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Analysis of requirements for scientific articles and Brazilian legislation on rainwater harvesting systems

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ABSTRACT

The main aim of this study was to assess the determining factors, such as storage capacity, water quality and public policies, involved in the publication of scientific articles. It also sought to investigate the influence of Brazilian legislation on particular systems for harnessing rainfall in Brazil. The methodology entailed conducting a bibliographical research of the municipal, State and federal legislation in force in Brazil for the governance of technical standards and the scientific articles about the harvesting of rainwater. A total of 6 technical standards were analyzed, together with 56 legal referrals and 63 articles from national and international periodicals taken from the Google Cloud Platform for Education, SciELO, Science Direct and CAPES, and based on the principal keywords such as a "system for harnessing rainfall" and "rainwater harvesting systems". The results show that the works that predominated were studies on the qualitative and quantitative features of rainfall and that around 80% of the publications analyzed, addressed/made use of the main legislative instruments with regard to storage, water quality and the construction and operation of systems. All the Brazilian States with the exception of three (Minas Gerais, Roraima and Pará), have at least one incentive policy for the creation or installation of catchment systems, storage and the harvesting of rainwater in the country. It can be concluded that the laws sanctioned in Brazil for rainwater are of recent origin and that they provide mechanisms for offering incentives and ensuring their enforcement in accordance with technical criteria. However, they need updating so that there can be a broader understanding of the question of how policies for the management of water operate in the country.

Keywords: Bibliographical review; Rainwater; Public policies

RESUMO

O objetivo principal deste trabalho foi avaliar determinados aspectos como a capacidade de armazenamento, qualidade da água e políticas públicas relacionados à publicação de artigos científicos e a influência de legislações brasileiras em categorias específicas, quanto aos critérios de implantação de sistemas de aproveitamento de águas pluviais no Brasil. A metodologia consistiu de pesquisa bibliográfica de legislações municipais, estaduais e federais, normas técnicas, em vigor no Brasil, e artigos científicos, sobre aproveitamento de água de chuva. Foram analisadas um total de 6 normas técnicas, 56 referências de aspectos legais e 63 artigos de periódicos nacionais e internacionais, a partir das plataformas do Google Acadêmico, Scielo, Science Direct e CAPES, a partir de palavras-chave principais, como "sistema de aproveitamento de água de chuva" e "rainwater harvesting systems". Os resultados indicam predominância de trabalhos sobre estudos dos aspectos qualitativos e quantitativos de águas pluviais e que cerca de 80% das publicações analisadas, atenderam/utilizaram os principais instrumentos da legislação, quanto à capacidade de armazenamento, qualidade de água, construção e operação dos sistemas. Com exceção de 3 estados brasileiros (Minas Gerais, Roraima e Pará), os demais possuem ao menos uma política de incentivo para a criação ou implantação de sistemas de captação, armazenamento e aproveitamento de água de chuva no país. Conclui-se que as leis sancionadas sobre águas pluviais são recentes no Brasil e que apresentam mecanismos de incentivo e obrigatoriedade, de acordo com critérios técnicos, no entanto necessitam de atualização, como formas de ampliar a compreensão sobre o assunto das políticas de gestão das águas pluviais no país.

Palavras-chave: Revisão bibliográfica; Águas pluviais; Políticas públicas

1 INTRODUCTION

Brazil is a country of huge territorial extension, with a wide range of different ecosystems and has the greatest biological diversity in the world (BRASIL, 2021). In global terms, it is regarded as a country with a large water supply and is in 1st place in the world ranking since it has a total of 15.8% of the world´s renewable water resources (FAO, 2017). The average annual rainfall in Brazil is 1760 mm, which is largely due to its continental dimensions and it ranges from 500 mm in the semi-arid North-East region to more than 3000 mm in the Amazon (ANA, 2020). In light of this, it can be regarded as a country with suitable conditions for the installation of water intake systems, storage and the harnessing of rainwater, as alternative sources of water supply and for finding technical ways of meeting lower requirements with regard to the use of water (MAYKOT and GHISI, 2020; SEMAAN, *et al*., 2020; TAMAGNONE, *et al*., 2020; BAIYEGUNHI, 2015).

At the same time, the conditions for the supply of water are affected by climate seasonality and an increase in the number of extreme hydrological events.

Population growth, combined with industrialization, climate change, urbanization, and the greater use of water for agriculture, has led to a global crisis in supply as a result of an increase in demand, particularly in the large urban centers (SANTOS *et al*., 2020; ADHAN, *et al*., 2019; MUSAYEV, *et al*., 2018). Thus the rainwater harvesting systems can alleviate the situation by helping to achieve hydric security and to some extent, offset the reduction in the supplies of the conventional systems caused by urbanization and climate change.

Although there have been historical records about the use of rainwater since 830 AD, in the Mohabbat Stone, in Israel and the Knights Templar stronghold in Portugal (1160) (TOMAZ, 2009), it was only at the beginning of the 21st Century that scientific research was carried out with results published about harvesting rainwater. Similarly, it is only fairly recently that laws and regulatory standards have acted as instruments for providing incentives and assistance in the installation of these systems (TESTON, *et al.*, 2018).

Law nº 13.501, 31st October, 2017 (BRASIL, 2017), establishes the harnessing of rainwater as one of the objectives of the National Water Resources Policy, enacted by Law nº 9.433 (BRASIL, 1997), as a means of encouraging the intake, conservation and harvesting of rainwater. The incentive to make use of rainwater to meet lower requirements represents a way of conserving water resources and alleviating the demand for it, in so far as this is becoming a primary decentralized source of water, in response to the increased demands made on the supply systems of the large city centers (GONELA, *et al*., 2020; LEONG, *et al*., 2019). The retention of a part of the volume of rainfall can also serve to cushion the effects of surface run-off, particularly in the large urban centers (DEITCH and FEIRER, 2019; AMOS, *et al*., 2018).

Although legislation and regulatory standards about the use of water can be found in Brazil, there have been no studies that have consolidated or published them in specific terms so that they can be applied to particular regions in the country and meet the needs of the general public.

The purpose of this article was to analyze the technical and scientific publications regarding the legal instruments for governing the rainwater harvesting systems in Brazil, on the basis of criteria defined by technical factors related to storage capacity, water quality and public policies.

2 MATERIALS AND METHODS

The methodology employed in this study consisted of bibliographical research in the Scielo (https://scielo.org/), Science Direct [1] and Google Cloud Education [2] platformsand periodicals portal of CAPES [3]. A number of published articles were investigated, in particular those in scientific periodicals in the period from 2004 to 2020 with the indices: “rainwater”, “harnessing rainfall water”,“intake and usage of rainwater”, and“rainwater harvesting”. With regard to the documents about rainfall related to Brazilian legislation, sites were accessed from the government, and the environmental agencies and organizations of Brazilian States and municipalities, without being restricted to the period of the investigation. Use was also made of the research databases of Municipal Legislation (https://leismunicipais.com.br/), State Legislation (https://leisestaduais.com.br/) and technical standards obtained from the catalogue of the Brazilian Association of Technical Standards (ABNT)[4].

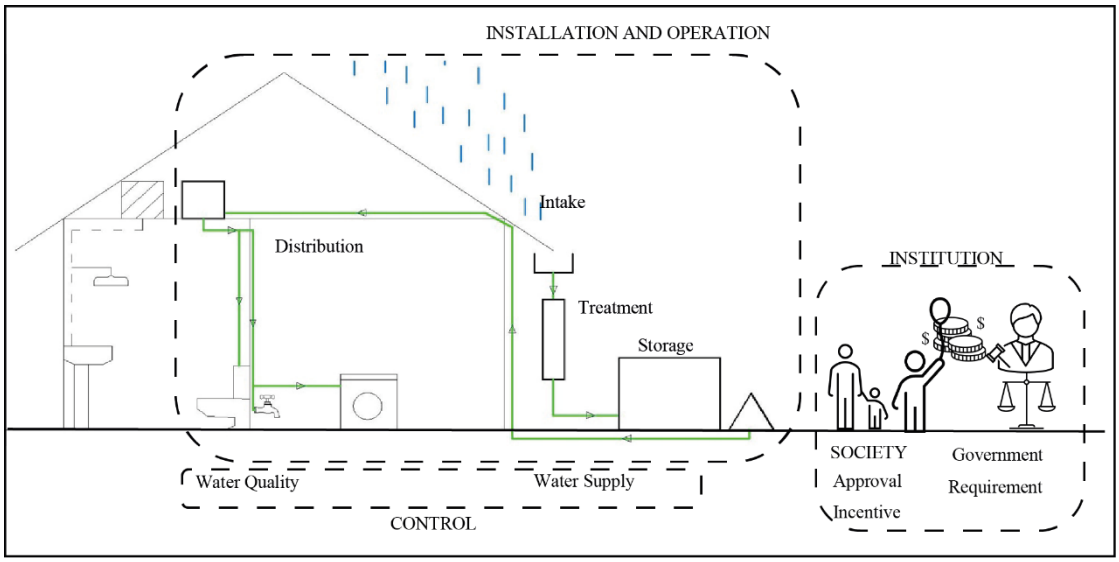
In making the selection in the designated area of published articles, a number of specific categories were defined in accordance with the required conditions for installing rainwater harvesting systems in each locality.The selected categories of the publications took note of the qualitative character of the research in seeking to meet the requirements and objectives of each study.The terminology employed when determining the required conditions for defining the categories,

[1] http://www.sciencedirect.com/
[2] http://scholar.google.com.br/
[3] https://www.gov.br/capes/pt-br
[4] https://www.abntcatalogo.com.br/

took into account the technical features of the installation and operation of the system for harvesting rainwater, as well as the proprietary/governmental (i.e. institutionalized) rights and responsibilities. The quantitative and qualitative aspects of the rainwater system were regarded as monitoring requirements.

Figure 1 illustrates the main features of a rainwater system and the possible conditions required for studies or research publications needed for an analysis of the categories.

Figure 1 – Elements of a rainwater harvesting system, features and categories of the study



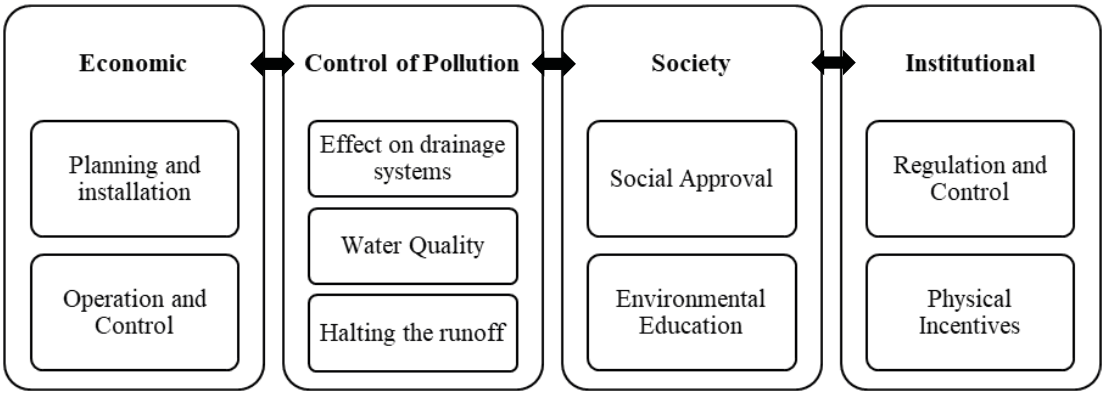
Source: Adapted from GANEM, 2019

Although this study does not cover the entire range of the research studies that have been published, in broad terms, it shows their scope for examining the most significant results of this output. The studies of rainwater harvesting have a multidisciplinary character in so far as they foresee a number ofbenefits with regard to socio-environmental factors and sustainability, such as: a potential saving of water, the effects on the drainage system, control of pollution and legal requirements.

Figure 2 shows the aspects of sustainability applied to the systems of rainwater harvesting which are characterized by planning, monitoring, operation

and/or associated requirements with a view to choosing the main categories set out in studies, publications and legislation.

Figure 2 – Aspects of sustainability and the categories employed for the study of rainwater systems



Source: Authors, 2021

Once the rainwater systems have been installed, details in construction can be observed with regard to their physical features and the hydraulic water facilities, in so far as they apply to the areas in the building reserved for the intake, transport, storage and distribution of water. In this respect and in general terms, the publications include analyses of parameters such as the following: typology and roof space, storage capacity in the rainwater tanks, water treatment techniques and distribution of rainwater to the consumer outlets, within a hybrid supply system for conventional purposes.

Choosing the right location of the system for harvesting rainwater is an essential requirement in the planning, especiallyfor determining the dimensions of the storage tank and with regard to the amount of available water provided by the local rainfall data. The Brazilian regions were divided on territorial lines – North, North-East, Centre-West, South-East and South – for the purpose of analyzing the studies of the rainwater systems in terms of categories. The reason for this was to enable an assessment of States with similar features to be made,with regard to locality and seasonal rainfall patterns. In this way, an investigation and analysis

were conducted of the scientific articles, laws and standards, (at a municipal, State and federal level in different regions of Brazil) as they applied to the harvesting of rainwater.

3 RESULTS AND DISCUSSION

63 articles were selected from the research carried out in the periodicals, 27 of which were international and 36 national – these were obtained from publications in periodicals and special scientific events. About 25 articles of the analyzed publications (or 40%), investigated the quality of the rainwater in the samples obtained from the storage tank and/or specific points of the rainwater system in various States in Brazil, such as Santa Catarina (ANDRADE *et al*., 2017), Rio de Janeiro (MOREIRA *et al*., 2019), Minas Gerais (MIMURA *et al*., 2016) and Paraná (TEIXEIRA *et al*., 2017). Most of the publications that appeared in foreign countries assessed the characteristics of rainwater in terms of the influence of geographical locality, climate and urbanization/industrialization on water quality.

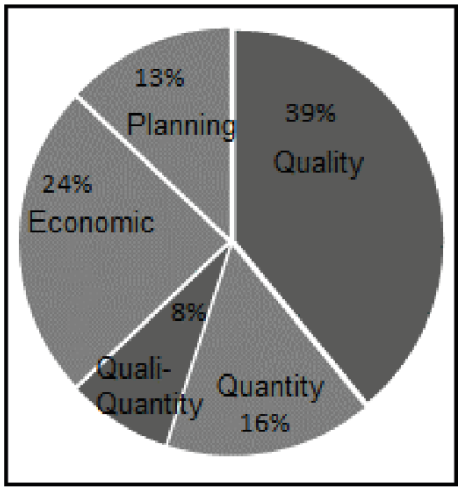
The deposition of air pollutants on the earth´s surface has led to variable concentrations of acid rain in particular regions of the United States owing to anincrease in the emissions of sulfur and nitrogen oxide caused by motorized vehicles, oil refineries and thermoelectric power plants (KERESZTES *et al*., 2020). The effects of dry and wet atmosphere deposition on the earth´s surface has also been assessed, to the extent that it is characterized by the chemical properties of rainfall at different stages of the hydrological cycle. In the city of Rio de Janeiro, the high concentration of metals during the rainy season, for example, have shown the atmosphere to be saturated in the form of aerossol andsuspended particles in the air (NUNES DA SILVA *et al*. 2020). In general, after the initial treatment of an amount of collected rainfall (through filtration technology and the disposal of the initial flow of contaminated water known as*first flush*), the volume that is stored is made available for the harvesting of water for lowerpurposes such as irrigating gardens,

flushing toilets and washing floors or vehicles.In these situations, specific treatments are recommended such as disinfectants, particularly because it is essential to prevent pathogens and microorganisms from being deposited and washed off the rooftops into the water tanks.(ANDRADE *et al*., 2017; TEIXEIRA *et al*., 2017, GUIMARÃES *et al*., 2019; ROCHA *et al*., 2011).

A total of 10 publications (or 16% of the total number of the articles analyzed), investigated the effects of rainwater storage, with regard to its capacity to retain the amount of rainfall drained off rooftops and to meet the demands for water in the buildings. In general, the studies that were assessed, showed the feasibility of harvesting rainwater, as a means of providing or replacing the conventional supply of water (SARMENTO *et al*., 2017; FLORES *et al*., 2012; REZENDE and TECEDOR, 2017).However, there is a need to examine whether the ability to meet the demands for water use is reliable, to the extent that it can lead to an increase in the number of users and reduce the catchment area. (SILVA and ORRICO, 2015).The studies related to the volume of rainfall were carried out in the States of Alagoas, Bahia, Ceará, Paraíba, Pará, Minas Gerais, São Paulo and Rio de Janeiro.

Figure 3 shows the key requirements that were studied in the publications of the 63 articles that were analyzed. The criteria for the selection of the required conditions took account of the objectives and main conclusions reached in each study. It should be noted that the definition of the requirements for the analysis can be distinguished from the results of the research studies.

Figure 3 – Research requirements for the publications analyzed about the rainwater systems



Source: Authors, 2021

The articles on economic feasibility and the projects for the installation of rainwater systems were analyzed in 23 publications (37%), on the basis of studies carried out in the following States: Belém, Rio Grande do Norte, Sergipe, Minas Gerais, Santa Catarina and São Paulo,and in the following countries: Australia, India, Iran, Italy, Mexico and the United Kingdom. The systems for harvesting rainwater were generally shown to be economically feasible as an alternative supply of water, particularly if they were in the appropriate catchment area with regard to the regional rainfall data (MAYKOT and GHISI, 2020; KUCHINSKI and GASTALDINI, 2017). The systems for harvesting rainwater in Italy proved to be efficient and showed a saving of water of up to 85%in catchment areas of between 200 and 300 m2 (NOTARO *et al*., 2016). Considerable social importance can be attached to planning rainwater systems in so far as they involve assessing their technical and economic feasibility and dealing with any irregularities in the supply of water, as well as seasonable factors such as long period of drought. A number of articles (18%) were also found that included reports on social effects and environmental education in certain communities (CHAIB *et al*., 2015; TUGOZ *et al*., 2020 and MELLO *et al*., 2014).

The legislation and Brazilian standards relating to the intake, storage, harvesting and distribution of rainwater to consumption points, included guidelines, technical criteria and policies as measures for encouraging the catchment, conservation and harvesting of rainwater (BRASIL, 2017). 67 municipal, State and federal laws were found together with 6 technical standards (Table 1), related to rainwater studies and projects. The main technical standard for rainwater is the NBR [Brazilian Regulatory Standard] nº 15527/2019 (ABNT, 2019), which lays down the required conditions for harvesting rainwater from rooftops for non-drinking purposes.

Table 1 – Technical standards related and applied to rainwater in Brazil

ABNT	Year	Description
NBR 5626	2020	Hot and cold water systems in buildings - planning, execution, operation and maintenance
NBR 15527	2019	Harvesting rainwater from rooftops in urban areas for non-drinking purposes
NBR 16782	2019	Conservation of water in buildings–required conditions, procedures and guidelines
NBR 16783	2019	Use of alternative sources of non-drinking water in buildings
NBR 16098	2012	Minimum testing requirements of appliances used for improving the quality of drinking water
NBR 10884	1989	Rainwater installations for buildings – procedure

Source: Authors, 2021

A total of 56 laws were found that were about rainwater and related areas - 27 State, 26 Municipal and 3 from the Federal District.These are not represented in the comprehensive legislative list for the classification of water bodies, (such as bathing quality, sewage disposal) and the National Policy Statement for Water Resources (BRASIL, 2017). Chart 1 shows the State and municipal laws which apply

to the establishment of systems for the intake, storage and harvesting of rainwater in Brazil. However, no legislation was found about rainwater in the States of Minas Gerais, Roraima and Pará. The State of Sergipe has planned the creation of a program for the harvesting and reuse of rainwater, but no inquiry has yet been put into effect.

Chart 1 – State and municipal laws about rainwater enacted in Brazil

Region	State	Description
North	Acre (AC)	Law nº 2.540, 4th January 2012. Determines that the system for the catchment and storage of rainwater should be included in the architectural projects for the State´s school facilities. State of Acre.
	Amapá (AP)	Law nº 1.349, 7th July 2009. The Executive Power was authorized to institute a State Program for conservation,the Rational Use of Water and Energy Savings in Buildings, the use of alternative sources for the catchment of water, the reuse of water in new buildings, and finally for increasing awareness and energy efficiency. State of Amapá.
	Amazonas (AM)	Law nº 4.570, 14th March 2018. Rules that it is obligatory for property owners with a built-up area of 300 sq.m or more, to instal a rainwater catchment tank within the State of Amazonas.
		Law nº 1.192, 31stDecember 2007. Determines that a water treatment plant (¨pro águas¨) should be set up in the municipality of Manaus, for the rational use of water in the buildings. Imposed by issuing Decree nº 9849/2008. Municípality of Manaus.
		Law nº 4.779, 18th January 2019. Rules on the use of rainwater by installing a catchment system at the drive-through car-wash service stations within the State of Amazonas.
	Pará (PA)	No information found
	Rondônia (RO)	Ordinary Law nº 2.425, 3rd March 2011. Rules that it is obligatory to instal a catchment system and make use of rainwater in new public buildings. Municipality of Porto Velho-RO.
	Roraima (RR)	No information found
	Tocantins (TO)	Law nº 3.261, 2nd August 2017. Lays down the State Policy for the Carchment, Storage and Harvesting of Rainwater. State of Tocantins.
North-East	Alagoas (AL)	Law nº 7.590, 25th March 2014. Instititutes the Program for the Conservation and Use of Water in Public and Private Buildings in the State of Alagoas.
	Bahia (BA)	Ordinary Law nº 13.581, 14th September 2016. Rules on the installation of a system for the re-harvesting of rainwater in the residential dwellings built by the Government of the State of Bahia.

Continued...

Chart 1 – Continuation

Region	State	Description
North-East	Bahia (BA)	Ordinary Law nº 13.460, 10th December 2015. Introducesthe ¨State Program of Socio-productive Inclusion – a Better Life¨ and takes other necessary measures. State of Bahia.
		Law nº 7.863, 25th May 2010. Rules that it is obligatory to establish a mechanism for the catchment and storage of rainwater in the rooftops of the buildings. In addition, the catchment, recycling and storage of water should serve subsequent purposes in activities that do not require the use of treated water, in various household and commercial undertakings in the Municipality of Salvador-BA.
	Ceará CE)	Law nº 16.033, 20th June 2016. Rules on the policy for the re-use of non-drinking water within the State of Ceará.
	Maranhão (MA)	Law nº 10.200, 8th January 2015. Rules on the State Policy for the Integrated Management of Urban Waters and takes other measures. State of Maranhão.
		Law nº 10.309, 16th September 2015. Lays down the guidelines for the State Program of Awareness, Conservation and the Rational Use of Water. State of Maranhão.
	Paraíba (PB)	Law n° 9.130, 27th May 2010. Sets up the Program for the Conservation and Rational Use of Water in the Public Buildings of Paraíba, as specified as well as adopting other measures. State of Paraíba.
		Law nº 10.575, 24th November 2015. Amends, Law n° 10.033, 3rd July 2013, which introduced the State Policy for the Catchment, Storage and Harvesting of Rainwater in the State of Paraíba.
		Law nº 10.033, 3rd July 2017. Institutes the State Policy for the Catchment, Storage and Harvesting of Rainwater in the State of Paraíba.
	Pernambuco (PE)	Law nº 14.572, 27 December 2011. Establishes standards for the rational use and re-harvesting of water in the buildings of the State of Pernambuco.
		Law nº 16.584, 10th July 2019. Amends Law nº 14.572, 27th December 2011, which lays down standards for the rational use and re-harvesting of water in the buildings, with a view to ruling on the collection and re-use of water in the climatization system of the buildings. State of Pernambuco.
		Law nº 15.911, 31st October 2016. Amends Law nº 14.572, 27th December 2011, which lays down standards for the rational use and re-harvesting of water in the buildings of Pernambuco.
		Law n° 18.112, 13th January 2015. Rules on making improvements to the environment of the buildings by making it obligatory to instal a ¨green roof¨ and construct water tanks to accumulate or retain the run-off of rainwaterthat flows to the drainage system. Municipality of Recife-PE.
	Piauí (PI)	Law nº 7.292, 6th December 2019. Strictly regulates the rational use of water resources, the re-use of rainwater and the water services. State of Piauí.

Continued...

Chart 1 – Continuation

Region	State	Description
North-East	Piauí (PI)	Law nº 4.774, 19th August 2015. Institutes the Official Policy for Catchment, Storage and Harvesting of Rainwater in the Municipality of Teresina, and takes other measures. *Diário Oficial de Piau,* 31st August 2015. Municipality of Teresina-PI.
		Law nº 6.280, 5th November 2012. This led to the creation of the Program for the Catchment of Rainwater collected from roofs, the tops of buildings, terraces and open decks, in large quantities, whether accumulated or not, and had a waterproof area in excess of 500sq.m. State of Piauí.
	Rio Grande do Norte (RN)	Law nº 3.333, 21st July 2017. Sets out the program for the Conservation and Rational Use of Water in the Municipality of Currais Novos-RN.
	Sergipe (SE)	Ongoing
South-East	Espírito Santo (ES)	In Preparation - Law nº 584/2019, 16th July. Is designed to establish the State Policy for the Catchment, Storage and Harvesting of Rainwater and definethe general standards for its implementation in the State of Espírito Santo.
		Law nº 10.624 12th January 2017. Makes it obligatory to instal a system with devices for the catchment, treatment and storage of rainwater in service and supply stations for vehicles and similar trafficin the State of Espírito Santo.
		Law nº 7.079, 14th September 2007. Institutes a program for the conservation, reduction and rationalization of the use of water in public buildings in the municipality of Vitória, Espírito Santo.
	Minas Gerais (MG)	No information found
	Rio de Janeiro (RJ)	Law nº 4.393, 16th September 2004. Rules that it is obligatory for quantity surveyors and civil engineering companies to fit residential dwellings and commercial buildings with rainwater catchment tanks. State of Rio de Janeiro
		Law nº 2.630, 7th January 2009. The Tribune. Strictly regulates the procedures related to the storage of rainwater for re-harvesting and checking its discharge into the public drainage system. Municipality of Niterói, RJ.
		Law nº 348, 3rd June 2011. Establishes a system for the reuse of rainwater for non-drinking purposes in public institutions such as schools, hospitals, and health centers in the Municipality of São Gonçalo, RJ.

Continued...

Chart 1 – Continuation

Region	State	Description
		Law nº 9.164, 28th December 2020. Regulates the procedures for storing and retaining the flow of rainwaterin the urban perimeters for the delay and postponement of its discharge into the drainage system. As well as this, it controls the accumulation of clear gray water for treatment so that it can be used for purposes where water does not need to be of a drinkable quality, as defined by the technical standards. The law also rules on other measures and repeals Law nº 7.463, 18th October 2016
South-East	Rio de Janeiro (RJ)	Planning Law nº 3137/2020. This means it now regulates the procedures for storing and retaining the flow of rainwater harvesting in urban perimeterseither a) for its use or b) for the postponement of its discharge into the public drainage system. In addition, it regulates the accumulation of clear gray water so that it can be treatedand used for purposes where water does not need to be of a drinkable quality as defined by the technical standards. The law alsoincludes other measures andrepeals Law nº 7.463, 18th October 2016.
		Law nº 2.626, 30th December 2008. Rules on the installation of solar water heating systems and the harvesting of rainwater in the construction of public and private buildings, It also setsup a municipal commission for urban sustainability. Municipality of Niterói-RJ.
		Law nº 2.801, 24th May 2018. Institutes a program for the conservation, rational use and reuse of water in buildings in the Municipality of Maricá-RJ.
		Law nº 772, 6th November 2017. Rules on the construction of water tanks for the runoff and reuse of excess water within the State of Rio de Janeiro.
	São Paulo (SP)	Law nº 12.526, 2nd January 2007. Establishes standards for flood containment and measures to find a destination for rainwater. State of São Paulo.
		Law nº 16.402, 22nd March 2016. Strictly regulates the subdivision, use and occupation of land in the Municipality of São Paulo-SP.
		Lawnº 16.174, 22nd April 2015. Lays down regulations and measures to encourage the re-use of water for non-potable drinking applications, arising from treatment of wool scouring wastewater in the sewage system, recovery of rainwater, underground drainage and the lowering of the water table, within the Municipality of São Paulo-SP.
		Law nº 10.578, 22nd February 2010. Establishes a system for the re-use of non-drinking water in building complexes, clubs, entities, housing estates and other residential, industrial and commercial property in the Municipality of São José do Rio Preto, SP.
		Law nº 16.172, 17th April 2015. Bans the cleaning of pavements with treated or drinking water provided by means of SABESP [São Paulo State Water and Sewage Service] which supplies the Municipality of São Paulo, as well as carrying out other activities.

Continued...

Chart 1 – Conclusion

Region	State	Description
		Law nº 2.621, 7th July 2007. Authorizes the executive power to institute a program for rainwater harvesting within the Municipality of Itapeva, SP.
South	Rio Grande do Sul (RS)	Law nº 18.611, 9th April 2014. Regulates the control of urban drainage. Municípality of Porto Alegre-RS.
		Law n° 2.256, 27th April 2005. Rules that rainwater harvesting is mandatory in the Municipality of Canela-RS.
South	Paraná (PR)	Law nº 10.785 18th September 2003. Establishes the Program for the Conservation and Rational Use of Water in Buildings in Curitiba. Municipality of Curitiba-PR.
		Law nº 3185, 1st September 2005. Makes the catchment and use of rainwater mandatory in new buildings as well as taking other measures. Municípality of Francisco Beltrão-PR.
		Decree nº 293, issued on 18th September 2003. Regulates Law n° 10.785/03 and gives a ruling about the criteria for the rational use and conservation of water in buildings. Municípality of Curitiba-PR.
	Santa Catarina (SC)	Complementary Law nº 691, 29th September 2008. Institutes the Program for the Conservation and Rational Use of Water in Blumenau, with the aim of taking measures to encourage the conservation of water, particularly in buildings and to make users aware of the importance of conserving water. Municipality of Blumenau-SC.
		Law nº 4.675, 11th June 2007. Ruling which makes it obligatory for quantity surveyors and civil engineering companies to provide residential dwellings and commercial property with rainwater harvesting equipment. Municipality of Jaraguá do Sul, SC.
		Ordinary Law nº 8.080, 9th November 2009. Institutes the municipal program for the conservation, rational use and re-use of water in buildings. Municipality of Florianópolis-SC.
Center-West	Federal District (DF)	Complementary Law nº 929, 28th July 2017. Makes a ruling on the devices used for the catchment of rainwater for the purposes of retention, harvesting and artificial groundwater recharge in the properties and companies located in the Federal District.
		Resolution nº3, 19th March 2019. Lays down the guidelines for the instalation and operation of non-drinking systems in residential buildings. Federal District.
		Law nº 6065, 9th January 2018. Institutes the Policy for providing Incentives for Rainwater Harvesting in the Federal District.
	Goiás (GO)	Law nº 17.128, 18th August 2010. Ruling which makes it mandatory to instal a) equipment for treatment and the re-use of water employed for washing vehicles and b) equipment for reharvesting rainwater. Municipality of Goiânia-GO.
	Mato Grosso (MT)	Law nº 9.674, 19th December 2011. Authorizes the Executive Power to set up mechanisms that can provide an incentive for rainwater harvesting and to take other measures. Municicipality of Cuiabá, MT.
	Mato Grosso do Sul (MS)	Law nº 4.699, 20th September 2015. Institutes the Awareness Campaign for the Use of Water within the Stateof Mato Grosso do Sul.

Source: Authors, 2021

The laws obtained about the use of rainwater are recent – none are earlier than 2003 and most were enacted in the 10 years after 2010. In general, they are laws that give judicial rulings about how to define a) terminology, b) the criteria for the rational use of water and c) the limits of use, while seeking to ensure that quality standards are met with regard to customer service. There are laws that strictly regulate the subdivision, use and occupation of land (SÃO PAULO, 2016; see details in the table above, corresponding to the State and year of the enactment of the law). In addition, the question of containing floods (SÃO PAULO, 2007) is included in the list in the form of articles that define how it is mandatory to reserve a supply of rainwater for harvesting that is stored in the buildings and can be used for non-drinking purposes when there are plots of land with an area greater than 500 sq m.

Some excesses and material discrepancies were found in the examination of particular laws of a municipality, as, for example, in the case of Niterói-RJ, with regard to Laws nº 2630/2009 and 2626/2008, which showed divergences in the hydrological dimensioning of the water tanks and themethodology employed for the detention and accumulation tanks. It was also noted that there was a degree of repetition in the dimensioning of the tanks in different locations because they only had sealed areas above 500 sq.m. (PERNAMBUCO, 2015; PIAUÍ, 2012; RIO DE JANEIRO, 2018; RIO DE JANEIRO, 2016; RIO DE JANEIRO, 2011; RIO DE JANEIRO, 2009).

Although the laws were concerned with control measures and dealing with the quality of rainwater for non-drinking purposes, there was no consensus about the aims of the service and its uses at consumption points. For example, there were signs of discrimination in favor of the use of rainwater in toilet bowls in the following: the municipality of Manaus (AMAZONAS, 2007), the States of Bahia (BAHIA, 2016 e 2007), Espírito Santo (ESPÍRITO SANTO, 2019), Maranhão (MARANHÃO, 2015), Pernambuco (PERNAMBUCO, 2011), the municipality of Jaraguá do Sul (SANTA CATARINA, 2007), the city of Florianópolis (SANTA CATARINA, 2009), the city of São José do Rio Preto (SÃO PAULO, 2010)and the municipality of

São Gonçalo (RIO DE JANEIRO, 2011). In contrast, the use of rainwater in toilet bowls was not permitted by the following: the Federal District (2017), the city of Curitiba (PARANÁ, 2003), the town of Francisco Beltrão (PARANÁ, 2005), the municipality of Currais Novos (RIO GRANDE DO NORTE, 2017), the State of Rio de Janeiro (2004), and the city of Rio de Janeiro (RIO DE JANEIRO, 2011).Thus there are signs of misuse with regard to the way rainwater is employed in Brazil, even within the same State. For example in the case of Rio de Janeiro, State Law nº 4393/2004 does not permit the use of rainwater to flush toilet bowls, whereas Municipal Law nº 348/2011, of the municipality of São Gonçalo,legislates in favor of this.

Generally speaking, the municipal and State laws institute policies for formulating policies for the catchment, storage and use of rainwater which are clearly distinguished in terms of strategies and categories and have a clear hierarchical structure. These categories can be listed as follows:

a. **Incentive**: this is of a comprehensive character without being defined in particular detail and shows in a general way, the policy for the creation and/or installation of systems for the catchment, and harvesting of rainwater. In some cases, it includes specifications of the area under construction, the types of installations/ services carried out, and definitions of technical terms, together with an overall presentation of the standards laid down for the use of rainwater;
b. **Mandatory requirements**: more detailed than the previous category, this ateory sets out the required conditions for the installation of rainwater systems in buildings with regard to certain determining factors such as the type of service, the area under construction and whether it is waterproof and
c. **Technical factors**: more meticulous than the previous categories, this is designed to reflect the standards that form the basis of the technical parameters such as the run-off coefficient, formulas for calculating the volume of the intake, the materials that will be used in the system, the method of construction and the site chosen for the installation. As well as this, there are the quality criteria or

parameters (e.g. physical, chemical and microbiological) for assessing the water; entrance quotes, resolutions and lawsthat recognize the limits to the service that can be provided by the environmental and health agencies.

More than half (57%) of the Brazilian laws about rainwater are expressed in a comprehensive way and take the form of legal incentives for compliance with policies for installing rainwater harvesting systems, without technical details concerning the installation or operational requirements, and maintenance of the system. The category “mandatory requirements” can be found in 20 of the laws (36%) that have been enacted in the country, which include specified conditions such as the site selected or type of installation. About 7% (i.e. 4 laws) include technical criteria for the installation of rainwater systems such as the methodology employed for dimensioning, the storage capacity of the tanks and the constraints arising from the quality of the rainwater. Table 2 displays the number of laws in accordance with the categories formulated for the policies about rainwater in the Brazilian regions.

Table 2 – Number of State and municipal lawsabout rainwater for the Brazilian regions in accordance with their legal categories

Region	Incentive	Mandatory Requirements	Technical Factors	Total
North	2	5	0	7 (13%)
North-East	13	4	1	18 (32%)
Center-West	2	1	0	3 (5%)
South-East	10	5	2	17 (31%)
South	3	5	0	8 (14%)
DF	2	0	1	3 (5%)
Total	32 (57%)	20 (36%)	4 (7%)	56

Source: Authors, 2021

It should be noted that the semi-arid region of the North-East has been traditionally concerned with harvesting rainwater, through non-governmental

initiatives such as the ¨Program one million cisterns¨ (P1MC) and the ¨One land and two waters program¨ (P1+2) (RIBEIRO, 2019). The South-East region has the largest number of laws found on rainwater in the ¨mandatory requirements¨ and ¨technical¨ categories; strictly speaking, this is because they include more well- established criteria on the methods for gauging the storage capacity of the tanks and defining the standards required for water quality that is being used for non-drinking purposes.For example, the qualitative and technical features of these laws limits the pHto between 6 and 9, there is a lack of floating devices and the recommended disinfection water treatment must be kept to a concentration of 50 mg/L with a minimum contact time of 12 hours (RIO DE JANEIRO, 2016).No legislation of a ¨technical¨ character was found in the regions of the North, Center-West or South of the country,which had laws that were less detailed but more comprehensive than those in the North-East and South-East.

4 FINAL CONSIDERATIONS

An assessment was made of 63 articles published in national and international publications and out of these a total of 40 publications (63%) were research studies on the qualitative and/or quantitative features related to the characterization of rainfall eventswhile at the same time examining the storage capacity of the volume of rainfalland the effects of pollution on the quality of the rainwater. Economic feasibility studies (or plans) were analyzed in 23 (37%) of the articles published, together with data that show the importance of quantitative surveys as a basic requirement for enhancing financial viability and reducing the payback period.

In the analysis of 56 State and municipal laws about rainwater, enacted and in force in Brazil, some progress has been made in the acceptance of policies for setting up programs for the catchment, storage and harvesting of rainwater in buildings through State and municipal legislation in Brazil.With the exception of

the States of Minas Gerais, Roraima and Pará, all the States in Brazil have laws which deal with the question of providing incentives for the creation of rainwater harvesting systems in the country. However, it was noted that there were deviations from the purposes of particular laws of a technical nature and with regard to their statutory authority; these concernedthe ways rainwater should be used and the fiscal responsibilities of the State and municipal governments.In light of this, there is clearly a need to update and revise the Brazilian legislation currently in force, such as the management of rainwater harvesting.

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