Range	105						
Sub-categorization of variables - Micro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	6.4	4.5	5	25	NA	1	NA
Total Range	41BA						

Comments:

Municipality of Araripe

Form for field engineer 1 of 2													
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste collection**	**Scores**	**Solid waste treatment**	**Scores**	**Drainage**	**Scores**
Coverage of water supply in the Urban Area	5	Coverage of sewage systems in the Urban Area	1	Water quality indicators	14	Receiving-body	0	Coverage of solid waste collection	5	Storage	0	Coverage of the superficial network	1
Coverage of water supply in the Rural Area	3	Coverage of sewage systems in the Rural Area	1	Water treatment techniques and technologies	70	Pre-treatment	1	Coverage of selective solid waste collection	1	Transportation	0	Coverage of the underground network	1
Water supply based on fountains, cisterns, wells or other decentralized forms	1	Coverage of rudimentary tank or open sewage	0			Primary treatment	1			Processing	0		
Water supply from water truck	1	Use of septic tank	1			Secondary treatment	1			Final destination	0		
Water distribution Network	5	Coverage of the sewage collecting network	1			Tertiary treatment	0						
						Post-treatment	0						
Total score	15	Total score	4	Total score	84	Total score	3	Total score	6	Total score	0	Total score	2

Municipality of Araripe

Form for field engineer 2 of 2									
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste**	**Scores**
Water distribution Network	20	Wastewater collection network	14.3	Water treatment techniques and technologies	5	Receiving-body	NA	Final destination	1
						Pre-treatment	3		
						Primary treatment	3		
						Secondary treatment	3		
						Tertiary treatment	NA		
Total score	20*	Total score	14C	Total score	5	Total score	13	Total score	

Sub-categorization of variables - Macro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	15	4	84	3	6	0	2
Total Range	114						
Sub-categorization of variables - Micro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	20*	14.3	5	9	NA	1	NA
Total Range	49C						

Comments:

* Missing data

NA stands for Not Applicable

In the reports, water supply in the rural area is 90% but because its supply is not a public service it does not follow the same standard hence not being considered. The total coverage (rural and urban) is then decreased from 90% each to 50% for the rural area and 90% in the Urban Area.

Puts a note if all the water quality parameter are correct.

Selective solid waste is inexistent.

Report does not mention percentage of water distribution loss or any other way to calculate.

From the analysed cities, Araripe is the only one with some underground drainage system but in such bad conditions that the research disregard it to use micro classification on it.

Municipality of Barbalha

Form for field engineer 1 of 2													
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste collection**	**Scores**	**Solid waste treatment**	**Scores**	**Drainage**	**Scores**
Coverage of water supply in the Urban Area	5	Coverage of sewage systems in the Urban Area	3	Water quality indicators	14	Receiving-body	1	Coverage of solid waste collection	4	Storage	0	Coverage of the superficial network	1
Coverage of water supply in the Rural Area	1	Coverage of sewage systems in the Rural Area	1	Water treatment techniques and technologies	70	Pre-treatment	1	Coverage of selective solid waste collection	1	Transportation	1	Coverage of the underground network	1
Water supply based on fountains, cisterns, wells or other decentralized forms	1	Coverage of rudimentary tank or open sewage	0			Primary treatment	1			Processing	1		
Water supply from water truck	1	Use of septic tank	1			Secondary treatment	1			Final destination	0		
Water distribution Network	4	Coverage of the sewage collecting network	1			Tertiary treatment	0						
						Post-treatment	0						
Total score	12	Total score	6	Total score	84	Total score	4	Total score	5	Total score	2	Total score	2

Municipality of Barbalha

Form for field engineer 2 of 2									
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste**	**Scores**
Water distribution Network	18.3	Wastewater collection network	14.4	Water treatment techniques and technologies	7	Receiving-body	4	Final destination	1
						Pre-treatment	6		
						Primary treatment	6		
						Secondary treatment	6		
						Tertiary treatment	NA		
Total score	18.3	Total score	14.4	Total score	7	Total score	22	Total score	1

Sub-categorization of variables - Macro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	12	6	84	4	5	2	2
Total Range							
Sub-categorization of variables - Micro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	18.3	14.4	7	22	NA	1	NA
Total Range							

Comments:

Water distribution network in some districts are privately operated and does not have prior treatment.
There is no mention of the sampling and testing of the parameter for water quality. It just mention the ones that are not conform so we consider the worst condtion.

Municipality of caririaçu

Form for field engineer 1 of 2													
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste collection**	**Scores**	**Solid waste treatment**	**Scores**	**Drainage**	**Scores**
Coverage of water supply in the Urban Area	5	Coverage of sewage systems in the Urban Area	1	Water quality indicators	3	Receiving-body	0	Coverage of solid waste collection	3	Storage	0	Coverage of the superficial network	3
Coverage of water supply in the Rural Area	1	Coverage of sewage systems in the Rural Area	1	Water treatment techniques and technologies	15	Pre-treatment	0	Coverage of selective solid waste collection	1	Transportation	0	Coverage of the underground network	1
Water supply based on fountains, cisterns, wells or other decentralized forms	1	Coverage of rudimentary tank or open sewage	0			Primary treatment	0			Processing	0		
Water supply from water truck	1	Use of septic tank	1			Secondary treatment	0			Final destination	0		
Water distribution Network	4	Coverage of the sewage collecting network	1			Tertiary treatment	NA						
						Post-treatment	0						
Total score	12	Total score	12	Total score	18	Total score	0	Total score	4	Total score	0	Total score	4

Municipality of caririaçu

Form for field engineer 2 of 2									
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste**	**Scores**
Water distribution Network	12	Wastewater collection network	0	Water treatment techniques and technologies	2	Receiving-body	NA	Final destination	1
						Pre-treatment	NA		
						Primary treatment	NA		
						Secondary treatment	NA		
						Tertiary treatment	NA		
Total score	12*	Total score	0	Total score	2	Total score	0	Total score	1

Sub-categorization of variables - Macro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	12	4	18	0	4	0	4
Total Range							
Sub-categorization of variables - Micro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	12*	0	2	0	NA	1	NA
Total Range							

Comments:

*Data missing

There is no wastewater service available in the city thus the recommendation is to score 0 and not the minimum.

Not enough data on water quality: non-conform parameters are not presented and only colour, Turbidity and residual chlorine are tested.

Municipality of Carius

Form for field engineer 1 of 2													
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste collection**	**Scores**	**Solid waste treatment**	**Scores**	**Drainage**	**Scores**
Coverage of water supply in the Urban Area	4	Coverage of sewage systems in the Urban Area	1	Water quality indicators	5	Receiving-body	0	Coverage of solid waste collection		Storage	0	Coverage of the superficial network	3
Coverage of water supply in the Rural Area	1	Coverage of sewage systems in the Rural Area	1	Water treatment techniques and technologies	25	Pre-treatment	0	Coverage of selective solid waste collection		Transportation	0	Coverage of the underground network	1
Water supply based on fountains, cisterns, wells or other decentralized forms	1	Coverage of rudimentary tank or open sewage	0			Primary treatment	0			Processing	0		
Water supply from water truck	1	Use of septic tank	1			Secondary treatment	0			Final destination	0		
Water distribution Network	3	Coverage of the sewage collecting network	1			Tertiary treatment	0						
						Post-treatment	0						
Total score	10	Total score	4	Total score	30	Total score	0	Total score	4	Total score	0	Total score	4

Municipality of Carius

Form for field engineer 2 of 2									
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste**	**Scores**
Water distribution Network	26	Wastewater collection network	0	Water treatment techniques and technologies		Receiving-body	NA	Final destination	2
						Pre-treatment	NA		
						Primary treatment	NA		
						Secondary treatment	NA		
						Tertiary treatment	NA		
Total score	26*	Total score	0	Total score	10	Total score	0	Total score	2

Sub-categorization of variables - Macro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	10	4	6	0	4	0	4
Total Range							
Sub-categorization of variables - Micro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	26*	NA	2	NA	NA	2	NA

Comments:

*Missing data

There is not wastewater service in the municipality.

There is no data regarding the losses in the pipes for water distribution

Escherichia coli is an additional test realized by the municipality however, with the there is no enough information to support the other parameter are also assessed.

The scoring of water treatment under micro classification is given based on the existing sampling and testing only.

Municipality of Faria brito

Form for field engineer 1 of 2													
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste collection**	**Scores**	**Solid waste treatment**	**Scores**	**Drainage**	**Scores**
Coverage of water supply in the Urban Area	4	Coverage of sewage systems in the Urban Area	1	Water quality indicators	14	Receiving-body	1	Coverage of solid waste collection	4	Storage	0	Coverage of the superficial network	2
Coverage of water supply in the Rural Area	1	Coverage of sewage systems in the Rural Area	1	Water treatment techniques and technologies	50	Pre-treatment	0	Coverage of selective solid waste collection	1	Transportation	1	Coverage of the underground network	2
Water supply based on fountains, cisterns, wells or other decentralized forms	1	Coverage of rudimentary tank or open sewage	0			Primary treatment	0			Processing	0		
Water supply from water truck	1	Use of septic tank	1			Secondary treatment	0			Final destination	0		
Water distribution Network	1	Coverage of the sewage collecting network	1			Tertiary treatment	NA						
						Post-treatment	0						
Total score	8	Total score	4	Total score	65	Total score	1	Total score	5	Total score	1	Total score	2

Municipality of Faria brito

Form for field engineer 2 of 2									
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste**	**Scores**
Water distribution Network	7.5	Wastewater collection network	NA	Water treatment techniques and technologies	3	Receiving-body	3	Final Destination	1
						Pre-treatment	NA		
						Primary treatment	NA		
						Secondary treatment	NA		
						Tertiary treatment	NA		
Total score	7.5	Total score	0	Total score	3	Total score	3	Total score	1

Sub-categorization of variables - Macro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	8	4	64	1	5	1	2
Total Range							
Sub-categorization of variables - Micro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	8.5	NA	3	3	NA	1	NA
Total Range							

Comments:

Aluminium is test and is level of non-conformity is 12.5% of the samples.
Not enough information about how much of the distribution network is made with Iron, Asbestos and PVC so we consider the worse situation: Asbestos
Wastewater collection network is insignificant and there is no registration of the service or system

Municipality of Jardim

Form for field engineer 1 of 2													
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste collection**	**Scores**	**Solid waste treatment**	**Scores**	**Drainage**	**Scores**
Coverage of water supply in the Urban Area	5	Coverage of sewage systems in the Urban Area	3	Water quality indicators	0	Receiving-body	1	Coverage of solid waste collection	5	Storage	0	Coverage of the superficial network	1
Coverage of water supply in the Rural Area	1	Coverage of sewage systems in the Rural Area	1	Water treatment techniques and technologies	0	Pre-treatment	0	Coverage of selective solid waste collection	1	Transportation	0	Coverage of the underground network	1
Water supply based on fountains, cisterns, wells or other decentralized forms	1	Coverage of rudimentary tank or open sewage	0			Primary treatment	0			Processing	1		
Water supply from water truck	1	Use of septic tank	1			Secondary treatment	0			Final destination	0		
Water distribution Network	2	Coverage of the sewage collecting network	1			Tertiary treatment	0						
						Post-treatment							
Total score	10	Total score	7	Total score	0	Total score	1	Total score	6	Total score	1	Total score	2

Municipality of Jardim

Form for field engineer 2 of 2									
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste**	**Scores**
Water distribution Network	8*	Wastewater collection network	NA	Water treatment techniques and technologies	NA	Receiving-body	3	Final Destination	1
						Pre-treatment	NA		
						Primary treatment	NA		
						Secondary treatment	NA		
						Tertiary treatment	NA		
Total score	8*	Total score	0	Total score	2	Total score	3	Total score	1

Sub-categorization of variables - Macro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	10	7	0	1	6	1	2
Total Range							
Sub-categorization of variables - Micro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	8*	0	NA	3	NA	1	NA
Total Range							

Comments:

NA stands for non-applicable

There is no data for water distribution losses

There is no mention of drainage system nor wastewater treatments

There is no measurement of water quality and the water that is distributed is not treated: Clorine addition only.

Municipality of Limoeiro do norte

Form for field engineer 1 of 2													
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste collection**	**Scores**	**Solid waste treatment**	**Scores**	**Drainage**	**Scores**
Coverage of water supply in the Urban Area	4	Coverage of sewage systems in the Urban Area	1	Water quality indicators	6	Receiving-body	1	Coverage of solid waste collection	5	Storage	0	Coverage of the superficial network	1
Coverage of water supply in the Rural Area	1	Coverage of sewage systems in the Rural Area	1	Water treatment techniques and technologies	30	Pre-treatment	1	Coverage of selective solid waste collection	1	Transportation	0	Coverage of the underground network	1
Water supply based on fountains, cisterns, wells or other decentralized forms	1	Coverage of rudimentary tank or open sewage	0			Primary treatment	1			Processing	1		
Water supply from water truck	1	Use of septic tank	1			Secondary treatment	1			Final destination	0		
Water distribution Network	1	Coverage of the sewage collecting network	1			Tertiary treatment	0						
						Post-treatment	1						
Total score	8	Total score	4	Total score	36	Total score	5	Total score	8	Total score	1	Total score	2

Municipality of Limoeiro do norte

Form for field engineer 2 of 2									
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste**	**Scores**
Water distribution Network	19.3	Wastewater collection network	12.4	Water treatment techniques and technologies	3	Receiving-body	3	Final Destination	3
						Pre-treatment	9		
						Primary treatment	9		
						Secondary treatment	9		
						Tertiary treatment	NA		
Total score	19.3	Total score	12.4	Total score	3	Total score	30	Total score	3

Sub-categorization of variables - Macro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	8	4	36	5	8	1	2
Total Range							
Sub-categorization of variables - Micro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	19.3	12.4	3	30	NA	3	NA
Total Range							

Comments:

There is no data on receiving-body's condition

NA stands for non-applicable

Municipality of Nova olinda

Form for field engineer 1 of 2													
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste collection**	**Scores**	**Solid waste treatment**	**Scores**	**Drainage**	**Scores**
Coverage of water supply in the Urban Area	5	Coverage of sewage systems in the Urban Area	3	Water quality indicators	14	Receiving-body	1	Coverage of solid waste collection	3	Storage	0	Coverage of the superficial network	3
Coverage of water supply in the Rural Area	1	Coverage of sewage systems in the Rural Area	1	Water treatment techniques and technologies	70	Pre-treatment	0	Coverage of selective solid waste collection	1	Transportation	0	Coverage of the underground network	1
Water supply based on fountains, cisterns, wells or other decentralized forms	1	Coverage of rudimentary tank or open sewage	0			Primary treatment	0			Processing	1		
Water supply from water truck	1	Use of septic tank	1			Secondary treatment	0			Final destination	0		
Water distribution Network	3	Coverage of the sewage collecting network	1			Tertiary treatment	0						
						Post-treatment	0						
Total score	11	Total score	6	Total score	84	Total score	`	Total score	4	Total score	1	Total score	4

Municipality of Nova olinda

Form for field engineer 2 of 2									
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste**	**Scores**
Water distribution Network	19.4	Wastewater collection network	NA	Water treatment techniques and technologies	8	Receiving-body	3	Final Destination	3
						Pre-treatment	NA		
						Primary treatment	NA		
						Secondary treatment	NA		
						Tertiary treatment	NA		
Total score	19.4	Total score	0	Total score	8	Total score	3	Total score	3

Sub-categorization of variables - Macro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	11	6	84	1	4	1	4
Total Range							
Sub-categorization of variables - Micro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	19.4	0	8	3	NA	3	NA
Total Range							

Comments:

Change the definition of the municipalities of what is selective collection of solid waste

Municipality of Santana do cariri

Form for field engineer 1 of 2													
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste collection**	**Scores**	**Solid waste treatment**	**Scores**	**Drainage**	**Scores**
Coverage of water supply in the Urban Area	3	Coverage of sewage systems in the Urban Area	1	Water quality indicators	14	Receiving-body	0	Coverage of solid waste collection	3	Storage	0	Coverage of the superficial network	1
Coverage of water supply in the Rural Area	1	Coverage of sewage systems in the Rural Area	1	Water treatment techniques and technologies	84	Pre-treatment	0	Coverage of selective solid waste collection	1	Transportation		Coverage of the underground network	1
Water supply based on fountains, cisterns, wells or other decentralized forms	1	Coverage of rudimentary tank or open sewage	0			Primary treatment	0			Processing	0		
Water supply from water truck	1	Use of septic tank	1			Secondary treatment	0			Final destination	0		
Water distribution Network	1	Coverage of the sewage collecting network	1			Tertiary treatment	0						
						Post-treatment	0						
Total score	7	Total score	4	Total score	84	Total score	0	Total score	4	Total score	0	Total score	2

Municipality of Santana do cariri

Form for field engineer 2 of 2									
Water supply	**Scores**	**Sewage collection**	**Scores**	**Drinking water treatment**	**Scores**	**Sewage treatment**	**Scores**	**Solid waste**	**Scores**
Water distribution Network	13*	Wastewater collection network	NA	Water treatment techniques and technologies	9	Receiving-body	NA	Final destination	1
						Pre-treatment	NA		
						Primary treatment	NA		
						Secondary treatment	NA		
						Tertiary treatment	NA		
Total score	13*	Total score	0	Total score	9	Total score	0	Total score	1

Sub-categorization of variables - Macro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	7	4	84	0	4	0	2
Total Range							
Sub-categorization of variables - Micro classification							
Variables	**Water supply**	**Sewage collection**	**Drinking water treatment**	**Sewage treatment**	**Solid waste collection**	**Solid waste treatment**	**Drainage**
Score Range	13*	0	9	0	NA	1	NA
Total Range							

Comments: