ORIGINAL ARTICLE

# Perception of professionals working in João Pessoa and surroundings regarding sustainable urban drainage

*Percepção de engenheiros civis, engenheiros ambientais e arquitetos a respeito da drenagem urbana sustentável*

**Data de entrada:** 30/07/2021

**Data de aprovação:** 24/05/2022

**Maria Cecília Paiva Nóbrega[1] | Adriano Rolim da Paz[2*] | Luciana Andrade dos Passos[2] | Giulliane Cahino Ferreira[2]**

DOI: https://doi.org/10.36659/dae.2023.032

**ORCID ID**
Nóbrega MCP https://orcid.org/0000-0003-4230-7070
Paz AR https://orcid.org/0000-0003-0243-7006
Passos LA https://orcid.org/0000-0002-0642-5734
Ferreira GC https://orcid.org/0000-0002-4960-6674

## Abstract

In Brazil, the adoption of sustainable urban drainage (SUD) measures is modest, and the conventional approach prevails. This research evaluates the perception of 377 professionals (civil engineers, environmental engineers and architects) that work in João Pessoa and surroundings regarding their knowledge on SUD, their preferences and barriers for adopting SUD. Most of them demonstrate limited knowledge on the subject, with difficulty distinguishing between conventional and sustainable measures. But the vast majority of professionals were willing to adopt SUD facilities in their projects, preferably infiltration trenches, permeable pavements and green roofs. The maintenance of the devices and the hirer/user acceptance were key aspects for this choice, while superiors' disinterest, the unfamiliarity of entrepreneurs and financiers, and lack of governmental support were the primary barriers. There is a need to improve the academic education of these professionals and provide basic understanding of SUD principles for several other actors.

**Keywords:** Stormwater. Green infrastructure. Low impact development. Source-control.

## Resumo

*No Brasil, a adoção de medidas da drenagem urbana sustentável (DUS) se apresenta tímida, e prevalece a abordagem convencional. Esta pesquisa avalia a percepção de 377 profissionais (engenheiros civis, engenheiros ambientais e arquitetos) que atuam em João Pessoa e arredores quanto a conhecimento, preferências e barreiras sobre a adoção de DUS. A maioria demonstra conhecimento insuficiente sobre DUS, com dificuldade de distinguir entre medidas convencionais e sustentáveis. A grande maioria dos profissionais se interessa por adotar DUS nos projetos, com preferência por trincheiras de infiltração, pavimentos permeáveis e telhados verdes. A manutenção desses dispositivos e a aceitação pelo contratante/usuário foram os aspectos chave para tais escolhas, enquanto o desinteresse dos superiores, o desconhecimento de empreendedores e financiadores e a falta de suporte governamental foram apontados como as principais barreiras. Há a necessidade de melhorar a formação desses profissionais e propiciar o entendimento básico de DUS para diversos atores.*

***Palavras-chave:*** *Águas pluviais. Infraestrutura verde. Desenvolvimento de baixo impacto. Controle na fonte.*

[1] Universidade Federal de Pernambuco - Araçagi - Pernambuco - Brazil.
[2] Universidade Federal da Paraíba - João Pessoa - Paraíba - Brazil.
* **Corresponding author:** adriano.paz@academico.ufpb.br.

## 1 INTRODUCTION

In Brazil, urbanization is still growing and being associated to soil imperviousness (Gurgel and Righetto, 2016), from the largest cities to the small and medium ones. One of major consequences of this process is surface runoff increase when rainfall occurs (Mendes and Mendiondo, 2007). Aiming at minimizing such impact, the concepts and methods of conventional urban drainage are the most largely employed, focused on getting, conveying and putting away the stormwater within the maximum efficiency possible. This conventional solution is a palliative approach, as it enlarges the stormwater drainage system and provides an effective contribution to solving the problem just temporarily, besides transferring and amplifying the runoff downstream. The result is the tendency to produce more frequent and larger urban inundation events, with stronger impact regarding risk to human life, urban mobility, disease spreading, and damage to public and private assets, and other economic losses (Lafortezza et al., 2018; Fátima and Cabral, 2013).

Dealing with urban drainage considering this conventional point of view does not target the source of the problem (Esmail and Suleiman, 2020; Larsen et al., 2016). On the contrary, the sustainable approach is focused on runoff generation, which is the problem's origin (Hua et al., 2020; Loc et al., 2017). This practice considers both structural and non-structural actions to avoid transferring downstream the problem, to control runoff generation on the source and to maintain or recover the natural hydrological processes (Lafortezza et al., 2018; Hamel et al., 2013). Several other benefits may arise from adopting sustainable urban drainage (SUD) measures, such as aesthetic improvement, groundwater recharge, improvement of air and water quality, thermal and acoustic comfort, biodiversity increasing, habitat creation for wildlife, human resilience, mental health and other social benefits, and so forth (Qiao et al., 2018). In fact, the intense urbanization in large cities may need to combine both conventional and sustainable solutions. The stormwater management is a current strong challenge, which can be exacerbated according to increase in rainfall intensities due to climate change (Carlson et al., 2015; Larsen et al., 2016).

In Brazil, since the 1990's there has been an increase in development of academic and scientific works related to SUD. They have primarily focused on evaluating the functioning of detention or infiltration facilities, such as detention tanks (Drumond et al., 2018; Baptista and Paz, 2018), infiltration trenches (Graciosa et al., 2008), rain gardens (Melo et al., 2014), bioretention swales (Ferreira et al., 2019), green roofs (Tassi et al., 2014), permeable pavements (Jabur et al., 2015; Castro et al., 2013) and other devices; estimating the benefits of source-control measures over the downstream urban drainage system (Zanandrea and Silveira, 2019); or discussing regulatory issues (Tucci and Meller, 2007). In parallel, some Brazilian cities have developed legal instruments to runoff source-control, mostly directed to new buildings of medium or large sizes, such as Porto Alegre (Porto Alegre, 2006), Belo Horizonte (Belo Horizonte, 1996), São Paulo (São Paulo, 2002), Rio de Janeiro (Rio de Janeiro, 2004), Recife (Recife, 2015) and João Pessoa (João Pessoa, 2005). Additionally, some cities have elaborated urban drainage master plans, including sustainable urban drainage key concepts, such as Porto Alegre (Tucci, 2005), São Paulo (São Paulo, 2012), Recife (Recife, 2016) and Natal (PDDMA, 2009).

However, in practice, the adoption of sustainable urban drainage measures worldwide is far from being the most desirable (Qiao et al., 2018), and in Brazil it seems much more modest and lesser employed than in developed countries, despite the transition from conventional to sustainable approaches being actually a lengthy process (Esmail and Suleiman, 2020; Perales-Momparler et al., 2017; Barbosa et al., 2012). In the Brazilian context, a remarkable discussion on the barriers to SUD is presented by Vasconcelos et al. (2020).

Literature has categorized the barriers to SUD in a wide range, such as technical, scientific, institutional, legal, managerial, political, monetary and social (O'Donnell et al., 2017; Rooney, 2018). The causes for the very limited use of sustainable approach on urban drainage could be summarized as being mostly related to (i) political issues, (ii) cultural aspects; (iii) technical issues, and (iv) professionals working on urban drainage, which are closely related to each other.

The first set of aspects refer to political and governance factors, which are one of the main reasons for the slow pace of developing sustainable solutions worldwide (Qiao et al., 2018). The deficiency in updated knowledge regarding SUD is largely evident for the public managers and urban planners (Sharma et al., 2016; Perales-Momparler et al., 2017; Souza, 2005), due to the absence of specific technical training (Tasca et al., 2017; Godwin et al., 2008; Souza, 2013).

Additionally, there is the non-existence or lack of autonomy of municipal institutions or departments specifically in dealing with urban drainage issues in Brazil (Vasconcelos et al., 2020; Souza, 2005), the lack of leadership for decision making and the lack of support from governmental high level authorities (Podolsky, 2012), besides the discontinuity of public policies (Goldenfum et al., 2007) and the lack of connectivity between distinct related sectors (Martins, 2012; Vasconcelos et al., 2020). Another political issue is the non-interest in preventive measures while preferring the emergency ones when urban flooding occurs, owing to the easy access to resources after declaring public calamity (Tucci, 2003; Souza, 2005).

Regarding cultural issues, the population associates large-scale actions as the most effective for eliminating flooding, such as constructing large hydraulic facilities and cleaning, and widening urban river channels. Non-structural measures are practically not perceived or valued by population. SUD devices face cognitive barriers (Dhakal and Chevalier, 2017), as there is unfamiliarity and distrust concerning their functioning, their conservation and maintenance, and there is even the non-recognition of these structures as urban drainage devices (Santos et al., 2016; Oliveira, 2018; Almeida, 2014). There are also preferences among these structures related to socioeconomic status (Tassi et al., 2016), and more acceptance for implementing public SUD devices (Loc et al., 2017).

By involving the population in the conception of environmental sanitation projects (Pathak et al., 2019; Buytaert et al., 2014), there is an increase in the recognition of their benefits and more chance to further get people to correctly use them and worry about their maintenance (Lisboa et al., 2013; Carlson et al., 2015). The engagement of people reduces the opposition faced by innovation when being presented (Perales-Momparler et al., 2017) and plays a key role for consolidating a smarter and more sustainable city in a broader sense (Macedo et al., 2017).

In the third group of issues, there is a lack or shortage of urban drainage specialists in the technical teams acting on municipalities (Vasconcelos et al., 2020; Martins, 2012; Parkinson et al., 2003). Some of these specialists have out of date knowledge on the matter and are used to working with the conventional urban drainage approach (Vasconcelos et al., 2020). This issue is also present in technicians of the funding institutions of the urban drainage sector (Bochi and Reis, 2013).

One of the origins of this knowledge limitation of these technicians is the relatively scarcity and shallowness of updated information regarding sustainable urban drainage being provided to undergraduate students (Vasconcelos et al., 2020; Martins, 2012), since this subject is often more deeply discussed in postgraduate courses or in single theme-specific courses (Martins, 2012). Dhakal and Chevalier (2017) claim the need for universities to strengtheneducation on graduate and undergraduate level to civil engineering students in stormwater management, according to their research survey in United States. It is worth mentioning, however, that in the last years there has been an accelerated expansion and diffusion of knowledge about sustainable urban drainage among professionals, but there is not a quantification of this process to evaluate its representativeness. Additionally, the development of SUD solutions is creating a demand for professionals with better skills on analytical thinking and on working across disciplinary boundaries (Johnson et al., 2019).

Technical issues related to sustainable urban drainage structures represent the fourth set of aspects but are intimately related to the three previous groups of issues. Even the heterogeneity of terminology involved in the subject is an element to hinder the comprehension of such structures (Fletcher et al., 2015). But the major question is that the relationship between the functioning of each structure and local conditions is one of the principles for defining the sustainable measure to be used (Podolsky, 2012; Godwin et al., 2008). There is limited evidence based on actual monitoring on the performance of the SUD devices (Perales-Momparler et al., 2017), and this is especially more serious regarding the use of such structures applied to Brazilian conditions (Souza et al., 2012).

There are technical recommendations that are too generic or that have been initially proposed based on studies abroad, under very distinct conditions from Brazilian ones. These recommendations end up being merely replicated and may not be adequate to local conditions (Baptista and Nascimento, 2002; Souza, 2005; Podolsky, 2012). The difficulty in understanding the sustainable facilities induces the persistence of adopting the conventional urban drainage measures, as their functioning is widely known (Parkinson et al., 2003) and also due to a kind of "pro-gray mindset", i.e. the professionals being used to using gray infrastrucure (Dhakal and Chevalier, 2017). Major reasons for that are the lack of trustworthiness of SUD shown by professionals (Porse, 2013), the fear of liability issues (Olorunkya et al., 2012) and their reluctance to perceived risks of adopting such structures (Dhakal and Chevalier, 2017). Thus, it seems crucial to understand the professionals' point of view, regarding their preferences and barriers for adopting SUD (Wang et al., 2020), including the cognitive barriers as discussed by Dhakal and Chevalier (2017).

In that context, this research aims at evaluating the perception of civil engineers, environmental engineers and architects regarding the sustainable urban drainage, taking as study area the city of João Pessoa and neighbouring cities. We aim to i) diagnose the knowledge level of these professionals about key aspects of urban drainage sustainability, including their capacity to distinguish between conventional and sustainable drainage measures, as well as we have focused on: ii) evidencing their opinion regarding the barriers for not adopting sustainable measures, and iii) on quantifying their preferences concerning sustainable facilities and to which extent distinct factors are relevant to their choice. The city of João Pessoa was chosen because it can be considered representative of a typical scenario in Brazil: it is a state capital and considered a middle city with expressive urbanization growth during last decades, consequently suffering the increase of urban flooding impacts, while not still presenting an urban drainage master plan. Thus, our findings may be roughly considered representative of that typical scenario.

## 2 MATERIAL AND METHODS

### 2.1 Study area

Questionnaires were applied to professionals that work in João Pessoa city and surroundings, in Paraiba state. The area of João Pessoa is about 210,044 km² and it borders the cities of Bayeux, Santa Rita, Conde and Cabedelo. The GDP (Gross Domestic Product) per capita of João Pessoa city is about R$ 24,319.82 for the year of 2017, while its HDI (Human Development Index) is equal to 0,763 in 2010 and roughly 70.8% of the population had sanitary sewage cover in 2010 (IBGE, 2020). From total population, 46.69% are men and 53.31% are women, while 18.6% of the total has some bachelor's degree (IBGE, 2020).

The study area was chosen for three main reasons. Firstly, João Pessoa is considered a middle city that has shown expressive growth in last decades. In 1991, its population was about 497,600 inhabitants, increasing to 597,934 inhabitants in 2000, which represents a 20.2% increase in these 9 years. From 2000 to 2010, a similar population growth occurred (21.0%), reaching a total of 723,515 inhabitants and resulting in a demographic density of 3,421.28 inhab./km². The estimated population for 2019 was 809,015 inhabitants (IBGE, 2020). It still means an expressive growth (11.8% in 9 years), but a slowdown relatively to the prior time period.

This population growth has been associated with urban surface expansion prevailing soil imperviousness. According to estimates from Silva et al. (2015), the urban surface of João Pessoa covered approximately 116.5 km2 in 2011, an increase of 27.8% since 1992. Consequently, there are problems raised by rainfall events, such as urban floods that have apparently increased in frequency and size, despite of lacking a specific study to quantify this process — this is the second reason for choosing João Pessoa for this research. The third motivation refers to the absence of a municipal urban drainage master plan, which certainly highlights how the sustainable drainage approach may be further away than for those cities presenting this kind of master plan.

### 2.2 Ethical issues and data collection

This research was developed based on ethical issues involving human beings, as determined by the federal resolution 466/12 from the National Health Council, having been approved by the local ethical research committee of the institution of the authors. Furthermore, all the interviewees were asked to accept the free and informed consent form prior to answering the questionnaire. The online survey was available on social media and e-mail, from the authors to their professional and personal contacts and with the aid of local academic and technical institutions. The data collection occurred from 19$^{th}$ June to 2$^{nd}$ July of 2020.

### 2.3 Population and sample

The population of this research comprises all the environmental engineers, civil engineers and architects working or doing postgraduate courses on the study area. It was not possible to have the exact number of these professionals, but our best estimates rely on those formally registered and active on the CREA-PB (Regional Council of Engineering and Agronomy) and CAU-PB (Regional Council of Architecture and Urbanism), which sum 480 environmental engineers, 9504 civil engineers and 2482 architects in July 2020. Some professionals, however, may have concluded their bachelor's degree and directly started the postgraduate course, but still not being registered in the regional councils.

A total of 467 professionals have answered the online questionnaire, but 90 of them have informed that they were working outside our geographical study area. Thus, these 90 interviewees were disregarded, and the sample population of this research corresponded to 377 professionals: 163 civil engineers, 106 environmental engineers and 108 architects. Considering a confidence level of 95%, the sample populations for each profession of this research may represent a margin of error lower than 10%, even inflating by 20% the corresponding population size estimates based on professionals formally registered in the regional councils. It is important to highlight that it is not known which of these professionals actually work or have worked with urban drainage. The purpose was to evaluate the professionals working on the geographic study area, regardless of their area of expertise.

### 2.4 Questionnaire for data collection

The online questionnaire was elaborated using the Google Forms tool and was composed by 43 questions organized in 6 sections. The first two sections refer to socioeconomic characteristics (questions 1 to 3: gender, age, average monthly salary) and general education and professional information (questions 4 to 10: sector, local and time length of current work; type (public/private) and name of bachelors' degree institution; time length since this degree; profession). Thereafter, section 3 embraces a set of questions regarding the specific education related to stormwater urban drainage (questions 11 to 15: whether the professional has attended a specific course on this theme during their bachelors' degree; whether they have postgraduate degree, and in which type of institution (public/private), how much time and whether they have attended a specific course on urban drainage during such postgraduate course).

In section 4 (questions 16 to 23), the specific aim was to evaluate the current knowledge of the interviewees regarding sustainable urban drainage: if they have ever heard of it, if they have formally studied this subject and in which circumstances (bachelors' degree, postgraduate course, short course or seminar). We also questioned whether each interviewee has seen in person any sustainable urban drainage solution; if so, they were asked to specify this.

In this same section, the following questions evaluate more objectively their knowledge level on sustainable urban drainage, asking them to mention a device that could be used for this aim and to answer if they agree or not with an incorrect statement defining sustainable urban drainage: *"The main concern in a sustainable urban drainage project is the efficient and economical removal of stormwater, conveying it along the micro and macro drainage systems. This contributes to avoid excess of rainfall from causing flooding and other problems, as long as the design and execution of the project meet current technical requirements"*. The last question of section 4 asks them to identify among 13 options which of them effectively contribute to sustainable urban drainage (the interviewee could check all that he/she think as "yes").

After the 4$^{th}$ section, the online form showed the interviewees some basic concepts on sustainable urban drainage and presented illustrative pictures and basic descriptions of seven sustainable drainage facilities (infiltration trench, infiltration swale, infiltration well, permeable pavement, bioretention swale, green roof and on-site detention tank). The purpose of this part of the questionnaire was to guarantee a minimum knowledge level for all interviewees, preparing them to better answer the remaining questions.


Revista DAE | São Paulo | v. 71, n 240 / pp 199-215 | Abr a Jun, 2023

The section 5 (questions 24 to 33) assessed the acceptance of sustainable urban drainage facilities by the professionals, asking them whether they would use some SUD device in their project, and also to identify among seven alternatives which of them they evaluate as more relevant as barriers to a broader application of SUDS. This section ended asking whether each interviewee had already witnessed some sort of opposition for SUDS from higher hierarchical positions or sectors and, if yes, they needed to specify among the five given alternatives.

The last section (questions 34 to 43) asked how important is to the interviewees to think about having a specific course on stormwater urban drainage during their graduation course and how prepared the professionals in general are to work with SUDS. This section also evaluated the preferences of the interviewees concerning which sustainable urban drainage facilities they would more probably adopt in their project. Another question of this section asked the interviewees to scale the relevance of six aspects that they would consider when choosing SUD facility for a project.

## 3 RESULTS AND DISCUSSIONS

### 3.1 Socioeconomic characterization of interviewees

Among the 377 professionals that have answered the online form and were considered for being analysed in this research, 163 are civil engineers, 106 are environmental engineers and 108 are architects (Fig. 1-a). This sample presents a predominance of male professionals among the civil engineers (66%) and female ones for environmental engineers (56%) and architects (71%) (Fig, 1-b). Young professionals (< 35 years old) are the majority in the three professions analysed (Fig. 1-c). Around 12% of the civil engineers are older than 50 years, while this percentage is even lower for other professions.

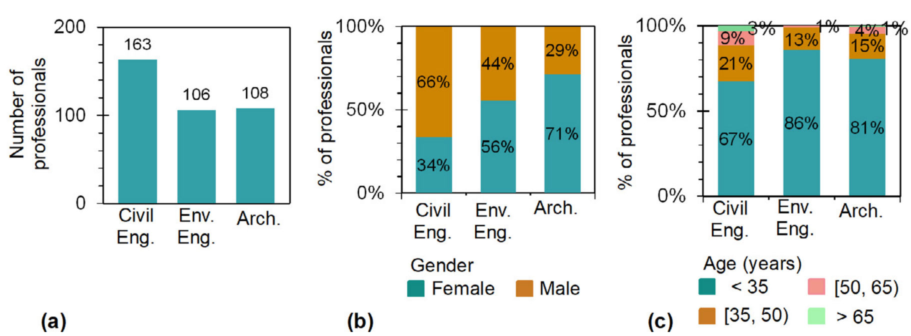


**Figure 1** - (a) Number of professionals interviewed; (b), (c) Distribution of interviewees according to gender and age.

### 3.2 Professional and academic education characterization of the interviewees

Almost half of the civil engineers were working on private sector (Fig. 2-a), while this percentage is quite smaller for environmental engineers and the largest one for the architects. Environmental engineering was the profession with the largest number of interviewees that are exclusively dedicated to postgraduate studies (37%), which is related to the younger ages of this sample relatively to the other two professions. For the three groups of professionals, most of the interviewees are working in João Pessoa (65%-79%, Fig. 2-b).

Regarding the type of institution in which they have concluded their bachelors' degree, there is a clear predominance of public institutions for civil (85%) and environmental (75%) engineers, while for architects there is a balanced distribution between public and private institutions (Fig. 2-c). As our sample is formed predominantly by young professionals, the time length since bachelors' degree was primarily low, with roughly 60% of the sample with less than 5 years (Fig. 2-d).

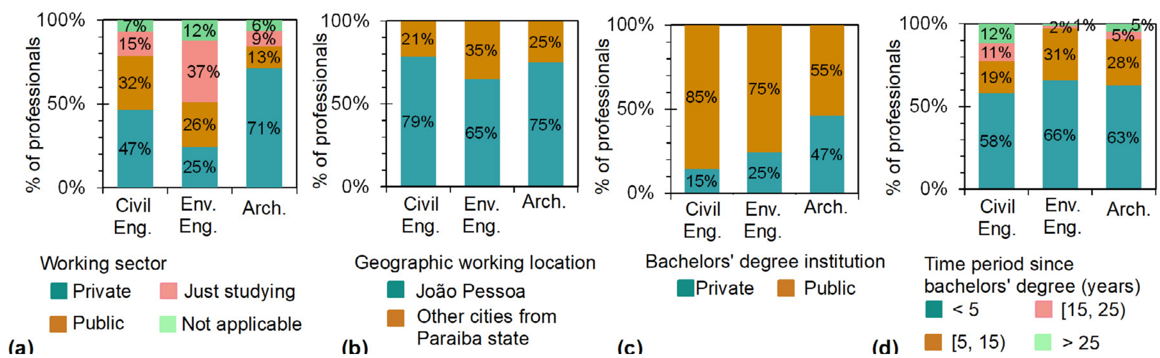


**Figure 2** - Distribution of interviewees according to work sector (a), geographic work location (b), type of bachelor's degree institution (c) and time length since bachelors' degree (d).

## 3.3 Previous knowledge on sustainable urban drainage

Most of the interviewees answered that they had already heard about SUD (Fig. 3-a). The higher percentage obtained for the environmental engineers may be related to the environmental engineering course and profession, which are more intimately related to the sustainability issue, increasing the chance of these professionals at least having heard of SUD.

Accordingly, there is probably a larger chance that environmental engineers have formally studied SUD, justifying the largest percentage obtained for this question (41%) relatively to civil engineers and architects (Fig. 3-c). But for all these three groups of professionals, the proportion of the ones that had formally studied SUD may be considered remarkably small. There is a slight tendency that this proportion increases for the most recent professionals relatively to the eldest ones (Fig. 3-d), probably due to more exposition to updated information during undergraduate courses.

However, even more remarkable is the fact that most of the professionals that have heard of SUD have never known a SUD facility personally (ranging from 77% to 86%; Fig. 3-b). This highlights the lack of practical experiments inside academic facilities, and it also may be considered indirect evidence of low occurrence of sustainable devices in João Pessoa and other cities of Paraiba state, despite of the predominance of young professionals with few years of field work experience. This finding agrees with Vasconcelos et al. (2020), which consider the big gap between the theoretical and practical knowledge regarding SUD as one of the most common barriers to SUD. This is also in accordance with the study of Olorunkiya et al. (2012), which showed that professionals without previous practical experience on SUD have large aversion to taking risks related to SUD projects. Thus, Goulden et al. (2018) claim for developing more demonstration projects and increasing applied research, which would contribute to improve professional training.

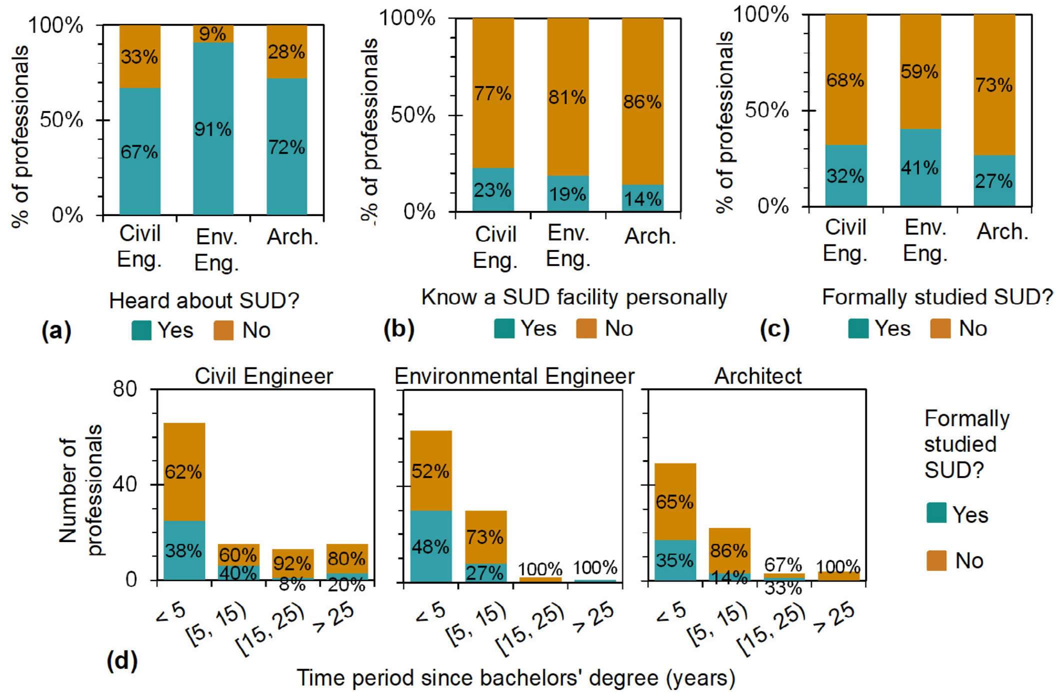


**Figure 3** - Percentage of professionals that have heard about SUD (a), that have known a SUD facility personally (b), and that have formally studied SUD (c); (d) same as (c), but dividing the number of professionals according to time length since bachelors' degree.

When asked to agree or not with a statement referring to the main concern of a sustainable urban drainage project in an incorrect way (Fig. 4-a), the majority of professionals agreed. There is a surprisingly large number of professionals that wrongly agreed that the sustainable urban drainage approach is focused on efficiently and economically conveying the stormwater, draining it along the micro and macro drainages.

The statement clearly describes the conventional urban drainage point of view, despite the second part of it, that specifies the aim of avoiding flooding and worries about the correct dimensioning and execution following technical requirements. When analysing just the professionals who have previously declared that have formally studied SUD (Fig. 4-b), the percentage of agreement is slightly reduced for civil engineers and environmental engineers and remains almost unchanged for architects.

Even considering that some professionals may have answered this agreement question carelessly or that the statement may have caused some sort of misinterpretation, the percentage of agreement in the responses is still high. There are key aspects in that statement that should have been identified by the professionals as erroneously associated to SUD, such as the main concern of efficiently conveying the stormwater and draining it along the micro and macro drainages. These are strong elements to not agree with the statement, even though they are not sure or confused about other parts of the question.

According to the authors' opinion, these results clearly highlight a lack of adequate understanding of the hydrologic concepts and principles of urban drainage sustainability for most civil and environmental engineers, and for the vast majority of architects. This is in agreement to the authors' perception based on their contacts during research, classes, projects and seminars, and it also emphasizes the need to improve the quality of education on the theme. A similar conclusion is pointed out by Vasconcelos et al. (2020), based on their survey with teachers at higher education and research institutions working within urban drainage in Brazil. These findings are also in agreement with the work of Dhakal and Chevalier (2017), which highlight the need to offer curriculums that include green infrastructure and also research opportunities to engage civil and environmental engineering students worldwide. Accordingly, Paiva et al. (2020) advocate for the need to improve teaching quality and to urgently revise curriculum and subjects of undergraduate courses regarding the water resources area as a whole.

The interviewees were also asked to mention a SUD device, as an open-ended question. Between 50% and 58% of them pointed out an acceptable answer (Fig. 4-c), while the remaining (between 42% and 51%) presented incorrect answers or stated that they did not know. There are also remarkable proportions of professionals with inadequate knowledge on the theme, reinforcing our worry about their academic education. However, these percentages indicate a more satisfactory quality of answers than the one related to the agreement statement.

A possible explanation may be that some devices, such as permeable pavement and green roof, are themselves more easily and directly recognized as related to SUD by the professionals than the key hydrologic principles of SUD related to infiltration and storage. In other words, they strongly associate devices such as porous pavements and green roofs as contributing to SUD based on the names and images of these facilities, but they probably have incomplete understanding of their functioning.

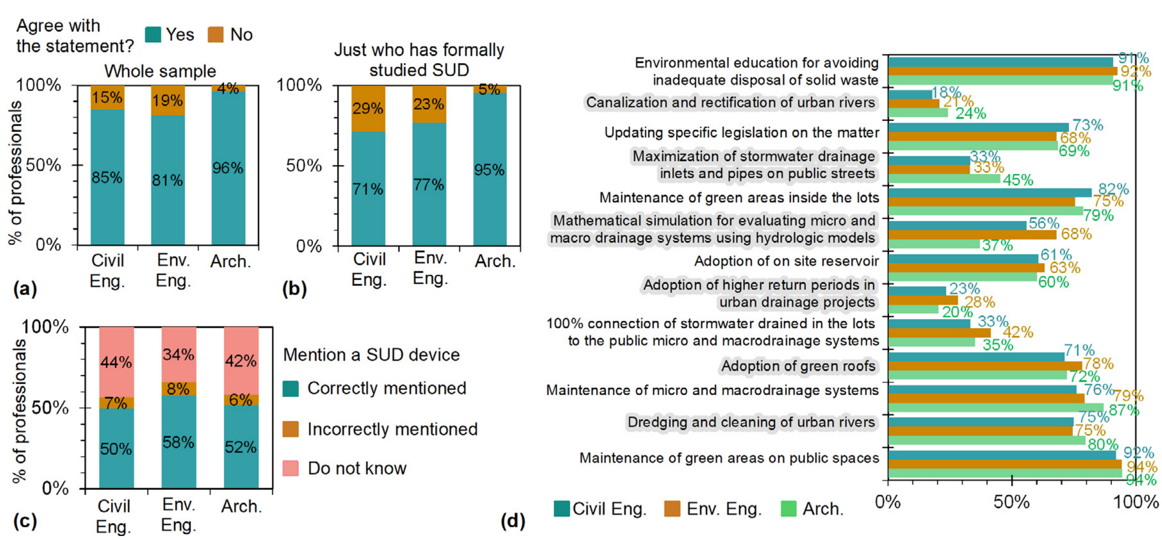


**Figure 4** - (a) Percentage of professionals who agree with the statement about the main concern of SUD; (b) same as (a), but only considering professionals who have formally studied SUD; (c) Distribution of professionals according to their mention to a SUD device; (d) Percentage of answers for each measure pointed out as effectively contributing to SUD.

Particularly during classes of undergraduate courses of several distinct subjects, architects may study and discuss the use of green roofs, associating them to several benefits such as thermal comfort, acoustic insulation, habitat creation for wildlife, aesthetically pleasure and psychological welfare to people around the roof, as well as rainwater absorption. But they are not trained in greater depth concerning the quantitative impact that a green roof may cause in runoff generation reduction. Nor are the civil and environmental engineers without formally studying SUD devices.

This finding is followed by the results shown on Fig. 4-d, concerning the percentage of answers that pointed out each given measure as effectively contributing to SUD. Interestingly, a very similar behaviour of answers was found between the three professions: measures like use of green roofs (71% to 78%) and maintenance of green areas in public spaces (92% to 94%) and in private lots (75% to 82%) were correctly pointed out by most professionals, but dredging and cleaning of urban rivers (75% to 80%) and maintenance of micro and macro drainages (76% to 87%) were also largely selected. Other remarkably wrong alternatives were also selected by a not negligible number of professionals: canalization and rectification of urban rivers (18% to 24%), adoption of larger return periods in urban drainage projects (20% to 28%) and 100% connection of private lots for stormwater draining to the public micro and macro drainages (33% to 42%).

### 3.4 Preferences on sustainable urban drainage devices

Henceforth, the results refer to the questions that were answered by the professionals after they have been introduced to key concepts and description about SUD and about seven SUD devices. This may have contributed to the massive positive responses (94% - 96%) when they were asked if they would adopt SUD facilities in a project if they had the chance (Fig. 5-a). Their sympathy and empathy with the purpose of the online survey and research may also have worked together to this high acceptance of SUD. But in agreement to our findings, the research of Vasconcelos et al. (2020) also showed that professionals are not unwilling to a paradigm shift towards SUD.

In general, among the seven SUD devices they could choose, their preferences show similar pattern between the three professions (Fig. 5-b), with infiltration trench being the most selected device, followed by permeable pavements. These results may also have been influenced by the perception the professionals have formed, based on the description and images that were presented in the online form prior to these questions. But green roof is an exception to the general pattern, with more than double preference among architects in relation to civil and environmental engineers. This is another evidence of that discussion regarding how architects are usually willing to the idea of conceiving a green roof due to its multiple benefits.

Bioretention swale also was preferably chosen by architects (56%) rather than by environmental (42%) and civil engineers (29%). The percentages achieved by bioretention swale and online detention tank show another pattern: a gradient of preference of green structure and its aesthetic appeal from architects to environmental engineers and them to civil engineers, and in the opposite direction the slight gradient of preference regarding the easiness to design and build as represented by online detection tanks, preferably chosen by civil engineers.

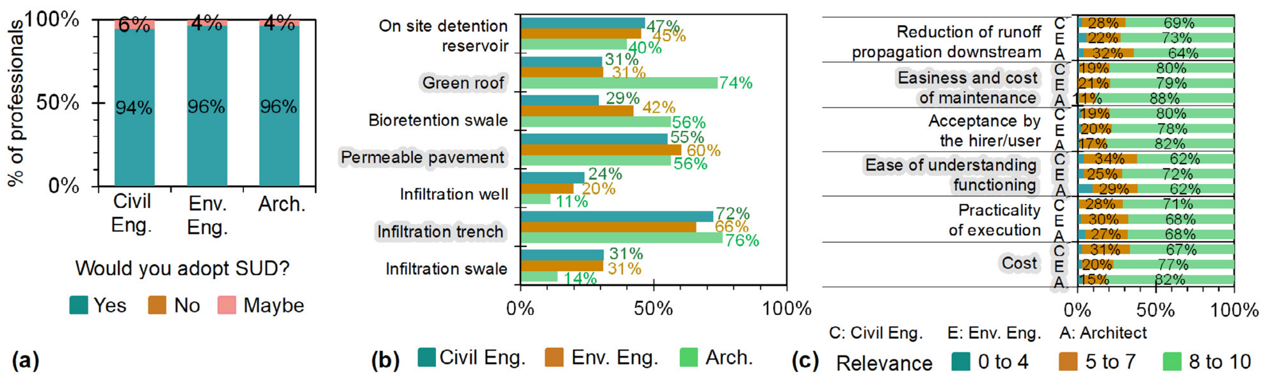


**Figure 5** - (a) Percentage of professionals that would adopt SUD in their project; (b) Their preference to seven SUD devices; (c) Degree of relevance (scale 0 to 10) for six aspects considered when choosing a SUD device for a project.

Figure 5-c shows the degree of relevance (scale 0 to 10, but grouped in three categories for easier understanding) for six aspects that the professionals would worry about when choosing a SUD device for their project. In general, all devices predominantly received higher scores, ranging from 62% to 88%, and presented similar patterns between the three professions. The cost and easiness to maintain the devices together with the acceptance by the hirer/user were the two aspects that slightly received the largest proportion of higher scores (79%-88% and 78%-82%, respectively) and smaller proportion of lower scores (less than 2%). Maintenance uncertainty was also one of the key challenges pointed out by stormwater professionals in Auckland, Australia (Wang et al., 2020) and also by local government practitioners in South Australia (Sharma et al., 2016). Indeed, these are two key aspects for designing and adopting the use of SUD devices and for which there is a need to develop more studies and construct such knowledge. For instance, results of Tassi et al. (2016) showed an association between the user preferences and their socioeconomic class: lower income users being more favourable to online detention tanks due to rainwater reuse possibility; higher income users showed larger preference for infiltration trenches, basically because of environmental and aesthetic concerns.

### 3.5 Barriers to urban drainage sustainability

Almost the same proportion (~45%) of the three professions stated that they have already witnessed some sort of opposition to adopting SUD facilities by higher hierarchical positions (Fig. 6-a). This is a noteworthy result, indicating that professionals are being pruned by their superiors' actions or omissions when trying to adopt concepts and devices lined up with SUD. The perception of a reluctance to support novel approaches to flood management was also the barrier most cited by professionals on the study of O'Donnell et al. (2017) and considered as one major issue also highlighted in the study of Vasconcelos et al. (2020).

The type of opposition they most witnessed was related to the disinterest for costlier project solutions (Fig. 6-b). This is really a key challenge, as making decision beyond the financial issue by incorporating social and environmental concerns is very complex (Kandakoglu et al., 2018). The unfamiliarity of entrepreneurs and financiers with SUD was the second largest type of opposition pointed out by the three professions, slightly higher for civil engineers.

The results of these two most selected types of opposition are somewhat coherent, as architects indeed are more directly related to the initial conception and design of the projects and thus are more subject to cost related decisions, while civil engineers are in greater contact with constructors and thus more influenced by their unfamiliarity with SUD. For both cases, the improvement in understanding SUD principles and benefits by their superiors could help overcome these barriers (Barbosa et al., 2012). On the contrary, environmental engineers may be considered the most often related to governmental issues relatively to civil engineers and architects, and thus the lack of support from higher governmental positions were pointed out by them more often (25%) than double of the other two professions.

When asked to select the degree of relevance of seven possible barriers for adopting SUD devices in a project, similar patterns of results were obtained among the three professions (Fig. 6-c). The most cited barrier for the higher scores of relevance was the lack of planning from public institutions. The other barriers were very similar, ranging from 50% to 74% of higher scores. These results may reveal that most of the interviewees miss improved planning and decisions from public actors and that this would probably serve as guidelines for encouraging larger adoption of SUD concepts, as advocated by Godwin et al. (2008) and Podolsky (2012), for example. Indeed, the existence of an urban policy favourable to SUD was pointed out by Suleiman et al. (2020) as a fundamental driving force.

Despite the barriers and the current lack of deep knowledge on the subject, most professionals pointed out higher scores for the relevance of having a specific urban drainage course during bachelors' degree (Fig. 7-a). These results highlight their recognition to the significance of urban drainage for their academic education and may encourage institutions to rethink and improve their curricular structures, as claimed by Vasconcelos et al. (2020) and Dhakal and Chevalier (2017).

Finally, the last question to be discussed regards how the interviewees evaluated the degree of qualification of professionals in general to work with SUD (Fig. 7-b). In general, the three professions presented similar results (54% - 66% of them assigned scores less or equal than 7), with environmental engineers being slightly less critical than architects and civil engineers.

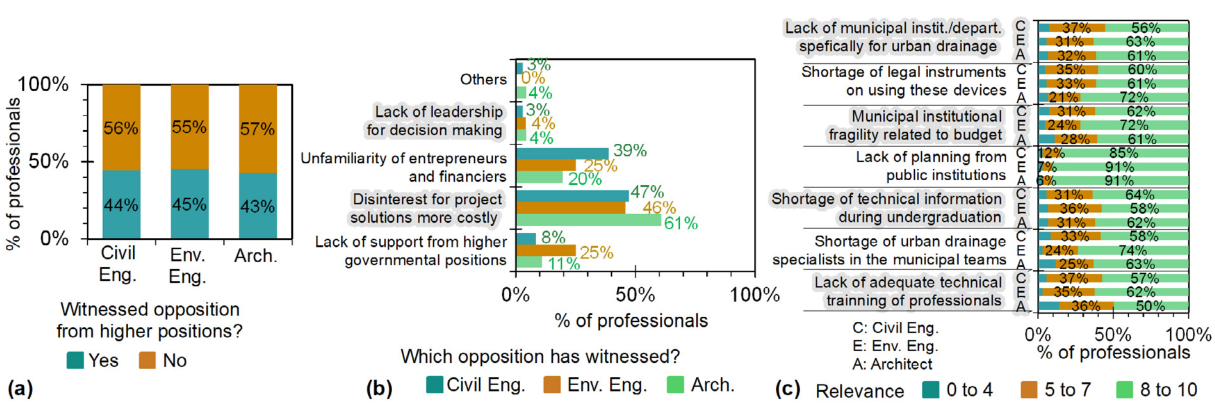


**Figure 6** - (a) Percentage of professionals that have witnessed some type of opposition from higher positions; (b) Type of opposition they have witnessed; (c) Degree of relevance of seven barriers to adopting SUD in a project.

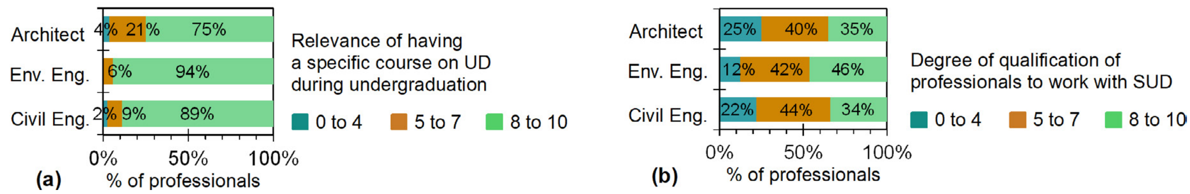


**Figure 7** - (a) Degree of relevance of having a specific course on stormwater urban drainage during bachelors' degree; (b) Degree of qualification of professionals for working with SUD.

## 4 CONCLUSIONS

Based on this research that analysed the responses of an online survey of 377 professionals (civil engineers, environmental engineers and architects) that work or study in João Pessoa and other cities of Paraiba state, we can conclude that:

- There is a clear need to improve academic education of civil engineers, environmental engineers and architects related to SUD. A specific course of stormwater urban drainage should be part of the mandatory classes during their undergraduate courses. Preferably, they should have contact with practical experiments on SUD devices inside academic facilities or visit devices actually functioning in their city. This direct experience has a large potential to reduce the gap between professionals presenting environmental awareness and concern (i.e. environmental attitude) to actually showing pro-environmental behaviour, as discussed by Kollmuss and Agyeman (2002) in a broader environmental sense.

- There is a need to develop more studies regarding experimental monitoring of SUD devices and to propose adaptations for local sites and conditions. Specifically, the design, cost and maintenance aspects should be emphasized. Additionally, the existing studies should be given more publicity nationwide and their results should constantly update material used for teaching SUD classes in undergraduate courses for civil engineers, environmental engineers and architects.

- Civil engineers, environmental engineers and architects are widely favourable to adopting SUD devices on their projects, with clear preferences and several barriers, the latter mostly related to practical issues. Developing constructive guides would be essential towards a wider dissemination and adoption of SUD devices. These guides could be elaborated based on updated results of experimental monitoring and considering adaptations to local conditions.

- Finally, there is a need to provide basic understanding on SUD principles, concepts and devices for several other actors such as entrepreneurs, financiers, decision makers, stakeholders, politicians, and users (citizens), but with language and level of detail adapted for each of them. Building practical experiments for long-term monitoring could serve didactically to aid in this knowledge dissemination and also to reduce the opposition of these actors – again, the direct experience would largely contribute for moving from environmental attitude to pro-environmental behaviour. Additionally, the major idea and concepts of SUD could be introduced to children with other related subjects on environmental education such as climate change, solid waste, environmental pollution etc. This definitely would be a key step towards achieving better knowledge, attitudes and behaviours from society as a whole.

## 5 ACKNOWLEDGEMENTS

The authors would like to thank everyone who helped to disseminate the online questionnaire, especially all the professionals who kindly agreed to participate in this research by answering to this questionnaire. The second author acknowledges the research grant received from the Brazilian Agency CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico).

## 6 AUTHORS' CONTRIBUTIONS

**Conceptualization:** Nóbrega MCP, Paz AR, Passos LA e Ferreira GC; **Methodology:** Nóbrega MCP e Paz AR; **Investigation:** Nóbrega MCP, Paz AR, Passos LA e Ferreira GC; **Writing – first draft:** Nóbrega MCP, Paz AR, Passos LA e Ferreira GC; **Writing – Review & Editing:** Nóbrega MCP e Paz AR; **Resources,** Nóbrega MCP; **Supervision:** Paz AR.

## 7 REFERENCES

ALMEIDA, M., 2014. **Aplicação de técnicas compensatórias na drenagem urbana, sob a ótica dos usuários do espaço: estudo de caso em São Carlos – SP** Dissertação (Mestrado). Universidade Federal de São Carlos, São Carlos.

BAPTISTA, M.; NASCIMENTO, N., 2002. Aspectos institucionais e de financiamento dos sistemas de drenagem urbana. **Revista Brasileira de Recursos Hídricos**, 7(1), 29-49. https://doi.org/10.21168/rbrh.v7n1.p29-49

BAPTISTA, V.; PAZ, A., 2018. Cost-efficiency analysis of a runoff detention reservoir with integrated hydraulic and structural dimensioning. **Revista Brasileira de Recursos Hídricos**, 23, 1-13. https://doi.org/10.1590/2318-0331.231820170168

BARBOSA, A.E.; FERNANDES, J.N.; DAVID, L.M., 2012. Key issues for sustainable urban stormwater management. **Water Research**, 46, 6787-6798. https://doi.org/10.1016/j.watres.2012.05.029

BELO HORIZONTE (Cidade) 1996. **Lei Municipal nº 7.166**, de 27 de agosto de 1996. Belo Horizonte.

BOCHI, T.; REIS, A., 2013. A reprodução da gestão dos recursos hídricos no ambiente construído de Porto Alegre. In: XV ENANPUR 2013. São Paulo. **Anais...**

BUYTAERT, W. et al., 2014. Citizen science in hydrology and water resources: opportunities for knowledge generation, ecosystem service management, and sustainable development. **Frontiers in Earth Science**, 2, 1-21. https://doi.org/10.3389/feart.2014.00026

CARLSON, C.; BARRETEAU, O.; KIRSHEN, P.; FOLTZ, K., 2015. Storm Water Management as a Public Good Provision Problem: Survey to Understand Perspectives of Low-Impact Development for Urban Storm Water Management Practices under Climate Change. **Journal of Water Resources Planning and Management,** 141, 04014080. http://doi.org/10.1061/(ASCE)WR.1943-5452.0000476

CASTRO, A.; GOLDENFUM, J.; SILVEIRA, A.; MARQUES, D., 2013. Avaliação da Evolução do Comportamento Quantitativo de Pavimentos Permeáveis no Controle do Escoamento Superficial. **Revista Brasileira de Recursos Hídricos**, 18(1), 263-273. http://dx.doi.org/10.21168/rbrh.v18n1.p263-273

DHAKAL, K.; CHEVALIER, L. Managing urban stormwater for urban sustainability: barriers and policy solutions for green infrastructure application. **Journal of Environmental Management 203**, 171-181, 2017. https://doi.org/10.1016/j.jenvman.2017.07.065

DRUMOND, P.; MOURA, P.; COELHO, M., 2018. Comparison the monitoring data of an on-site stormwater detention (OSD) and the results in the use of theoretical methods for its design. **Revista Brasileira de Recursos Hídricos**, 23, 1-12. https://doi.org/10.1590/2318-0331.231820170149

ESMAIL, B.; SULEIMAN, L., 2020. Analyzing Evidence of Sustainable Urban Water Management Systems: A Review through the Lenses of Sociotechnical Transitions. **Sustainability**, 12(11), 4481. https://doi.org/10.3390/su12114481

FÁTIMA, M.; CABRAL, J. J. S.P., 2013. Impacto na Saúde por Deficiência de Drenagem Urbana no Município de Jucurutu — RN. **Revista Brasileira de Recursos Hídricos**, 18(3), 181-191. https://doi.org/10.21168/rbrh.v18n3.p181-191

FERREIRA, L.; NEVES, M.; SOUZA, V., 2019. Puls method for events simulation in a lot scale bioretention device. **Revista Brasileira de Recursos Hídricos**, 24, 1-9. https://doi.org/10.1590/2318-0331.241920180133

FLETCHER, T. et al., 2015. SUDS, LID, BMPS, WSUD and more – The evolution and application of terminology surrounding urban drainage. **Urban Water Journal**, 12(7), 525-542. https://doi.org/10.1080/1573062X.2014.916314

GODWIN, D.; PARRY, B.; BURRIS, F.; CHAN, S.; PUNTON, A., 2008. **Barriers and opportunities for low impact development: case studies from three Oregon communities**. Oregon State University, Corvallis, Oregon, USA.

GOLDENFUM, J.; TASSI, R.; MELLER, A.; ALLASIA, D.; SILVEIRA, A., 2007. Challenges for the sustainable urban stormwater management in developing countries: from basic education to technical and institutional issues. In: NOVATECH 2007: 6th International Conference on Sustainable Techniques and Strategies in Urban Water Management, Lyons, France. **Anais...**

GRACIOSA, M.; MENDIONDO, E.; CHAUDHRY, F., 2008. Metodologia para o Dimensionamento de Trincheiras de Infiltração para o Controle do Escoamento Superficial na Origem. **Revista Brasileira de Recursos Hídricos**, 13(2), 207-214. https://doi.org/10.21168/rbrh.v13n2.p207-214

GURGEL, G.; RIGHETTO, A., 2016. Crescimento urbano e seus impactos no sistema de drenagem de uma bacia em Natal, RN.

**Revista de Gestão de Água da América Latina**, 13(1), 54-68. https://doi.org/10.21168/rega.v13n1.p54-68

HAMEL, P.; DALY, E.; FLETCHER, T., 2013. Source-control stormwater management for mitigating the impacts of urbanisation on baseflow: A review. **Journal of Hydrology**, 485, 201-211. https://doi.org/10.1016/j.jhydrol.2013.01.001

HUA, P.; YANG, W.; QI, X.; JIANG, S.; XIE, J.; GU, X.; LI, H.; ZHANG, J.; KREBS, P., 2020. Evaluating the effect of urban flooding reduction strategies in response to design rainfall and low impact development. **Journal of Cleaner Production**, 242, 118515. https://doi.org/10.1016/j.jclepro.2019.118515

Instituto Brasileiro de Geografia e Estatística - IBGE. Available from: <https://cidades.ibge.gov.br/brasil/pb/joao-pessoa/panorama>. Access on: 5 july 2020.

JABUR, A.; DORNELLES, F.; SILVEIRA, A.; GOLDENFUM, J.; OKAWA, C.; GASPARINI, R., 2015. Determinação da capacidade de infiltração de pavimentos permeáveis. **Revista Brasileira de Recursos Hídricos** 20(4), 937-945. https://doi.org/10.21168/rbrh.v20n4.p937-945

JOÃO PESSOA (Cidade) 2005. **Lei Municipal nº 10.479**, de 09 de junho de 2005. João Pessoa.

JOHNSON, C.; TILT, J.; RIES, P.; SHINDLER, B., 2019. Continuing professional education for green infrastructure: Fostering collaboration through interdisciplinary trainings. **Urban Forestry & Urban Greening**, 41, 283-291. https://doi.org/10.1016/j.ufug.2019.04.021

KANDAKOGLU, A.; FRINI, A.; AMOR, S., 2018. Multicriteria decision making for sustainable development: A systematic review. **Journal of Multi-Criteria Decision Analysis**, 26, 202-251. https://doi.org/10.1002/mcda.1682

KOLLMUSS, A.; AGYEMAN, J., 2002. Mind the Gap: Why do people act environmentally and what are the barriers to pro-environmental behavior?, **Environmental Education Research**, 8:3, 239-260. https://doi.org/10.1080/13504620220145401

LAFORTEZZA, R.; CHEN, J.; VAN DEN BOSCH, C.; RANDRUP, T., 2018. Nature-based solutions for resilient landscapes and cities. **Environmental Research**, 165, 431-441. https://doi.org/10.1016/j.envres.2017.11.038

LARSEN, T.; HOFFMANN, S.; LÜTHI, C.; TRUFFER, B.; MAURER, M., 2016. Emerging solutions to the water challenges of an urbanizing world. **Science**, 352, 928-933. https://doi.org/10.1126/science.aad8641

LISBOA, S.; HELLER, L.; SILVEIRA, R., 2013. Desafios do planejamento municipal de saneamento básico em municípios de pequeno porte: a percepção dos gestores. **Engenharia Sanitária e Ambiental**, 18(4), 341-348. https://doi.org/10.1590/S1413-41522013000400006

LOC, H.; DUYEN, P.; BALLATORE, T.; LAN, N.; GUPTA, A., 2017. Applicability of sustainable urban drainage systems: an evaluation by multi-criteria analysis. **Environ. Syst. Decis**, 37, 332-343. https://doi.org/10.1007/s10669-017-9639-4

MACEDO, L.F.; JACQUES, J.J.; PIAZZATO, G.Z.A., 2017. The role of sustainable development in the construction of the city. In: VI Simpósio Brasileiro de Design Sustentável e International Symposium on Sustainable Design. Belo Horizonte. **Anais...**

MARTINS, J., 2012. Gestão da drenagem urbana: só tecnologia será suficiente? **DAEE**, São Paulo. Available from: <http://www.daee.sp.gov.br/outorgatreinamento/ Obras_Hidr%C3%A1ulic/gestaodrenagem.pdf>. Access on: 15 april 2020.

MELO, T.; COUTINHO, A.; CABRAL, J.; ANTONINO, A.; CIRILO, J., 2014. Jardim de chuva: sistema de biorretenção para o manejo das águas pluviais urbanas. **Ambiente Construído**, 14(4), 147-165. https://doi.org/10.1590/S1678-86212014000400011

MENDES, H.; MENDIONDO, E.; 2007. Histórico da expansão urbana e incidência de inundações: o caso da bacia do Gregório, São Carlos – SP. **Revista Brasileira de Recursos Hídricos** 12(1), 17-27. https://doi.org/10.21168/rbrh.v12n1.p17-27

O'DONNELL, E.; LAMOND, J.; THORNE, C., 2017. Recognising barriers to implementation of Blue-Green Infrastructure: a Newcastle case study, **Urban Water Journal**, 14:9, 964-971. https://doi.org/10.1080/1573062X.2017.1279190

OLIVEIRA, A. 2018. A relevância da percepção do usuário na implantação e uso de técnicas compensatórias de drenagem nas áreas urbanas. **Cadernos Zygmunt Bauman**, 8(18), 360-374.

OLORUNKIYA, J., FASSMAN, E., WILKINSON, S. Risk: a fundamental barrier to the implementation of low impact design infrastructure for urban stormwater control. **Journal of Sustainable Development** 5(9), 2012. http://dx.doi.org/10.5539/jsd.v5n9p27

PAIVA, R.C.D. et al., 2020. Advances and challenges in the water sciences in Brazil: a community synthesis of the XXIII Brazilian Water Resources Symposium. **Revista Brasileira de Recursos Hídricos** 25, e5. https://doi.org/10.1590/2318-0331.252020200136

PARKINSON, J.; MILOGRANA, J.; CAMPOS, L.; CAMPOS, R. Drenagem Urbana Sustentável no Brasil. In: Relatório do Workshop em Goiânia-GO. Goiânia: UFG, 2003. **Anais...**

PATHAK, S.; GARG, R.; JATO-ESPINO, D.; LAKSHMI, V.; OJHA, C. Evaluating hotspots for stormwater harvesting through participatory sensing. **Journal of Environmental Management**, 242, 351-361, 2019. https://doi.org/10.1016/j.jenvman.2019.04.082

PDDMA 2009. Plano Diretor de Drenagem e Manejo de Águas Pluviais – Natal/RN. Diagnóstico do Plano Diretor de Drenagem e Manejo de Águas Pluviais da cidade de Natal. **Estudos Hidrogeológicos: segundo relatório.**

PERALES-MOMPARLER, S., ANDRÉS-DOMÉNECH, I., HERNÁNDEZ-CRESPO, C., VALLÉS-MORÁN, F., MARTÍN, M.; ESCUDER-BUENO. I.; ANDREU, J., 2017. The role of monitoring sustainable drainage systems for promoting transition towards regenerative urban built environments: a case study in the Valencian region, Spain.

**Journal of Cleaner Production**, 163, S113-S124. https://doi.org/10.1016/j.jclepro.2016.05.153

PODOLSKY, L., 2012. **Barriers to Low Impact Development.** Prepared by the Local Government Commission for the Southern California Stormwater Monitoring Coalition. Sacramento, CA. https://doi.org/10.3390/w5010029

PORSE, E. Stormwater Governance and Future Cities. **Water 2013**, 5, 29-52. Porto Alegre (Cidade) 2006. Decreto Municipal nº 15.371, de 17 de novembro de 2006. Porto Alegre.

QIAO, X.; KRISTOFFERSSON, A.; RANDRUP, T., 2018. Challenges to implementing urban sustainable stormwater management from a governance perspective: A literature review. **Journal of Cleaner Production**, 196, 943-952. https://doi.org/10.1016/j.jclepro.2018.06.049

RECIFE (Cidade) 2015. **Lei Municipal nº 18.112**, de 12 de janeiro de 2015. Recife.

RECIFE (Cidade) 2016. Plano Diretor de Drenagem da cidade do Recife. **Relatório consolidado dos estudos de concepção para gestão e manejo de águas pluviais e drenagem urbana do Recife**. PDDR.

RIO DE JANEIRO (Cidade) 2004. **Decreto Municipal nº 23.940**, de 30 de janeiro de 2004. Rio de Janeiro.

ROONEY, J.; GILL, L. A critical evaluation of sustainable stormwater management practice and policy in Dublin. In: Institution of Civil Engineers – Engineering Sustainability. **Anais...** https://doi.org/10.1680/jensu.17.00022

SANTOS, M.F.N.; REIS, M.R.M.; PAIVA, S.B.; GONÇALVES, L.M.; BARBASSA, A.P., 2016. Descentralizando o manejo das águas pluviais: como promover a participação da comunidade?. In: PLURIS. Maceió, AL. **Anais...**

SÃO PAULO (Cidade) 2002. **Lei Municipal nº 13.276, de 05 de janeiro de 2002**. São Paulo.

SÃO PAULO (Cidade) 2012. Secretaria Municipal de Desenvolvimento Urbano. **Plano Diretor de Drenagem e Manejo de Águas Pluviais de São Paulo PMAPSP**. São Paulo.

SHARMA, A. et al. Water Sensitive Urban Design: An Investigation of Current Systems, Implementation Drivers, Community Perceptions and Potential to Supplement Urban Water Services. **Water 2016**, 8, 272. https://doi.org/10.3390/w8070272

SILVA, M.; CASTRO, A.; SILVA, B.; SILVEIRA, J.; SILVA, G., 2015. Crescimento da Mancha Urbana na Cidade de João Pessoa. **Cadernos de Arquitetura e Urbanismo**, 22(30), 65-83. https://doi.org/10.5752/P.2316-1752.2015v22n30p64

SOUZA, C., 2005. **Mecanismos Técnico-Institucionais para a Sustentabilidade da Drenagem Urbana Dissertação** (Mestrado). Universidade Federal do Rio Grande do Sul, Porto Alegre.

SOUZA, C.; CRUZ, M.; TUCCI, C., 2012. Desenvolvimento Urbano de Baixo Impacto: Planejamento e tecnologias verdes para a sustentabilidade das águas urbanas. **Revista Brasileira de Recursos Hídricos**, 17(2), 9-18. https://doi.org/10.21168/rbrh.v17n2.p9-18

SOUZA, V., 2013. Gestão da drenagem urbana no Brasil: Desafios para a sustentabilidade. **Revista Eletrônica de Gestão e Tecnologias Ambientais**, GESTA, 1(1), 58 – 72. https://doi.org/10.9771/gesta.v1i1.7105

SULEIMAN, L.; OLOFSSON, B.; SAURÍ, D.; PALAU-ROF, L.; SOLER, N.; PAPASOZOMENOU, O.; MOSS, T., 2020. Diverse pathways—common phenomena: comparing transitions of urban rainwater harvesting systems in Stockholm, Berlin and Barcelona. **Journal of Environmental Planning and Management**, 63, 396-388. https://doi.org/10.1080/09640568.2019.1589432

TASCA, F.; FINOTTI, A.; POMPÊO, C.; GOERL, R. O papel da drenagem urbana na prevenção de desastres hidrológicos na bacia hidrográfica do Rio Itajaí-Açu. **Revista Brasileira de Cartografia** 69, 1, 2017. https://doi.org/10.14393/rbcv69n1-44036

TASSI, R.; PICCILLI, D.; BRANCHER, S.; ROMAN, C., 2016. Preferências da população de diferentes estratos sociais no manejo das águas pluviais urbanas. **Ambiente Construído**, 16(3), 39-52. https://doi.org/10.1590/s1678-86212016000300091

TASSI, R.; TASSINARI, L.; PICCILLI, D.; PERSCH, C., 2014. Telhado verde: uma alternativa sustentável para a gestão das águas pluviais. **Ambiente Construído**, 14, 139-154. https://doi.org/10.1590/S1678-86212014000100012

TUCCI, C., 2003. Inundações e Drenagem Urbana. In: C. Tucci; J.C. **Bertoni, Inundações urbanas na América do Sul** (pp. 45-150). Porto Alegre: Associação Brasileira de Recursos Hídricos.

TUCCI, C., 2005. **Plano Diretor de Drenagem Urbana: Manual de Drenagem Urbana**. Porto Alegre, Instituto de Pesquisas Hidráulicas - Universidade Federal do Rio Grande do Sul, 167 p.

TUCCI, C, 2016. Regulamentação da drenagem urbana no Brasil. **Revista de Gestão de Água da América Latina**, 13, 29-42. http://doi.org/10.21168/rega.v13n1.p29-42

TUCCI, C.; MELLER, A., 2007. Regulação das águas pluviais urbanas. **Revista de Gestão de Água da América Latina**, 4(1), 75-89.

VASCONCELOS, A., BARBASSA, A.; SANTOS, M.; IMANI, M. 2020. **Barriers to Sustainable Urban Stormwater Management in Developing Countries: The Case of Brazil**. engrXiv. September 2. https://doi.org/10.31224/osf.io/9e5sy

WANG, Y.; VAN ROON, M.; KNIGHT-LENIHAN, S., 2020. Opportunities and challenges in water sensitive industrial development: an Auckland case study, New Zealand. **International Journal of Sustainable Development & World Ecology**, 1-14. https://doi.org/10.1080/13504509.2020.1783717

ZANANDREA, F.; SILVEIRA, A.; 2019. Uso de técnicas de low impact development no controle de impactos hidrológicos. **Engenharia Sanitária e Ambiental**, 24(6), 1195-1208. https://doi.org/10.1590/S1413-41522019188729