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Notes

Stormwater management and urban sustainability. A review

Gestión de aguas pluviales y sustentabilidad urbana. Una revisión

Natyely Barranco-Mejía[1], ORCID: https://orcid.org/0000-0001-6171-1111

Fredy López-Pérez[2], ORCID: https://orcid.org/0000-0002-1372-6252

María del Carmen Torres-Salazar[3], ORCID: https://orcid.org/0000-0002-2119-8998

Pedro Misael Albornoz-Góngora[4], ORCID: https://orcid.org/0000-0002-1242-1051

[1]Universidad Autónoma del Estado de Morelos, Cuernavaca, Mexico, bmno100417@upemor.edu.mx

[2]Universidad de Medellín, Medellín, Colombia, jflopez@udemedellin.edu.co

[3]Universidad Autónoma del Estado de Morelos, Cuernavaca, Mexico, mariadelcarmentorress@gmail.com

[4]Comisión Nacional del Agua, Tlaxcala, Mexico, ptrsmsl@gmail.com

Corresponding author: Natyely Barranco Mejía, bmno100417@upemor.edu.mx

Abstract

One of the best-known environmental effects of cities is that they induce soil impermeabilization, which in turn increases the impacts of global warming. The construction of infrastructures, such as streets and sidewalks made of pavement or concrete, leads to disruption between the population's activities and the natural hydrological cycle. The change in land use and extraction for drinking water supply without urban sustainability criteria aggravates the situation in many cities around the world.

In the development of the review article, a comparative reading was made on the management of rainwater in the contexts of the integral urban water cycle and sustainability; 61 records were reviewed that allow observation that Sustainable Urban Drainage Systems are an essential alternative to counteract the effects of climate change, and although they imply a challenge of implementation, their development is necessary to mitigate the important variations in the distribution of annual rainfall patterns in different regions, especially for Latin American cities.

Keywords: Sustainable urban drainage systems, urban sustainability, climate change, urban drainage, urban storm-water management, urban resilience.

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Resumen

Uno de los efectos ambientales más conocidos de las ciudades es que inducen a la impermeabilización de suelos que a su vez incrementan los impactos del calentamiento global. La construcción de infraestructura, como calles y banquetas hechas de pavimento o concreto propician una disrupción entre las actividades de la población y el ciclo hidrológico natural. El cambio de uso de suelo y la extracción para el abastecimiento de agua potable sin criterios de sostenibilidad urbana agrava la situación en muchas ciudades del mundo.

Para el desarrollo de este trabajo se efectuó una lectura comparada sobre el manejo de las aguas pluviales en los contextos del ciclo integral del agua urbana y la sostenibilidad. Se revisaron 61 artículos que permiten observar que los sistemas urbanos de drenaje sustentable son una alternativa esencial para contrarrestar los efectos del cambio climático y mitigar las variaciones importantes en la distribución de los patrones de pluviosidad anual en diferentes regiones, especialmente en ciudades latinoamericanas.

Palabras clave: sistemas urbanos de drenaje sustentable, sostenibilidad urbana, cambio climático, drenajes urbanos, gestión de aguas pluviales urbanas, resiliencia urbana.

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Introduction

The review of books and articles by various authors in this paper covers a wide variety of topics related to the hydrological cycle and its impact on urbanization, as well as the fundamentals of the current sewerage system and its disadvantages; the evolution of the urban water cycle; its integrated management; the socio-political, institutional, and legal approach to its sustainable management; water management in resilient cities; and the environmental challenges of urban drainage.

By deepening these topics, it was shown that an important factor to consider is the behavior of rainfall when developing effective plans for the design of urban drainage systems, where there are several criteria that can help define urban sustainability associated with water resource management (Gomes-Miguez, Moura-Rezende, & Pires-Veról, 2015; Potter & Vilcan, 2020).

Urbanization increases the change in soils to increasingly impervious surfaces, which alters the urban hydrological cycle, causing an increase in the volume of surface runoff and peak flow. It is important to mention that during the urbanization process, the construction of conventional drains and culverts, whose main objective is the rapid removal of stormwater from urban areas, generates undesirable effects, such as a decrease in water quality (Mguni, Herslund, & Jensen, 2016). This also triggers other consequences, such as a decrease in rainwater infiltration and thus a reduction in aquifer recharge (Peña-Guzmán, Melgarejo, & Prats, 2016).

However, urban development cannot be affected by environmental factors. It is necessary to make the population aware that this is a current and a priority problem to be solved (Brears, 2016).

To address these challenges, a type of engineering called sustainable urban drainage system (SUDS) is currently being developed, a term that comes from the United Kingdom and implies a set of practices and infrastructure assembly for the control of stormwater runoff and its effects.

They may also be known as BMPs in the United States (Best Management Practices) (Castro-Fresno, Rodríguez-Bayón, Rodríguez-Hernández, & Ballester-Muñoz, 2005); Sustainable Urban Drainage Systems (SUDS), or Sustainable Urban Drainage Techniques (TDUS) in Spain and some Spanish-speaking countries; Alternative Drainage Techniques (TAD) in Chile (Castro-Fresno *et al*., 2005; Momparler & Andrés-Doménech, 2015; Rodríguez, 2008); low-impact development (LID) or water-sensitive urban design (WSUD) in Australia, and LIUDD (low-impact urban design and development) in New Zealand (Elliot & Trowsdale, 2007). Ditches, swales, and infiltration areas were among the different drainage components that developed.

SUDS has influenced low-impact development with innovation and has proven to increase in popularity over time in different countries, such as the United Kingdom, Spain, Australia, New Zealand, Germany, France, the United States, and Sweden. In addition, a fundamental principle of the SUDS is to maintain the hydrological post-development of a site to meet conditions such as natural land behavior without anthropogenic modifications (Neupane, 2018).

This review is one of the results of a master's thesis in Environmental Engineering and Sustainable Technologies that focuses on the design and evaluation of infiltration areas of medians according to urban sustainability criteria in the city of Cuernavaca, Morelos (Mexico). This highlights the advantages of implementing projects of this type, which contribute to sustainable urban development by allowing the infiltration of treated rainwater into the subsoil in urban areas. Additionally, these projects promote a holistic vision of integrated stormwater management in urban areas.

Materials and methods

For this literature review, we first used a search equation with the following terms: "("sustainable drainage system*" OR rainwater) AND ("urban sustain*" OR "sustain* cities")." The equation was used in the Web of Science, Scopus, and EbscoHost databases and was delimited using filters of temporality, thematic field, document types among articles, book chapters, and reviews. A total of 377 documents were identified, which were then analyzed with the Tree of Science algorithm, available at https://tos.coreofscience.com/ and with Bibliometrix to optimize the search and selection of the documents to be analyzed, which made it possible to focus the analysis on a total of 37 sources.

After this selection, the content of each article and book was qualitatively analyzed using the computational tool ATLAS.ti to establish the central ideas of the review.

In this work, a comparative methodology is used, and the contributions of the different authors and the state of the art related to the subject matter of this review are synthesized, classified, and interpreted.

Literature and material analyzed

During the literature review, the following authors were identified as the most relevant: M. G. Faram, Sara Perales Momparler, Ignacio Andrés-Doménech, R. R. Brown, Megan Farrelly, Alexander Elliott, Sam Trowsdale, Patricia Göbel, Christos Makropoulos, V. Grace Mitchell, Allison H. Roy, David Butler, John W. Davies, Edgar L. Villarreal, Andrew Dixon and T. H. F. Wong.

The main journals in which they publish the content of interest in this review are *IWA Publishing Water Science & Technology-WST*, *Elsevier Environmental Modelling & Software*, *Elsevier Journal of Contaminant Hydrology*, *Springer Science + Business Media*, *Taylor & Francis Group Urban Water Journal*, *Elsevier Water Policy*, and *Elsevier Building and Environment*.

The main countries of affiliation of the authors with the most relevant publications on the subject were the United Kingdom, Spain, Australia, New Zealand, Germany, France, the United States, and Sweden.

With respect to urban drainage, the following section presents an analysis detailing the criteria to support its advantages and disadvantages as well as its development and implementation.

Results

The hydrological cycle and its modifications

It is important to fully understand the water cycle and its mechanisms to optimize its management in urban areas. The hydrological cycle describes the constant presence and activity of water on Earth, as it moves and changes continuously.

However, urban areas alter the hydrological cycle because precipitation tends to carry particulate matter from air. In addition, water runs off roofs and pavements, carries particulate pollutants, suspended solids, organic matter, heavy metals, and hydrocarbons, and eventually settles on the ground. In the city, green interception areas are limited, and human activities in space limit the soil permeability.

As a result, there is an increase in the velocity of surface runoff on firm and solid surfaces, as well as through gutters and pavements, concentrated rapidly in sewer systems. This is in contrast with the natural movement of water over natural surfaces and streams. Consequently, the flow of water arrives and leaves quickly, which reduces the infiltration of rainwater through the soil and significantly decreases the recharge of groundwater reserves. It is important to mention that rainwater infiltration must be pretreated (Butler & Davies, 2004). Therefore, in urban areas, infiltration is scarce and local aquifers are partially excluded from the natural process of the water cycle (Rodríguez, Rodríguez, & Gómez-Ullate, 2007).

Figure 1 shows the changes resulting from stormwater runoff, showing urbanized and undeveloped lands.

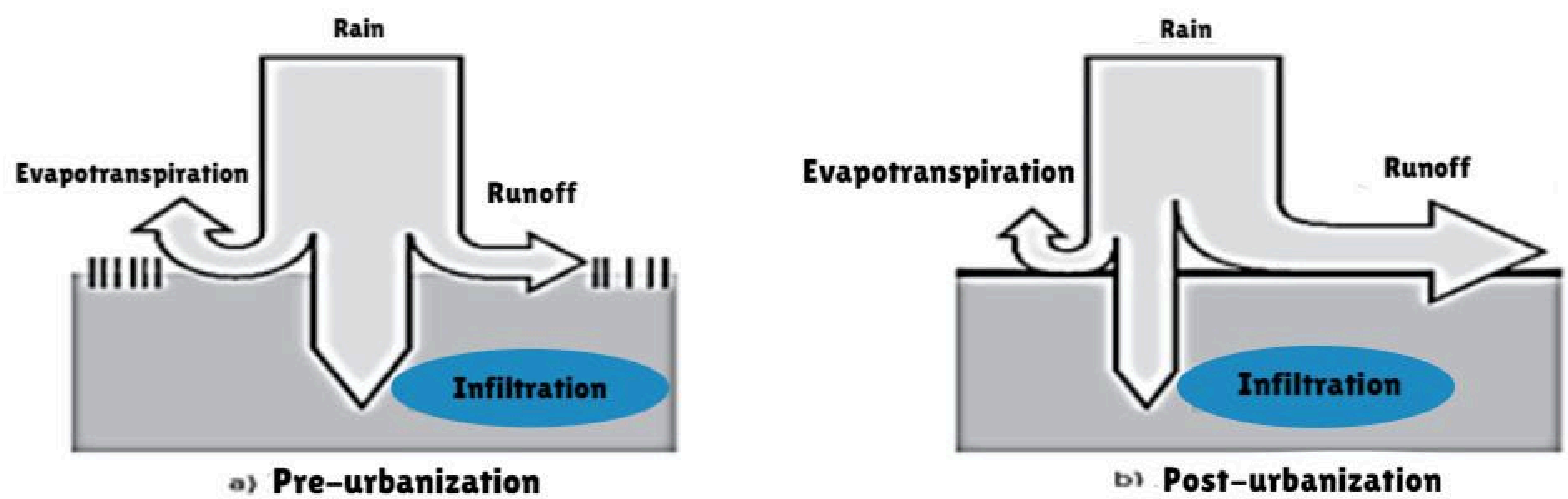

Figure 1. Effect of urbanization on stormwater runoff during storm events. Source: Butler and Davies (2004).

Fundamentals of today's sewage system

In the 16th century, the sewage system was able to collect and transport wastewater and stormwater runoff through a single network of pipes to a nearby body of water. Because it was a mixed system, it was called a "unitary system" (Faram, 2000).

This system is commonly used in cities in European countries and in Latin America. However, over time, some of these networks have become inefficient (Scholz & Grabowiecki 2007).

One of the known problems of these networks is that their capacity is not sufficient to carry the flows generated, especially by heavy rainfall, which causes overflows or hydraulic failures at different points of the drainage system, resulting in flooding or extensive waterlogging in urban areas (Castro Fresno *et al*., 2005; Faram, 2000).

On the other hand, in the United States and Australia, a different sewerage system called the separative system was implemented (Faram, 2000). This system consists of carrying wastewater through one pipe and stormwater runoff through another, which does not receive treatment because of its low pollutant load. In this way, only wastewater is treated before it is reintroduced into the environment, instead of being treated together with stormwater, as in other systems.

Stormwater and urban sustainability

The objective of sustainability is to protect and conserve natural resources, promote different lifestyles, and develop a support infrastructure of indefinite duration, avoiding the depletion of resources and degradation of environmental quality (Wong & Eadie, 2000). Therefore, quantifying or operating sustainability is a controversial and ambiguous process that must be addressed considering the specific characteristics of each line of research (Natsis, Makropoulos, Liu, Butler, & Memon, 2006).

Currently, the aim is to meet the objectives of sustainability, which is why international movements have been generated to build sustainable, green, and healthy cities that encompass economic viability and social stability in order to make wise use of resources (Leitmann, 1999).

A more specific option is the transformation of conventional cities to water-sensitive cities, which requires a socio-technical review (Wong & Brown, 2009). This implies the use of criteria and indicators focused on sustainability to measure optimal urban development. Table 1 provides some examples for clarity.

Table 1. Criteria and indicators for evaluating the sustainability of sustainable urban water management projects.

Capital	Criterion	Indicator
Atmosphere	use of resources	Water use (litres/use) Water loss (litres/use) Energy use (kWh/use) Chemical use (liters/use) Land use (m^2)
	Provision of services	Provision of services*
	Environmental impact	Environmental impact*
Economy	Life cycle costs	Life cycle costs*
	Willingness to pay	Willingness to pay*
	Affordability	Affordability*
	Exposure to financial risks	Exposure to financial risks*
	Capital Costs ($)	Capital Costs ($)
	Operating costs ($/l)	Operating costs ($/liter)
Social	Risks to human health	Risks to human Health*
	Acceptance	Acceptance*
	Participation / Responsibility	Participation/Responsibility*
	Public awareness	Public awareness*
	Social inclusion	Social inclusion*
Technical	Scenery	Scenery*
	Reliability	Reliability*
	Durability	Durability*
	Flexibility/Adaptability	Flexibility/Adaptability*

*It means that the indicators do not have units since they quantify sustainability qualitatively.

Source: Modified from Makropoulos, Natsis, Liu, Mittas and Butler (2008).

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Integral urban water cycle

Improving the drainage system is essential in urban areas because of the interaction between population activities and the natural water cycle. In this interaction, the ways in which rainwater, wastewater, and groundwater are regulated and altered by the conditions imposed by urban infrastructure must be considered. The management of this complex is referred to as the Comprehensive Urban Water Cycle (CUWC) (Mitchell 2006).

This interaction manifests itself in two main ways: first, the extraction of water from natural cycles to supply the population; and second, changes in land use and its coverage with impervious surfaces, diverting stormwater away from natural and regional drainage systems. Both of these anthropogenic impacts modify the global climate, especially changes in rainfall patterns; therefore, new drainage designs must take this into account (Kabisch, Korn, Stadler, & Bonn, 2017; Graham, 2016).

The current scope of water infrastructure in cities comprises three main components: drinking water delivery, infrastructure for wastewater conveyance and treatment, and storm drainage (Makropoulos *et al*., 2008).

Evacuating stormwater with minimum possible discomfort to people is one of the main objectives of water management in cities. The purpose of drainage is to protect people's health, avoid interrupting daily activities, prevent flooding, and protect property damage and urban settlements from the risks generated during or after storm events. Currently, in addition to focusing on draining stormwater from the surface, it is also considered important to conserve its quality and quantity, because runoff can negatively impact the water bodies to which it is directed.

With the realization of these criteria, the integrated water cycle has become increasingly important in cities, and interest in more natural methods of stormwater disposal, including infiltration and storage, has grown. The overall intention is to reverse the trend of the runoff rate, which in urban areas increases sharply compared to the rate in rural or forested areas. Figure 2 shows the changes in runoff generated during storm events in three different areas: rural, semi-urban, and urban areas (Butler & Davies, 2004).

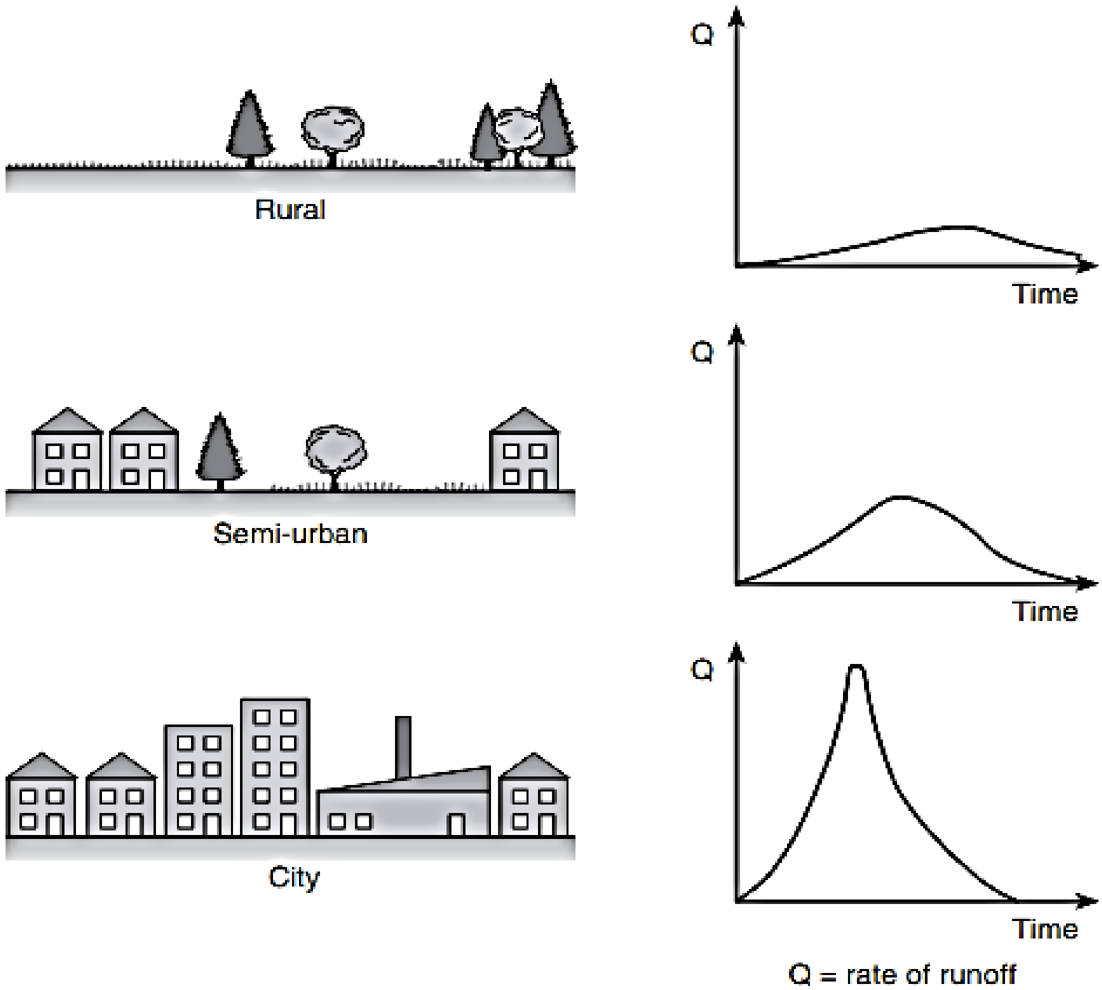

Figure 2. Effect of urbanization on peak runoff flow rate. Source: Butler and Davies (2004).

The fact that actions are proposed in cities to generate CUWC facilitates the transformation and development of "water sensitive cities," so the focus will remain on the "how" with ideas from the best thinkers and responsible practices in urban water management, urban design and applications in social and institutional systems.

Holistic-vision water management

Niemczynowicz (1999) stated that urban water management is becoming integrated with land-use policies, and landscape planning is beginning to be integrated with urban development, building construction, economics, regulation, legislation, education, acceptance processes, and social commitment (Mitchell, 2006).

Urban water systems must include a holistic vision that allows the water supply, wastewater treatment, and stormwater drainage to be seen as interacting components within a single system. Therefore, it is opportune to weigh the impacts of this change to visualize their effectiveness in advance (Makropoulos *et al*., 2008).

Integrated Urban Water Management (IUWM)

To achieve the main objectives of Integral Urban Water Management (IUWM), it is important to know that the existing paradigms of urban water systems (integrated management of stormwater, infrastructure, and behavior of urban waters) are constantly changing due to changes emerging paradigms. Some of these results are listed in Table 2.

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Table 2. Characteristics of the old and emerging paradigms of urban water systems.

Integral management of urban water	
Old paradigm	**Emerging paradigm**
Limited complexity and use of standardized solutions. Limited technologies developed by urban water professionals define the water infrastructure	The allowance of various solutions. The group of decision makers is multidisciplinary Allowing new management strategies and technology
Integration by accident. Regarding water supply, wastewater and stormwater should be managed by the same agency simply by historical chance. Physically three types of systems function separately	Physical and institutional integration from design. Linkages must be made between water supply, wastewater and stormwater, thus necessitating rigorously coordinated management
Collaboration = public relations. Other agencies and the general public are approached when approvals or pre-established solutions are required	Collaboration = commitment. Other agencies and the general public are officially listed and taken into account in the search for effective solutions
Wastewater and stormwater are considered waste streams that need to be directed out of the urban environment and transported to final disposal as quickly as possible	Increased change in perception of wastewater and stormwater as resources that need to be exploited rather than inevitable by-products of urbanization

Integral management of urban water	
Old paradigm	**Emerging paradigm**
Rainwater management is not executed in an integrated manner with other types of urban water and is considered a detriment to urban areas	Comprehensive management is carried out and rainwater tends to have great potential and the valuation of the resource is considered, it can be for water supply, infiltration and retention to recharge aquifers, natural water channels and natural vegetation
Gray infrastructure. The infrastructure is made of concrete, metal, or plastic	Green infrastructure. Infrastructure not only includes pipelines and treatment plants, made of concrete, metal, and plastic, but also soils and vegetation
The larger and more centralized the collection systems and treatment plants are, the better	Small and decentralized is possible, often desired for the collection system and treatment plants

Sources: Modified from Mitchell (2006), Makropoulos *et al*. (2008), Roy *et al*. (2008).

It is perceived then that the concept of IUWM is related to that of WSUD (Water Sensitive Urban Design) (Brown & Farrelly, 2009). The WSUD reintroduces the aesthetic factor and the intrinsic value of rainwater ways to return them within the urban landscape, contributing to the well-being of the community. It also increases the surplus value of the surrounding urban settlements and the conservation of land value, all of which can help increase public acceptance and boost its implementation in cities (Roy *et al*., 2008; Nóblega-Carriquiry, Sauri, & March, 2020).

The more WSUD is implemented, it is estimated that storm drainage design costs will decrease, and institutions and the public will be more receptive to sustainability and integrated stormwater management. However, it would be of great relevance to generate more cost-benefit analyses to provide convincing evidence to on-site decision-makers (Roy *et al*., 2008).

The feasibility of such systems contributing to the IUWM depends on the capital, operating costs, and benefits of the stormwater harvesting system. This is the case of reduced consumption of drinking water extracted from various sources (often groundwater) and made potable, increased local water infiltration, and independence from the main water supply system. There will also be educational and prestige benefits for the population; it will then be easy for people to make a connection between natural resources and their behavior, fostering a sense of responsibility towards proper water use. In terms of prestige, residents will be part of progressive thinking; therefore, carrying out strategies towards IUWM in cities is an innovative project that benefits society as well as the environment (Villarreal & Dixon, 2005).

Such benefits of implementing an IUWM have been reflected in countries such as the Netherlands, Australia, the United States, and France (Mitchell, 2006).

The techniques of WSUD and low impact development (LID), as it is called in the United States, and where SUDS are involved, are designed to capture and temporarily retain stormwater, such as detention ponds. There are also some designs for water infiltration, such as permeable pavement or infiltration areas in medians that are built with filters to eliminate pollutants or are connected with pipes to send stormwater for treatment prior to infiltration into the subsoil (EPA UE, 2000). In the latter, the runoff that runs over the impervious surface is diverted to the median at the same time that it infiltrates the soil. The device provides a storage section and improves the ability of the soil to accept water by generating a surface contact area (CIRIA, 2015). Capturing stormwater using these techniques reduces the frequency of flooding.

In a stormwater treatment train, infiltration techniques are considered a secondary treatment and a fundamental part of WSUD because they filter pollutants and partially remove sediments, heavy metals, and pathogenic bacteria so that they do not reach groundwater through vegetated infiltration strips, green swales, detention ponds, bioretention areas, infiltration areas in medians, infiltration ponds, and infiltration trenches, which involve physical and biochemical processes (Ronald-Mangangka, 2018).

The removal of contaminants through physical processes is achieved by sedimentation, filtration, and infiltration of particulate or suspended solids, and therefore includes contaminants bound to elements such as phosphorus. Biochemical processes occur in relation to certain contaminants such as hydrocarbons, which are digested or processed by vegetation and soil microorganisms. Therefore, optimizing pollutant removal requires the contact time between stormwater runoff, vegetation, and the soil surface. In addition, the removal of soluble contaminants in vegetated infiltration strips depends on the infiltration rate, considering that removal occurs when the contaminants infiltrate the soil, where some of them are absorbed by the roots of the vegetation.

Other factors that influence the removal of pollutants from infiltration areas in vegetated swales and ditches are the length, slope, permeability of soil and vegetation, height and density of vegetation, catchment area, particle size, pollutant concentration, sedimentation velocity, runoff velocity and flow rate, and contact time (Ronald-Mangangka, 2018).

It is important to mention that although numerous studies have focused on the physical processes of pollutant removal, little information is available in these treatment processes to explain the biochemical processes by vegetation and soil microorganisms involved in the removal of hydrocarbons and dissolved pollutants. Therefore, further studies must be conducted to better understand these processes (Ronald-Mangangka, 2018). WSUD techniques have the potential to mitigate water quantity and water quality problems in streams.

The relevant use of WSUD and proper execution of LID are shown in Figure 3, with a general IUWM train.

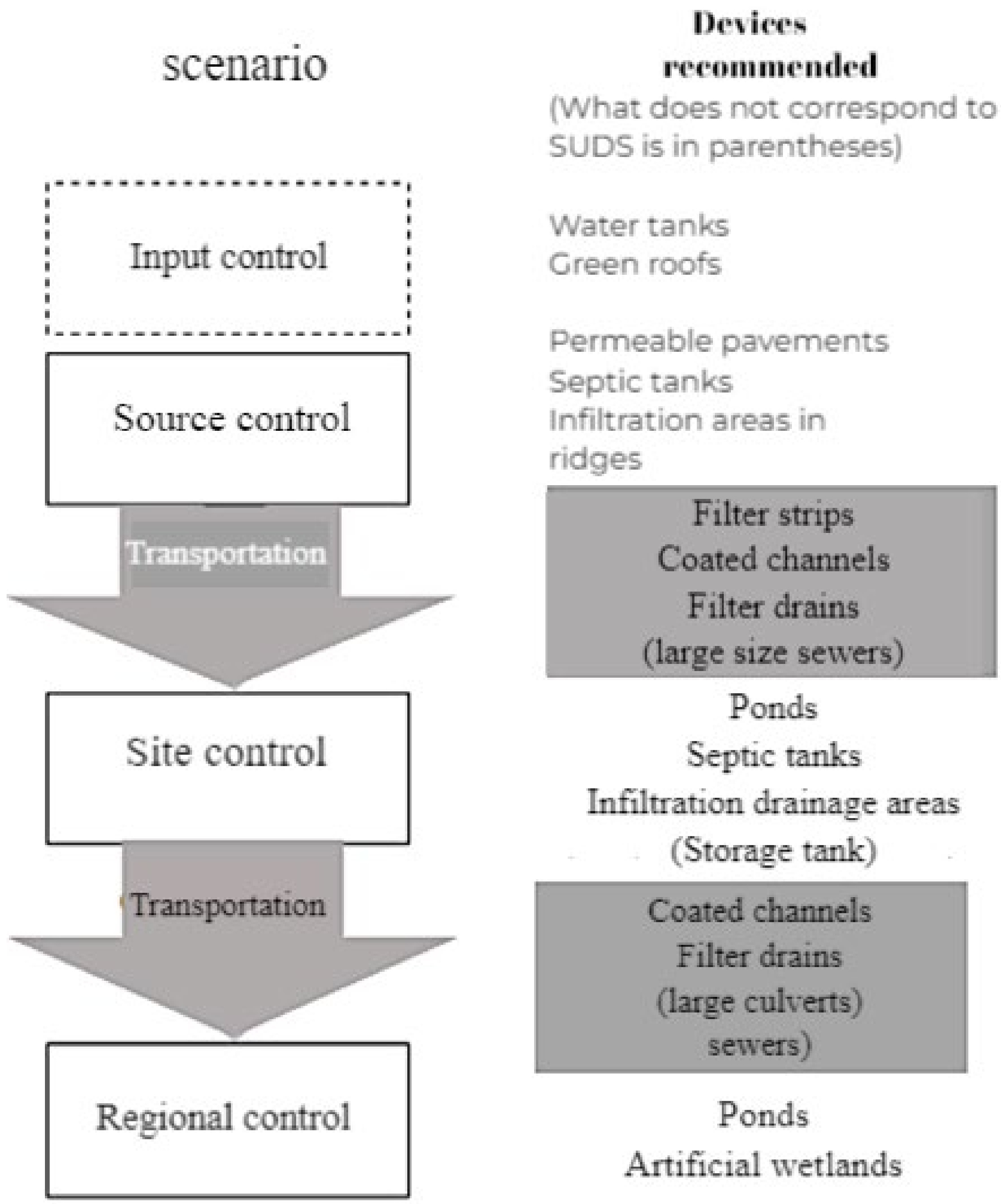

Figure 3. Integrated urban water management flow. Source: Butler and Davies (2004).

Urban environmental challenges of urban drainage

The 21st century presents environmental challenges for urban drainage systems, such as the need for cost-effectiveness and socially acceptable technological improvements. The need to perform impact assessments of these systems and implement sustainable solutions is a challenge that cannot be viewed as a single professional responsibility. Legislators, engineers, environmentalists, and citizens have different positions that must be exercised in partnership. Engineers must understand not only the technical aspects but also the broader context, and those who influence policy must understand the technical aspects (Butler & Davies, 2004; Bell, 2017).

These issues can be the physical impacts of streams on surfaces and barriers in urban areas and impacts on water quality, as stormwater runoff carries pollutants (Roy *et al*., 2008). Despite such problems, regulation is sometimes introduced to regions without adequate changes specific to the characteristics of the territory, and thus, regulation fails (Brown & Keath, 2008).

It is necessary to disseminate information through various media and hold exhibitions to increase public awareness to decrease skepticism or resistance to IUWM. Therefore, the following concrete actions are recommended to address major impediments to the IUWM (Roy *et al*., 2008):

a) Establishing cost and performance research behaviors at the watershed scale.

b) Create a management model and promote guidance documents and manuals.
c) Establish integrated management through different levels of government and the entire water cycle.
d) Develop specific workshops for continuing education of professionals.
e) Use institutions or colleges as the backbone to obtain support for ordinances and regulations.
f) To address the current obstacles to market approaches to provide financing mechanisms.
g) Educate and engage the community through action.

Despite the challenges of sustainable development in urban drainage, several commentators such as professionals, academics, and technicians, among others, recognize that the current progress towards the goals of Sustainable Urban Water Management (SUWM) has been slow if we take into account the development of new technologies and infrastructure in the last 20 years. This assessment can be generalized to both emerging and developed economies (Brown, Farrelly, & Keath, 2007).

Socio-political, institutional and legal approach to sustainable urban water management

Some authors emphasize that a legal framework is not entirely the priority, but that beyond the discrepancies between institutions and by formulating an integrated approach to water management, the basis for basin-scale management can be established (Roy *et al*., 2008). In fact, advanced institutional capacity for sustainable urban water management is recognized as reinforcing various technological solutions (Wong & Brown, 2009).

In order to involve such stakeholders, including politicians and businessmen, in the implementation of sustainable urban water management, the "hydro-social contract" has been developed in some countries to describe prevailing values and often implicit agreements between communities, governments, and businessmen/executives on how to implement appropriate management. This contract is formed according to the dominant cultural perspective and historically embedded water-urban values, expressed through institutional arrangements and regulatory frameworks, along with physical representations of water infrastructure (Brown, Keath, & Wong, 2009; Neto, 2016).

Resilient Cities and Urban Water

According to Wong and Brown (2009), and Folke (2006), a city as a resilient system is interpreted as follows:

a) The amount of adversity that a system can absorb and remain in the same state.
b) The degree to which the system is able to organize itself (against organizational weakness or organization forced by external factors).
c) The degree to which the system can build and increase its capacity to learn and adapt.

Resilience is not just about being persistent or strong in the face of adversity but also reflects how systems create opportunities in the face of adversity to renew themselves and pursue new trajectories and lifestyles.

Discussion

There are different terms in the world for the technological development of sustainable drainage, although the SUDS was used in this study.

During the bibliographic review, it was observed that there were different classifications of the SUDS. These classifications are based on their functions, the type of system it performs, and the location of its installation. In addition, the SUDS is perceived as an integral way for sustainable urban development. This is because legal, institutional, political, social, social, technical, and economic aspects are considered in their design. Such systems also promote environmental conservation, controlled land use, low-impact development, and preservation of the health of urban societies.

The SUDS also has the capacity to control stormwater runoff volumes, reduce the velocity and destructive force of surface water, minimize flood risks, and conserve the quality of downstream streams. In addition, these systems remove pollutants from stormwater, promote aquifer recharge with prior treatment to maintain river and stream flows during dry periods, conserve wetland landscapes, protect and improve water quality, provide significant opportunities for wetland habitat creation, and conserve the well-being of people and communities by influencing the harmony of urbanized land by favoring evapotranspiration and climate regulation in urban territories.

However, these advantages are not compatible with the design of the current urban storm drainage systems. The main objective of the current urban storm drainage systems is to accelerate the transport of runoff, which limits its contact with people, urban settlements, and infrastructure. As a result, the following disadvantages of these systems stand out:

- Increased frequency, volume, and duration of surface runoff.
- High peak discharge and flow velocities.
- Changes in the base flow regime (dry weather).
- Increased risk of overflow.
- Increased surface runoff temperature.
- Loss of wetlands and loss of terrestrial habitats.
- Damaged habitats and ecosystem modifications are associated with erosion of riverbeds and slopes, generating sediment and pollutant transport, increased channel width and instability, and deterioration of aquatic and terrestrial habitats.
- Introduction of new sources and types of pollutants.
- Increased transfer of contaminants, some of which are potentially toxic and have a long duration, leads to changes in water quality.

Therefore, there are ample opportunities in engineering, legislation, science, sustainability, and various fields of study and implementation of urban infrastructure to achieve hydrological restoration, which can be developed by implementing natural drainage to restore urban streams and promote ecosystem sustainability.

To achieve WSUD or IUWM it is necessary to overcome challenges over the next decades on urban water management such as organizing cross-sectoral cooperation among various stakeholders to introduce in the design of cities technological innovations for water, management systems, institutional arrangements to develop capacity to meet the objectives and develop sensitivity towards water management as it is considered as a fundamental building block towards sustainable and resilient cities.

Train and transmit to the community strategies for sensitive water management, strengthen links between academics and politicians to implement WSUD projects and give them continuity to avoid that many of them are only pilot projects or that they are only limited treatments where only one of the components of the SUDS train is implemented, furthermore, promoting programs to facilitate access to economic capital to implement SUDS development in cities and build such systems with their complete treatment train including primary stormwater treatment to remove large debris, secondary treatment to remove sediments, heavy metals and pathogenic bacteria, and tertiary treatment to remove fine sediments, metals and pathogenic bacteria that have resisted the previous treatment can make the difference from a "vulnerable" city to a "resilient" and water-sensitive city.

Conclusions

Surface runoff of stormwater can be reduced by collecting it to later contribute to the drinking water supply and by installing non-piped solutions for urban drainage, such as SUDS, to reduce water stress in the area.

The philosophy of urban drainage design requires an approach for the construction of an SUDS, considering that the application of these systems does not correspond to alternative works, but rather favors their integration and is complemented by some minor components. This design strategy directs rainwater to green areas, grass strips and/or vegetation-covered pits, to name a few. This reduces runoff velocity and volume, dampens peak flows, and encourages the infiltration of stormwater into the subsoil.

Likewise, in the case of stormwater, people will see its efficient diversion as part of "progress" if one considers the perspective that in low-developed or emerging countries, increases in rainfall are generally associated with significant impacts on daily life with a low probability of resilience, whereas in developed economies, rainfall impacts tend to be lower and resilience is higher.

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