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Public policy: urban stormwater in a paradigm shift, is it the end or just the beginning?

Carlos Novaes* and Rui Marques

CERIS, IST, Universidade de Lisboa, Lisbon, Portugal
*Corresponding author. E-mail: cnovaes.augusto@gmail.com

CN, 0000-0002-2713-7539

ABSTRACT

The perception that urban stormwater policies are non-existent, incomplete, or lacking in aspects that concern the environment and quality of life in cities has become increasingly common. This is partly due to the increased frequency and magnitude of rainfall events resulting from climate change and its economic, social, and environmental consequences. Population concentration and changes in patterns of living, construction, and urbanization contribute to the pollution of water runoff and receiving waters. Thus, quantity and quality problems add up and often require costly solutions, which are then addressed as economic issues. To deal with all these aspects, many of which were previously absent, stormwater public policies require a paradigm shift to break away from institutional inertia and dependence on the previous path. Without the aim of exhausting the subject, this paper discusses the policy aspects that concern stormwater management and the current and desired paradigm shift.

Key words: city management, public policy, stormwater management, urban drainage, urban water

HIGHLIGHT

- Urban stormwater issues are highly complex as they involve many actors, conflicting interests, difficult to predict future trajectories and causes that are fuelled by consequences. Public policies addressing complex issues are the result of decisions reached by consensus, but not unanimity, among stakeholders and, as institutions, are path dependent and decisive for the outcomes to be achieved.

1. INTRODUCTION

Decisions made by governments are materialized through public policies that direct actions to achieve certain pre-defined objectives. Policies can be created and implemented through different instruments such as laws and regulations, specific actions, or even funding priorities. Policies can be responsible for leveraging incentives for sustainable service delivery and for enhancing and transforming the existing institutional and regulatory framework (Mumssen *et al.* 2018).

There are many interpretations of the word policy and one of them is a definition, according to Hill's review of the term (Hill & Varone 2021), present in the Oxford English Dictionary, 2nd ed. of 1989: '*A course of action adopted and pursued by a government, party, ruler statesman, etc.*' In this sense, for example, Water Sensitive Urban Design (WSUD), is a water policy adopted and purposed by governments and professional institutions in Australia.

Public policies have two fundamental aspects: their formulation and their evaluation after application, which is the third and intermediate aspect, between the other two. The implementation stage has as determinants the organizational and political conditions, that is, the political and the associated social costs within a governance structure and economic policy of the sector where, for example, some actions may have difficulties of political and public support for their implementation, despite being efficient (Mumssen *et al.* 2018). Several factors can inhibit policy implementation such as lack of qualified personnel, lack of leadership, opposition, corruption, and many others.

This article aims to present an overview of urban stormwater management policies as they relate to institutions and regulation, but with a special focus on the paradigm shift underway (Dhakal & Chevalier 2016) in several aspects that the complexity of the subject requires. Urban stormwater management is a complex issue, i.e., it involves multiple actors, is interdisciplinary, does not allow for accurate predictions as to its future course, and has consequences that feedback into its causes. The ongoing paradigm shift takes place about most of the aspects involved such as: technological, environmental,

economic, social, political, legal, and institutional (Furigo 2020). In technological terms, the perception that quantitative control, or control of volumes associated with precipitation, can be better carried out at the source and not at the end of the runoff makes it possible to resort to smaller and more cost-effective solutions, not excluding the simultaneous 'end of the pipe' treatment, but which has a different conception. As for the issue of runoff quality, or in terms of contamination, previously considered practically non-existent, which concerns the environmental aspect, imbricated with the technical solutions, there are treatment alternatives (Chouli 2006) also at the source or along with the runoff, but before the outlet, through techniques called alternatives, favoring the infiltration and evapotranspiration, as in detention basins, retention, bio-drainage ponds, porous pavements, and other alternatives. In the economic aspect, the present reflection is on the alternatives for obtaining resources and financing for the construction, operation, and maintenance of infrastructure systems. Questions about the best way to obtain resources, whether from users (Zhao *et al.* 2019), taxpayers or through creative solutions such as public–private partnerships (PPPs) or other forms that are legally and politically acceptable to society, and the absence of specific sources of funding for the activity, as is the case in most countries nowadays, transforms its funding into an aspect of change (Veiga *et al.* 2021), the same occurring with the institutional, organizational and management structures, including the structure of personnel and their training for the activity. In a simultaneous movement with the actors involved and their diverse interests, all these aspects require organizational and institutional structures subject to distributed governance, that is, with the democratic participation of the actors aimed at reaching consensual solutions.

Various aspects are being questioned such as the costs of alternative solutions in the face of budget restrictions, which on the one hand present barriers to their construction, but on the other hand present opportunities for change towards other ways of obtaining resources and financing systems and management structures with the participation of other stakeholders, including users or investors or those who for any reason have an interest in participating in projects and actions related to urban stormwater.

The methodology used is based on a narrative constructed from the bibliography available through research in databases such as Scopus, but also in various other means available, in networks and other sources of documents. The text was based on research, experience, and reflection and took into consideration the existing recent papers available in the literature accessed relying, therefore, on the international experience built over the last decades.

The main contribution of this research lies in the effort to systematize relevant issues around the subject of urban stormwater from a public policy perspective, which in practice are almost totally absent in most countries, regardless of their stage of development and their technical, socio-economic, and cultural context. For several reasons, this absence, materialized by the limited capacity to respond to rainfall events across the globe (Kondratenko *et al.* 2021), has caused concern among scholars and the public, for whom we hope to provide useful contributions.

The results obtained with existing policies or their absence are reflected in the fragile conditions presented by cities about rainfall events that invariably, whether in developed or developing countries, resulting in disruption and material and human losses. There are no ready formulas for dealing with stormwater runoff, but in each place, the structures in charge of these tasks deserve to be built, where they do not exist, or rethought in the light of new demands arising from the confluence of old and new events such as accelerated urbanization and climate change. All these elements have required changes in the way urban stormwater is treated, which we call a paradigm shift (Bertrand-Krajewski 2021). This change has already been occurring to varying degrees depending on the specific economic and social characteristics of each location with varying results, but with little impact on the specialist literature, reflecting the incipient discussion of this issue in academia or the lack of transparency of the discussions.

This article is structured in four sections in addition to this brief introduction. Section 2 deals with public policies including the Sustainable Development Goals (SDGs). Section 3 addresses the drainage policies emphasizing its financing. Section 4 discusses the results obtained and, finally, section 5 presents the concluding remarks.

2. PUBLIC POLICIES

2.1. Background

Public policies are always choices in a framework of preference conflicts, mediated by inclusive political institutions to a greater or lesser degree, which reflect the degree of influence of different actors in the decision-making process (Sarti *et al.* 2018).

Thus, public policies, as a result of political decisions established in political processes characterized by the existence of different, and often conflicting conceptions (in terms of values and ideas) about the role of the state and its degree of intervention in society, are built not always from real problems, but from the understanding by political actors, both governmental and non-governmental, of what are problems or problematic situations that deserve to be part of a government agenda through a particular public policy.

Water and sanitation whose main function is the prevention and promotion of health refer to public policies related to health (Sarti *et al.* 2018), which is different from the classic policies of service provision as market goods. Since water and sanitation are not separated from health policies, intersectionality between these policies is necessary. However, this is not always the reality observed, which leads to a limited approach to health policies.

Changes in certain policies depend, however, on conjunctures, invariably provided by crises in which there are institutional imbalances favorable to change or opportunities for political transformations such as changes in government, economic changes, and others.

Additionally, from the perspective of the new institutionalism approach, in which institutions play a decisive role in policy outcomes, the alternatives of available policy choices are conditioned by the institutional effects of previous choices, that is, conditioned by past policies that established different actors and institutionalized certain practices and rules, configuring a relation of *path dependence* with the State as the structuring agent.

Public policies are also important rules of the game and, therefore, can be included in the list of institutions, and lead to the constitution of organizations and other institutions to enable their implementation.

In societies under democratic regimes, in which power alternates, water and sanitation public policies, including in long-term planning, are State policies and not just government policies, since the latter is transitory.

2.2. Sustainable development goals – SDG's policies

Water and sanitation as a right, recognized by the United Nations (UN) General Assembly (Resolution 64/292) and the Human Rights Council (Resolution 15/9) in 2010, refers to universal access to the related services and, therefore, the need for policies that consider, where not achieved yet, the issue of access to all in an equitable way. Universalization encompasses the inclusion of all water and sanitation services, non-intermittent and quality water supply, and comprehensive, including, when possible, fair tariffs established in a way that does not constitute an obstacle to universal provision (Neto & Camkin 2020).

In 2015, all UN Member States adopted the 2030 Agenda for Sustainable Development, including a goal (SDG6), with the main objective of ensuring the availability and the sustainable management of water and sanitation for all, but unless current rates of progress increase substantially, targets will not be met by 2030.

Thus, in 2020, according to UN, even though handwashing is one of the cheapest, easiest, and most effective ways to prevent the spread of diseases, and also coronavirus an estimated 3 billion people worldwide could not wash their hands at home. However, nothing is said about rainwater, which is absent from the statistics and therefore from the analysis, even though it can be considered an important resource in solving the urban scarcity and other questions.

The level of water stress (SDG6.4.2 target), characterized by greater consumption of water from natural sources, is a phenomenon that occurs in most regions of the world. Urban consumption, besides trying to be more efficient, can have policies which improve the control of losses in the networks, use rainwater for non-potable uses, and also reuse the water used.

A recent World Bank study estimates that meeting the sixth of the SDGs could cost USD116 billion per year through 2030. These costs unbundle into the separate costs of providing safe water (USD37.6 billion per year), safe sanitation (USD19.5 billion per year), safe fecal waste management (USD49 billion per year), and hygiene facilities and education (USD2 billion per year) (Staddon *et al.* 2020). These costs are, however, minor compared to the costs necessary to get the economy going again in the post-pandemic period and may be smaller if rainwater is considered as a resource.

About SDG 11.3.1 and urban planning, given the expected increase in rainfall, studies in Hamilton, near Toronto, Canada, have found that population growth is higher than the increase in land use, which is a good indicator for urban stormwater management (Philip 2021).

2.3. Policies for the universalization of services

The biggest challenges for the universal access to water and sanitation services are the rural areas and the peripheral areas of the cities, including the big cities, such as São Paulo in Brazil, where the issue of water security is very sensitive to several conditions such as social inequalities, environmental and climatic conditions, political processes and past events.

São Paulo, compared to London in the UK, despite their differences and similarities, brought to light, during the event of the COVID-19 pandemic, the risks to which both populations are permanently subjected, especially the poorest and most vulnerable, and the importance of policies focusing on water security. There are several vulnerabilities, such as insufficient water reservoirs, inequalities in access to and use of water, overcrowded housing, and lack of shelter for many (Alves *et al.* 2021).

During the pandemic of COVID-19, at the same time as water scarcity for handwashing occurs, flooding events occurred in 70 countries (Simonovic *et al.* 2021). While the pandemic requires isolation and social distancing, flooding events require or entail, on many occasions, proximity between people, making the goals contradictory for given moments. This reality makes it necessary to think about policies that consider the possible occurrence of multiple simultaneous adverse events (e.g., pandemic and water scarcity or excess). This can be taken into account through scenario simulations considering the concept of dynamic resilience, i.e., in which actions may be modified according to the evolution of events. This possibility is unusual among decision-makers who need to adapt to the concept of dynamic resilience by receiving information in advance so that they can formulate policies and plan actions, i.e., that include the greatest possible resilience of existing systems, which requires a change in thinking from static to dynamic resilience and from one adverse event to multiple simultaneous adverse events.

The implementation of policies aimed at the use of rainwater, within the logic of the urban water cycle, in the same way that the conscious use of groundwater which can even count on receiving contributions from rainwater, deserves to be encouraged, not only for the potential of facing the urban water shortage and, therefore, not only to meet the proposed in SDG6, but also to combat situations of vulnerability to diseases, especially those related to floods.

Urban rainwater certainly has an important role to play in combating situations of scarcity or excess in cities, but to do so it needs to have adequate management policies that are integrated with health, housing, and territorial and infrastructural planning policies.

3. DRAINAGE POLICIES

3.1. Drainage policies in a nutshell

Drainage policies, except for in the USA, whose existence dates back to 1987 with the Clean Water Act (CWA), and in Australia, where the Australian Drinking Water Guidelines exist since 1996 (Fletcher *et al.* 2015), do not have a long history. In Europe, drainage has recently received more attention; however, in other countries, such as Brazil, it is almost imperceptible (Montenegro 2017). In China, with the recent greater development of cities, since 2015 there is a growing concern and the establishment of a national policy under the title of Sponge Cities (Yin *et al.* 2021).

Another aspect that influences the structuring of policies in the sector concerns the more general political structures, federalist, democratic and distributed, as in the USA, or like China, with centralized political power. The legislation also follows this logic, with each country, state, municipality, district, county, or consortium and other forms of a grouping of federative entities having specific rules and ways to obtain different resources. It is important to note that stormwater does not follow the logic of administrative divisions and subdivisions, but rather that of hydrographic basins or hydrographic regions, containing several basins, as is the case in Portugal (Arezes *et al.* 2019).

The logic of analysis by watersheds, however, is not exhausted in itself and leads us to think about natural and built territories, and thus, about the planning of their use and occupation, that is, about territorial planning as a basis. The territory is the space where planned actions take place as a result of negotiations and political interactions between the various actors present or with interests that occur in the territory. Through collective decisions, the municipalities seek to ensure quantity with quality, prevent floods and mitigate droughts, without pushing problems from one municipality to another.

Urban water management is subject to the interaction of numerous public interest groups, private or otherwise, which have contradictory and conflicting behaviors, but without them, it is difficult to obtain solutions that derive from shared decisions whose main objectives are flood and pollution control. Each optimal solution chosen represents the best possible compromise between the various interests at a given moment.

In this perspective of participation, it is in the territories, spaces where the actions take place, that the urbanistic projects, new or of urban requalification, respond to the interests of certain social groups and illustrate the political priorities (water saving, economic growth, health security, better standard of living, and environmental quality) that determine the decisions and choices made and to be made. This has been the case since the nineteenth century, a time when water and sanitation

infrastructure was seen as a sign of modernity and urban comfort. However, since then, such technical superiority has foundations and arguments of socio-political order having been, for example, the Parisian option for what became known as 'tout-à-l'égout', a strategic political decision in which the State assumed responsibility for the water evacuation and treatment, because Paris, being an important capital, could not have its image damaged by the ways of handling water and sanitation as the transportation of sewage through the streets (Chouli 2006).

Urban hydrology, which had hygiene as its philosophical and theoretical foundation, is today a hybrid science involving physical phenomena, technical problems, urban society, and public policies and as such is in permanent evolution, not only in its technical and innovative aspects but because it has to consider socio-economic and environmental conditions.

Decisions within a preference system are made as a result of negotiations and depend on the existing players and available information. Thus, the decision process itself may influence the decision made, such as, for instance, depending on the players who may propose, through an environmental institution, that environmental impact studies be considered or, for instance, if the technicians only present solutions based on channeling, other alternatives are discarded even though they are based on better accepted public policies, such as those that aim at water-saving, controlling urban rainwater runoff at the source and avoid the significant use of channeling.

The instruments used by actors to implement a public policy are represented by all activities, decisions, and measures aimed at solving a certain problem (laws, working methods, information campaigns, assignments of roles and powers, decisions to include different actors, or the choice of a management model). These instruments are characterized by their objectives and for urban stormwater management they can be classified into three types: command and control (legislation and regulation); fiscal incentive policies (runoff charges based on impermeable m^2) and technical expertise, information, and public awareness, but one type of instrument may achieve several objectives at the same time (Chouli 2006).

Stormwater management in Europe can be described as a combination of four variables: direct or delegated management, management at the national, regional, or local level, management by the public or private sector, and management with or without partnerships, for example, direct management by the municipality or by a private company delegated by the central state or managed through a public partnership between local authorities and many other forms.

Alternative techniques, under the principle of decentralization and control of stormwater pollution at source, require new decision-making processes based on multidisciplinary collaboration, consensus between different actors and different institutional, organizational structures, political (legal, economic, and socio-political) enforcement instruments. It is the legislation that creates the obligations to establish means including the installation of treatment plants or results such as the reduction of the concentrations of specific pollutants in the receiving bodies.

The European directives, e.g., Water Framework Directive (WFD) 2000/60/EC and the Directive 2007/60/CE, also known as the Floods Directive (FD), which has as its main objective the establishment of a general framework for the assessment and management of flood risks, do not focus on stormwater.

Initially, the WFD focused on the mitigation of pollution sources, such as agriculture, industry, effluent treatment plants, overflows from combined systems, and direct sewage discharges into receiving water bodies. Without paying attention to separate systems, especially stormwater discharges, disregarding its quality, considered until then as not a major problem, neither the WFD nor the FD use the term 'stormwater'. WFD only mentions the word 'drainage' about the classification of surface waters as artificial or strongly impacted and when dealing with the contamination of groundwater by artificial recharge anthropogenically altered by rainwater runoff drainage. And finally, the word 'precipitation' is used in the WFD only to describe characteristics of rivers and FD never uses these words (Jensen *et al.* 2020).

Thus, an important policy change would be to not only adopt the terms but to consider the effects of the separate systems so that in Europe all impacts on the receiving bodies would be considered, aiming at total pollution control, which does not occur by leaving aside the stormwater separate system.

In Europe, concerning the technology and investment priorities associated with water management in cities, the first priority is related to the storage of water supply. The second is wastewater treatment, especially for sanitary reasons and to maintain the quality of receiving water bodies (lakes and rivers), often also used as a source of water resources, as is the case of rivers in France, Germany, the United Kingdom, and the Netherlands. Finally, the third priority refers to diffuse pollution that originates from two main sources: urban runoff and agriculture, the latter due to the use of pesticides and fertilizers.

In Portugal, there are references to stormwater in the Regulatory Decree No. 23/95, but stormwater drainage lacks specific regulation. However, the General Drainage Plan of Lisbon – PGDL 2016–2030, is a municipal strategic document that has as

its political objective the preparation of the city for the future, mitigating the consequences of climate change expressed by significant and increasingly frequent rainfall events. One of the principles of this plan is the flow control at the source through the construction of retention and infiltration basins and drainage trenches, in addition to tunnels, pavements, and other interventions, amounting to a total value of 250M€ (Béraud *et al.* 2021).

Urban runoff, however, presents different problems when there are combined or separate systems, the former being more important in controlling overflows in rainy periods. This latter problem can be solved by the construction of separate systems and disconnection of stormwater from the combined system or by expanding sewers and treatment plants. In the case of separate systems, polluted effluent is also received in stormwater networks, especially in rainy periods due to the first flush, but also in dry periods due to illegal or poorly constructed wastewater connections and infiltration. Each situation presented requires specific policies for its solution. Additionally, a priority that runs parallel to the other three is flood protection.

3.2. Funding and financing policies

In Europe, the importance of urban stormwater management and, therefore, stormwater policies, increases over time, correlates with other technical priorities related to water quality, and can also be understood as the sum of the importance of flood protection and urban water quality. Such priorities, in each municipality, are influenced by local contexts and by national and regional policies, as well as by European Union policies.

Public policy funding actions refer to the real or perceived needs of coalitions of actors, especially those in power, and thus the funding of drainage systems requires them to be perceived as important by actors, especially decision-makers and society in general.

Water policies in cities have always focused mainly on water supply and wastewater, leaving rainwater in the background and, consequently, also the issues and policies related to it. From the end of the last century onwards and more recently, with the sense that issues of urban pollution, water scarcity, heat islands, and flooding, partly due to climate change, impact well-being and have undesirable costs on lives and property, rainwater has been better understood, in particular from the perspective of being considered as a resource rather than being seen as a problem, following the logic of the urban water cycle (Goulden *et al.* 2018).

As a result, the urban infrastructure responsible for stormwater management has received more attention in terms of the necessary resources to keep it running, but so far it has not received sufficient funds and financing to cope with the increasing demands that are being made on it.

There is no single solution for the funding issue, and in each place, the funding policy reflects the particular context, but as the necessary amounts are quite significant, it has been necessary to count on government funds at all levels (federal, regional, and local) through general or specific budgets, plus contributions from users and the private sector, or even donations.

As an example, in the USA, a country of large dimension, and due to the variety of configurations and legislation, there are several ways of financing and organizing the provision of services, among which the well-known stormwater entities, existing 1,600, of the 7,550 allowed, with dedicated sources of funds such as fees and rates (EFAB & USEPA 2020).

In that country, where the annual operation, maintenance, and capital estimated funding gap for drainage systems is approximately USD7–10 billion (EFAB & USEPA 2020), as in many others, there are policy barriers to obtaining funds and financing that range from the popular perception of the importance of the systems to the existence of legislation that in some places requires popular consultations with minimum quorums of participants.

The EPA identified stormwater runoff as the single fastest-growing source of pollution in the country and, starting in the 1990s, began to regulate the issue through a policy that relied on the permit program through the Federal Water Pollution Control Act, better known as the already mention CWA. In this context, in the USA, since then, 7,855 discharge permits have been issued, according to the National Pollutant Discharge Elimination System (NPDES), which means a reach of 80% of the population.

The existence of systems with different characteristics, sometimes separate and other times combined, despite making matters more complex both in terms of those responsible for operation and maintenance and those who must provide the financial resources, does not prevent estimates of the financial needs. In research conducted in 2012 and published in 2016, the EPA estimated a need for USD67.2 billion over the next 20 years in investments both separate and combined systems. These amounts are equivalent to those spent in the past to initiate the construction of the interstate highway system or to upgrade wastewater treatment plants (EFAB & USEPA 2020).

In Brazil, between 2014 and 2033, the financing capital required according to the National Plan of Basic Sanitation – PLANSAB, in its version of 2013, is estimated at USD33.6 billion over the 20-year period or USD1.7 billion/year (Montenegro 2017).

The need for funds and financing mechanisms for this infrastructure is always raising due to regulatory requirements, water quality degradation, flood risks, climate change, and aging infrastructure itself, and the costs of doing nothing outweigh these costs. Thus, all alternatives deserve to be considered: general public budgets, fees, tariffs, grants, loans, revenue bonds, partnerships, PPPs, volunteer programs, and other innovative approaches (e.g., sponsorship of stormwater infrastructure).

Part of the necessary resources for stormwater management systems can be obtained from each owner of the impermeable areas, according to the type of use (commercial, residential and industrial) in proportion to what they contribute to the runoff plus what would occur if there was no impermeability, according to the user pays principle. The computation of these impermeable areas, however, is still not a simple task for a large part of the municipalities, which do not even have the staff and expertise for this, which requires measurements with the use of information technology and satellite images. The forms of cost attribution encounter technical and legal difficulties, and even in the USA, there is a lot of questioning, mostly demanded by non-residential owners, regarding both the legality of ownership for the imposition of fees and rates and the calculation of the parcels themselves. One aspect of interest is the proportion between areas of public responsibility, such as roads, squares, public buildings, and private areas. About this, in some locations in the USA, measurements identified between 65% and 75% of private areas able to receive green infrastructures (Dhakal & Chevalier 2016) and in Brazil, specifically in the Federal District, the split was approximately 50% between public and private.

Incentives through exemptions can also act as an incentive for private landowners to construct rainwater storage or utilization devices on their plots (e.g., green roofs) or to disconnect from public stormwater systems, leading to savings. Another form of incentive is paid to municipalities for the discharge of treated water of specified quality levels into receiving waters, as is already the case in Brazil, but only for wastewater effluent, which could be extended to stormwater. Brazil adopts a similar mechanism for effluents discharged into rivers, by ANA-PRODES program, that seeks to encourage greater treatment of effluents.

All these issues show that stormwater solutions are typical of complex systems that require the participation of all actors, involving multiple disciplines, and have a great capacity to measure various items so that they can be fairly and equitably distributed.

The issue is not only the quantification of runoffs, which can be considered through the calculation of impermeable areas but also the quality aspects that, although they can be indirectly estimated through the classification of predominant uses, also bring complexity in the evaluation, for instance, of the types of existing pollutants, requiring, in each specific case, control and treatment alternatives with different costs, which leads to the valuation of the charge according to the polluter pays principle.

Financing policies involve items related to environmental, social, economic, organizational, institutional, and political issues, which demand the kind of robustness only found with the participation of all actors and multidisciplinary foundation so that they obtain relevant results and leverage society's values.

4. DISCUSSION

To achieve positive results in terms of human and environmental demands, policies addressing urban stormwater management require the challenging confrontation of a broad and deep paradigm shift, i.e., a change in the status quo of the provision of these services.

The change, grounded in a view of stormwater as a resource rather than a problem, extends to the services that can be achieved through its use and not simply by controlling its quantity and quality, i.e., by taking care of floods and their contamination and pollution. The position as a component of the urban environment, attending the role of participating element of the urban water cycle and contributor in the achievement of the SDGs requires its accounting not only in economic terms but as a contributor of valuation aspects under other criteria, as of amenities: urban ecology, recreation and aesthetic attractions to the cities.

Concerning the role of rainwater as a resource, an idea present in the new paradigm of urban stormwater management, the epidemic of COVID-19 highlighted the need not only for policies to universalize water supply through traditional sources (surface water, groundwater and desalinated water) but also to implement policies to do so through the use of rainwater. For example, the political decisions to suspend supply cuts during the pandemic due to the default of low-income families,

in several states in Brazil, as well as the free distribution of residential water tanks to this part of the population, in the state of São Paulo, demonstrate the need for policies designed to address events such as this or the combination of multiple events (floods and Covid-19; dengue and Covid-19; drought and Covid-19), for which policy can and should consider the use of rainwater.

Economic aspects can be significant from several perspectives such as the savings provided by stormwater when compared to treatment or use permits from other sources and even expensive flood control structures, or about the energy consumed by reuse water or desalination. The control of pollution at the source has been reported to be less costly than the traditional 'end of the pipe' control.

The management structures, however, as they exist today, centralized and with few staff and expertise, are not sufficient for the decentralized service required, which demands adaptation of operational and organizational structures, the same happening with institutional structures such as laws, decrees, and regulation that lack experience in the matter (Montenegro 2017).

Concerning social actors, their participation is more necessary than in the centralized model in which decisions are made under technological viewpoints only, without taking into account other perspectives in management.

The consideration of interested actors from the point of view of resources and the financing of services necessarily brings about the perspective of their economic sustainability and the ways to make it feasible (Azevêdo 2019), causing policies to be designed 'with the public' interested not only in the provision of services but in the planning of feasible actions and operations with economic sustainability over time.

Finally, the inclusion of little-used innovations in the policies, represented, for example, by real-time monitoring and remote operation technologies coupled with meteorological data and flood warning systems, also has the potential to include more efficiency and economy in the operation of the stormwater systems.

Where they exist, drainage policies are reflected in legislation and codes to a greater or lesser degree of detail and also in policies and practices for funding and financing. For the most part, the legal, institutional, organizational, and management structures are linked to urban flooding issues or pollution control issues. Despite all the available knowledge, whether sufficient or not, policy decisions on stormwater are at present very tentative, if not non-existent. The paradigm shift from considering rainwater as a problem to an opportunity and a resource requires a policy change.

From this point of view, its use can result in a decrease in the needed amount of city water supply and even in the quantities of water to be treated and drained to the receiving water bodies.

The interrelationship between water supply and wastewater systems and urban stormwater is therefore clear, including concerning the revenue that each system generates, remembering that in many places wastewater revenue is linked to the drinking water supply and therefore a reduction in drinking water consumption through switching to rainwater has an impact on tax collection.

The obstacles related to the amount of funding as almost insurmountable barriers without advancing on the growth forecast of increased urban rainfall that already occurs and without quantifying them makes the unquantified resource an absent element of policies.

For stormwater to become part of policies, it is essential to quantify it under a new paradigm in which it is considered as part of the solution, rather than a problem, and thus perceived by the population, as policies result from perceptions of reality that arise from conflicts between actors. Such perceptions, felt by policy and decision-makers, are not always based on reality, but on what is perceived by them. Thus, the academy has the task, initially, of quantifying stormwater, which should be done locally and, finally, contribute to the explicitness of the necessary paradigm shift in its various aspects, economic, social, and environmental, proposing technological and management solutions, and with the support of an actively participating society, so that the steps to be defined do not remain only on paper, as happened with the MDGs.

There is already a concern about meeting the SDGs on several fronts, especially in the academy, which is reflected in a few publications and studies on the relationship between urban stormwater management and SDGs. Some aspects were presented, which are, however, worthy of further reflection to increase knowledge and understanding of the relationship between stormwater and SDGs, pointing out the need for ways to measure its effects.

The road may seem long, but if the first step is not taken, which is quantification and planning that take into account stormwater, followed by the development of policies under the new paradigm, supporting them with institutions and structures, and the implementation under appropriate management and supervision, the provision of urban stormwater management services in a sustainable manner will be a very difficult and more complex task.

The existing examples and experiences gained over the years through Integrated Water Resources Management (IWRM) or Integrated River Basin Management (IRBM) policies that present lessons of success and failure and their difficulties in implementation (Tortajada & Biswas 2018) deserve to be well analyzed for policymaking under a new paradigm. There are also economic instruments based on the polluter pays principle, formulated by the OECD in 1972 and adopted by the Council of European Communities in 1975, such as systems of fines and bonuses where fines must be higher than the profits gained from pollution and bonuses must be greater than the cost of pollution abatement, but these are instruments that require accurate information on the amount of pollution.

Finally, when considering the necessary participation of actors, one should not lose sight of the fact that consensus solutions should prevail, knowing that consensus does not mean unanimity, much less is carried out by actors on equal terms and resources, even if policies can be understood as resulting from conflicts of interest between participants with diverse interests and objectives in democratic contexts of participation, and more, that what we have today is the result of the application of successive public policy choices made previously, that is, it depends on the paths built by previous policies shaped within the optics of an old and aged paradigm.

As examples of successful Water Sensitive Urban Design (WSUD) policy implementation in Australia and the USA, from which relevant numbers and conclusions can be drawn, can be cited: Etowah HCP Stormwater Management Policy in Georgia, USA; Portland's Downspout Disconnection Program, in Oregon, USA; Nine Mile Run Rain Barrel Initiative in Pennsylvania, USA; KC'S 10,000 Rain Gardens Initiative in Missouri, USA; Victorian Stormwater Initiative (and Clause 56, etc.) in Melbourne, Australia and Healthy Waterways Partnership in SE Queensland, Australia (Roy *et al.* 2008).

In terms of figures, one important aspect, perhaps the greatest, concerns the number of impervious surfaces, as these areas generate surface runoff that should be the target of public policies for the management of rainwater runoff that encourage its reduction over time, for example, by using the polluter pays principle. Some examples are worth noting: (1) in the German city of Munich, since 1995 more than 4.5 million m^2 of impermeable surfaces have been removed, resulting in a reduction of runoff by 3,000 million L per year; (2) in Melbourne, Australia 608GL (more than 300,000 L per household) are generated on the streets and roofs in an average year with 650 mm rainfall. Policies designed with appropriate incentives, based on the polluter pays principle, can generate benefits for all, with reductions in Water and Sanitation Services bills, for German cities, estimated to average 14% with the potential possibility of reaching 28% with optimization of stormwater use (Vietz *et al.* 2018).

5. CONCLUSIONS

This research discusses the policies regarding urban stormwater drainage and management services, where they exist, from a theoretical perspective, i.e., their relationship with existing institutional and regulatory frameworks, but also from a practical perspective, by addressing ongoing actions that seek to implement these policies in various locations and those global policies, such as SDG6, that should be present across the board in all countries.

The contribution of this paper brings elements to reflect on what exists but also on what remains to be done to ensure that stormwater management services take their rightful place among the various urban services offered to the city's population. The existing gap, however, presents itself as demanding a paradigm shift that is necessary to make the provision of these services not just a wish but a reality.

Besides the conclusion that a paradigm shift is necessary and involves technological (e.g. source control), social (e.g. multi-stakeholder participation), economic (e.g., equitable and multi-source funding), managerial (e.g., hybrid centralized and decentralized), institutional, regulatory, and organizational (e.g., legislation and structures) and many others, there is a strong emerging view that policies for stormwater infrastructure and services must be premised on meeting multiple challenges simultaneously such as epidemics (e.g., dengue, Covid-19) and other events that occur at the same time as flooding or scarcity. Therefore, they must be flexible and embrace the concept of dynamic resilience of complex urban systems and the infrastructure that supports them.

By considering these concepts, political solutions might be more successful since they will have the capacity to adapt according to the evolution of events that demand them, abandoning the static and rigid vision of policies centered on conservatism and the maintenance of the status quo, whatever it may be.

DATA AVAILABILITY STATEMENT

All relevant data are included in the paper or its Supplementary Information.

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