Application of an integrated methodology for the synthesis of water networks and wastewater treatment in the pulp and paper industry

Aplicação de uma metodologia integrada para síntese de redes de água e tratamento de efluentes na indústria de papel e celulose

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ABSTRACT
The increase in the costs of water and wastewater treatment makes it relevant to develop tools that allow the efficient use of water in the industry, aiming at reduce costs and respecting the disposal limits imposed by the legislation. Thus, the objective of this work is to apply an integrated methodology for the synthesis and analysis of water networks and industrial wastewaters, combining the Wastewater Sources Diagram (WWSD) method with the results of the Water Sources Diagram (WSD) to the data representative of the pulp and paper industry. A case study considering the relevant contaminants present in the wastewaters from this process was carried out. The wastewater treatment network generated with the WWSD reduced the need for wastewater treatment by 35.20%, allowing lower costs and environmental impacts.

Keywords: Water sources diagram, Wastewater sources diagram, water reuse, wastewater treatment.

RESUMO
O aumento nos custos de tratamento de água e de efluentes torna relevante o desenvolvimento de ferramentas voltadas para o uso eficiente da água na indústria, a fim de reduzir custos e de atender aos limites de descarte estabelecidos pela legislação. Assim, o objetivo deste trabalho é aplicar uma metodologia integrada para a síntese e análise de redes de água e de efluentes industriais, combinando o método Diagrama de Fontes de Efluentes (DFE) com os resultados obtidos com o método Diagrama de Fontes de Água (DFA) a partir de dados representativos da indústria de papel e celulose. Foi realizado um estudo de caso considerando a presença de contaminantes relevantes nos efluentes deste processo. A rede de tratamento de efluentes gerada com o DFE reduziu a necessidade de tratamento em 35,20%, permitindo que se alcancem menores custos e impactos ambientais.

Palavras-chave: Diagrama de Fontes de Água, Diagrama de Fontes de Efluentes, Reúso de água, Tratamento de efluentes.

1 INTRODUCTION

The development of methodologies for the optimization of water use in pulp and papermaking processes represents an effective mechanism for environmental management and water sustainability, whose consumption can reach 700,000 L of water (MIERZWA; HESPANHOL, 2005). An important tool of Process Engineering is the Wastewater Sources Diagram (WWSD) method (DELGADO et al., 2009; MOREIRA et al., 2015), based on the algorithmic-heuristic procedure called the Water Sources Diagram (WSD) (CALIXTO et al., 2020; GOMES et al., 2007; 2013). This type of approach uses the concept of transfer of contaminant species from a process stream to an aqueous stream, in an operation that uses water as a mass transfer agent.

The WWSD method was initially developed to select the best sequence of final treatment techniques (for discharge in water bodies) for a set of effluent streams, depending on the removal efficiency. At the same time, the objective is to establish a technical configuration of an effluent treatment sequence with the lowest flow rate possible. For this purpose, flow rate and concentration data of the contaminants in the effluents, limit concentration for disposal (legislation), treatment units and their respective efficiencies are required for the removal of these contaminants. In this way, the application of the method by means of concentration ranges allows the generation of treatment structures, comparing the flow rate to be treated according to the configuration possibilities, either of the distributed type (streams wastewater are treated separately before being collected for disposal) or centralized (effluents are picked up and unified in order to treatment in a plant). Normally, treated effluent flow rate and costs tend to be lower with the practice of distributed treatment (WANG; SMITH, 1994).

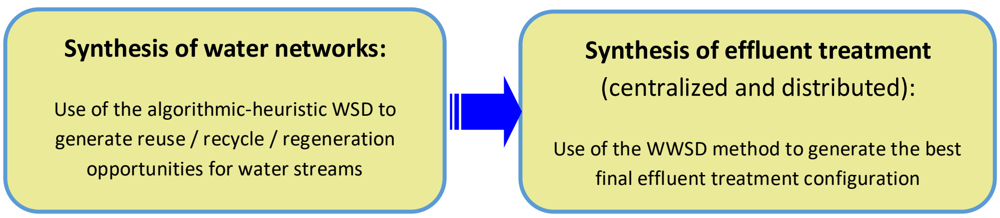
Integrated approaches to reuse wastewater among industrial processes (for example, between petroleum refinery and petrochemical complex) (MIRRE; PESSOA; MELO, 2019), and to reduce fresh water consumption among industrial plants in the same hub, have also been proposed applying the WSD (CALIXTO; PESSOA; MIRRE, 2021).

Although the WSD method has been applied to pulp and paper manufacturing processes, as in the works of Marques et al. (2008) and Francisco et al. (2014; 2018), the WWSD method has not been yet tested for treatment characteristics involving data from this type of industry. The achievement of integrated water and effluent networks becomes a timely strategy to demonstrate the importance of working potentially with techniques aimed at reuse of water and treatment of industrial effluents. Thus, this work aims to demonstrate the results of the application of the WWSD method, sequential and integrated to the WSD, as a basis for the improvement for a later assessment of scenarios impacts, as well as to help the systematic selection of sustainable water networks as well as industrial wastewater treatment networks. In this case, representative effluents from the pulp and paper industry are used, obtained from previously established water networks for reuse opportunities.

2 METHODOLOGY

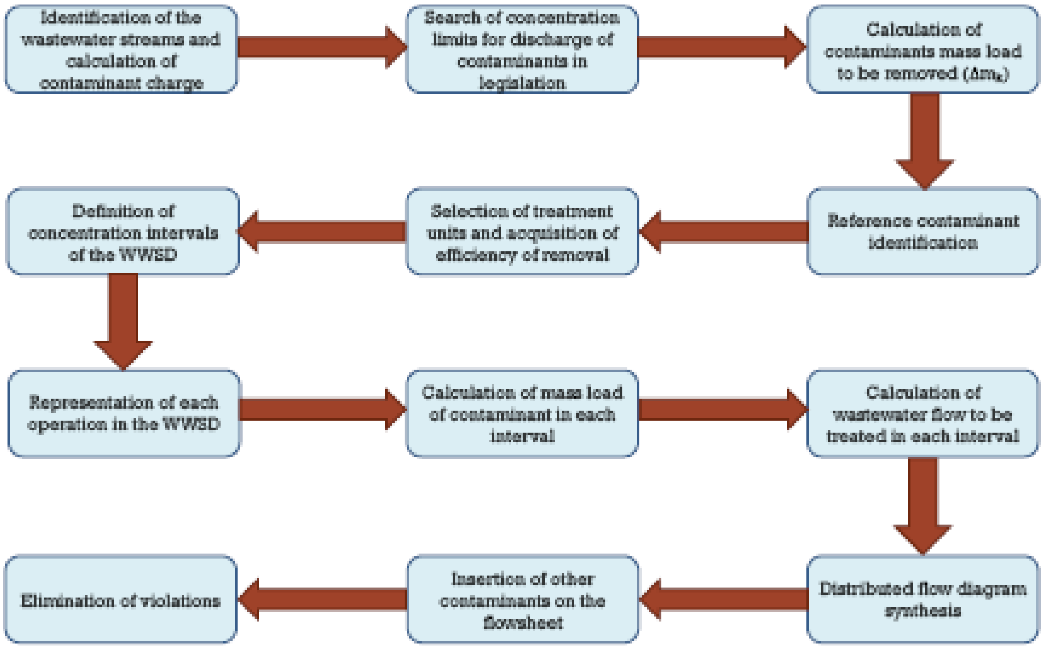
Figure 1 outlines the application sequence of the methodology for the generation of integrated networks for reuse and treatment of water resources. The combination of the use of WSD and WWSD supports the integrated analysis of the sustainability of industrial processes in relation to the efficient and rational use of water.

Figure 1 – Sequence of application of the methods for generation of water reuse networks, networks of final treatment of effluents and evaluation of impact of scenarios



The procedure for the application of WWSD is detailed in the Pacheco (2014) study, which used WSD and WWSD to evaluate the reduction of primary water consumption and the generation of effluents in petroleum refineries, as well as the determination of the minimum effluent to be treated, according to the discharge limits of contaminants. External treatment will only be performed if there is no internal effluent with a concentration lower than the effluent to be treated available for mixing. The wastewater treatment network is generated from the last interval of each operation in the WWSD. Figure 2 illustrates the general steps to apply of WWSD method.

Figure 2 – WWSD steps



The application of the established methodology for this study is carried out from data of processes that represent a paper industry. The data are obtained from Francisco et al. (2018) to generate water networks with the WSD method under the maximum reuse condition. It is considered the presence of two contaminants in the process: chemical oxygen demand (COD) and suspended solids (SS). It was also proposed an evolutionary strategy for the method, with the allocation of a new by-pass to each treatment unit.

3 RESULTS AND DISCUSSION

The results incorporate the application of the methodology for the WWSD method for a case of maximum reuse water network, based on the effluent characteristics of the network developed by Francisco et al. (2018). Thus, Figure 3 shows the network corresponding to the application of the concentration range diagram considering the centralized treatment. Figure 4 shows the network obtained with the possibility of configuration of distributed type treatment and Figure 5 shows the network generated with the proposal of the second by-pass. For the application of the method, aerobic granulation (AGS) and aerated lagoon treatment techniques are considered to have COD and SS removal efficiencies of 90% and 97% and 60% and 98%, respectively.

Figure 3 – Flow diagram representative of centralized treatment without the presence of violations on the network

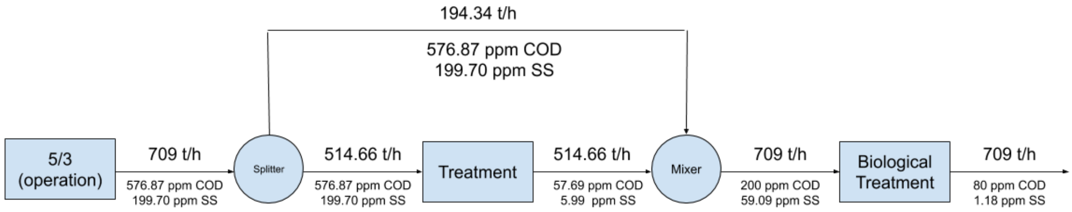


Figure 4 – Flow diagram representative of the distributed treatment without the presence of violations on the network

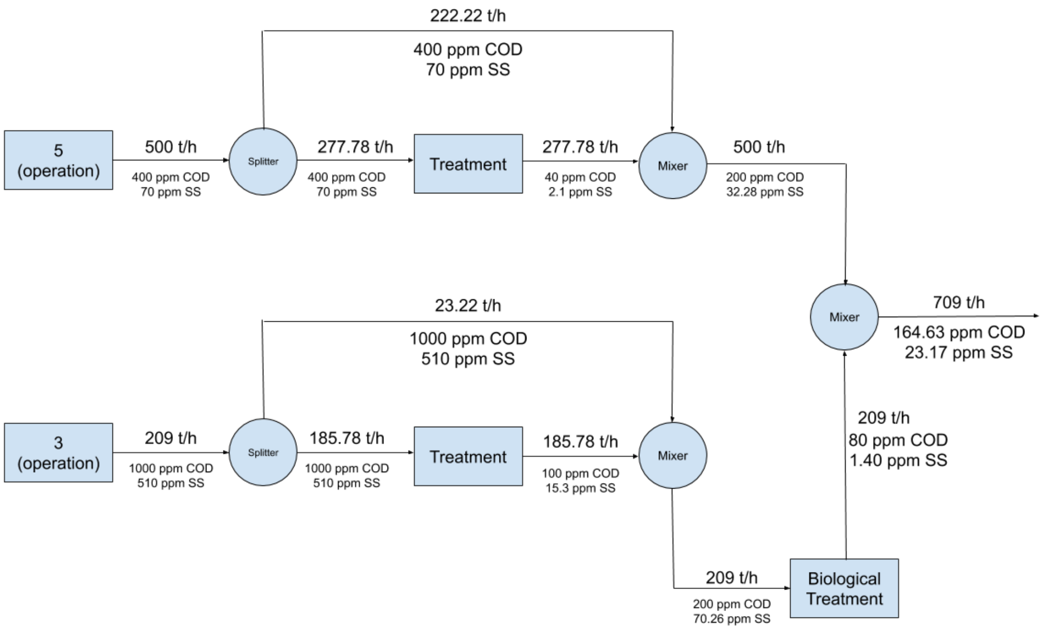
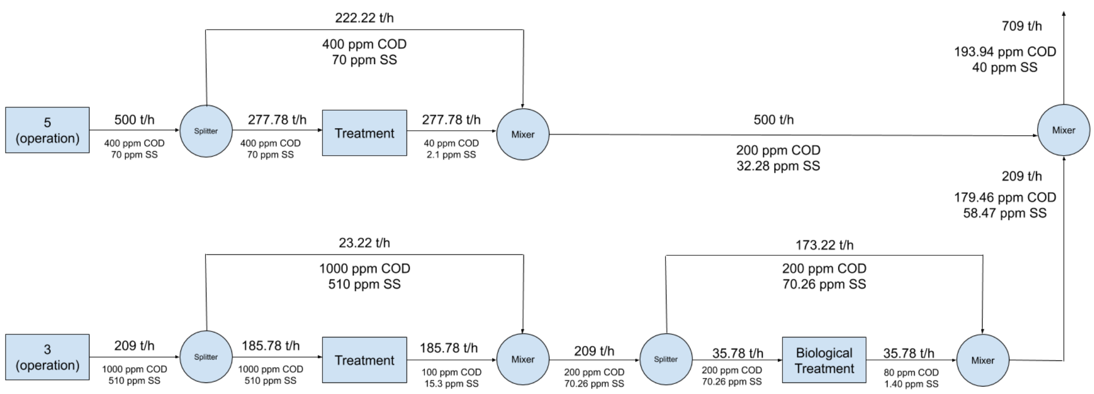


Figure 5 – Flow diagram representative of the distributed treatment without the presence of violations and with the allocation of the second by-pass



The allocation of the second by-pass leads to the reduction of the flow rate to be treated by 11.50% in relation to the distributed treatment and 35.20% when compared to the centralized treatment, which suggests a reduction in treatment costs and environmental impact.

4 CONCLUSIONS

The objective of this work was to propose a combined strategy for the evaluation of scenarios of treatment of centralized and distributed final effluent with the use of a tool that helps to optimize the use of water in industrial processes. In this case, the results of the application to representative data of the pulp and paper industry allowed to test the procedure for the operational characteristics of this sector, making it possible, in future stages, to evaluate the scenarios under the technical, economic and environmental aspects.

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