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Industrial wastewater reuse in inter-plant water networks

Reúso de águas e efluentes entre plantas industriais

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ABSTRACT

This work aims to use a Process Integration method to extend a methodology that involves the selection of water reuse networks among industrial processes. A case study from data representative of an oil refinery and a petrochemical complex was carried out. The results with the inter-plant water networks indicated external sources that can be used for the unidirectional reutilization of the water processes from the refining to the petrochemical. Refining processes with maximum reuse had a 39% reduction in relation to the original consumption, while petrochemicals reduced by around 36%. The scenario involving the integration of both plants, with the incorporation of a distribution central tank and a regenerative process, reached a complementary reduction of about 7% of the water catchment. This integration allows the achievement of new opportunities for reuse, making it an important strategy in environmental decision making in organizations.

Keywords: Water reuse, inter-plant water networks.

RESUMO

Este trabalho tem como objetivo utilizar um método de Integração de Processos para a extensão de uma metodologia que envolva a seleção de redes de reúso de águas entre unidades industriais. Realizou-se um estudo de caso a partir de dados representativos de uma refinaria de petróleo e de um complexo petroquímico. Os resultados com a rede de águas entre plantas indicaram fontes externas que podem ser empregadas para o reaproveitamento unidirecional dos processos hídricos do refino para a petroquímica. Os processos de refino com máximo reúso tiveram redução de 39% em relação ao consumo original, enquanto que a petroquímica reduziu em torno de 36%. O cenário envolvendo a integração de ambos os processos, com a incorporação de uma central de distribuição e um processo regenerativo, alcançou redução complementar de cerca de 7% da água captada. Este tipo de integração permite o alcance de novas oportunidades de reaproveitamento, tornando-se uma estratégia importante na tomada de decisões ambientais nas organizações.

Palavras-Chave – Reúso de água; redes de água entre plantas.

1 INTRODUCTION

One of the greatest challenges for the achievement of industrial sustainability is in ensuring the efficient and rational use of water. The management of the distribution of water resources in the industry can be accomplished through systematic tools that allow the maximum use of water and the minimum generation of effluents. In the literature, several papers deal with systematic methods aimed at better allocation of water resources in industrial processes from restricted (limited) sources of supply (BAGAJEWICZ, 2000). Most of the work belongs to a category of methods of Chemical Process Integration, engineering area focused on the design and optimization of integrated systems of industrial processes.

Gomes et al. (2007) proposed the Water Source Diagram (WSD) method as an alternative and practical tool for the process engineer, aiming at reducing water consumption and effluent generation in industrial processes. This algorithmic procedure uses flow rate data of water process streams and quantification of components and parameters relevant to the process, allowing to generate reuse scenarios (reuse and / or recycle). Its application is based on the concept of mass transfer of contaminants in operations that use water to guide the allocation of flow rate in a diagram of concentration ranges, according to available water sources (internal or external). The methodology has already been applied successfully to different industrial sectors, according to Mirre et al. (2015). The method allows generating proposals for reuse of water process streams.

In order to select the scenarios considered promising for practical implementation, the integrated water resources management model called P+WATER (MIRRE et al., 2013) was developed, using criteria based on operational cost, indexes that reflect the realignment of water process streams, the investment in regenerative processes, as well as the configuration of the final effluent treatment (DELGADO et al., 2009) and the negative impact value of effluent disposal (AUDEH et al., 2015).

By extending the use of these tools to industrial complexes, it is possible to adopt mechanisms for verticalization of water allocation networks, favoring the rational use shared between the different sectors. The integration, in terms of water consumption, allows the obtainment of structures with maximum utilization and lower environmental impact, contributing to industrial sustainability. Direct and indirect integration schemes can be achieved using central water sources, allowing the reduction of pipeline costs due to distances between plants, usually larger than the operations that make up individual plants (CHEW et al., 2008). Several approaches have been developed to generate networks of integration between plants in eco-industrial parks (BOIX et al., 2015, LIU et al., 2016).

The objective of this work is to study the possibility of reducing water consumption and the generation of effluents in water networks in industrial complexes that represent an eco-industrial park as a complementary tool for the decision-making of the integrated management model P+WATER. A case study involving data representative of an oil refinery and a petrochemical complex is conducted.

2 METHODOLOGY

Figure 1 illustrates the trajectory of establishing direct reuse from one process to another, after identifying opportunities for internal reuse by the WSD method. It represents a simplification of the possibilities of interaction between plants by means of water currents, in the case of a refinery and a petrochemical complex. It is observed that the effluents go through the conventional treatment process, which can be established to adjust the quality standard for eventual reuse in another operation. The effluents treated in the respective plants can also be recycled as an external source of water to another plant, before being centralized for disposal in the receiving body. On the other hand, the effluents can be segregated for a final treatment of the type distributed (DELGADO et al., 2009). Primary water sources represent the quality obtained for their distribution in the plant. It is possible to use a distribution center for equalization of the load to be allocated in the subsequent processes.

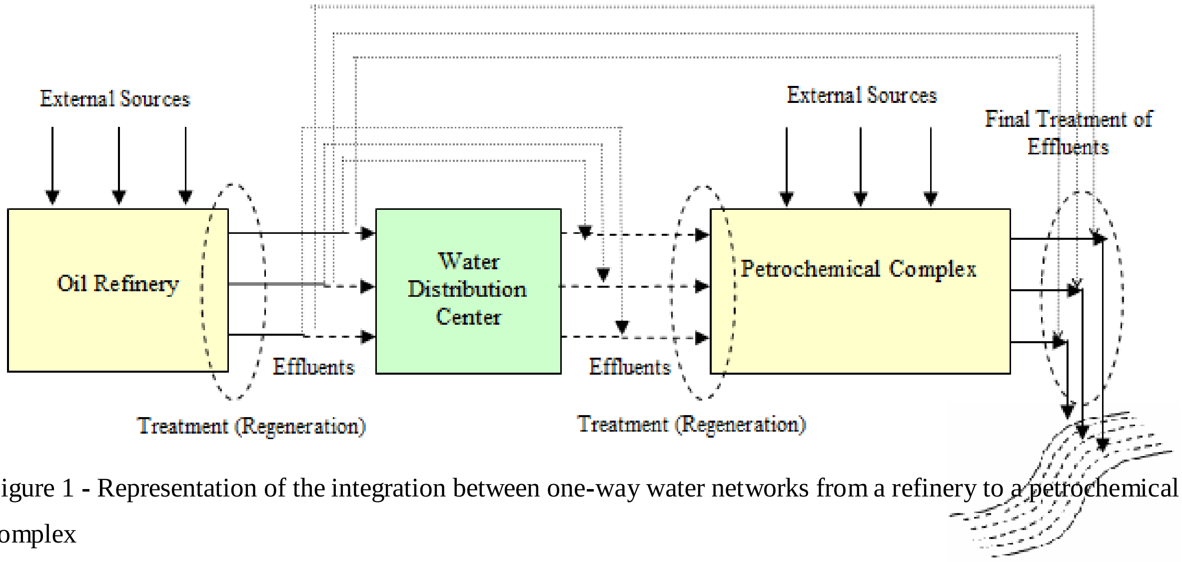


Figure 1 - Representation of the integration between one-way water networks from a refinery to a petrochemical complex

In the approach of this study, the refining-petrochemical integration is performed unidirectional from the maximum reuse networks, without integration between plants, that is, the refinery effluents are used upstream of the final treatment; these are then made available as an external source of water for the petrochemical processes. In the case presented here (MANN and LIU, 1999), the petrochemical has only an external source, in the quality of 0 ppm.

The priority of reuse actions should be offered to the internal reuse in relation to the external reuse (from another plant), after measures aimed at elimination or reduction at source, taking into account the premise of Cleaner Production to prioritize internal reuse. On the other hand, the refinery's effluent treatment can be carried out in a way that allows it to fit petrochemical operations. Two possibilities are opened: (1) regeneration with fixed output concentration, to adjust the reuse in the operation (s); (2) use of a specific regenerator, with a given contaminant removal efficiency. In this work, we opted for the first strand, aiming to expand the possibilities of reuse, without previously identifying the regeneration equipment.

3 CASE STUDY

Refining-petrochemical integration involving water networks becomes an important proposal for the industrial sector, as it allows to manage the effluents of two large water consumers and reduce the potential of environmental impacts generated by their activities. In this study, the synthesis of the networks involving maximum reuse in each plant is performed initially, and then the integration of previously improved networks is established, and then the evolution of the structure obtained is established.

In order to obtain integrated networks, a case study was carried out involving data from an oil refinery (MOHAMMADNEJAD et al., 2011) and a petrochemical (MANN and LIU, 1999), whose representative contaminant is suspended solids. The integration is performed between water networks for maximum reuse, obtained by applying the WSD method.

For the oil refinery, the water process flowsheet and data from the study by Mohammadnejad et al. (2011). In this case, the WSD was applied for the generation of the water network involving maximum reuse. The following three sources were considered: (A) utility system effluent (45 m^3/h at 1 ppm), (B) boiler purge (20 m^3/h at 0 ppm) and (C) fresh / fresh water (always available, at 0 ppm) (MUGHEES et al., 2013). As these sources have similar qualities in relation to this contaminant, the purge of the boiler becomes a priority source in relation to that of fresh water. Three operations are selected for the possibilities of reuse: cooling tower, desalter, and general consumption (plant, drinking water, fire water). It is observed, in Figure 2, the water network applied to the condition of maximum reuse. This network has a consumption of water at 0 ppm (fresh + boiler purge) of 207.8 m^3/h, a reduction of 39% in relation to the original consumption of 340 m^3/h, considering the main operations of this process. The consumption of fresh water (0 ppm) is 187.8 m^3/h, which is equivalent to a 45% reduction in relation to the original consumption.

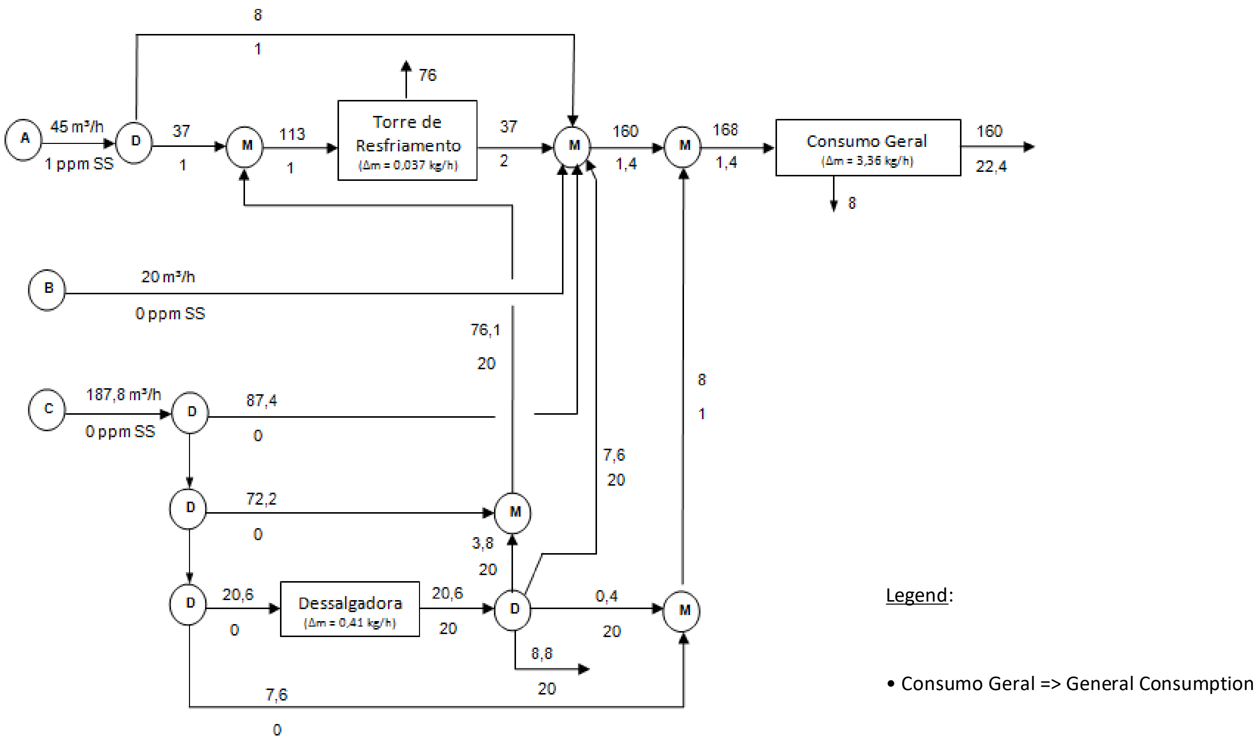
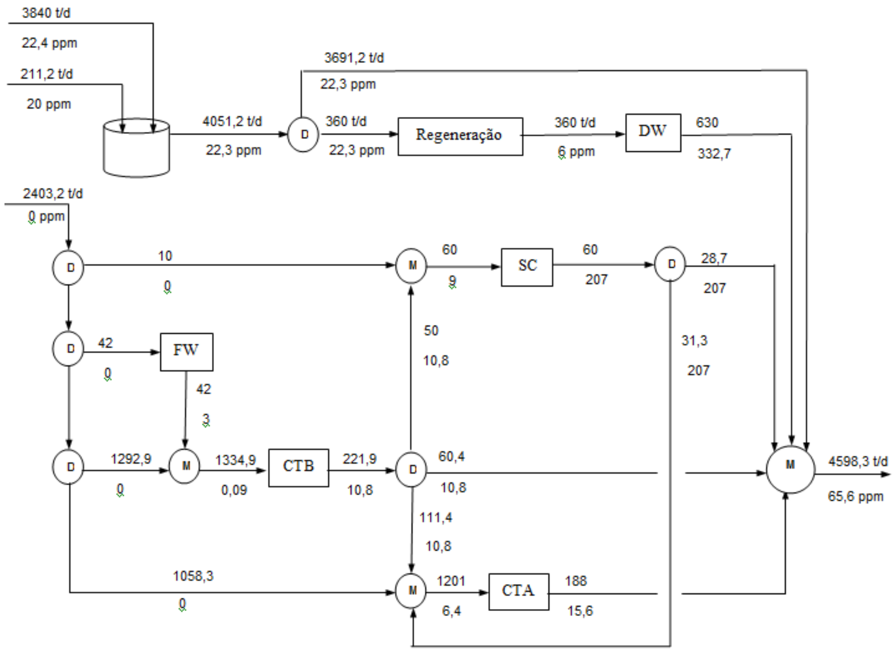


Figure 2 - Refinery water network obtained with the WSD method for condition of maximum reuse

The petrochemical complex used in this study refers to that presented by Mann and Liu (1999), whose plant is located in Taiwan and produces styrene, ABS resin (acrylonitrile-butadiene-styrene terpolymer) and SAN resin (styrene-acrylonitrile copolymer). In this case, the water network from the WSD was obtained by Scarlati (2013). The distribution of 3,037 t/d in 5 water consuming operations was considered, as follows: DW - Filtration and drying of filters; CTA - Cooling tower A; CTB - Cooling Tower B; SC - Gas Cleaning; and FW - Equipment washing. The total consumption of the external water source (0 ppm) in this plant is 5,430 t/d. This scenario of maximum reuse led to the reduction of water consumption to 0 ppm of 14% and effluents of around 36% (SCARLATI, 2013).

From the refinery's effluents, the possibilities of generating scenarios in which a distribution center was considered to redistribute the effluents were raised. The proposals dissociate the submission of the streams to the final treatment of refinery effluents; however, it uses regenerative processes to meet the quality of water for reuse in petrochemicals.

It was verified that the effluents coming from the refinery leaving the distribution center have a lower quality than the allowed input concentration in the operations of the petrochemical complex. For this reason, the reuse would only be possible if the amount of water to be used would lead to a significant reduction of the external source to 0 ppm of the petrochemical. A scenario involving the recovery of refinery effluent quality was obtained to be redistributed as an external source for petrochemicals. Figure 3 shows the integration of the processes for this proposal, through the presence of a water allocation center, providing an additional external source for petrochemicals of 168.8 m^3/h (4051.2 t/d) at 22.3 ppm. Units of measure were standardized for t/d.



Legend:

Figure 3 - Water network of the refining-petrochemical processes

The water network of the integrated units involves a regenerative process for water quality adjustment for reuse, whose output concentration is determined by the input concentration value of the receiving operation. The regeneration criterion adopted refers to obtaining the concentration value of the stream with the highest constant flow, which, under these conditions, corresponds to the operation called filter filtration and drying (DW) (360 t / d) (in this case, without analyzing the gain that this operation presents, since the WSD, for application purposes, divides operations of variable flow). This scenario allowed the regeneration of only the quantity required for allocation in the receiving operation (DW), which led to a reduction of the water consumption of the external source (0 ppm) of the petrochemicals around 7%, in relation to its original capture. However, it should be noted that costs related to distance between units should be analyzed so that this proposal is considered promising for implementation purposes, which was not done in this study.

The integration between plants provided an increase in the reduction potential when compared to those obtained by refining and petrochemicals individually, indicating a greater contribution of this type of configuration, although current costs are not considered at present. However, given the complexity of the problem, a proposal for scenario generation would be to verify the performance of the centralized and distributed treatment settings (for each plant separately, including the evaluation of the respective costs), and from there consider the possibility of reuse in other plants (plant integration), or to send the treated effluents to a distribution center (combination of streams) in order to redirect to the respective process units.

4 CONCLUSION

This work is inserted in the purpose of incorporating a procedure for selection of scenarios involving integration between plants. The case study carried out generated preliminary results highlighting the importance and feasibility of this application, since these are industrial sectors that consume significant amounts of water. Among the options to be analyzed, the evaluation of final effluent treatment networks (centralized and distributed), as a distribution center, can be used to adjust the effluent for eventual reuse in the (receiving) plant. In this perspective, it is intended to provide conceptual subsidies for the structuring and the continued development of a model of sustainable management of water resources, being an additional and alternative instrument in the environmental decision making in the organizations.

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