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Regulation of urban stormwater management is not a matter of choice, but performance

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ABSTRACT

Public services regulation is not a new subject and neither is its application to urban water services. Regulation is part of the set of instruments available for running public policies but does not occur alone, i.e., without institutions, the rules governing interactions between actors. However, when it comes to stormwater management, regulation is not always present, either in a soft form, through best practice guides, or in harder forms, such as command-and-control mechanisms. Literature and practice show that their absence hinders the desired provision of stormwater services. This paper seeks to present and discuss aspects related to the subject of regulation focusing not only on the need for regulation but also on the alignment between policies, institutions, and regulation (PIR) around the goal of achieving performance in delivery services. The objective and novelty of the reflections presented here consist in contributing to creating a new mentality on the need for this alignment. Aligning regulation issues within the PIR context creates opportunities to save resources and to bring better performance. This is not few and nor a matter of choice, but of the need to improve performance to face urban demographic increase, aging and obsolescence of infrastructure, and climate change challenges.

Key words: Mentality change, Public policy, Regulation, Stormwater management, Utility services

HIGHLIGHT

- This text goes beyond the precipitation of rainwater; it is about brainstorming. Brainstorming of aspects situated in this lackluster interface between the regulation and management of urban stormwater services. It seeks not only to illuminate the penumbra that exists there, but also to provoke more than just reflection. It seeks to encourage action from those who decide which public policy changes are necessary.

1. INTRODUCTION

Policies, institutions, and regulation (PIR) are part of a set of interconnected aspects that determine the incentives for the adequate provision of services. Policies provide the guidelines for action, and institutions (formal, such as laws, and informal, such as habits and behaviors) are the rules of the game, i.e., they govern the set of interrelations between the actors (government, private initiative, and civil society) that participate in the actions (North, 1990), institutions limiting and defining the actor's decision space (Geyler *et al.*, 2019). Regulation controls the progress of actions and results toward the goals set by policies. The alignment of these three aspects around the goal of adequate service delivery allows the desired results, and when this does not happen, performance is insufficient to meet society's expectations (Mumssen *et al.*, 2018a).

In cities where wastewater and stormwater runoff systems are combined, the management and regulation of sewage systems are carried out jointly, with no explicit mention of stormwater runoff systems. In the case of separative sewer systems, the need for the regulation of these systems becomes more evident as they are clearly shown to be a public service, independent of wastewater, and as such should receive economic and financial support in addition to having the quality of their service performance evaluated.

The fact that the management of these services is carried out directly by municipalities and that their costs are borne by general municipal budgets contributes to the prevalence of the view that their effects on the well-being of society are not as relevant as they are. Another feature that reinforces this view is the fact that their use is little noticed, i.e., only during rainy periods when stormwater drainage systems and infrastructure are effectively in demand.

The reality, however, has been altered in recent decades as a result of: demographic changes, which have produced increased storm runoff due to the growth of sealed urban areas; climate changes, which are producing both increased rainfall (frequency), higher peaks (intensities), and durations (volumes), and shortage events while runoff infrastructure is aging and becoming obsolete. These facts make budgets insufficient for all demands, whether in quantity or quality.

Thus, stormwater management becomes significant within the urban water cycle, whether during times of scarcity or abundance, in the first case considering the possibility of its use as a resource and in the second due to the need of controlling it, avoiding damage and pollution.

The regulation of these waters is, therefore, a question of economic and environmental efficiency, not only in the use of an available resource but also in the management of the other material and environmental urban resources present. Stormwater regulation is not just an option but an effective way to increase the performance of urban systems and the well-being of cities.

Regulation can be defined as the control, exercised through self-regulation, contracts, or by a public agency over the activities that have value for society and involve establishing and ensuring the application of rules, whether economic such as, for example, the setting of tariffs or of service delivery and quality standards, and may include goals of access and equity (Marques, 2005).

Thus, the establishment of, for example, a policy of charging tariffs on the waterproofed areas on each lot, supported by clear and fair rules (institutions), allows the regulation to determine acceptable levels of tariffs to encourage demand management by users and contribute to efficiency gains by suppliers. Such a policy, supported by established rules (the institutions) and enforced through appropriate regulation, aligns the PIR tripod and creates incentives for runoff reduction acting as a driver to the improved performance of urban stormwater runoff systems. So does a policy of subsidizing the construction of stormwater ponds on lots.

Similarly, the establishment of stormwater policies, such as Water Sensitive Urban Design (WSUD) in Australia, requires that in addition to formal institutions (e.g., laws and ordinances), informal ones (e.g., customs and behavior's) and enforceable regulation are all aligned and properly accepted by the society to produce effective results.

Regulatory changes or reforms will be introduced by diverse actors such as politicians, policymakers, senior government officials, and donors who will choose what types of policy, institutional, and regulatory interventions and what incentives will be encouraged with them.

The will of political actors alone cannot, however, promote the necessary long-term incentives, especially given the alternation between administrations (Kresch & Schneider, 2020), but when regulatory incentives are aligned with local needs and institutional capacities, good results in terms of service delivery can be achieved (Mumssen *et al.*, 2018b). The water sector may suffer from political interference such as, for example, the practice of reduced tariffs for electoral purposes, reflecting on the performance of service provision (Berg, 2013).

This paper aims to analyze some issues, not very frequently addressed in the literature, related to the urban stormwater management service regulation. Its relevance is debated using international experience, understanding that this discussion may contribute to reflections, mind change, and to decision-makers in achieving better performance results.

This article, based on a methodology of narrative analysis and case studies, refers to what exists in the literature and practice, and seeks to reach the subject of regulation from the point of view of its connection to political and institutional aspects and how the alignment between the PIR makes the enabling environment for the effectiveness of actions. It makes several contributions to the literature since curiously there are few publications discussing these matters. Besides the discussion and the relevance of the topic, the paper reviews and analyses several international experiences of stormwater management regulation.

It is necessary to point out that there are limitations in the methodological approach adopted, especially due to the literature span and countries discussed, which, although far-reaching, evidently did not cover everything that exists, and the same can be said about the authors' experience.

The paper is organized as follows. Section 2 deals with the technical and economic regulation of stormwater systems. Section 3 presents the international experience in the regulation of stormwater systems. Section 4 analyses the Brazilian case, a developing country, because it has undergone recent regulatory initiatives, still under construction, which can be an example for other developing countries and also on how the PIR alignment can work. Brazil was also chosen due to the proximity and knowledge of the authors on the regulation in this country. Section 5 discusses the results and section 6 draws the main conclusions.

2. REGULATION OF STORMWATER SYSTEMS

2.1. Quality and equity as objectives – technical regulation

For a long time, attention on stormwater runoff was focused on solving quantitative issues, i.e., water volume. As a result of this view, the quality of stormwater runoff, plus the pollution it carries, only became important after studies demonstrated that runoff is a significant source of contamination of the environment and receiving water bodies (Todeschini *et al.*, 2014).

Both urban runoff that occurs during wet periods and dry periods, such as runoff from agricultural activities (e.g., runoff from landscape irrigation), began to receive attention as sources of pollution produced by human activities.

The regulation of service quality emerged in many places based on the pollution perception. Linked to stormwater pollution, as it was in the USA in the 1980s, through Section 402 (p) of the Clean Water Act (CWA) enacted in 1972, based on the Federal Water Pollution Control Act, enacted in 1948, CWA establishes the basic structure for regulating discharges of pollutants into waters of the USA.

Quality regulation is generally carried out, taking into account criteria and parameters not only present in laws and regulations but also with the use of performance indicators, which are widely used since the 1990s (Bolognesi & Pflieger, 2021), and should evolve in the stormwater sector, considering not only pollution aspects, but also others related to the provision of urban services not so easily measurable. These services include those associated with the well-being of cities, such as heat islands, water recreation, and urban beautification, which are classified as amenities (Coutts *et al.*, 2013), as well as the growing use of stormwater to replace traditional potable water uses, such as toilet flushing and the irrigation of green areas.

Technical regulation is now focused on managing the quality of the stormwater resource rather than the quality of the assets that transport or accommodate the physical volumes of stormwater, and this is a result of the paradigm shift that is underway involving a shift in focus from quantity to quality management. The demographic growth of cities, combined with the aging of existing infrastructure and climate change, means that quality aspects are added to new quantity aspects, creating new performance and regulatory standards for urban stormwater systems.

More than that, in places where the universalization of services has not yet been achieved and in which economic and social inequality is a striking feature, as is the case in Brazil, regulation should seek not only purely economic objectives and goals, but also others that imply the inclusion of the excluded and equity in access and use of urban water systems.

Universalization as a policy goal and regulation as an instrument to achieve it, as intended by the new Brazilian water legal framework, should also be built taking into account solutions for urban water in slums and the peripheral urban fringes, located at the urban–rural interface.

2.2. Regulation as an incentive for efficiency – economic regulation

Economic regulation of municipal stormwater services, either public or private, is affected by the new technical and quality regulation requirements and standards as they affect costs and are transferred to tariffs within limits set by economic regulators. This is the case in England and Wales (Molinos-Senante *et al*., 2020).

Economic regulation also achieves aspects of equity in the use of infrastructure by promoting through the user and polluter-pays principles, more equitable distribution of burdens on those who are responsible for larger sealed areas (e.g., large parking lots), and higher pollutant loads (e.g., industrial and commercial areas) in the runoff than was previously the case, with system costs falling on everyone.

Economic efficiency and competition, although not an end in themselves, are instruments used to achieve economic and social developments as ultimate goals. In the absence of competition, efficiency losses occur, as is the case of monopolistic markets such as water services, characterizing the so-called market failure, thus giving rise to the participation of the regulatory state to act to compensate for this failure, and circumvent, through regulation, the power of monopolies and the lack of competition (Marques, 2010).

There are also other market failures, the so-called externalities, through which an individual suffers positive or negative effects of the activities of others. Network externalities, in which the existence of a network benefits the users who participate in it, occur also in stormwater management systems, raising the issue of non-exclusion of access and non-rivalry in consumption, which allows the emergence of the phenomenon of 'free rider', in which users participate in consumption but not in the provision of services, leading to inefficiency.

Regulation can, therefore, be seen as a source of incentives for efficiency in service provision. One way to create these incentives is through a tariff policy that includes productivity earnings, which can lead to the formation of municipal consortia, especially when the municipalities realize that the economy of scale offsets the higher transaction costs of shared management (Narzetti & Marques, 2021).

The determination of fair and reasonable tariffs, which consider the measurement of impervious areas over which precipitation occurs, is divided into two parts, i.e., the public, consisting of roads and public places such as squares and parks as well as public buildings, and the private, consisting of properties and buildings under a private domain (Ribeiro, 2016), constitutes an economic incentive for the good use of soil and stormwater. By reducing soil sealing, it will be possible to obtain more efficiency in the use of infrastructure favoring its economic support from the perspective of the user-pays principle. The use of rainwater as a resource, for example, for non-potable uses (toilet flushing and garden watering) is configured as another form of efficiency, not only through savings in the use of water supply, but also a decrease in revenue related to water supply and wastewater tariffs, without a reduction in the use of sewerage infrastructure which can be configured as an economic inefficiency.

Besides that, the pricing structure where wastewater costs are estimated from water supply volumes does not encourage the use of rainwater as it leads to the loss of revenue by reducing the water supply metering. The simplicity of revenue determination and tariff regulation from this type of pricing structure becomes a disincentive for efficiency when rainwater use comes into the picture. In this way, the price and tariff structure are barriers not only to the use of rainwater as a resource, but also to the full use of the urban water cycle, and consequently can delay universalization where it has not been achieved (Machete & Marques, 2021), which is one of the objectives of regulation.

Another type of inefficiency arises from the exclusion of part of the population, implying a loss of economic scale and revenue. The tariff affordability should be considered so as not to exclude from the services those communities with lower incomes. As suggested by Gomes *et al*. (2008), in a calculation methodology aimed at financing urban stormwater systems, the water supply, wastewater collection, stormwater services, urban property, and land taxes should be limited to a total of 5% of the household income.

In the case of combined system (CS, wastewater and stormwater), the estimated portion of operation and maintenance costs incurred by stormwater is between 20 and 35% of the total, and the amount of capital investments is around 30–50% of the total of these systems (Abdelmaki, 1999). These values, if confirmed, according to the characteristics of each location and service provider, deserve to be segregated and accounted to the stormwater systems in terms of revenues to contribute to their economic support.

Furthermore, in combined wastewater systems, charging is done usually through a percentage on the water bill and this includes an estimated charge for wastewater services. In the absence of stormwater regulation, there is undue taxation of a service that is not provided, i.e., of stormwater regulation, which is yet another type of economic inefficiency.

Lastly, concerning regulation costs, the creation of stormwater regulation brings costs to providers that are reflected in the tariffs, through regulation fees, which can be significant for smaller municipalities with less than 10 thousand households, due to economies of scale. As pointed out, multisector regulation (joint regulation of several sectors such as electricity, gas, and water) could be an alternative to reduce regulation costs (Henten *et al*., 2003; Jordana & Levi-Faur, 2010). Another alternative is the union of municipalities in regulatory consortia, which allow the dilution of costs among several municipalities, as is being proposed in Brazil.

3. INTERNATIONAL REGULATION OF STORMWATER SYSTEMS

3.1. United States (USA)

The first country to be included in the study is the USA because it is where the federal regulation of urban stormwater is at a very advanced stage and where it has even pioneered the adoption of stormwater utilities as a way to organize the collection of funds to meet the increasing demands (since 1948, with the Federal Water Pollution Control Act –FWPCA) for strict legislation for the control of diffuse urban stormwater pollution in municipalities of all sizes.

In the USA, where stormwater utilities are widely used in the operation, management, and disposal of urban stormwater, regulation is originated from concerns over effluent quality and the contamination of receiving bodies and is mainly carried out through determinations issued by the Environment Protection Agency (EPA), since 1972, in accordance with the CWA. According to the EPA, the regulated area comprises 4% of the American territory but corresponds to more than 80% of the total population.

The concern with the quality and pollution of receiving water bodies was the motivation for the control of surface runoff that occurs mainly through the Municipal Separate Storm Sewer System (MS4), i.e., the transport systems of stormwater runoff, neither to be confused with CS, nor with the systems of the treatment of runoff effluents.

Discharge authorizations are a requirement for MS4 operators, as are stormwater management programs to prevent the input and conveyance of pollutants through the MS4. The programs detail the measures taken to control pollutants and state authorities are assigned responsibility for the National Pollutant Discharge Elimination System (NPDES), and in some locations, this is carried out by the EPA as the responsible authority (Office of Water, 2005; EPA, 2010).

Since 1990, NPDES-compliant discharge permits have been required of MS4 operators in two phases: phase I, in 1990 (regions with more than 100,000 inhabitants; construction activity disturbing 5 acres of land or more; 10 categories of industrial activity; 855 utilities; covered by 250 individual permits) and phase II, in 1999 (regions with less than 100,000 inhabitants; small construction activity disturbing 1–5 acres of land; 6,695 utilities; covered by State General Permits (SGP), but some states use individual permits). There are also three watershed permits covering 3 phase I and 40 phase II MS4 (Collins *et al.*, 2012).

The development of phase II involved extensive stakeholder participation through consultations convened in a committee, constituted under the Federal Advisory Committee Act (FACA), with representatives of small entities and comments about the proposed rules submitted by more than 500 individuals and organizations during 90 days of public consultation.

In 2020, a survey collected information about the stormwater utilities. The regulatory requirements they were subject to, presented, as a result: 100% of the sample utilities are submitted to an MS4 permit; 51% to total maximum daily load (TMDL); 49% to NPDES wastewater discharge permit; 10% to combined sewerage/excess/long-term control program (LTCP); 7% to other special permits; 7% to sanitary sewer overflow (SSO) management plan; and 4% to integrated watershed permit (Black & Veatch, 2021).

The survey, in terms of decision priorities and levels of annual capital expenditure, pointed a score of 3.9 to regulatory compliance, on a scale of 1–5 (very strong), ranking third, after the management of stormwater conveyance infrastructure (2nd) and flood control (3rd). For the item that contributes most to improving management, the expansion of regulations came fourth, with a score of 3.7, after funding adequacy (1st), awareness and support of society (2nd), and aging infrastructure (3rd).

There is state legislation authorizing the collection of stormwater tariffs by municipalities (84%), and the collection of tariffs is carried out on an area basis (according to 89%) with total areas or impervious areas computed (86%) and in the remaining 14% both types.

The computation of areas is based on aerial and digitized images of the impervious areas (54% of the answers) through the analysis of the footprints of the buildings from the tax systems (28%), a total gross area with an impervious factor (9%), and other methods (9%). The type of residential charging structure is based on: uniform tariffs (flat fee) (66% of respondents), calculated individually on a case-by-case basis (12%), and 22% stating that they use tiered tariffs in up to five levels. The average monthly residential tariff value, different in each state and city, varies from US$ 0.84 to US$ 25 (Black & Veatch, 2021) and is related to aspects of geographic location, population density, and home value (Kea *et al.*, 2016).

Register updating of total and impervious areas of units is carried out through the Geographical Information System (GIS) (Sydnor & Dunn, 2015) in 59% of respondents.

Prices are considered by users as affordable or most affordable in 68% of respondents. Most of the utilities (68%) inform that they do not offer discounts. There are exemptions, based either on legislation or on the utilities' own rules, for certain areas such as streets, roads, public spaces, or public passage (63% of the utilities) and several others.

Most utilities (79%) did not face legal challenges (Mcgovern & Hampton, 2016) and the remaining (21%), mostly were challenged by users in the nonresidential categories (79%), regarding the collection of tariffs.

There is a provision of incentives for reductions in runoff volumes and peaks, water quality, education, direct discharge into surface water bodies, good practices (such as oil separation and sweeping), and zero discharges. The modalities of incentives are cost-sharing (60% of respondents), design assistance for best management practices (BMPs) (50%), discounts for implementation (20%), reduced interest for loans (10%), and stormwater grants (30% of respondents).

In the USA, CS are designed to collect and convey large volumes of stormwater and wastewater, while the sewerage system (SS) conveys only small amounts of stormwater and groundwater to treatment plants. These result in overflows that cause the contamination of water bodies and return to buildings with adverse health effects. These occurrences are due to blockages, bursts, defects in pipes and networks, pumping failures, or design and vandalism and are, according to the EPA, responsible for about 23,000–75,000 SSO events annually, disregarding the returns to buildings (EPA, 2022).

Concern about these events has led stormwater management programs to take them into account by setting as one of their objectives the reduction of pollutant discharges to certain levels considered to be the 'maximum practicable' or the maximum extent practicable (MEP), protecting water quality and complying with the CWA.

Phase II MS4 programs consider stormwater as point sources of discharge and rely on six joint minimum objectives to achieve the MEP: education and outreach on stormwater impacts (Biehl & Buechter, 2011), societal engagement, elimination of illicit discharges (Irvine *et al.*, 2011; Derrick & Moore, 2015), construction of runoff controls, post-construction stormwater management, management in new and rehabilitated developments, and the implementation of best practices and pollution prevention for municipal operations.

3.2. Europe

In Europe, stormwater management falls under the Water Framework Directive (WFD) 2000/60/EC – ecocentric – and also the Floods Directive (FD) 2007/60/EC – human-centric (Jensen *et al.*, 2020) – the latter integrated with the former to promote integrated management by the catchment, but with specific variations in each country, produced by a mix of regional and central agencies, but not always adopted in local legislation. The focus, however, refers to aspects of water quality and quantity, mainly directed at the receiving water bodies, leaving the approach on the origin and generation of urban runoff to a secondary level, without even mentioning the term 'stormwater' or, in a more detailed way, the economic aspects of regulation, such as the polluter-pays principle for stormwater management systems with the sharing of responsibilities for the generation of runoff in qualitative and quantitative terms.

The WFD refers to drainage only twice (Jensen *et al.*, 2020), firstly when dealing with the artificialization or modification of surface water bodies that suffer from the effects of rainfall-runoff draining onto land, and secondly when identifying potential groundwater pollution through recharge with runoff from rainfall drained artificially into groundwater.

In Germany, there is increasing decentralization in urban stormwater management, and regulation is carried out by municipalities using mainly incentive instruments such as tariffs and discounts on usage and compulsory connection, following the establishment of local and national laws and codes and multidimensional objectives. Decentralization receives, however, questioning due to the loss of economies of scale and the high transaction costs involved (Bedtke *et al.*, 2019). The disconnection of impervious areas contributes to the better performance of the systems and is an important aspect to be regulated. In areas of dense, consolidated urbanization, however, it encounters many obstacles. The city of Berlin, which has a separate system, was analyzed with the use of GIS technology, and the result concluded that it is possible to easily disconnect 30% of the impervious areas (Sieker & Klein, 1998).

In France, the existence of some 36,000 municipalities makes it difficult to comply with the principle of subsidiarity, especially regarding urban stormwater where ownership and problems are under the responsibility of the communes and therefore the control and regulation of services lie at the local level. Nevertheless, water agencies are responsible for setting charges to users for water use, leading to the financing of wastewater and stormwater infrastructure with resources obtained from water bills, which raises questions as the French option is for a separate wastewater system and there is also a provision in the law for associations of municipalities to charge for stormwater management (Barraqué, 2013).

In the United Kingdom (UK), since the water system privatization, the body responsible for the economic regulation of water services is the Office of Water Services (OFWAT), while water quality regulation is a responsibility of two agencies: the Environment Agency (EA) and Drinking Water Inspectorate (DWI). The governance of this system has become more complex and sophisticated, but paradoxically with budgets that do not grow in the same magnitude as the demands, which is a great challenge. There is a Sustainable Drainage Systems (SuDs) guidance, produced by Construction Industry Research and Information Association (CIRIA), with aspects of compliance to the SuDS principles that is followed by all actors and serves as regulation rules.

3.3. Australia

Australia, which has undergone a long transition process concerning urban water over the last decades, highlights the fact that policies are not implemented on their own and depend on instruments such as regulation to make them work. Like policy frameworks, regulation is part of a set of factors conditioning actors' behavior and can be classified in two formats: 'soft' like policy frameworks or best practice guidelines, which only encourage behavior, or 'hard' like command-and-control structured regulation, which compels it. The Australian policy shift toward WSUD was characterized by several phases and the coexistence of 'soft' and 'hard' regulations. Initially, there was a successful phase with an institutional reversal creating the perception that transition processes of complex systems require regulation and attention in their trajectories as was the case of the transition from the traditional model of urban stormwater management in South-East Queensland to WSUD (Werbeloff & Brown, 2016). Anyway, in the most important urban areas such as the Sydney metropolitan area in New South Wales or the Melbourne region in Victoria, the multisector regulators set tariffs and quality guidelines for the stormwater systems (by Independent Pricing and Regulatory Tribunal – IPART in the former and Essential Services Commission – ESC in the latter).

3.4. Other regions

In Latin America, regulation is almost non-existent and even in Chile, considered as an example of water regulation, there is no specific regulation for stormwater services.

In China, there are projects implemented locally, at the municipal or sub-provincial level, under the Sponge Cities Initiative (SCI) program, a national initiative for the construction of sponge cities. Under the Low Impact Development (LID) idea, the central government program has edited a preliminary technical guideline, aiming to establish a regulatory structure, but still lacks financing and management models such as Public–Private Partnership (PPP) arrangements, which, despite being encouraged (Jiang *et al.*, 2017), do not yet have mature legislation and regulation (Zhang *et al.*, 2019). In the prosperous city of Ningbo, for example, which is undergoing rapid expansion, only one PPP project was initiated until 2018 according to government information (Griffiths *et al.*, 2020; Qi *et al.*, 2020).

4. REGULATING STORMWATER SYSTEMS IN BRAZIL

4.1. Introduction

In Brazil, according to legislation (decree no. 7.217/2010), urban stormwater management services include urban drainage, urban water conveyance, detention and retention of urban stormwater to dampen flood flows, and treatment and final disposal of urban stormwater.

The public service of urban stormwater management, being a water service of local nature, i.e., a public function of common use to be provided locally, is owned by the municipalities and, therefore, its provision is performed directly by the municipality or by third parties under delegation (law no. 11.445/2007).

However, even though it requires a specific administrative structure and its own revenues for its proper functioning, most municipalities provide services directly without disentangling this service from other municipal functions, and accounting for their costs and other resources jointly. Besides, they usually do not count on dedicated revenues, legal instruments, and exclusive staff (Baptista & Nascimento, 2002).

Infrastructure related to urban stormwater management services is incorporated into the municipal assets and depends on the overall municipal budget for maintenance and expansion, or on state and federal resources which, in turn, have priorities that are not always identical to those of the municipality. The road system is part of the municipal urban stormwater systems and, as the latter is often considered part of the former, is included in the roads budget (Nascimento *et al*., 1999).

The integration and complexity of urban stormwater management involve aspects related to the road system, land use and occupation, management of permanent preservation areas, protection of aquifer recharge areas (Caprario *et al*., 2019), and flood mitigation, as well as care in endemic areas related to various diseases (malaria and dengue). The planning activity involves a coexistence between three plans: municipal master, water and sanitation (WSS), and urban drainage, which are all mandatory for municipalities to obtain resources from other federal entities (Decree 7.217/2010). In addition to the dialogue between all these municipal plans, it is required to exist integration with plans for water resources, preservation areas, and hydrographic basins and health, which are activities that cannot be delegated (law no. 11.445/2007). Regulation and execution of services, which are also municipal responsibilities, can, however, be delegated to other entities, including consortia (Oliveira & Marrara, 2017).

4.2. The role of the National Agency for Water and Wastewater (ANA)

Recently, the regulatory landmark of water services was updated by Law No. 14.026 of 2020 intending to speed up the universalization of water services in Brazil. This new law was prepared in such a way as to allow for the standardization of existing experience and knowledge to make the universalization of services feasible and provide for greater involvement of private capital, given the reality of fiscal stress and insufficient public resources to meet the necessary demands.

Among the new features, Law No. 14.026/2020 created a federal regulator (ANA) for water services with responsibility for establishing reference standards which are guidelines that subnational regulatory agencies must comply with. These guidelines should aim at economic sustainability, reducing costs, improving quality, and expanding the coverage of existing stormwater networks, all of which are aspects that depend on information about what exists, including how stormwater management is perceived by the population.

Reference standards will be prepared after listening, through public hearings, of all stakeholders and subnational agencies and, before coming into effect, submitted to a regulatory impact analysis (RIA). They will not be mandatory, but their acceptance will be a condition for access to federal public resources. It is also up to ANA the challenge of making water resource plans (basin level) compatible with the urban stormwater and solid waste (municipal level) plans (ANA, 2020).

This recent legal determination (Brasil, 2020), to assign responsibility to ANA for the elaboration of national reference standards regarding water regulatory issues in Brazil, has raised expectations of improving the performance and results of the sector. As to this, however, the observations made for water services, by Berg (2013), are pertinent, including urban stormwater management:

'…sector regulation must be embedded in an adequate and consistent institutional framework to have a positive impact on performance. Sector regulation alone is no guarantee of performance improvements in water supply and sanitation services. The case studies and empirical analysis suggest that without significant changes in the institutional environment, typical regulatory tools will not be effective. This finding is of concern, especially for developing countries, as it means that the creation of a regulatory agency may raise expectations, but ultimately the agency's rules may not be of improving the performance of the provider(s), without additional politically difficult initiatives being taken.'

4.3. Regionalization

To allow the universalization of services, an aspect of regulation, taking into account that a large part of the municipalities have deficits and receive subsidies from other municipalities through the cross-subsidization mechanism, the creation of 'blocks' of municipalities was encouraged by the new law to generate economies of scale turning blocks economically sustainable.

The design of 'blocks' considering only economic and tariffs aspects of WSS, without taking into account the costly infrastructure of urban stormwater, makes the intended integrated vision to suffer from the exclusion of a water urban cycle component that, in most countries, for a long time has no longer been considered as 'off accounting and economic regulation'. These costs are especially significant due to the effects of increasing rainfall related to climate change and its costly natural consequences like disasters. This non-inclusion, or just its consideration in a third level, can be deemed, however, a mistake in terms of management of the water urban cycle. From the aspect of cost recovery, if we want to seriously consider the performance and economic balance of the 'blocks', also the socio-economic-environmental quality existing today in the territories and which is intended to be achieved with universalization must be taken into account.

Quantification is not an easy task, but one that must be faced under the unavoidable consequences in the construction of unsustainable 'blocks', whether economically or politically, calling into question the strategy of universalization by the use of regionalization or leading to enforced authoritarian decided solutions, under §3° article 52 of law no. 14.026/2020, which is in opposition to the principles of democratic participation present in the legislation (law no. 11.445/2007).

4.4. State regulation by agreement

In the municipality of São Paulo (SP), the largest urban agglomeration in South America, the regulation of water and gas is carried out through a multisector agency, the Water and Energy Regulatory Agency of the State of São Paulo – ARSESP (São Paulo, 2007). The investments in the municipality are defined jointly by the State of São Paulo and SP Municipality, according to the municipal and State Plans through a management committee composed of representatives of the two federative entities.

By means of law no. 14.934 of the municipality of São Paulo (Prefecture of São Paulo, 2009), an agreement was signed between the municipality, the State, ARSESP, and the São Paulo Water State Company (SABESP), aiming at regulating the shared offer of WSS in the municipality of São Paulo, provided by SABESP, valid for 30 years, extendable for an equal period, in which a minimum of 7.5% of gross revenue from services (after the deduction of certain taxes) is allocated to the Municipal Environmental Sanitation and Infrastructure Fund (FMSAI), and 13% is earmarked for investments in water and environmental actions. The FMSAI is accounted for and operated by the Municipal Housing Secretariat and managed by a council that must apply the resources according to the investment priorities contained in the Municipal Sanitation Plan, as shown in Figure 1.

The fund's actions (Figure 1) focus on aspects related directly or indirectly to stormwater urban water management, such as cleaning, depollution, and channelization of the water lines, the implementation of systems to capture, store, and use stormwater in public facilities and areas of influence or occupied predominantly by low-income populations, the implementation of linear parks and areas to protect natural conditions and of water production, land regularization, and social housing, and the improvement of mobility in areas of precarious settlements. There are positive aspects in the FMSAI institutional organization, especially regarding the maintenance of a permanent source of funding, although this is not exclusive to stormwater management actions, sharing resources with other areas, such as housing. Within the scope of the FMSAI, however, the integration with other areas, such as health, environment, planning, water resources, land use, land occupation, and urban policy (some of which have seats on its Steering Committee), is seen as a positive factor, since water services are transversal and correlated with territory and society (Montenegro *et al.*, 2021).

The linking of revenues from the stormwater management component to the water supply component, however, deserves to be analyzed to verify if this form is not a limiting factor to the development of actions that are required for the efficiency of planning, management, and its regulation and inspection.

4.5. Stormwater regulation in the Federal District (Brasilia)

The lack of institutionalization of stormwater management services in Brazil is generally reflected in the absence of public entities specializing in the provision of these services, specific revenues to fund the activity, few urban stormwater master plans, integrated with municipal WSS plans, and no regulatory activities.

One of the few exceptions to this general picture can be found in the Federal District (Brasilia), where the Water and Power Regulatory Agency (ADASA) has been developing activities aimed at encouraging the structuring of urban stormwater management services, including aspects related to economic regulation, with support from the proposed tariff collection based on impervious areas and taking into account land uses and the population's ability to pay, according to the legislation in force.

The barriers to the implementation of the proposals issued by ADASA, however, do not differ from the rest of the municipalities regarding the lack of specialization of the body in charge of the stormwater management, i.e., Urbanization Company of New Capital (in Portuguese, the Companhia Urbanizadora da Nova Capital – NOVACAP). This company does not have specialized staff and a concession contract and competes with other bodies for resources from the general budget of the Federal District (FD). Therefore, it finds obstacles to

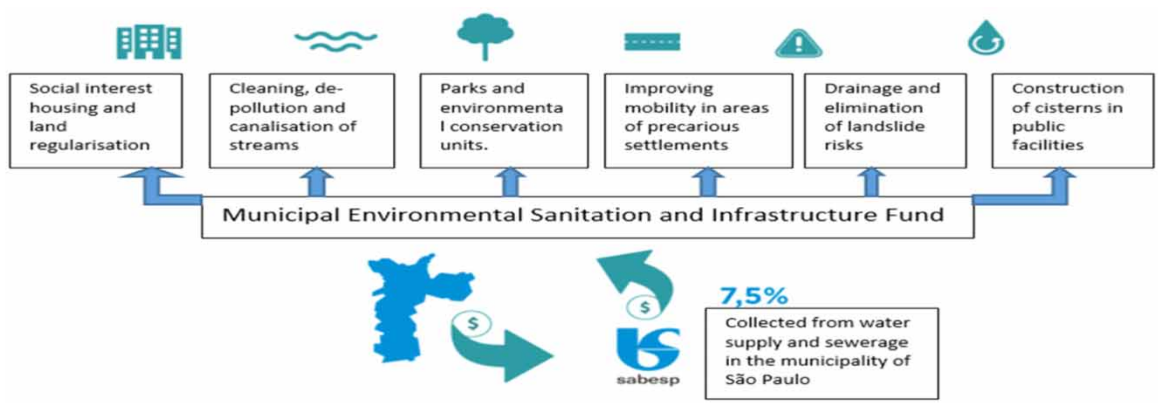

Fig. 1 | Municipal Environment Sanitation and Infrastructure Fund (FMSAI) sources and applications (https://www.prefeitura.sp.gov.br/cidade/secretarias/habitacao/fmsai/apresentacao/index.php?p=145635, adapted).

the maintenance of services in an adequate way, a fact that is reflected in the few investments for the maintenance and replacement of the dedicated stormwater infrastructure with the consequent and frequent flooding.

Concerning the planning, the existence of an Urban Drainage Master Plan (PDDU) and a Federal District Basic Water and Sanitation Plan (PSBDF) are important instruments, but in the absence of permanent sources of funds, they are of little use.

Ongoing efforts toward the quantification of impervious areas, whether public or private, will allow the individual estimation of each lot contribution to runoff to the existing public network and thus, also the calculation of the amounts necessary for the materialization of the user-pays principle and the economic sustainability of stormwater systems. The establishment of individualized tariffs with possible reductions to owners who have retention devices or other ways of using rainwater that falls on their lots, or even disconnection from the networks, may be possible and is a reason for regulation by the agency, as they constitute incentives to reduce runoff and associated costs.

The portion corresponding to the rainfall occurring in public areas, such as roads, streets, squares, and others for common population use and public buildings, should receive resources from the public budget. ADASA's study has computed that results for the percentage of impermeable areas in the Federal District of Brazil are 49% for private areas and the remaining 51% for public areas of the common use of the population (Montenegro, 2019).

Thus, the importance of regulation is visible in the actions and proposals made by ADASA, in which the regulatory agency develops relevant contribution by identifying and qualifying the alternatives for the institutionalization of services through the improvement of the organization of service provision and the study of the charging model to be adopted. This latter involves not only the costs of the system, but also the quantification of social tariffs, cross-subsidies, and other parameters necessary for the economic and quality of service regulation of the urban stormwater management in the Federal District.

Finally, the State's performance in its role as a planner, a regulator, and responsible for the activities at all levels of government and as a participant in the financing and management, following constitutional precepts, does not escape the focus of the debate on social democratic rights to water and also economic efficiency (Neto & Camkin, 2020).

5. RESULTS AND DISCUSSION

The absence of regulation as a performance leverage tool that should be part of stormwater management cannot be attributed to the lack of an object to be regulated but to the absence of its institutionalization and of policies. This arises from the fact that it is not present in the mindset and will of political decision-makers and the population, as one issue requires public policies and consequently with a gap in the provision of resources (Werbeloff & Brown, 2016). As in other sectors, we may question the ideal moment to implement its regulation: before, during, or after the institutionalization of the activity.

This is, however, a false question, which may arise due to the erroneous view that only private concessions should be regulated. In its origin, as it is known today, regulation was originated in the USA and in the water sector in England and Wales, linked to privatization issues. However, in Chile, for example, the regulation of water services, which is considered successful, was initiated before their privatization (Ducci, 2007), but until now without no stormwater regulation. The regulation idea has evolved, and examples regarding the forms and moment of their implementation show that there is no general rule, but that, as well as the allocation of resources, it must always be present for better performance of the systems. In this scope, well-regulated private sector services, in addition to economic issues, may contribute to universalization. However, well-designed stormwater regulation also involves regulating the performance of the public sector which, as we have seen, is responsible for a large part of the impervious areas of the territories and consequently a large part of urban stormwater. Regulation is based on two pillars: economic efficiency and quality of service. Both require planning, contracts, and resources invested.

Stormwater management is an intermittent service and it is not always seen as important, so the investment always stays behind the required (Dobbs *et al.*, 2013). It is only when disasters occur that political decision-makers are present, but with a short-term vision that often exacerbates the perception that only specific actions and funds earmarked for that specific event are the solution.

The institutionalization of economic and financial support for stormwater management systems requires a permanent flow of dedicated revenues, as is the case with stormwater utilities in the USA (Campbell & Bradshaw, 2021). It also implies the existence of regulation as a means of making resource flows more efficient economically and politically, according to defined policy goals, with equally explicit objectives of urban economic development (infrastructure growth and maintenance), environment (river clean-up), and social (well-being, people participation, and access to systems) seeking to bring equitable welfare to the entire population.

The economic regulation can meet multiple objectives as is the case of social tariffs in Brazil, Chile, Uruguay (Narzetti & Marques, 2020), Spain, and South Africa. Quality service regulation also show environment good results, like in Australia and the USA, or directly linked results to the performance of stormwater infrastructure networks, as occurs in Germany (e.g., in Munchen) with the incentives for the participation of the private sector in disconnection (Sieker & Klein, 1998).

In urban stormwater management systems, there is, all over the world, a multiplicity of situations and formats of management and regulation (Table 1) according to different stages of the paradigm shift underway in the sector. In Brazil, for example, the regulation of urban stormwater management systems is in its infancy, with few, diverse, and fragile rules drafted or in preparation, such as the future reference standards of ANA, awaiting experimentation and results. Brazil can still shift paradigm and put stormwater management as a priority. So, aligning regulation in PIR is key to increase organization and performance.

China is experimenting the institutionalization of the LID concept through the idea of sponge cities in 30 cities, but with results expected in the medium (2030) and long term (one generation). The country seeks to encourage PPP arrangements but does not yet have models for this (Jiang *et al.*, 2018).

In other countries, such as the USA, the rules already have results from older applications, despite the great diversity of alternatives and Australia can be considered at an advanced stage, with broad voluntary participation of like-minded people including regulators, but with its own dynamics and diversity of regulation in each location (Radcliffe, 2018).

The general panorama of stormwater management, evidenced by the international and Brazilian examples, presented as a result in Table 1, shows that there is no influence of Gross Domestic Product (GDP) per capita, as it might seem, on the alignment between PIR. In the same way, one cannot affirm that the smaller or larger participation of the private sector, through the privatization of providers, as is the case in the UK, has an impact on PIR alignment, the same occurring with decentralization as in France and Germany, although in different formats. In Germany, a country where decentralization has a significant importance, good results are highlighted in some areas, such as Munich, which, however, deserve a deeper analysis of the institutional and regulatory structure. The two countries where the alignment is most noticeable (Australia and the USA), still partially, with some gaps in aspects and locations, leave questions to be answered, such as the how path dependency or institutional inertia contribute to existing alignments.

On the performance side, what can be said is that economic and quality regulation in the two countries where greater alignment is observed show positive results, both in terms of economic and environmental sustainability, without meaning that they cannot further improve.

Table 1 | GDP per capita of some searched countries and PIR alignment.

Country (US$ GDP/capita in 2020)[a]	Policy (P)	Institutions (I)	Regulations (R)	PIR alignment
USA (63,206.5)	Pollution control, low impact development – best management practices (LID- BMP)	Environment Protection Agency (EPA) rules, stormwater utilities, Federal Acts, State and Municipal Laws	EPA Rules, MS4, NPDES, State and Municipal Laws	Aligned in many places, but not all aspects
Germany (42,252.7)	Pollution control and multiobjectives	Federal, Local (Länd), and Municipalities laws and Water Companies rules, Verbänd (river managers) guidance's, WFDs	Self-regulation	Not aligned
France (39,037.1)	Flood control	Communes (municipalities) laws, 6 Agencies de L'Eau rules, watershed institutions, contractual rules	Contractual arrangements	Not aligned
UK (41,059.2)	National funding of reduction flooding vulnerability, SuDS	OFWAT, EA, DWI, and Municipality rules. Flood and Water Management Act, 2010	No stormwater regulation, just CIRIA – SuDS Guidance[b]	Not aligned
Australia (51,680.3)	WSUD	Multisector Regulators, IPART (Independent Price Authority Regulatory Tribunal), and ESC (Essential Services Commission) rules	Each state has its own regulatory body and its own rules	Aligned in some places
Chile (13,231.7)	Integrated Water Resources Management (IWRM)	Superintendencia de Servicios Sanitarios (SISS) rules	No stormwater regulation	N/a
China (10,500.40)	Sponge cities initiative – low impact development (LID)	Technical Guidelines	No stormwater regulation	N/a
Brazil (6,796.8)	IWRM	Municipality laws, and all levels Agency-Independent Regulators rules	Few initiatives	Not aligned

[a]Data.Worldbank.Org/Indicator/NY.GDP.PCAP.CD.
[b]Kellagher *et al.* (2019).

6. CONCLUSIONS

The study has limitations because stormwater is a service of local responsibility, but subject to a multitude of PIR spread over all levels of administrative organization of the state, in all localities, which have distinct institutions, making it impossible for the literature to contain everything, and local research in many cities is extremely difficult, time-consuming, and costly. This is one of the reasons why the text contains many details from places where we have had greater knowledge, as is the case in Brazil.

The search showed that in one way or another, by contract or by agency, or even in their absence (self-regulation), the owners, i.e., the municipalities, exercise control over urban stormwater management systems. Policies, institutions, and the institutionalization of the regulation and of resources allocation to urban stormwater management systems are a weak part of the organization and determination of performance, given the increasingly evolving demands and the lack in PIR alignment.

The greater or lesser degree of the alignment between policies, institutions (formal and informal), and regulation, as we tried to demonstrate with examples, according to each local reality, and the related performance of service provision, was not very well confirmed, but in both countries where some degree of alignment was found the perceived performance is high.

In the current situation, regulation, as well as the attention given to the institutionalization of urban stormwater services, is almost absent in many countries (Table 1). So, aligning regulation in PIR deserves to be better considered, firstly because regulation is a question of efficiency and resources saving, secondly because efficient management and use of existent infrastructures also has the potential to reduce the costs of climate changes improving capacity to economic grown and development.

The lessons provided by the regulation of various sectors, together with the few initial experiences concerning urban stormwater, provide starting points for the evolution of the subject, which is expected to grow in the coming years. These are questions for near future research studies.

It should be noted, however, that the regulation of the stormwater sector is much more complex than that of other water and public services due to its hybrid public–private character with inseparable interaction between the two, as regulation should cover both public and private aspects of sealed territories and the water that falls on them, making it impossible, for example, for financing systems to be covered by only one part of this complex whole.

Finally, just waiting for the establishment of institutions that will take care of the regularization of land title or the implementation of the entire infrastructure to meet urban stormwater demands means abandoning the goal of water services for all, the Sustainable Development Goal 6 (SDG6), perpetuating exclusion and inequality with obvious consequences for urban social cohesion and society inefficiency in many parts of the world.

In future studies, it may be interesting to choose places with recognized stormwater systems performance to verify what the PIR are and how they work, so that comparisons can be made, without leaving aside the fundamental question of the mechanisms instituted for the contribution of resources and their magnitudes.

AUTHOR CONTRIBUTIONS

C.A.F.O.N. and R.C.M. conceptualized and visualized the whole article. C.A.F.O.N. conducted data curation and formal analysis. C.A.F.O.N. investigated the article, and C.A.F.O.N. and R.C.M. developed the methodology. R.C.M. administered the project, found resources, and supervised the article. C.A.F.O.N. and R.C.M. wrote the original draft and reviewed and edited the article. All authors have read and agreed to the published version of the manuscript.

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DATA AVAILABILITY STATEMENT

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

CONFLICT OF INTEREST

The authors declare there is no conflict.

REFERENCES

Abdelmaki, L. (1999). *Les techniques alternatives d'assainissement pluvial par infiltration – enjeux technico-economiques et perspectives*. Lyon, France.

ANA (2020). *Dirigentes da ANA e do MDR debatem mudanças trazidas pelo novo Marco Legal do Saneamento Básico (ANA and MDR leaders discuss changes brought by the new Sanitation Legal Framework)*. Available at: https://www.gov.br/ana/pt-br/assuntos/noticias-e-eventos/noticias/dirigentes-da-ana-e-do-mdr-debatem-mudancas-trazidas-pelo-novo-marco-legal-do-saneamento-basico (Accessed March 17 2022).

Baptista, M. & Nascimento, N. (2002). Aspectos institucionais e de Financiamento dos Sistemas de Drenagem Urbana (Institutional and financing aspects of urban drainage systems). *Revista Brasileira de Recursos Hídricos 7*(1), 29–49. https://doi.org/10.21168/rbrh.v7n1.p29-49 (in Portuguese).

Barraqué, B. (2013). As Agências Francesas de Água têm 50 anos: lições a tirar dessa experiência controversa (French water agencies are 50 years old: lessons to be learned from this controversial experience). *Revista da Universidade Federal de Minas Gerais 20*, 254–271. https://doi.org/10.35699/2316-770x.2013.2700<otherinfo (in Portuguese).

Bedtke, N., Geyler, S. & Gawel, E. (2019). Sustainable stormwater management in existing settlements municipal strategies and current governance in Germany. *Sustainability (Switzerland) 11*(19), 5510.

Berg, S. V. (2013). *Best Practices in Regulating State-Owned and Municipal Water Utilities*. Economic Commission for Latin America and the Caribbean (ECLAC), Santiago, Chile, p. 65.

Biehl, R. & Buechter, M. T. (2011). MSD storm water phase II communication efforts through publication education, outreach, and involvement. In *2011 World Environmental and Water Resources Congress*. Palm Springs, May 22–26, ASCE.

Black & Veatch (2021). *Stormwater Utility Survey Report Black &Veach*. Available at: http://bv.com/docs/default-source/management-consulting-brochures/2014-stormwater-utility-survey.

Bolognesi, T. & Pflieger, G. (2021). In the shadow of sunshine regulation: explaining disclosure biases. *Regulation and Governance 15*, 200–225. https://doi.org/10.1111/rego.12286.

Brasil (2020). *Lei 14.026/2020 – Novo marco legal do saneamento (New Legal Framework of Sanitation)*. Brasilia. Available at: http://www.planalto.gov.br/ccivil_03/_ato2019-2022/2020/lei/l14026.htm (in Portuguese).

Campbell, W. & Bradshaw, J. (2021). *Western Kentucky University Stormwater Utility Survey 2021*. Kentucky University. Available at: http://www.wku.edu/engineering/civil/fpm/swusurvey/western_kentucky_university_sw%5Cnu_survey_2014.pdf.

Caprario, J., Rech, A. S. & Finotti, A. R. (2019). Vulnerability assessment and potential contamination of unconfined aquifers. water science and technology: water supply, florianópolis. *Brasil 19*(4), 1008–1016. https://doi.org/10.2166/ws.2018.147.

Collins, K. A., Pentilla, R. V. & Glass, J. S. (2012). Middle Rio Grande watershed-based MS4 permit. In *2012 World Environmental And Water Resources Congress*, Environmental & Water Resources Institute (EWRI) of the American Society of Civil Engineering, p. 3466–3474. https://doi.org/10.1061/9780784412312.349.

Coutts, A. M., Tapper, N. J., Beringer, J., Loughnan, M. & Demuzere, M. (2013). Watering our cities: the capacity for water sensitive urban design to support urban cooling and improve human thermal comfort in the Australian context. *Progress in Physical Geography 37*(1), 2–28. https://doi.org/10.1177/0309133312461032.

Derrick, B. E. & Moore, M. (2015). An alternative approach to illicit discharge detection with aerial infrared thermal imagery. A case study of MS4 dry weather illicit discharge screening. In *88th Annual Water Environment Federation Technical Exhibition and Conference*, pp. 1290–1308. https://doi.org/10.2175/193864715819539245.

Dobbs, R., Pohl, H., Lin, D., Mischke, J., Garemo, N., Hexter, J., Matzinger, S. Palter, S. & Nanavatty, R. (2013). *Infrastructure Productivity: How to Save $ 1 Trillion a Year*. McKinse Global Institute.

Ducci, J. (2007). *Salida de operadores privados internacionales de agua en América Latina (Exit of International Private Water Operators in Latin America)*. Washington. Available at: https://publications.iadb.org/es/publicacion/15948/salida-de-operadores-privados-internacionales-de-agua-en-america-latina (in Spanish).

EPA (2010). *NPDES Permit Writers Manual*.

Geyler, S., Bedtke, N. & Gawel, E. (2019). Sustainable stormwater management in existing settlements – municipal strategies and current governance trends in Germany. *Sustainability 11*, 1–23. https://doi.org/103390/SU11195510.

Gomes, C. A. B. M., Baptista, M. B. & Nascimento, N. O. (2008). Financiamento da Drenagem Urbana: Uma Reflexão (Financing urban drainage: a reflection). *Revista Brasileira de Recursos Hídricos 13*, 93–104. https://doi.org/10.21168/rbrh.v13n3 (in Portuguese).

Griffiths, J., Chan, F. K. S., Shao, M., Zhu, F. & Higgitt, D. L. (2020). Interpretation and application of Sponge City guidelines in China. *Philosophical Transactions of the Royal Society A: Mathematical, Physical and Engineering Sciences 378*, 2168. https://doi.org/10.1098/rsta.2019.0222.

Henten, A., Samarajiva, R. & Melody, W. (2003). Designing next generation telecom regulation: ICT convergence or multi-sector utility? *ICT 5*(1), 26–33. https://doi.org/10.1108/14636690310473863.

Irvine, K., Rossi, M., Vermette, S., Bakert, S. & Kleinfelder, K. (2011). Illicit discharge detection and elimination: low-cost options for source identification and trackdown in stormwater systems. *Urban Water Journal 8*(6), 379–395. https://doi.org/10.1080/1573062x.2011.630095.

Jensen, D. M. R., Thomsen, A. T. H., Larsen, T., Egemose, S. & Mikkelsen, P. S. (2020). From EU directives to local stormwater discharge permits: a study of regulatory uncertainty and practice gaps in Denmark. *Sustainability (Switzerland) 12*, 1–34. https://doi.org/10.3390/SU12166317.

Jiang, Y., Zevenbergen, C. & Fu, D. (2017). Can 'Sponge cities' mitigate China's increased occurrences of urban flooding? Aquademia: water. *Environment and Technology 1*, 1–5. https://doi.org/10.20897/awet.201703.

Jiang, Y., Zevenbergen, C. & Ma, Y. (2018). Urban pluvial flooding and stormwater management: a contemporary review of China's challenges and 'sponge cities' strategy. *Environmental Science and Policy 80*, 132–143. https://doi.org/10.1016/j.envsci.2017.11.016.

Jordana, J. & Levi-Faur, D. (2010). Exploring trends and variations in agency scope. *Competition and Regulation in Network Industries 11*(4), 342–360. https://doi.org/10.1177/178359171001100401.

Kea, K., Dymond, R. & Campbell, W. (2016). An analysis of the patterns and trends in United States stormwater utility systems. *Journal of the American Water Resources Association 52*(6), 1433–1449. https://doi.org/10.1111/1752-1688.12462.

Kellagher, R., Woods Ballard, B., Wilson, S., Udale-Clarke, H., Illman, S., Scott, T. & Ashley, R. (2019). *The SUDS Manual*, 2 version edn. CIRIA, London. *E-book*.

Kresch, E. P. & Schneider, R. (2020). Political determinants of investment in water and sanitation: evidence from Brazilian elections. *Economics Letters 189*, 109041. https://doi.org/10.1016/j.econlet.2020.109041.

Machete, I. & Marques, R. (2021). Financing the water and sanitation sectors: a hybrid literature review. *Infrastructures 6*(1), 1–25. https://doi.org/10.3390/infrastructures6010009.

Marques, R. (2005). *Regulação de Serviços Públicos (Public Services Regulation)*. Edições Sílabo, Lisbon (in Portuguese).

Marques, R. (2010). *Regulation of Water and Wastewater Services. An International Comparison*. International Water Association Publishing, London, p. 402, ISBN 972-618-380-4.

Mcgovern, T. & Hampton, C. (2016). When permit coverage are not enough. In *89th Annual Water Environment Federation Techinical Exibition and Conference – WEFTEC*. Water Environment Federation, pp. 3345–3352. https://doi.org/10.2175/193864716819705843.

Molinos-Senante, M., Maziotis, A. & Villegas, A. (2020). Estimating technical efficiency and allocative distortions of water companies: evidence from the English and Welsh water and sewerage industry. *Environmental Science and Pollution Research 27*(28), 35174–35183. https://doi.org/10.1007/s11356-020-09850-6.

Montenegro, M. H. F. (2019). Desafios dos Serviços Públicos de Drenagem e Manejo de Águas Pluviais nas Cidades Brasileiras (Challenges of public drainage and stormwater management services in Brazilian cities). In *ABAR –Agencia Brasileira de Agencias de (org.). Coletânea Regulação do Saneamento Básico*, 1st edn. ABAR, Brasilia, pp. 147–162 (in Portuguese).

Montenegro, M. H. F., Silva, E. A., Pollachi, A., Faustino, A. & Moretti, R. S. (2021). *Realização dos direitos humanos à água e ao saneamento – influências da remuneração e da cobrança pela prestação dos serviços de saneamento (Realising the Human Rights to Water and Sanitation – Influences of Remuneration and Charging for Sanitation Service Provision)*, 1st edn. Letra Capital, Rio de Janeiro, pp. 1–181 (in Portuguese).

Mumssen, Y., Saltiel, G. & Kingdom, B. (2018a). *Aligning Institutions and Incentives for Sustainable Water Supply and Sanitation Services*. World Bank, Washington. https://doi.org/10.1596/29795.

Mumssen, Y., Saltiel, G., Kingdom, B., Sadik, N. & Marques, R. (2018b). *Regulation of Water Supply and Sanitation in Bank Client Countries*. World Bank, Washington. https://doi.org/10.1596/30869.

Narzetti, D. A. & Marques, R. C. (2020). Models of subsidies for water and sanitation services for vulnerable people in South American countries: lessons for Brazil. *Water (Switzerland) 12*(7). https://doi.org/10.3390/w12071976.

Narzetti, D. A. & Marques, R. C. (2021). Isomorphic mimicry and the effectiveness of water-sector reforms in Brazil. *Utilities Policy* **70**, 101217. https://doi.org/10.1016/j.jup.2021.101217.

Nascimento, N. O., Baptista, M. B. & Sperling, E. V. (1999). Problemas de inserção ambiental de bacias de detenção em meio urbano (Problems of environmental integration of detention basins in urban environments). In *20o Congresso brasileiro de engenharia sanitaria e ambiental*, Rio de Janeiro, pp. 1–9 (in Portuguese).

Neto, S. & Camkin, J. (2020). What rights and whose responsibilities in water? Revisiting the purpose and reassessing the value of water services tariffs. *Utilities Policy 63*, 101016. https://doi.org/10.1016/j.jup.2020.101016.

North, D. C. (1990). *Institutions, Institutional Change and Economic Performance*. Cambridge University Press, New York. ISBN 10: 0521397340.

Office of Water USEPA (2005). *Stormwater Phase II Final Rule – Fact Sheet 1.0*.

Oliveira, R. M. F., Marrara, T., (2017). Consórcios para a prestação ou regulação de serviços de saneamento básico (Consortia for the provision or regulation of basic sanitation services). In *Tratado sobre o marco regulatório do saneamento básico no direito brasileiro*, 1st edn. Valim, C. A. J. & Carvalho, G. M. (eds). Editora Contracorrente, São Paulo, pp. 805–843 (in Portuguese).

Prefeitura de São Paulo (2009). *Lei 14.934/2009*. Fundo Municipal de Saneamento Ambiental e Infraestrutura: FMSAI (Municipal Fund for Environmental Sanitation and Infrastructure: FMSAI). (in Portuguese).

Qi, Y. Chan, F., Thorne, C., O'Donnell, E., Quagliolo, C., Comino, E., Pezzoli, A., Griffiths, L. Sang, Y. & Feng, M. (2020). Addressing challenges of urban water management in Chinese sponge cities via nature-based solutions. *Water (Switzerland) 12*(10), 1–24. https://doi.org/10.3390/w12102788.

Radcliffe, J. C. (2018). Australia's water sensitive urban design. In *2018 International Sponge City Conference*, pp. 38–52.

Ribeiro, W. A. (2016). Remuneração pelo serviço público de manejo de águas pluviais urbanas (Remuneration for the public service of urban stormwater management). In *IV Revista Jurídica da Confederação Nacional dos Municípios*, Brasília, pp. 111–128 (in Portuguese).

São Paulo (2007). *Lei Complementar No 1.025/2007*. Available at: http://www.legislacao.sp.gov.br/legislacao/dg280202.nsf/6279925b177ee40183256b6f00692f13/0e2a7f29cffa13f3032573ad004ef3a4?OpenDocument.

Sieker, H. & Klein, M. (1998). Best management practices for stormwater-runoff with alternative methods in large urban catchment in Berlin, Germany. *Water Science and Technology*, 91–97. https://doi.org/101016/S0273-1223(98)00737-9.

Sydnor, W. & Dunn, M. (2015). Digital detection for MS4 program efficiency: leverging dollars and data. In *88th Annual Water Environment Federation Technical Exhibition and Conference*, pp. 5771–5779.

Todeschini, S., Papiri, S. & Ciaponi, C. (2014). Stormwater quality control for sustainable urban drainage systems. *International Journal of Sustainable Development and Planning 9*(2), 196–210. https://doi.org/10.2495/SDP-V9-N2-196-210.

Werbeloff, L. & Brown, R. R. (2016). Using policy and regulatory frameworks to facilitate water transitions. *Water Resources Management 30*(11), 3653–3669. https://doi.org/10.1007/s11269-016-1379-6.

Zhang, L., Sun, X. & Xue, H. (2019). Identifying critical risks in Sponge City PPP projects using DEMATEL method: a case study of China. *Journal of Cleaner Production 226*, 949–958. https://doi.org/10.1016/j.jclepro.2019.04.067.

Reference to a website:

EPA (2022). NPDES – SSOs – Municipal Wastewater Sanitary Sewer System Overflow – EPA WEB PAGE. Available at: https://www.epa.gov./npdes/sanitary-sewer-overflows-ssos (Accessed March 20 2022).

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