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Evaluation of technical viability for urban rivers revitalization: Arroio Dilúvio case study in Porto Alegre/RS – Brazil

Avaliação da viabilidade técnica para revitalização de rios urbanos: estudo de caso de Arroio Dilúvio em Porto Alegre/RS – Brasil

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ABSTRACT

The degradation of urban rivers is a phenomenon caused by virtually all cities intersected by rivers. Currently, there is a substantial number of revitalization projects in progress. Nonetheless, their execution demands significant investments, particularly for water quality enhancement. Moreover, apart from the cost factor, the scarcity of space along their banks constrains the implementation of improvement systems. This study introduces a simplified methodology aimed at evaluating the technical feasibility of revitalization interventions within urban river segments, with a focus on enhancing water quality and user experience. The method follows a structured framework encompassing four sequential phases: execution of hydraulic, hydrological, and sanitary analyses concerning the watershed; development of foundational principles and intervention strategies pertaining to the riverbed; appraisal of the congruence between proposed interventions and the intrinsic attributes of the river channel; comprehensive assessment of the overall viability of the revitalization initiative. The method's validation was conducted through a case study involving the Dilúvio Stream in Porto Alegre, RS, showcasing its coherent application and adaptability within the predetermined premises. Thus, the methodology emerges as a preliminary decision-making support tool for projects related to the urban river requalification domain, facilitating the identification of met prerequisites and provision of informed guidance.

Keywords: Water quality recovery; Channel interventions.

RESUMO

A degradação dos rios urbanos é um fenômeno causado por praticamente todas as cidades com rios que as cruzam, e atualmente há um grande número de projetos de revitalização, no entanto a sua execução requer grandes investimentos, em especial, para melhoria da qualidade d´água. E além do custo a falta de espaço em suas margens limita a instalação de sistemas de melhoramento. Neste estudo, é proposto um método simplificado para avaliar a viabilidade técnica de intervenções de revitalização em trechos urbanos de rios, abordando melhorias na qualidade da água e na experiência de uso. O método é estruturado em etapas sequenciais: condução de análises hidráulicas, hidrológicas e sanitárias da bacia; formulação de premissas e estratégias de intervenção no leito do rio; avaliação da compatibilidade entre as propostas e as características da calha fluvial; avaliação global da viabilidade do projeto de revitalização. A validação do método foi realizada através de um estudo de caso no Arroio Dilúvio em Porto Alegre – RS, onde se evidenciou sua consistência e aplicabilidade em conformidade com as premissas estabelecidas. O método emerge como uma ferramenta de apoio à tomada de decisão preliminar em projetos de requalificação de rios urbanos, oferecendo a capacidade de identificar requisitos satisfeitos e direcionar escolhas informadas.

Palavras-chave: Recuperação de qualidade de água; Intervenções no canal.

INTRODUCTION

River water pollution is a recurring environmental problem, especially in developing and underdeveloped countries. Linked to the vast fields of use of water resources, this problem presents significant tensions and conflicts involving multiple actors and sectoral interests (Alonso, 2018; Md Anawar & Chowdhury, 2020).

Some of the main intensifiers of the quality degradation and reduction of water availability are social pressures for spaces to be occupied, ecologically inappropriate economic practices, as well as the negligence of public authorities in the face of the irregular release of domestic and industrial effluents without any treatment directly into the rivers (Tedesco et al., 2021). In addition, the mischaracterization of natural conditions through the canalization of rivers or even with their confinement by closed channels would contribute to the development of cities (Fagundes, 2022).

River systems operate within a natural flow limit called dynamic equilibrium. When changes exceed natural limits, the dynamic balance can be lost, resulting in adjustments in the ecosystem that may conflict with the needs of society. In some circumstances, a new dynamic equilibrium may develop eventually. Still, the timeframe in which this will happen may be prolonged, and may require significant changes to reach this new equilibrium (Silva, 2010; Magalhães Júnior & Barros, 2020).

Requalification is presented as an attempt to reverse the situation of negatively altered ecosystems, defined as the process of assisting in restoration of an ecosystem that has been degraded, damaged or destroyed (Darwich et al., 2018; Baptista & Cardoso, 2013). Thereby, the requalification of watercourses can be defined in 3 areas: restoration or revitalization: re-establishing the relationship between the body of water and the landscape to return the body of water to its natural condition, or as close as possible to the natural condition; rehabilitation or recovery: aimed at restoring the physical, chemical and biological conditions of the body of water, to restore its sanitary conditions; and revitalization: re-establishing the relationship between the body of water and the landscape functionally, that is, reintroducing the channel by giving it life again, without depriving other uses (Cengiz, 2013; Findlay & Taylor, 2006).

One of the significant challenges in a requalification project in urban rivers is the economic and social cost of vacating the floodplain areas, which becomes higher than this process´s viability. In this sense, it is necessary to adopt measures that minimize the damage caused by inadequate occupations and ensure the non-occupation of areas that are still unappropriated (Silva, 2017).

In an analysis of international literature on the urban river requalification, remarkable projects are observed that aimed to be more than just sanitation actions. In this context, there is an attempt to reintegrate rivers into the urban landscape, going beyond merely improving water quality as the ultimate goal of river requalification processes. These projects strive to promote public participation, connect public spaces, and enhance the environmental services provided to the city by the rivers. With this perspective in mind, several examples can be cited that incorporated river channels in revitalization projects: San Antonio River in Texas, USA; Cheonggyecheon River in Seoul, South Korea; Los Angeles River Project in California, USA; Li-Chuang River in Li-Chuang, Taiwan; and the Yangtze River in Zhangjiagang, China.

In this way, due to the lack of space on the margins of watercourses in urban areas, the use of the riverbed itself in the process of watercourses revitalization in urban areas becomes the alternative with minor impediments to consolidating the intervention in the river. With this premise, this article aims to present and discuss the results obtained, in a case study, of the simplified evaluation method for the technical viability of urban rivers revitalization with hydraulic structures and quality improvement of the water in the bed itself.

RECOVERY AND REVITALIZATION OF POLLUTED WATERS IN THE BED OF URBAN RIVERS

This work aims to reintegrate water into the urban landscape and reestablish a meaningful connection between the local population and water bodies. In urban environments, watercourses often become marginalized and concealed due to urbanization and infrastructure. Through the proposed revitalization interventions, the project seeks to reverse this trend by creating opportunities for the community to engage with the riverine environment.

In the context of urban river recovery and revitalization, one of the most inspiring and ambitious cases was the Cheonggyecheon River in Seoul, the economic heart of South Korea. This river faced common environmental issues such as pollution and degradation, typical of many other urban centers. The intervention focused on restoring the landscape of Seoul's main river, which had previously been channelized and covered, by transposing the watershed. This not only improved water quality but also facilitated the economic development of the surrounding areas (Seoul, 2011).

The availability of an area for the implementation of recoveries entails different levels of difficulty in achieving revitalization and, consequently, in the possibilities of integrating the watercourse with its surroundings (Cardoso & Baptista, 2013). Interventions in watercourses have a wide range of variables. Among them are: a direct performance in the river channel - in case of expanding hydraulic capacity and/or margin stabilization - or covering marginal areas in case of road system implementation, sanitary networks, or other urban infrastructure works (Souza, 2014; Carvalho, 2019).

The Novo Pinheiros Program, aimed at the restoration of the river bearing the same name, emerges as a substantial institutional challenge, serving as an exemplar of complexity in the required interventions to revitalize this crucial watercourse and restore its surroundings. This underscores the necessity of a comprehensive and collaborative approach involving multiple entities and sectors.

Ensuring pollution control at the source of water bodies should always be a priority. In this regard, proactively addressing contaminants and pollutants at their origin not only prevents their entry into aquatic ecosystems but also promotes a more effective and sustainable approach to preserving water quality. However, if pollution has not been prevented, this issue must be tackled by treating water in situ or controlling degradation at the point of origin. For this purpose, various methods can be applied, including physical, biological, ecological, and engineering techniques (Gao et al., 2018; Bai et al., 2020).

Engineering and physical treatment techniques can effectively improve the river´s water quality and sediments, resulting in the restoration of the river. However, some of these methods may have adverse effects, such as the destruction of natural ecosystems and an economic burden due to their high cost of implementation and maintenance (Ge et al., 2019).

Chemical treatment of polluted water by flocculation, precipitation, oxidation, and algicides may remove suspended solids and algae. These chemical processes provide rapid recovery of polluted water from the river (Ge et al., 2019), but are temporary and can produce secondary residues that can create other risks (Wang et al., 2012).

Several biological-ecological treatment technologies available in the literature, such as microbial bioremediation, biofilms, contact oxidation, membrane bioreactor technology, ecological lagoons, plant purification treatment, and eco-friendly and built wetlands (Bai et al., 2020). Some studies have used bioremediation or biodegradation processes assisted by microorganisms, plants, and aquatic animals to destroy or decompose organic chemical contaminants, absorb metals, remove chemical oxygen demand (COD), biological oxygen demand (BOD), odor, turbidity, and organic and inorganic contaminants (Ge et al., 2019; Zheng & Wang, 2017; Cui et al., 2018).

Thus, the processes evaluated in this article include combining different techniques to remove solids and reduce organic load and pathogens. For this, Table 1 presents the processes by which hydraulic structures can effectively improve the quality of river water and sediments, improving river water.

This article includes interventions in restricted stretches within the channel of urban watercourses, and the scale of intervention analyzed consists of intervention areas, possibly already consolidated in terms of urban occupation and with their natural conditions previously altered.

Using the riverbed in the revitalization process of watercourses in urban areas has become a viable possibility for consolidating the intervention in the river. Hence, it sought to propose indicators through the evaluation of water availability, hydraulic safety, and the river water quality to undergo a revitalization integrally in the channel so that the most significant possible number of conditions and aspects impacted in a revitalization would be integrated into the river channel.

Thus, it was verified that the variation of the water supply is a limiting factor for the water improvement system to keep working efficiently within the maximum capacity. Therefore, the project must assume that the intervention has a constant flow input in the landscape channel from the flow permanence of the river. Every system will be dimensioned for a landscape flow that allows minimum fruition, and that is adapted to be flooded eventually.

URBAN RIVER CHANNEL REVITALIZATION METHOD

Given the techniques of improvement, diversion and water transfer presented in Table 01, Figure 1 summarizes the decision method on the viability of revitalization using the riverbed through 4 methodological stages.

Stage 1: Hydraulic, hydrological and sanitary diagnosis of the watershed.

Regarding the diagnosis, the geomorphological, sanitary, hydrological, and hydraulic conditions of the section of watercourse channel to undergo intervention must be characterized. This diagnosis is based on data collection, given the preliminary nature of the analyzes to be developed in the study phase. Therefore, it is proposed to verify the conditions observed in the area under study, which are presented in the items: the peak flow of the watershed of a specific pre-defined return time; permanence curve of the river section; the total length of the river to be revitalized; topographic profile of the intervention section; maximum capacity of the river cross-section and the river water quality parameters (dissolved oxygen, thermotolerant coliforms, pH, BOD, water temperature, turbidity, total solids, nitrate, phosphate, and solid residue).

Table 1. Efficiency, advantages, and disadvantages of treatment techniques and transfer of water in situ in.

Treatment Techniques	Process description	Advantages	Disadvantages	Reference
Floating Barrier	Retention of floating residues.	Solid residues reuse system.	High periodicity of operation and maintenance.	(Silva, 2018)
Diversion and transfer of water	Separation of polluted water from the river and pollution dilution.	River flow control.	High cost of execution and specialized labor.	(Song et al., 2018)
Aeration system	Increased air flow in river water.	Improve water quality in relation to organic matter load.	Intensive cost during the operation and maintenance phase.	(Bai et al., 2020)
Built wetlands	Organic and inorganic contaminants removal through natural filtration.	Low cost of implementation, operation and maintenance compared to conventional systems.	Slow process.	(Santos et al., 2022)
Disinfection system	Self- purification of water from pathogens.	Low cost of implementation, operation and maintenance.	Requires a much larger area than other disinfection systems.	(Amaral et al., 2022)

Stage 2: Delimitation of premises and intervention layout in the section of watercourse.

In this stage, the premises and the arrangement that should guide all the stages of the method will be defined. The project assumes that the intervention has a regulated input, that is, constant flow in the landscape channel from the flow permanence of the river. For this, it is assumed the need to use a dam and a diversion of the excess flow until the flow reaches the value adopted as acceptable for the landscape channel to be flooded, according to Equation 1:

$$Q_{River} = Q_{Landscape} + Q_{Gallery} \quad (1)$$

where: Q_{River} is the flow permanence; $Q_{Landscape}$ is the landscape channel flow and $Q_{Gallery}$ is the galley flow.

In this sense, Figure 2 shows the configuration of the arrangement of the water quality improvement system and the lateral diversion of the river's natural flow. The water improvement system was designed to solids remove and dissolved oxygen increasing, organic matter load and nutrients reduce, also to pathogens elimination.

The proposed method aims to evaluate intervention alternatives for urban rivers and streams by establishing prerequisites that aim to assess, in a quantitative and technical manner, the geomorphological, hydrological, hydraulic, and water quality aspects of a section of an urban river undergoing revitalization.

The hydraulic equipment for damming and lateral flow diversion to the river channel must be designed according to a project flow, where the recurrence (return time) acceptable for flooding the landscape channel is defined, with consequences such as the possible reconstruction of equipment urban and site cleaning. For the landscape flow, it is proposed to be defined considering the water availability of the watershed through minimum permanence flows, adopting the desirable flow to comply with the intended uses in the landscape channel, such as rapids for kayaking, lakes for fish habitat and birds, as well as small recreational boats. Once the desirable landscape flow is defined, the capacity of the water quality improvement system is analyzed in function of the intended use quality requirements (primary or secondary contact). Thus, the ability to improve water quality is an important limiting factor for this arrangement.

Stage 3: Evaluation of the riverbed use in relation to each criteria.

To indicate the feasibility of using the riverbed in the proposed revitalization, we sought to encompass the most significant possible conditions and aspects impacted by a revitalization in any river channel. Thus, three prerequisites were proposed, based on technical factors, and aimed at ensuring the water safety of visitors during flood events that exceed the project's premise risk and meet the classification determined by CONAMA Resolution 357/2005 for freshwater - Class 3 (Brasil, 2005).

The first aspect analyzed was related to the quality of the river water to verify the quality of the river water through analyzing the pre-established parameters, observing the need to implement the structures to improve the parameters when they are outside the threshold for secondary contact as established by CONAMA Resolution 357/2005 for freshwater – class 3 (Brasil, 2005). In this way, it was established that the structures for improvement would be applied to obtain the necessary conditions, as shown in Figure 3.

The second aspect prevised the analysis of the margin occupation´s availability, accomplished when it is necessary to obtain flow control, becoming a point of concern. The available riverside is a limiting factor for implementing excess flow diversion in the studied river section. Therefore, this prerequisite evaluates the viability of the applicability of an intervention that regulates the flow within the channel, and, for this, it was adopted that the river and its margins must have sufficient area to implement a channel with a percentage of wet area defined of the sizing of the lateral gallery. This way, there is a safety margin with the increased runoff, preventing the conduit operates in whole section or total capacity.

Thus, it is possible to verify the viability of implementing side galleries through the maximum lateral extension of the river and the external width of the lateral gallery (Figure 4). We have that:

$$L_{Gallery} \leq E_{Lateral} \quad (2)$$

where, $L_{Gallery}$ = external width of the side gallery to the river (m) e $E_{Lateral}$ = extension for maximum lateral expansion (m).

Lastly, it is essential to analyze the water quality improvement structures listed above and how the channel extension will serve exclusively for operational use (water improvement system). In this sense, it is essential to perform and verify the number of interventions necessary to frame the quality of the river for secondary contact and to guarantee the control and regularization of the flow rate within the landscape channel. Thus, this prerequisite verifies whether the proportion of the section intended for the water improvement system (%) suits the goals defined in the premises (Figure 5). Therefore, we have that another limiting factor is the extension of interventions within the river channel.

$$C_{Inter} \leq P_{Dest},$$

where, C_{Inter} = length of structures to improve the river (m) and P_{Dest} = maximum portion intended for water improvement (m).

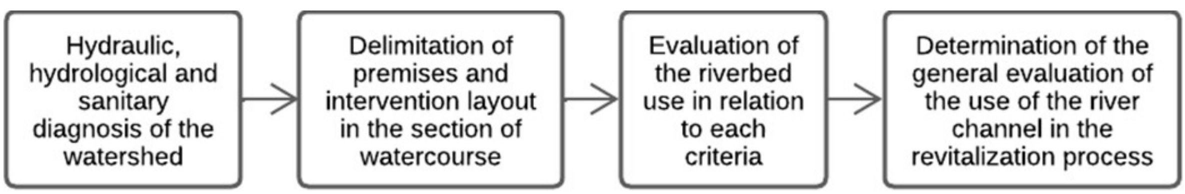

Figure 1. Methodological stages of the decision-making process for the viability of using the riverbed in the revitalization of urban rivers.

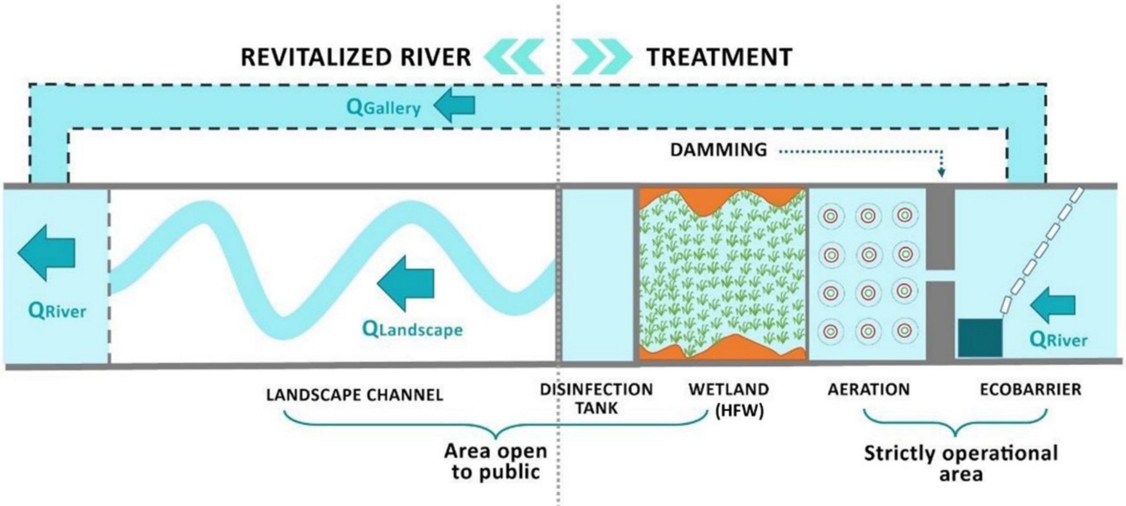

Figure 2. Configuration of flows in the project layout.

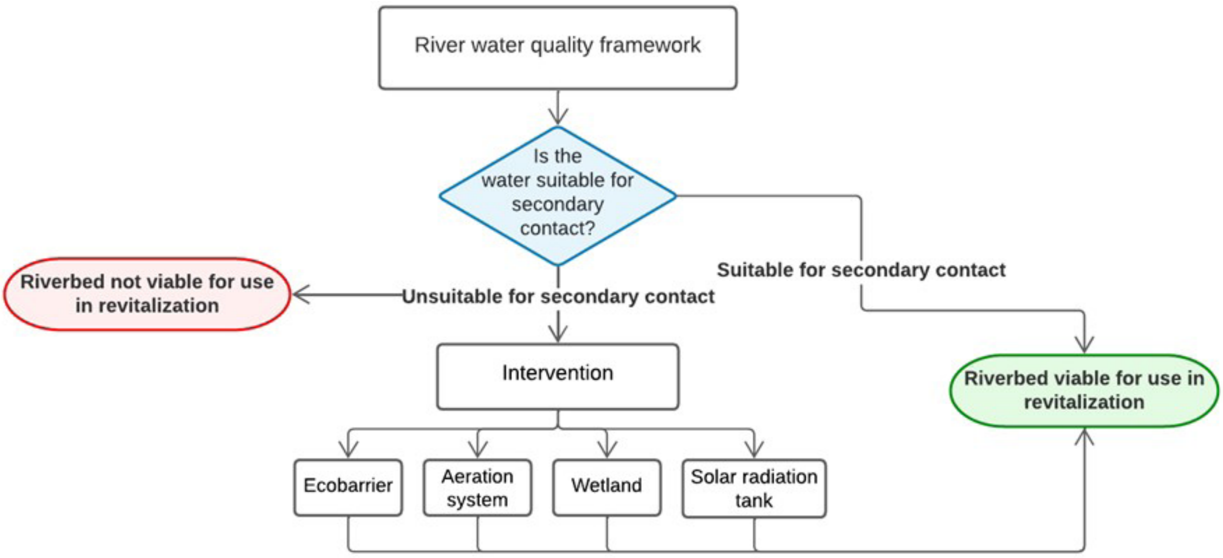

Figure 3. Pre-requisites regarding the water quality assessed in the river channel of the river revitalization process.

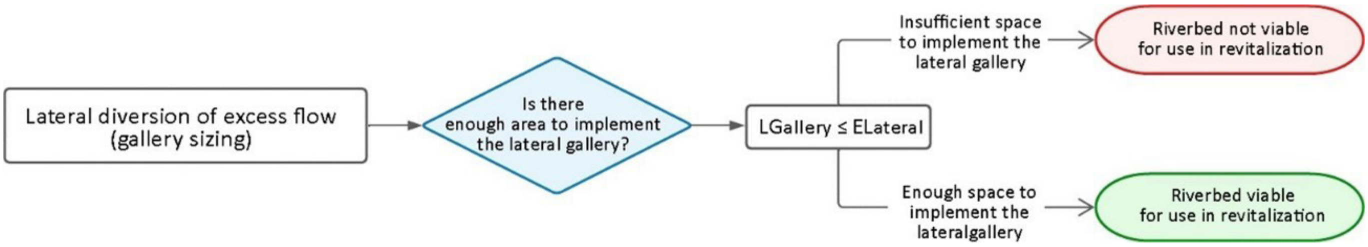

Figure 4. Prerequisites relating to the river margins in the river revitalization process.

The proposed methodology in this study evaluates the viability of beds used for secondary contact in revitalizations in urban watercourses, emphasizing the variables listed above, as well as how much of the linear area of the channel will serve exclusively for operational use about the whole projected section.

As from the application of the mentioned criteria, the interventions previse the maintenance of watercourses in the channeling and rectification format along with the existing roads in the studied region and the concrete coating of its bed and margins.

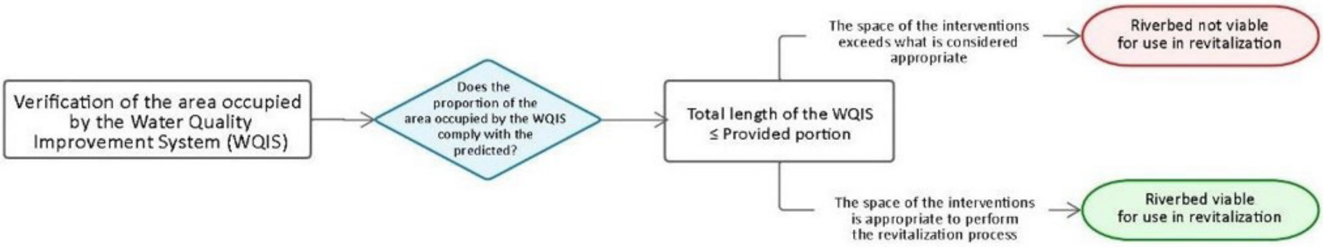

Figure 5. Prerequisites regarding the occupation of the section intended for the improvement of river water in the process of revitalization of the river.

Figure 6. Arroio Dilúvio parallel to Av. Ipiranga, located in Porto Alegre – RS (Brazil).

Stage 4: Determination of the general evaluation of the use of the river channel in the revitalization process

At this stage, the evaluation has a global character between the watercourse´s geomorphological, hydrological, hydraulic, and sanitary aspects. It is proposed that all metrics are analyzed broadly. So, a quantitative assessment of prerequisites, should consider the applicability and difficulty of applying interventions to the riverbed in the face of the premises adopted.

CASE STUDY IN ARROIO DILÚVIO, RIO GRANDE DO SUL -RS

The Arroio Dilúvio is a tributary of the watershed of Lake Guaíba. It has a drainage surface of 80 km^2, approximately a densely occupied area in the metropolitan region of Porto Alegre. The sub-watershed in question is one of the most densely constituted in the city, once the axis that borders the Arroio Dilúvio in almost all its extensions, Av. Ipiranga is one of the main waterways (Figure 6).

The section selected to apply the methodology was determined between the section of the canalized Arroio Dilúvio (Figure 7), observing whether the chosen part would not be influenced by the effects of the backwater of Lake Guaíba and by the possibility of the region to attract the river-goers.

Thus, the maximum occurrence flow of the river associated with the return time was obtained using the IPHS1 model, developed at the Instituto de Pesquisas Hidráulicas of UFRGS (IPH), according to the Urban Drainage Master Plan of the Arroio Dilúvio watershed (Prefeitura Municipal de Porto Alegre, 2014). The applied model resulted in a flow of 209.92 m^3/s with a return time of 25 years.

For dimensioning the diversion of river water, it was assumed that an occupancy rate of 80% would fit in the galleries, a landscape flow greater than or equal to 95% (0.306 m^3/s), and the maximum flows in the sections of the Arroio Dilúvio associated with the return times. In this way, considering the section of the river selected for the total intervention of 1 km and with no lateral flow contribution, the excess flows and the need for a lateral gallery 6 m wide and 7 m deep were calculated.

Thus, performing a comparative analysis between the limits for secondary contact for freshwater - Class 3, established

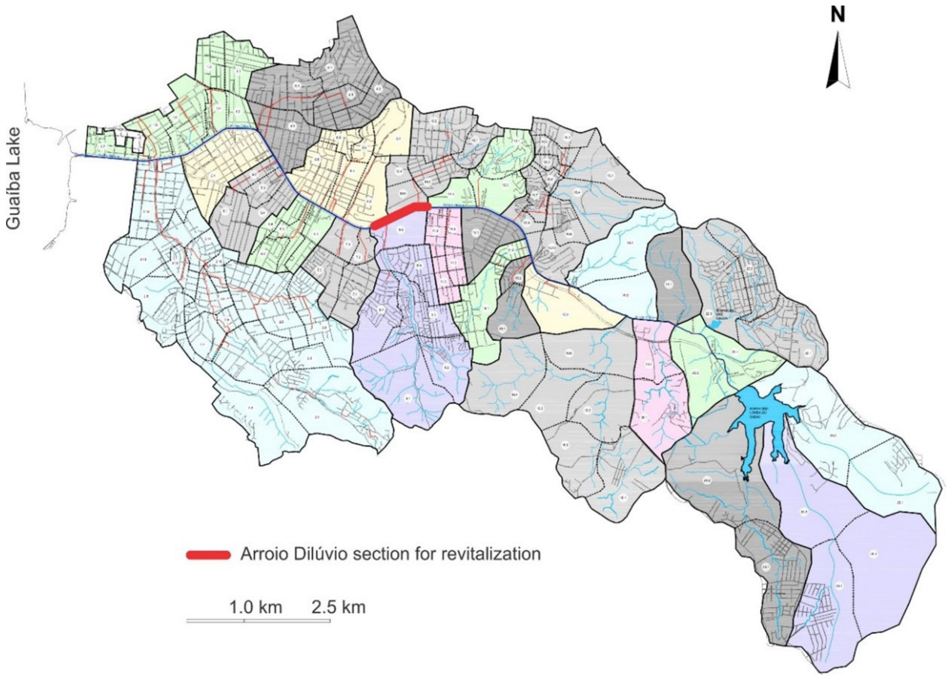

Figure 7. Arroio Dilúvio section chosen for revitalization feasible analysis method, located in Porto Alegre – RS (Brazil). Reference: adapted of Prefeitura Municipal de Porto Alegre (2014).

in CONAMA Resolution nº 357/2005 (Brasil, 2005), to the data obtained in the water samples collected by the Instituto do Meio Ambiente, in 5 points in Arroio Dilúvio (Instituto do Meio Ambiente de Alagoas, 2019). It was observed that the thermotolerant coliform parameters, BOD and phosphorus, were not within limits for secondary contact. In addition, it was chosen to add solid residue, due to the approximate volume of 150 tons/year collected downstream of the section proposed in this study, according to the Safeweb Project (2022) that contains floating residue in Arroio Dilúvio.

The proposed plan for improving the water in Arroio Dilúvio in this application followed the floating barrier, damming and water diversion, aeration system, built wetland, and disinfection system. After this system, it was established to follow the landscape channel available to the public.

In this way, the floating barrier must be installed between the margins of the main channel Arroio Dilúvio, in the free water surface, without riparian vegetation. The linear portion of this structure is about 20 meters long and has a 45° angle with the right margin.

A suitable cross-section was selected for the aeration zone in the aeration system, calculated using the original elevation provided. The system was subcategorized into two parts, one was for the continuity of the aeration process, and the other was for the sedimentation system. For the aeration zone, we assumed that the tank would be: 20 m wide, 4 m deep, and 40 m long. This part of the water improvement in Arroio Dilúvio must be restricted and isolated from the public due to the types of aerated particles resulting from the proposed system.

In the downstream sequence is the wetland system, an example of treatment technology that can bring numerous benefits, mainly related to cost reduction, efficiency for organic matter and nutrient removal, and pathogens elimination. For this, it was projected that the most used vegetation is Typha and a gravel system n° 01 (porosity of 0.4) to operate from 12 to 24 hours of hydraulic detention time with a slope of 1% of the bed, using the flow rate of 300 L/s. The first-order kinetics process was considered, and the surface area was obtained by adopting a removal rate of 87% of the organic load, according to Jordão & Pessôa (2011), after the aeration process. In addition to that, the length needed to accommodate the necessary area inside the Arroio Dilúvio channel is 136 m.

And finally, according to the experimental work performed by Paoli & Cordeiro (2010), the final effluent from the built wetland reached an average value of 98.2% efficiency for E. coli removal, while the average reduction obtained by Lourenço et al. (2018) in the constructed wetland was 88.5%. Thereby, for disinfection properties, a pond or an artificial tank must have a useful depth of $\leq$ 1.0 m (Mendonça & Piveli, 2004). This application method adopted a value of 1.0 m for the useful depth. The wetland´s total area will be 1,360 m^2, using a channel width of 20m. The required length is 68 m.

The analysis of the margin occupation regarding the implementation of the lateral galleries is a limiting factor for the diversion implementation of the excess flow in the section of Arroio Dilúvio. Thus, the adopted dimensioned gallery should have an external width of less than 6 m, considering the percentage of the wet area set at 80%. Therefore, it is possible to verify the viability of executing side galleries so the gallery´s width is equal to 6 m.

In this way, the last limiting variable verifies the technical viability between the proportion of the section destined for the water improvement system (floating barrier, aeration system, built wetland, and disinfection tank) that requires 20, 50, 136, and 68 meters, respectively, totaling 274 meters and the total length of the section (water improvement system and landscape channel). Thus, considering that the total length of the revitalization project is equivalent to 1,000 m, with a maximum rate of 30% for the exclusive use of water improvement, equivalent, therefore, to 300 m. In addition, this prerequisite was met, and accordingly, the viability of the water quality improvement system was verified.

CONCLUSIONS AND PERSPECTIVES

The development of the present research allowed the evaluation of the proposed methodology for selecting an intervention alternative in a revitalization project in the channel of densely urban watercourses and identifying significant developments and perspectives for the continuation of the work. In sections, three necessary conditions were proposed to assess the viability of revitalizing the watercourse, verifying the hydrological/hydraulic, environmental, sanitary, and topographical factors.

These proposed criteria encompass the main aspects of revitalization within the channel in watercourses. Throughout the development of the case studies, no other evaluation criteria were included regarding the solution performance evaluation.

For example, variables related to the collection of solid residues and sewage networks were not included in the scope of the proposed methodology, which considers only stretches of watercourses and their areas as an analysis scale. However, they are valid and very relevant considerations in a broad sense when considering the watershed as a spatial scale of analysis.

Within the scope of Brazilian watersheds, the application of in-situ urban water treatment techniques often encounters significant challenges due to space limitations. The increase in urbanization and the density of built-up areas have resulted in limited plots of land available for the implementation of treatment structures. Furthermore, existing infrastructure such as buildings and urban roads frequently occupies a substantial portion of the available space in urban areas. This scarcity of space can hinder the adoption of approaches that require a larger footprint, such as infiltration systems or retention green zones.

Financial limitations emerge as a highly relevant factor, exerting a direct impact on the feasibility of implementing in-situ urban water treatment techniques. This scenario places Brazilian institutions before a pressing challenge in adopting the proposed model, as limited financial resources establish themselves as the main obstacle to be overcome.

As to the prerequisites, there is the possibility of different results given the definition of the premises adopted, reinforcing the sensitivity of the results according to the premises. Therefore, the importance of a representative diagnosis of the physical and chemical conditions of the river and its riparian areas is emphasized here since the perception of the problems to be treated and possible generated impacts is of fundamental importance for elaborating proposals for revitalization with the local reality.

REFERENCES

Alonso, M. O. C. (2018). O debate ambiental contemporâneo: uma revisão crítica. *O Social em Questão*, *21*(40), 35-56. Retrieved in 2023, January 2, from http://osocialemquestao.ser.puc-rio.br/cgi/cgilua.exe/sys/start.htm?infoid=574&sid=55

Amaral, L. A., Nunes, A. P., Castania, J., Lorenzon, C. S., Barros, L. S. S., & Nader Filho, A. (2022). Uso da radiação solar na desinfecção da água de poços rasos. *Arquivos do Instituto Biológico*, *73*, 45-50. http://dx.doi.org/10.1590/1808-1657V73P0452006.

Bai, X. Y., Zhu, X. F., Jiang, H. B., Wang, Z. Q., He, C. G., Sheng, L. X., & Zhuang, J. (2020). Purification elects of sequential constructed wetland for the polluted water in urban river. *Water (Basel)*, *12*, 1054. http://dx.doi.org/10.3390/w10050643.

Baptista, M. B., & Cardoso, A. S. (2013). Rios e cidades: uma longa e sinuosa história. *Revista da Universidade Federal de Minas Gerais*, *20*(2), 124-153. https://doi.org/10.35699/2316-770X.2013.2693

Brasil. Conselho Nacional do Meio Ambiente – CONAMA. (2005, 18 de março). Resolução CONAMA nº 357, de 17 de março de 2005. Dispõe sobre a classificação dos corpos de água e diretrizes ambientais para o seu enquadramento, bem como estabelece as condições e padrões de lançamento de efluentes, e dá outras providências. *Diário Oficial [da] República Federativa do Brasil*, Brasília.

Cardoso, A. S., & Baptista, M. B. (2013). Metodologia multicriterial para orientação de processos decisórios relativos a intervenções em cursos de água em áreas urbanas. *Revista REGA*, *10*(1), 51-67. https://doi.org/10.21168

Carvalho, A. T. F. (2019). Sistemas Fluviais e o uso de indicadores de sustentabilidade: discussão sobre a utilização do instrumento para gestão de cursos d'água no Brasil. *Caderno Prudentino de Geografia*, *1*(41), 86-99. Retrieved in 2023, January 2, from https://revista.fct.unesp.br/index.php/cpg/article/view/6086/4939

Cengiz, B. (2013). Urban river landscapes. In M. Özyavuz (Ed.), *Advances in landscape architecture* (pp. 1-37). London: IntechOpen. https://doi.org/10.5772/56156

Cui, N., Chen, G., Liu, Y., Zhou, L., Cai, M., Song, X., & Zou, G. (2018). Comparison of two different ecological floating bioreactors for pollution control in hyper-eutrophic freshwater. *Scientific Reports*, *8*, 14306. http://dx.doi.org/10.1038/s41598-018-32151-5.

Darwich, T., Shaban, A., & Hamzé, M. (2018). The national plan for litani river remediation. In A. Shaban & M. Hamzé (Eds.), *The litani river, lebanon: an assessment and current challenges* (Vol. 85, pp. 147-160). Cham: Springer. https://doi.org/10.1007/978-3-319-76300-2_9

Fagundes, B. (2022). Rios urbanos e a política de canalização. *Sociedade & Natureza*, *32*, 396-406. http://dx.doi.org/10.14393/SN-v32-2020-44991.

Findlay, S. J., & Taylor, M. P. (2006). Why rehabilitate urban river systems? *Area*, *38*(3), 312-325. http://dx.doi.org/10.1111/j.1475-4762.2006.00696.x.

Gao, H., Xie, Y. B., Hashim, S., Khan, A. A., Wang, X. L., & Xu, H. Y. (2018). Application of microbial technology used in bioremediation of urban polluted river: a case study of Chengnan River, China. *Water (Basel)*, *10*, 643.

Ge, P. L., Chen, M., Zhang, L. C., Song, Y. J., Mo, M. H., & Wang, L. Y. (2019). Study on water ecological restoration Technology of river. *IOP Conference Series. Earth and Environmental Science*, *371*, 032025. http://dx.doi.org/10.1088/1755-1315/371/3/032025.

Instituto do Meio Ambiente de Alagoas – IMA-AL. (2019). *Diagnóstico e monitoramento ambiental do arroio dilúvio*. Retrieved in 2023, January 2, from https://www.pucrs.br/ima/projetos/diagnostico-e-monitoramento-ambiental-do-arroio-diluvio-eixo-ipiranga/

Jordão, E., & Pessôa, C. (2011). *Tratamento de esgotos domésticos* (7. ed.). Rio de Janeiro: Editora Abes.

Lourenço, L. S., Rodrigues, E. B., Moreira, M. A., & Skoronski, E. (2018). Remoção de matéria orgânica e nutrientes de esgoto doméstico por wetland horizontal de fluxo subsuperficial na estação de tratamento de aparecida-campos novos, SC. *Revista Brasileira de Agropecuária Sustentável*, *8*(1), 85-94. http://dx.doi.org/10.21206/rbas.v8i1.483.

Magalhães Júnior, A. P., & Barros, L. F. (2020). *Hidrogeomorfologia: formas, processos e registros sedimentares fluviais*. Rio de Janeiro: Editora Bertrand Brasil.

Md Anawar, H., & Chowdhury, R. (2020). Remediation of polluted river water by biological, chemical, ecological and engineering processes. *Sustainability*, *12*(17), 7017. http://dx.doi.org/10.3390/su12177017.

Mendonça, F. C., & Piveli, R. P. (2004). Uso agrícola de esgoto tratado em lagoas de estabilização: experiências do PROSAB em Lins – SP. *Exacta*, *2*, 37-54. Retrieved in 2023, January 2, from https://www.redalyc.org/pdf/810/81000204.pdf

Paoli e Cordeiro, A. (2010). *Análise de desempenho e comportamento de wetlands horizontais de fluxo subsuperficial baseado em modelos hidráulicos e cinéticos* (Dissertação de metrado). Escola de Engenharia, Universidade Federal de Minas Gerais, Belo Horizonte, MG.

Prefeitura Municipal de Porto Alegre – PMPA. (2014). *Plano diretor de drenagem urbana: Bacia do Arroio Dilúvio*. Porto Alegre: Prefeitura Municipal de Porto Alegre.

Safeweb Project. (2022). *Projeto Ecobarreira: Arroio dilúvio*. Retrieved in 2023, January 2, from https://institutosafeweb.org.br/#!/ecobarreira

Santos, M. F. N., Enokibara, M., & Fontes, M. S. G. C. (2022). Plant selection for green infrastructure: a review of recommended species for stormwater management devices. *Revista Nacional De Gerenciamento De Cidades*, *10*(75), http://dx.doi.org/10.17271/23188472107520223139.

Seoul. (2011). *Cheong Gye Cheon restoration project*. Seoul: Seoul Metropolitan Government.

Silva, A. S. D. (2018). *Ecobarreiras de baixo custo para retenção de resíduos sólidos em canais de macrodrenagem* (Monografia). Instituto de Pesquisas Hidráulicas, Universidade Federal do Rio Grande do Sul, Porto Alegre, RS.

Silva, J. C. A. (2017). *Bacias hidrográficas urbanizadas: renaturalização, revitalização e recuperação. Um estudo da Bacia do Jaguaré* (Tese de doutorado). Escola Politécnica, Universidade de São Paulo, São Paulo, SP.

Silva, L. C. (2010). Manejo de rios degradados: uma revisão conceitual. *Revista Brasileira de Geografia Física*, *3*(1), 23-32. Retrieved in 2023, January 2, from https://www.erambiental.com.br/var/userfiles/arquivos69/documentos/12684/ManejoRiosDegradadosRevisaoConceitual.pdf

Song, W. W., Xu, Q., Fu, X. Q., Zhang, P., Pang, Y., & Song, D. H. (2018). Research on the relationship between water diversion and water quality of Xuanwu Lake, China. *Int. J. Environ. Res. Pub. He.*, *15*, 1262. http://dx.doi.org/10.3390/ijerph15061262.

Souza, P. S. D. (2014). *Revitalização de cursos d'água em área urbana: perspectivas de restabelecimento da qualidade hidrogeomorfológica do córrego grande* (Dissertação de metrado). Centro de Filosofia e Ciências Humanas, Universidade Federal de Santa Catarina, Florianópolis, SC.

Tedesco, A. M., Oliveira, G. A., & Trojan, F. (2021). Avaliação da vulnerabilidade à contaminação das águas subterrâneas por meio dos métodos AHP e TOPSIS. *Engenharia Sanitaria e Ambiental*, *26*, 401-407. http://dx.doi.org/10.1590/S1413-415220190322.

Wang, J., Liu, X. D., & Lu, J. (2012). Urban river pollution control and remediation. *Procedia Environmental Sciences*, *13*, 1856-1862. http://dx.doi.org/10.1016/j.proenv.2012.01.179.

Zheng, L. G., & Wang, H. P. (2017). Ejects of combined ecological floating bed for eutrophic lake remediation. *AIP Conference Proceedings*, *1839*, 020058. http://dx.doi.org/10.1063/1.4982423.

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