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Proposals for water conservation in urban areas in Brazil

Propostas para a conservação da água em áreas urbanas no Brasil

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ABSTRACT: This study aims to propose measures for water conservation in urban areas in Brazil. Several measures are proposed, such as reduction of garden watering, water conservation in buildings, water reuse in urban areas and in buildings (greywater), use of rainwater, use of water from air-conditioners, control of losses in water supply systems, among others. Recommendations are made for actions to be developed in order to engage the community in water conservation programs. Measures for water conservation in urban areas are indicated. A national structure is proposed for a water conservation program in urban areas in Brazil. Also, it is proposed how the participation of national, federal and municipal agencies should be, indicating their respective attributions.

Keywords: losses control; water consume reduction; water reuse.

RESUMO: Este estudo tem como objetivo propor medidas de conservação da água em áreas urbanas no Brasil. Várias medidas são propostas, como redução da rega de jardins, conservação da água em edificações, reuso de água em áreas urbanas e nas edificações (águas cinza), uso de água da chuva, uso de água de aparelhos de ar-condicionado, controle de perdas em sistemas de abastecimento de água, entre outros. São feitas recomendações de ações a serem desenvolvidas para engajar a comunidade em programas de conservação da água. Medidas visando à conservação da água em áreas urbanas são indicadas. Propõe-se uma estrutura nacional para um programa de conservação da água em áreas urbanas no Brasil. Também é proposto como deve ser a participação de órgãos nacionais, federais e municipais, indicando-se suas respectivas atribuições.

Palavras-chave: controle de perdas; redução de consumo de água; reuso de água.

1. Introduction

Sustainable water management is one of the greatest challenges of the 21st century because water resources are being depleted rapidly. Population growth, extreme weather conditions (e.g., drought, fire, and floods), and increasing global food demand have increased human water consumption (Naigypál *et al*., 2020). During the last decade, several global regions have experienced severe droughts that have impacted regional water supply security. In addition, anthropogenic climate change is expected to increase drought risk in many areas around the world (Diffenbaugh *et al*., 2015).

Mekonnen & Hoekstra (2016) state that two--thirds of the world's population (4.0 billion people) live in conditions of severe water scarcity for at least one month of each year, with almost half of these people living in India and China. Half a billion people in the world face severe water scarcity throughout the year. According to Guppy & Anderson (2017), water is becoming an urgent social and geopolitical issue; in some regions, it is already a critical national concern. By 2035, up to 40% of the world's population will live in severely stressed areas, and the ability of ecosystems to provide fresh water will become increasingly compromised.

There is enough water available to meet the world's growing needs, but not without dramatically changing the way water is used, managed, and shared. The challenge with the global water crisis is one of governance, much more than resource availability, and this is where most of the action is required to achieve a water-secure world (WWAP, 2015).

Brazil is a privileged country in terms of total water availability. However, the supply of water, the demand for its use, and the adequacy of water infrastructure for its use and conservation are uneven across territories and between different periods in a year. The vision of Brazil as a country with abundant water resources has generated harmful effects, such as inadequate use of water resources, waste, lack of understanding throughout society that water is an economic good that must be preserved, and failure to establish water supply policies (Marchetto & Leal, 2016). Fortunately, the culture of water abundance has been progressively replaced by the idea of water as a finite good with economic value (ANA, 2019).

Water is one of the most important resources to promote the socioeconomic and industrial development of any society. In arid and semi-arid regions, the relevance of water is even more remarkable because economic activities can be limited by this resource (Ramos *et al*., 2019). Swarming water-related problems are threatening many arid and semi--arid regions of the Earth. The integration of these problems with health, environmental, political, socioeconomic, and sustainability issues has greatly increased the demand for managing these problems (Saatsaz, 2020). According to Hamududu & Ngoma (2020), managing water resources sustainably requires a good understanding of the current and future availability of these resources at the local level: how much water is available, where it is available, and when. Given the global and national scenario of scarcity of available water resources in terms of quantity and quality necessary for its various uses, it is necessary to adopt measures aimed at the rational use of water: reduce consumption, reduce waste, increase the efficiency of use and promote reuse (Mota, 2019).

In regions affected by long periods of water scarcity, such as the Brazilian semi-arid region, the need for efficient water management becomes fundamental (Moreira *et al.*, 2018). Measures aimed at water conservation are necessary to ensure the supply of the population and for its use in various activities.

According to Kumari & Singh (2016), water conservation can be defined as any beneficial deduction in water loss, use, or waste; a reduction in water use realized by implementing water conservation or water efficiency measures; or best water management practices that reduce or increase beneficial water use. A water conservation measure is an action, behavior change, device, technology or improved design or process implemented to reduce water loss, waste or use. Water efficiency is a water conservation tool that results in more efficient use of water and therefore reduces water demand. The value and cost-effectiveness of a water efficiency measure must be evaluated in relation to its effects on the use and cost of other natural resources.

The goals of water conservation efforts include:

(1) sustainability, to ensure availability for future generations, and thus the withdrawal of fresh water from an ecosystem should not exceed its natural replacement rate;

(2) energy conservation, since pumping, delivery, and wastewater treatment facilities consume a significant amount of energy; and

(3) habitat conservation, which refers to minimizing human water use to help preserve freshwater habitats for local wildlife, migratory water flow, and reducing the need to build new dams and other water detour infrastructure (Balasubramnian, 2019). Worldwide, water conservation is considered an important strategy in water planning and management.

The provision of a sustainable water supply is becoming an increasingly difficult task to achieve in many urban environments. This difficulty arises because of the pressures related to population growth and increasing *per capita* demand for water. In addition, climate change is impacting the natural water cycle in many locations, with a significant impact projected into the future (Hurlimamn & Wilson, 2018).

The rational use of water reduces the cost generated by the user, thus reducing the generation of waste and damage to the environment. Therefore, regions that efficiently use water are able to provide a better quality of life to their local communities (Marchetto & Leal, 2016).

Yiu *et al*. (2017) highlight the linkages between water, food, and ecosystems in a changing environment and suggest that trade-offs should be considered when developing regional adaptation strategies. There is also a need for an accurate and reliable water use model that can help water planners develop both responsive and strategic water conservation programs to meet short- and long-term water security outcomes (Moglia *et al*., 2018).

Water conservation depends on many different decision makers in both the public and private sectors. Some tools to ensure sufficient water supply to serve the needs of growing cities include building codes and other policies to address water intensity in new construction; incentives to encourage the installation of water-saving appliances or remove thirsty landscaping; informational campaigns; watering restrictions; and increased enforcement actions on water waste (Brelsford & Abbott, 2017). Facing the global challenge of water scarcity situations, many countries and organizations have increased their awareness of the risks of water scarcity and proposed effective policies to reduce their water use (Juan *et al*., 2016).

However, the most important step toward finding solutions to water and environmental conservation issues is to change the attitudes and habits of people, including each of us (Kumari & Singh, 2016). As an initiative in this direction, Drimili *et al*. (2019) applied an integrated approach to investigate public perception of residential water issues during a period of economic crisis in Athens, Greece. The results indicated that respondents had adopted water conservation practices, but there was still room for more water savings. Although the central and irreplaceable roles that water occupies in all dimensions of sustainable development have become progressively recognized, the management of water resources and the provision of water-related services remain considerably low on the scale of public perception and government priorities (WWAP, 2015).

This study proposes several measures for water conservation in urban areas in Brazil. Actions to involve the community in water conservation programs are recommended. A national framework for a water conservation program, identifying the agencies involved and their respective tasks, is then proposed.

2. Material and methods

This study is conducted in five stages:

In the first stage, an introduction is made on water conservation in urban areas, based on a review of national and international bibliographies.

In the second stage, measures aimed at water conservation in urban public areas are explained, and proposals to be adopted to reduce water consumption, such as reduction of landscape watering, water reuse and loss control in water supply systems, are composed.

Later, in the third stage, water conservation in buildings is discussed, and several measures are proposed to reduce consumption and control losses and use of other water sources.

In the fourth stage, actions are recommended to involve the population in waterconservation programs.

Finally, a national structure for water conservation programs in urban areas is proposed, including actions aimed at reduction of consumption and the rational use of water. Various types of guidelines for the use of different water sources are nominated, and the need to define quality standards for the various types of water is highlighted. Furthermore, the participation of national, federal, and municipal agencies and their respective roles is recommended.

3. Results and discussion

3.1. Water conservation in urban areas

The growth of urban areas, with large cities concentrating the majority of the population, is observed worldwide. This disproportionate growth of urban areas increases the water required to supply the population and for other activities. In Brazil in particular, it was estimated that by May 2020, 87.6% of the total population resided in urban areas (World Meters, 2020).

Actions aimed at water conservation in urban areas should be taken both in public spaces and in buildings. A water conservation program basically aims to match demand and supply.

The following are several measures that should be included in a program aimed at water conservation in urban areas.

3.2. Water conservation in public urban areas

3.2.1. Reduction of landscape watering

Urban green spaces in cities are essential to the health and well-being of their inhabitants. The quality of life in cities depends on the availability of green spaces. In the last decade, there have been several advances related to green areas, such as the creation of new parks (Carbone *et al.*, 2015). Green infrastructure offers several opportunities to improve public health and well-being, the environment, the economy, and society (Parker & Baro, 2019). The quality of an urban green space is critical to the sustainable development of the urban economy, society, the environment, and the quality of human life (Zhu *et al.*, 2019).

However, the increase of green areas in cities introduces a conflict between creating more green spaces and increasing the use of scarce water resources. Therefore, measures are needed to reduce water consumption in the irrigation of urban green areas.

The following measures should be adopted to reduce water consumption in public and private green areas (i.e., buildings):

1. Choose drought-tolerant plants; some plants are naturally adapted to flourish in low-water conditions.

2. Reduce grass cover; replace some parts of the grass with a groundcover that it is attractive, such as artificial grass, permeable sidewalk or gravel.

3. Use irrigation systems that water the plants right at the root (for example, drip irrigation*);* putting the water in the root zone reduces water consumption and keeps evaporation to a minimum.

4. Cover the soil with organic mulch (e.g., wood chips or shredded bark) around the plants to improve the soil, reduce moisture loss, and keep the roots cool.

5. Do not water the plants more than is necessary.

6. Identify and eliminate leaks in the irrigation system.

7. Use treated wastewater for irrigation of green areas.

3.2.2. Water reuse in urban areas

Water deficit is a problem in Brazil, especially in the semi-arid regions, which suffer severe droughts for much of the year, thus requiring the search for alternative water sources, such as the planned use of wastewater, which is a successful practice in developed countries (Ferreira *et al.*, 2019).

Recycling and reuse are essential for a circular economy-based approach and provide a strategy to improve water supply, thereby improving wastewater management. An integrated, interdisciplinary and holistic approach will facilitate the application of water reuse as part of an integrated water management strategy that could be significantly accelerated in the context of a circular economy (Voulvoulis, 2018).

Brazil is still struggling to overcome barriers related to sewage collection and treatment, despite its high potential for wastewater use, which has not yet been fully achieved, despite several promising preliminary initiatives (Stepping, 2016).

In the United States, urban reuse is one of the highest volume sources of water. Applications such as irrigation of recreational fields and golf courses, landscape irrigation, fire protection, and toilet flushing are important components of the reclaimed water portfolio of many urban reuse programs. Urban reuse is often divided into applications that are either accessible to the public or have restricted access, the latter in settings where public access is controlled or restricted by physical or institutional barriers, such as fences or temporal access restrictions (USEPA, 2012).

The United States Environmental Protection Agency (USEPA) classifies urban reuse into two categories: non-restricted and restricted. Table 1 lists the quality standards for urban reuse as proposed by USEPA.

The Ministry of Cities (Ministério das Cidades) prepared the "Action Plan to Institute a Policy for the Reuse of Treated Sanitary Effluents in Brazil" (MC, 2018). In this plan, urban water reuse was

TABLE 1 – United States Environmental Protection Agency suggested guidelines for water reuse – Urban reuse.

Urban Reuse	**Treatment**	**Reclaimed Water Quality**	**Reclaimed Water Monitoring**
Unrestricted The use of reclaimed water in nonpotable applications in municipal settings where public access is not restricted.	· Secondary · Filtration · Disinfection	· pH = 6.0 - 9.0 · ≤ 10 mg L^{-1} BOD · ≤ 2 NTU · No detectable fecal coliform 100 mg L^{-1} · 1 mg L^{-1} Cl_2 residual (min.)	· pH – weekly · BOD - weekly · Turbidity - continuous · Fecal coliform - daily · Cl_2 residual – continuous
Restricted The use of reclaimed water in nonpotable applications in municipal settings where public access is controlled or restricted by physical or institutional barriers, such as fencing, advisory signage, or temporal access restriction.	· Secondary · Disinfection	· pH = 6.0 - 9.0 · ≤ 30 mg L^{-1} BOD · ≤ 30 mg L^{-1} TSS · ≤ 200 fecal coliforms 100 mg L^{-1} · 1 mg $L^{-1}Cl_2$ residual (min.)	· pH – weekly · BOD – weekly · TSS – daily · Fecal coliform - daily · Cl_2 residual – continuous

SOURCE: USEPA (2012).

proposed based on two categories:

(1) unrestricted urban: landscape irrigation of parks, schools, residences, soccer fields, and golf courses; and indoor uses, such as toilet bowls in large buildings, washing of courtyards, and other public spaces; and

(2) restricted urban: landscape irrigation in bus stations, cemeteries, and shopping malls; indoor uses; cleaning of sewer systems, construction, and vehicle washing; and firefighting systems.

In Brazil, some cities implement urban reuse, mainly for landscape irrigation, washing public places, cleaning pipes, applying certain procedures in construction (e.g. dust reduction) and flushing toilets. The Companhia de Saneamento Básico do Estado de São Paulo (SABESP) supplies water for urban purposes. The wastewater treatment technology used is tertiary filtration followed by disinfection. Other types of treatment to increase the degree of purity can be incorporated (SABESP, 2017).

There is no specific legislation in Brazil about water reuse. Resolution number 54, of November 25, 2005, of the National Council of Hydric Resources (CNRH, 2005), established the following purposes for water reuse:

a) reuse for urban purposes: reuse of water for landscape irrigation, building and construction, and for washing public places and vehicles, cleaning pipes and fighting fires, within the urban area;

b) reuse for agricultural and forestry purposes: reuse of water for agriculture and forestation;

c) reuse for environmental purposes: reuse of water for environmental remediation projects;

d) reuse for industrial purposes: reuse of water for industrial processes, activities and operations; and

e) reuse for aquaculture: reuse of water for raising aquatic animals or cultivating aquatic plants. This resolution does not define quality standards for each water reuse purpose. In Brazil, only the states of São Paulo and Ceará have legislation on quality standards for wastewater reuse (Morais & Santos, 2019).

The regulation of the State of São Paulo - Resolution SES/SMA/SSRH number 01/2017 (São Paulo, 2017), determined standards for the direct reuse of non-potable water for urban purposes: landscape irrigation; washing of public places; civil construction; cleaning of rainwater galleries and sewage network; vehicle washing; and firefighting. According to the resolution, landscape irrigation is the practice of irrigation parks, gardens, urban sports and leisure fields or green areas in condominiums, cemeteries or highway slopes, with which the public has or may have direct contact.

Table 2 outlines the standards for treated wastewater for urban uses, as required in the state of São Paulo.

In the state of Ceará, the State Environment Council (COEMA) Resolution No. 02/2017 (Ceará, 2017) established standards for four water reuse purposes: urban; agricultural and forestry; environmental; and aquaculture. Reuse for urban purposes includes the use of reuse water for landscape irrigation, washing public places and vehicles, cleaning pipes, construction, buildings, and firefighting within the urban area.

According to COEMA Resolution number 02/2017, in the state of Ceará, Brazil, the external

TABLE 2 – Treated wastewater standards for urban uses. State of São Paulo, Brazil.

Standards		Reuse Categories	
Parameter	**Unit of Measure**	**Use with Moderate Restriction[1]**	**Use with Severe Restriction[2]**
pH		6 - 9	6 - 9
$BOD_{5,20}$	mg L^{-1}	≤ 10	≤ 30
Turbidity[3]	NTU	≤ 2	-
Total Suspended Solids	mg L^{-1}		≤ 30
Thermotolerant coliforms[4]	MPN 100 mL^{-1}	Not detected	< 200
Helminth eggs[5]	egg L^{-1}	< 1	1
Total Residual Chlorine	mg L^{-1}	< 1	< 1
Electrical conductivity (EC)[6]	dS m^{-1}	< 0,7	< 3,0
Sodium adsorption ratio (SAR)[6]		< 3	3 – 9
Total Dissolved Solids	mg L^{-1}	< 450	< 2.000
Chloride	mg L^{-1}	< 106[7]	< 350
Boron	mg L^{-1}	< 0,7	< 2,0

(1) Use with Moderate Restriction - it is intended for all modalities provided for in the Resolution.

(2) Use with Severe Restriction – it is intended for the uses of: landscape irrigation; washing of public places; civil construction; clearing of rainwater galleries and sewage network; vehicle washing, except internal washing of vehicles. Landscape irrigation with reuse water with Severe Restriction can only be performed in areas where the cultivated species are tolerant, so that there is no aesthetic damage.

(3) The Turbidity criterion must be respected prior to disinfection.

(4) If the *E. coli* parameter is used, the limit for restricted use should be 120 MPN 100 mL^{-1}.

[5] The viable eggs parameter of *Ascaris* sp., which should be limited to < 0.1 viable egg per liter for Moderate Restriction Use and 0.1 viable egg per liter for Use with Severe Restriction, may also be accepted.

[6] In order to minimize soil permeability problems, the SAR criterion should be interpreted in conjunction with Electrical Conductivity (EC).

[7] This standard applies for use in irrigation. For other uses, applies the standard of Use with Severe Restriction.

use of sanitary effluent for urban purposes must comply with the following parameters:

a) Thermotolerant coliforms (TC): up to 5,000 TC 100 mL^{-1}; for landscape irrigation purposes, the Thermotolerant Coliforms parameter should be up to 1,000 TC 100 mL^{-1};

b) Helminth eggs: up to 1 helminth egg L^{-1};

c) Electrical conductivity (EC): up to 3,000 µS cm^{-1};

d) pH: from 6.0 to 8.5.

Treated wastewater should be considered as a new source of water resources, and its use for urban purposes should be encouraged in Brazil. In thisway, betterquality water can be destined for other uses, such as supply for human consumption.

3.2.3. Loss control in water-supply systems

According to Rojek & Studzinski (2019), management of a municipal water supply network is a complex task in which three main objectives must be fulfilled: ensuring proper water quality, ensuring proper pressure at network user nodes, and eliminating water losses. They focused on the aspect of ensuring sustainable development related to urban areas, i.e., limiting water losses in the water supply system through early detection and location of leaks.

Water loss is a phenomenon frequently observed within water distribution systems (Covelli *et al.*, 2016). Losses in a water supply system can be physical (actual losses) or non-physical (apparent or commercial losses).

Physical loss is the water available for distribution that does not reach consumers. The non-physical loss is the water that was actually consumed, but not measured or accounted for by the sanitation company.

The main benefits of reducing water losses are reduced water pumping and treatment costs, increased water revenue, delayed investment for new water infrastructure, postponement of the need for new water resources, protection of water quality and reduced risk of waterborne diseases, reduced frequency of pipe bursts and water cuts, extended life of pipes and other equipment, and improved satisfaction of water subscribers (Muhammetoglu *et al.*, 2018).

Worldwide, the average leakage from piping systems in cities is 35%, and in Brazil it is close to 40% (Campisano *et al.*, 2017). According to the National Sanitation Information System (SNIS), for 2015, the loss rate in the distribution network for state-owned sanitation companies in the country was 36.7% (Brazil, 2017). Losses can occur at any stage of the water supply system, from the river basin to the point of consumption. With increasing demand and the water crisis in many countries, managing losses in water supply systems is relevant for all water supply services (Kusterko *et al.,* 2018).

According to Gupta & Kulat (2018), a platform is needed for more efficient managing water distribution systems by detection, localization, and controlling leaks as soon as, or even before, they occur, to ensure quality water services to consumers.

In many cases of practical interest, leakage reduction in water distribution systems can be realized by reducing the pressure through the system: this in turn leads to reduced costs associated with water loss. On the other hand, for pre-assigned leakage reduction, the number, positions and configurations of valves could be optimized to minimize their installation and maintenance costs (Covelli *et al*., 2016).

In a water distribution system, maintenance is an essential pillar to ensure efficient service delivery and to combat problems such as real water losses. Managing such system maintenance requires the involvement of multiple stakeholders, subjective variables, and a learning process to find necessary solutions (Pereira & Morais, 2020).

Some measures to control losses in water supply systems are as follow:

(1) Detect, locate and control leaks;

(2) Reduce the pressure through the system;

(3) Replace the hydrometers;

(4) Replace the water distribution networks;

(5) For network replacement or expansion projects: use more technologically developed pipes (which ensure lower losses) and piezometric compartmentalization, which makes it possible to work with lower pressures;

(6) Manage a permanent maintenance program for all water supply systems.

3.3. Water conservation in buildings

3.3.1. Rational use of water

The Brazilian Ministry of the Environment (Ministério do Meio Ambiente do Brasil) has produced the Practical Manual for the Use and Conservation of Water in Public Buildings (Manual Prático para Uso e Conservação da Água em Prédios Públicos). According to this manual, water conservation programs work in conjunction with investments in infrastructure, because these programs act directly through the end user, encouraging the reduction of water consumption through the adoption of measures for the rational use of potable water and alternative sources of water (MMA, 2014).

In Brazil, some states and municipalities have implemented programs for the rational use of water. The Basic Sanitation Company of the State of São Paulo (Companhia de Saneamento Básico do Estado de São Paulo, or SABESP) created the Rational Use of Water Program (Programa de Uso Racional da Água), or PURA in 1996. The following actions were proposed for this program on the rational use of water: diagnosis of the situation; detection and repair of leaks; exchange of conventional equipment with new high-efficiency models; studies on water reuse; and educational work.

With the implementation of the Rational Water Use Program in São Paulo, the reduction in water consumption ranged from 25% to 94%, as shown in Table 3.

Law No. 10,785, of September 12, 2003, of the municipality of Curitiba (PR), Brazil, created the Program for the Conservation and Rational Use of Water in Buildings (Programa de Conservação e

TABLE 3 – Water reduction in São Paulo, Brazil, after Rational Water Use Program implementation.

Building	Consumption Reduction (%)
Clinical Hospital	25
São Paulo University Campus	30
Fernão Dias Paes School	94
Toufic Jouliam School	78
State government headquarters (Palácio Bandeirantes)	39
Jardim Cidade Condominium	28
Mauá College	42
Fifty state schools	65
Administrative building – Sabesp	62
Institute of Technological Research (IPT)	52

SOURCE: Unesco & Adasa (2017).

Uso Racional da Água nas Edificações), or PURAE, to institute measures that induce conservation, rational use, and use of alternative sources for water in new buildings, and that raise users' awareness about the importance of water conservation.

There are several policies that can be enacted to ensure that water efficiency opportunities are maximized in buildings, as discussed in the further subsections.

3.3.2. Submetering of water

A building submetering is said to be implemented when each unit (e.g. apartment, condominium, or commercial unit) has its own separate water meter. Occupants pay for their individual usage, providing an economic incentive to conserve water. Sub-metering also allows leaks to be detected more quickly and accurately. So, occupants concerned about avoiding water losses can then have the leaks relevant to their own water meter fixed.

Law No. 13,312 of July 12, 2016 (Brasil, 2016) made water submetering mandatory in new condominium buildings in Brazil. Submergence results in water conservation and drastically reduces total consumption: we typically see 15-30% water savings after meters are installed. Submergence is also crucial for leak detection. In addition, common area water usage can be accurately metered and billed accordingly, and property managers and owners no longer have to waste time dealing with water bills. The subset also allows for more consistent monthly cash flows for property owners (NES, 2022).

Water consumption in buildings with individualized and collective water metering systems was analyzed by Souza & Kalbusch (2017) in the city of Joinville (SC), Brazil. The investigation was conducted for 30 buildings, and the data collected allowed the classification of the buildings and the measurement of water consumption rates. The buildings with individualized water measurement had lower *per capita* consumption, exhibiting a reduction of about 34%, compared to the buildings with collective measurement.

Therefore, should be encouraged sub-meter water in old buildings and made mandatory for new ones.

3.3.3. Water-saving plumbing fixtures

Replacing old pipes with new high-efficiency designs can achieve significant water savings. Several studies have been conducted on the use of water-saving plumbing, which have shown considerable reductions in water consumption in buildings.

Alexandre *et al.* (2017) evaluated whether replacing common plumbing fixtures with water--saving plumbing fixtures on a university campus in Brazil had an influence on water consumption. The results showed that replacing the faucets resulted in a significant change in the total daily water consumption in the building, with a reduction of 19.77%. According to an individual analysis of the plumbing, the replacement proved to be significant in the reduction of water consumption.

Meanwhile, Bertolozzi & Custodio (2020) analyzed economical solutions to reduce drinking water consumption in a residence in the city of Joinville (SC), Brazil. The reduction in water consumption, as an effect of replacing conventional equipment with aerators, flow restrictors, and flush valves with "dual flush" type finishes, was measured and evaluated. The above changes resulted in a 21% reduction in total consumption, with a 52 months return on investment.

Table 4 shows the savings in water consumption for various saving plumbing equipment.

It is important that policies are established to encourage industries to produce water-saving plumbing fixtures.

3.3.4. Control of water losses and wastage

Fixing leaks is a practice that can have a significant impact on reducing water waste in buildings. Leaks can be visible and invisible. Visible leaks are easily detected and fixed. These leaks occur in toilet flushes, faucets, and showerheads, among others. Invisible leaks, on the other hand, are not apparent and require testing to detect. These leaks are often identified by the presence of wet spots on walls, ceilings, and floors. Leaks in building installations must be detected and repaired.

3.3.5. Grey water use

Grey water is wastewater from showers, toilets, bathtubs, laundries, washing machines, dishwashers, and kitchen sinks. In some situations, grey water may not include wastewater from kitchen sinks or dishwashers.

The constituents of grey water are related to a diverse number of factors, such as source of water supply, household activities, and water-consuming installations (De Gisi *et al*., 2016). The recognition of graywater as a relevant secondary source of water and nutrients represents an important chance for sustainable water resource management. In the last two decades, many studies have analyzed the environmental, economic, and energy benefits of

TABLE 4 – Savings in water consumption for various saving plumbing fixtures.

Hydraulic Equipment	**Reduction in Water Consumption**
Sink tap	
Hydromechanical tap	15% compared to conventional tap
Tap with sensor	15% compared to conventional tap
Aerator placed at the end of the tap	5% compared to conventional tap
Toilet basin	
Two-volume systems (3 L for liquid and 6 L for solids)	18% compared to basins with 6.8 L per drive
Wall valve (fixed cycle) with 6.8 L per drive	50% compared to old toilet (9 L)
Urinals	
Drive by pressing the valve plunger	15% compared to conventional valves
Showers	
Showers for mixed water	15% comparing to a shower of 0.1 L/s and another of 0.60 L/s
Showers with devices for command for mixing water	5% compared to showers without this device
Taps for kitchen sinks	
Lever-driven valve with aerator	15% compared to conventional tap
Conventional tap with aerator	5% compared to conventional tap without aerator

SOURCE: Brasil (2015).

reusing treated graywater by nature-based solutions (Boano *et al*., 2020).

The most common uses for grey water in buildings are in flushing toilets, irrigation gardens, cleaning floors, and washing vehicles. According to De Gisi *et al*. (2016), toilet flushing is one of the most frequently discussed applications of grey water reuse, through which household indoor water demand can decrease by > 20%.

The results of the risk assessment of using treated domestic graywater indicate that given the same source of graywater, irrigation of food crops using graywater poses a higher health risk than flushing toilets under the same conditions; given the same exposure scenario, kitchen graywater poses the highest risk, followed by laundry graywater and toilet graywater; toilet and laundry graywater are safe for both toilet flushing and food crop irrigation after treatment via microfiltration; the treated graywater from the kitchen is not clean enough for irrigation of food crops, while it is harmless for flushing the toilet; many factors contribute to the uncertainties of the risk results, among which the dose-response model and the concentration of pathogens are the most critical in terms of accuracy of the estimates; and, in general, on-site graywater reuse should be promoted with due awareness of the risks involved (Shi *et al*., 2018). In general, grey water should not be used for irrigation of food crops, but can be used for the irrigation of building of green areas.

For the use of grey water in a building, it is necessary to install a suitable reservoir for its storage and a suitable pipe for its distribution. Before its use, grey water should be adequately treated to prevent causing harm to the health of residents and problems in the gardens.

Several buildings in many Brazilian cities already have systems for the use of graywater, without the associated problems. According to Law No. 13,312, of July 12, 2016, of the city of Niterói (RJ), Brazil, new buildings with consumption equal to or greater than 20 cubic meters of water per day are required to use graywater (Prefeitura Municipal de Niterói, 2016).

At the Hotel Confort Inn, located in Macaé, Rio de Janeiro state, a system for grey water use was implemented. The hotel's average monthly potable water consumption, which traditionally was about 1,515 m^3 month-1, was reduced, after the implementation of the reuse system, to 1,017m^3 month-1 (29% water savings). The cost of implementing the reuse system corresponded to 0.34% of the amount invested in the construction of the hotel. With the savings generated in water consumption, the investment in the reuse system had an estimated amortization period of 50 months (Gonçalves *et al.*, 2010).

3.3.6. Rainwater use

There is a high potential for the use of rainwater in buildings in Brazil. Rainwater can be used in buildings for non-potable applications, such as garden irrigation, floor cleaning, vehicle washing and landscaping. In addition, with rainwater collection and storage, problems with urban drainage are reduced, as the system retains a significant portion of the water that otherwise flow through streets and drains.

Several countries have laws and policies regulating the use of rainwater. In Brazil, Standard number NBR 15,527/2007, from the Brazilian Association for Technical Standards (Associação Brasileira de Normas Técnicas), or ABNT, imposed the use of rainwater in urban areas for non-potable purposes.

NBR 15,527 provides guidelines for designing rainwater harvesting systems from the roofs of buildings for non-potable use. However, besides being outdated, by not providing guidelines for the design of the system in a more modern way, the Brazilian standard does not cover guidelines for the safe use of rainwater for potable applications. Such considerations would be important because the country has semi-arid areas, where rainwater is the main source of water for most part of the year and is used not only for toilet flushing and cleaning, but also for cooking, showering and personal hygiene. In addition, the methods, parameters and sizing procedures are considerably outdated in relation to international practices (Teston *et al.*, 2018).

There are laws about rainwater collection and use in some cities in Brazil, such as São Paulo, Rio de Janeiro, Brasilia, Florianopolis, Porto Alegre, and others. The requirement for rainwater collection depends on the size of the buildings and can vary from city to city. For example, in the city of Rio de Janeiro (RJ), legislation requires rainwater collection for buildings with a waterproofed area larger than 500 m^2 (Municipal Decree No. 23,940/2004) (Prefeitura Municipal do Rio de Janeiro, 2004). This same area (500 m^2) is required in the state of São Paulo (Law No. 12,526/2007) (São Paulo, 2007). In the city of Florianópolis (SC), on the other hand, the corresponding area is 200 m^2 (Supplementary Law No. 561/2016) (Prefeitura Municipal de Florianópolis, 2016).

The proper sizing of the rainwater storage reservoir is vital to ensure the technical and economic feasibility of a rainwater harvesting system. In the sizing process, one seeks to determine the volumetric capacity capable of meeting the highest possible demand at the lowest cost, because excessively large reservoirs may be unfeasible both physically and economically (Rezende & Tecedor, 2017).

The rainwater can be mixed with greywater and destined for an independent reservoir, from where it will be distributed for non-potable uses in the building.

Brazilian legislation and public policies related to rainwater harvesting in Brazil are still in an initial phase and require more intensification by authorities and leadership (Teston *et al*., 2018).

3.3.7. Use of water from air conditioners

Among the possibilities for water conservation, air conditioning systems have a potential applicability because, during their operation, water is generated through condensation of moisture from the air, which is usually discarded (Scalize *et al*., 2018). Water from air conditioners can be used for non-potable purposes, such as flushing, washing floors, ornamental use, washing cars, and irrigating gardens.

Siam *et al*. (2019) studied the potential for recovering condensed water from air-conditioning systems in two Palestinian cities. The results showed that a great quantity of condensed water could be collected from air conditioning systems. More specifically, from a single capacity air conditioning unit, almost 8.63 and 15.1 L day^{-1} of water (based on average working hours) were observed in the cities of Ramallah and Jericho, respectively. Evaluation of the physical, chemical, and microbial data of the condensed water quality revealed that, in general, the condensed water had good water quality, which conformed to Palestinian standards for reused irrigation water. In comparison with drinking water standards, some parameters related to turbidity, and BOD and COD measurements, were discussed. Regarding the occurrence of heavy metals in the collected condensed water, no particular risk was recognized for both the drinking water and the reused water irrigation standards, except for an occurrence of Mn of 0.19 mg L^{-1} in only one of the 65 samples.

Meanwhile, Bastos & Calmon (2013) studied a system for the use of air conditioning water (with different cooling capacities in BTU) of a commercial building located in the city of Vitória (ES), Brazil. They determined a total volume of 4,298 L of water per day, enough to supply 80% of the building's daily toilet flushes.

In Brazil, some states and municipalities require the use of water from air conditioners. For example, Law 16,603 of July 9, 2018, in the state of Ceará (Ceará, 2018), made the use of air conditioner water mandatory for new residential, commercial, and multi-family industrial construction projects.

Water from air conditioners can be accumulated in the same reservoir used to collect greywater and rainwater.

3.3.8. Community engagement in water-conservation programs

In a water conservation program, the participation of the population is indispensable. Without the participation of the community, the program will not be complete and will not achieve its objectives. Environmental education must be a permanent process that allows individual and collective learning and must include measures such as giving lectures; preparing pamphlets and posters; preparing videos; preparing publicity materials for newspapers, television, magazines, and radio; and developing a specific program for education in schools. In addition, since it is easier to create habits than to change habits, the development of relevant educational work with children is of paramount importance.

Initiatives that provide community input should aim to inform, educate, or raise awareness; change individual or household behavior; and build political support. The principles for increasing the likelihood of effectiveness of different engagement processes may vary depending on the type of engagement process, but some important principles common to many of the processes are: know your audience/community; use diverse mechanisms to reach diverse communities; and frame the issue carefully (Dean *et al*., 2016).

It is estimated that just by the distribution of pamphlets and conducting lectures and activities with users, it is possible to achieve a reduction of almost 15% in a building's water consumption (MC, 2015).

In general, there is good evidence of the effectiveness of a range of approaches to reduce domestic water demand. While the effectiveness of an approach is likely to depend on the social and environmental context, studies have shown that public awareness and information campaigns can result in substantial reductions in domestic water use; estimates range from 2 to 25% (Dean *et al*., 2016).

According to the National Policy for Environmental Education (Law No. 9.795/99, Brazil), environmental education constitutes the processes by which the individual and the collective build social values, knowledge and skills, attitudes and competencies aimed at preserving the environment, commonly used for the good of people and essential for a healthy quality of life and its sustainability (Brasil, 1999).

A water conservation program should include the participation of the government, industries and the general population and have partnerships with universities and research institutes.

Through a water conservation education program, the population will adopt measures such as:

a) Use non-potable water sources (for example: treated wastewater, rainwater, well water, water from air conditioners) for applications that do not require water from the public supply system.

b) Do not use a hose when washing outdoors and sidewalks; whenever possible, reuse water for this purpose.

c) Do not use a hose when washing cars.

d) Use water from washing machines for other purposes.

e) Install low-flow water fixtures.

f) Install appliance with low water consumption (for example, washing machines and dishwashers with low consumption).

g) Choose drought-tolerant plants in gardens; reduce grass coverage and replace with permeable materials.

h) Whenever possible, use buckets and watering cans when watering the plants.

i) Turn off the tap while brushing teeth or shaving.

j) Take shorter showers.

l) Repair leaky plumbing; control water loss and waste.

3.4. Proposal of national structure for water-conservation program in urban areas

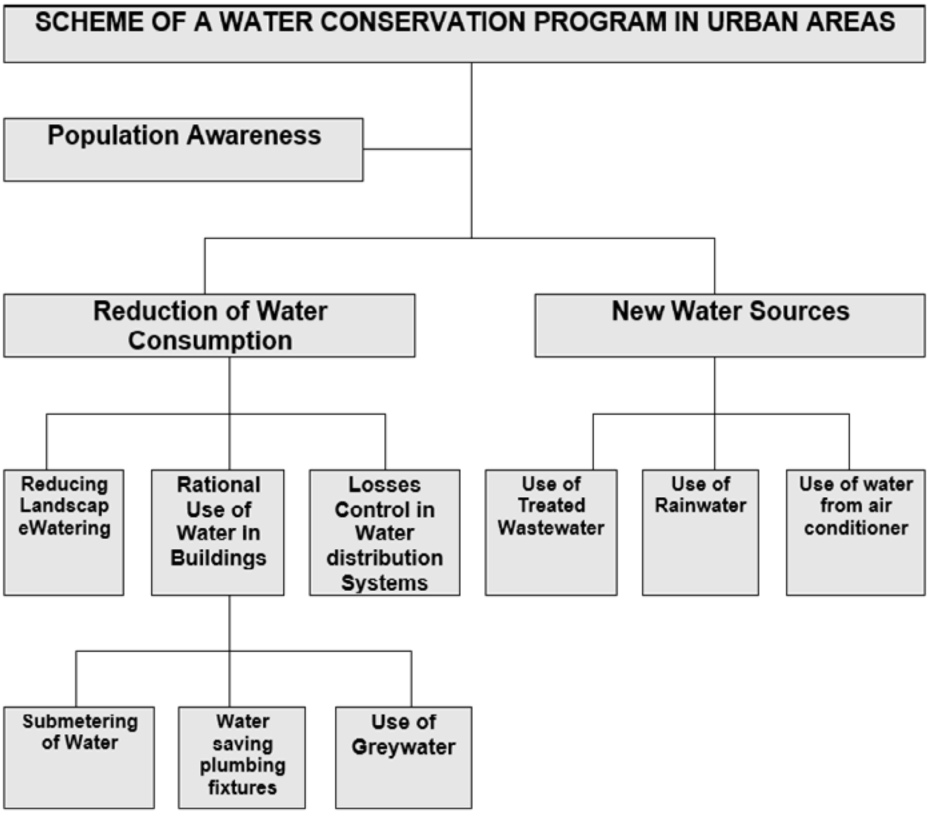

FIGURE 1 – Proposed scheme for a water conservation program in urban areas.

Figure 1 shows a proposed scheme for a national program for water conservation in urban areas. The Federal Government should develop guidelines for water conservation in urban areas, consisting of a national plan for water conservation in urban areas; definition of the federal, state and municipal agencies involved; guidelines for the various actions aimed at the reduction of water consumption and the rational use of water; guidelines for the use of different types of water; and assignment of quality standards to the various types of water. Figure 2 shows a diagram of what can be included in the guidelines for water conservation in urban areas.

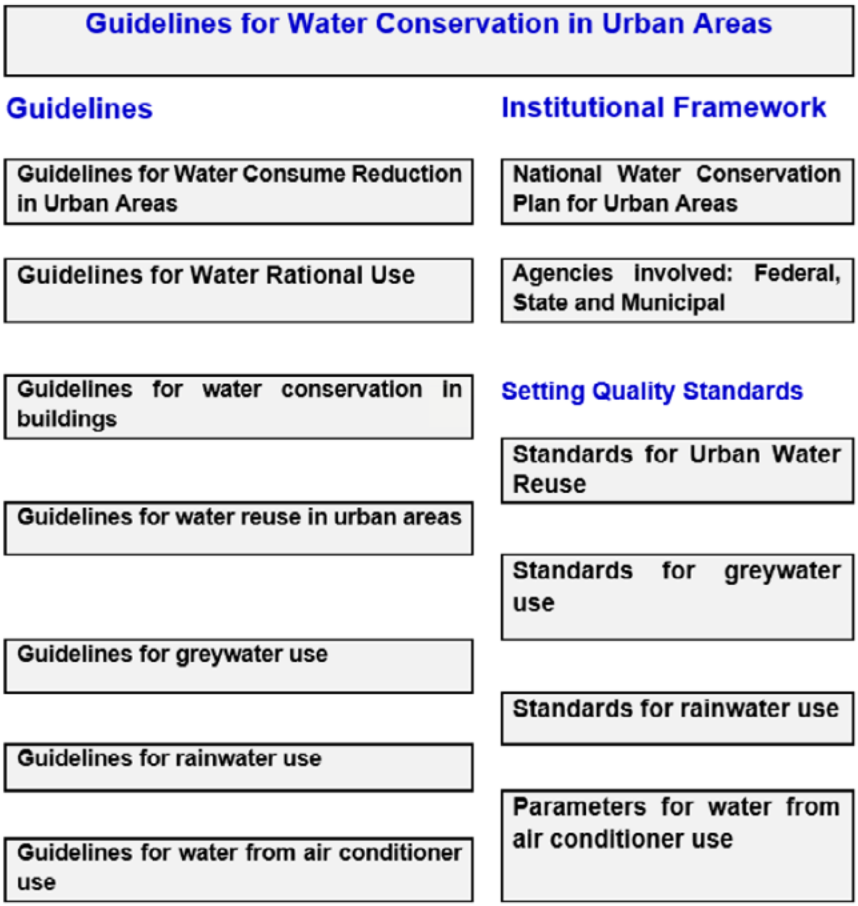

FIGURE 2 – Diagram of guidelines for water conservation in urban areas.

A water conservation program for water in urban areas should involve the participation of national, federal and municipal agencies, as well as the involvement of the population.

Table 5 shows the attributions of those responsible for water conservation in urban areas at different levels.

TABLE 5 – Responsibilities of those responsible for water conservation.

Level	Entities	Assignments
Federal	National Council for the Environment National Council for Water Resources	· Preparation of National Water Conservation Plan for Urban Areas. · Setting quality standards for water reuse, gre · Greywater use, rainwater use and water from air conditioner use. · Preparation of guidelines for water conservation in urban areas.
State	State Environmental Councils State Water Resources Councils State Departments of Water Resources and Environment State Sanitation Companies	· Preparation of specific state guidelines for water conservation in urban areas. · Development of actions aimed at water conservation in urban areas. · Loss control in water supply systems.
Municipal	Municipal Sanitation Companies City Halls	· Loss control in water supply systems. · Inclusion of water conservation measures in the Municipal Master Plan and the Building Code.
Buildings	Building managers and unit owners	Adoption of measures for water conservation (for example, install low-flow water fixtures; repair leaky plumbing fixtures; control water losses and waste).

4. Conclusions

As in other countries, Brazil faces water shortages in several regions, caused by irregular rainfall or high consumption. Therefore, there is a need for measures to reduce water consumption and increase supply. As Brazil is a country with a high concentration of people in urban areas, water conservation in cities is necessary and indispensable. Water conservation measures in cities should be implemented in public areas and buildings.

Water conservation in public urban areas should involve actions such as reducing landscape watering, reusing water, and controlling losses in water supply systems. In buildings, water conservation should include measures such as rational use of water, submetering water, water-saving plumbing, use of grey water, use of rainwater, and use of water from air conditioners.

Water reuse is an alternative for regions with water scarcity. However, Brazil has no political, legal and institutional basis for water reuse. It is necessary to establish recommendations for water reuse, and quality standards for the different uses of treated wastewater, including graywater, should be established.

In a water conservation program, the participation of the population is indispensable. Environmental education should be a permanent process that enables individual and collective learning. Through an education program focused on water, the population will adopt measures to reduce water consumption in urban areas.

In Brazil, there is no national water conservation program for urban areas. In this study, a national framework for a program for water conservation in urban areas is thus proposed. A program for water conservation in urban areas should involve the participation of national, federal and municipal agencies and the population. This study suggests the duties assigned to entities responsible for water conservation in urban areas at the federal, state, and municipal levels, and at the community level.

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