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EVALUATION OF FINAL EFFLUENT REUSE IN OIL REFINERY AIMING TO REDUCE WATER CAPTURE

Sílvia Lima Touma
Department of Interconnections and Utilities, Petrobras, Rio de Janeiro, Brazil
https://orcid.org/0000-0002-2809-9829

Gustavo Neves Duarte
Department of Interconnections and Utilities, Petrobras, Rio de Janeiro, Brazil
https://orcid.org/0000-0001-8887-3911

Paul Antoine Valery Nunes
Department of Water and Effluents, Petrobras, Rio de Janeiro, Brazil
https://orcid.org/0000-0002-5739-2995

Rubens André Bignetti
Department of Interconnections and Utilities, Petrobras, Rio de Janeiro, Brazil
https://orcid.org/0000-0002-5933-4000

Abstract: Industries are increasingly being pressured to seek viable alternatives for water supply, in order to maintain the sustainability of their operations, without neglecting the preservation of the environment. This pressure is exerted both by regulatory bodies, through restrictions in relation to the granting of permissions for the use of surface and groundwater, prioritizing public supply, and more restrictive standards for the release of industrial effluents, and by society, as a water crisis sets in on the national scene, reinforcing the influential roles they play in this dynamic. With this finding, the reuse of final effluents in an oil refinery has great potential for reducing water consumption. Therefore, the present work presents the design philosophy of a final effluent reuse system in an oil refinery, aiming to minimize the uptake of water in a spring, located in the Southeast region of Brazil, in a basin where, due to Due to water stress and high population density, the demand for water resources is subject to conflict. In addition, reuse would allow, as an additional benefit for the community, a significant reduction in the discharge of industrial effluents into the receiving water body. Based on the refinery's water balance, a reverse osmosis demineralization system was adopted as a tertiary treatment stage, after a membrane bioreactor (MBR), with the objective of placing the water for replacement in the cooling towers of the refinery. refinery. Thus, in the simulations carried out, it was possible to obtain reuse water flows between 900 m³/h and 1,700 m³/h, depending on the operational scenario. Thus, a potential reduction of 43% to 82% was estimated in relation to the current intake flow, close to 2,600 m³/h.
Keywords: Reuse of industrial effluents, reverse osmosis, oil refinery, reduction of water uptake, water balance.

INTRODUCTION

In view of the increasingly restrictive measures in relation to the use of water resources from surface and underground springs imposed by the control bodies, the standards for the release of industrial effluents are progressively more demanding at the federal (CONAMA, 2011), state or municipal and the priority use of this input to supply the population, the reuse of final effluent is shown as one of the viable alternatives for the industry to guarantee the operational sustainability of its business and preserve the environment, reinforcing the relevant role it plays in society (JUDD, 2003).

In this context, it is essential that industries first seek ways to reduce water consumption from surface or underground sources, such as rationing in production processes, adopting, when feasible, heat exchange equipment that does not use water, such as coolers. to air; application of energy integration concepts of currents; reduction of leakage losses; increase in the efficiency of water and effluent treatment processes; optimization of concentration cycles in cooling towers and boilers for steam generation; steam condensate recovery; internal recycling in the Water Treatment Station (ETA) (IPIECA, 2015; POMBO, 2011).

In particular, the downstream oil industry, over the years, has been consuming more and more water for the processing and refining of oil and the production of derivatives, with an average water/oil ratio of approximately 1:1 being considered. Sometimes, water consumption can exceed the unit, as shown in Table 1. The water abstraction index is calculated by the ratio between the volume of water captured and the volume of processed crude oil (CARVALHO et al, 2008).

Thus, in addition to the consumption reduction actions presented, the reuse of final effluents is a solution that has great potential

Refinery	2001	2002	2003	2004	2005	2006	2007
A	0,82	0,88	0,86	0,86	1,11	1,16	0,81
B	1,13	1,04	1,02	1,11	1,16	1,23	1,26
C	1,04	1,09	1,10	1,06	1,06	1,06	1,12
D	0,75	0,50	0,71	0,45	0,41	0,75	0,62
E	0,48	0,48	0,52	0,61	0,65	0,65	0,68
F	0,74	0,78	0,78	0,70	0,75	0,73	0,69
G	0,67	0,73	0,71	0,56	0,55	0,75	0,73
H	0,66	0,84	0,86	0,72	0,69	0,66	0,69
I	1,18	1,13	1,13	1,11	0,97	0,94	1,15
J	1,10	1,00	1,40	1,35	1,33	0,86	0,96

(Petrobras – SIGER, 2008 apud CARVALHO et al., 2008)

Table 1 - Water Uptake Index (ICA) in Oil Refineries in Brazil.

to contribute to the reduction of water capture in an oil refinery. Therefore, additional treatment steps may be necessary, in order to fit the final effluents to the specifications required for uses in the refinery. Cooling towers are the systems that consume the most water in a refinery, and do not require water quality specifications as restrictive as water for steam generation, being strong candidates to receive reuse water (POMBO, 2011).

GOAL

This work aims to present the design philosophy of a final effluent reuse system in an oil refinery, aiming to minimize water uptake in a surface water source, located in the Southeast region of Brazil, in a basin where the stress water supply and high population density sometimes cause conflicts of interest for water resources.

METHODOLOGY USED

The refinery in question segregates its industrial effluents, having two Industrial Waste Treatment Stations (ETDI), one for the so-called "contaminated" effluents, characterized by low salinity and the potential presence of oil, including purges from the cooling towers, and another for the so-called "oily" effluents, from processes of desalination and drainage from the bottom of oil tanks, presenting, therefore, high salinity and constant presence of oil, as shown in Figure 1.

The ETDI of contaminated effluents has a water-oil separator (SAO) as a treatment route, followed by a dissolved air flotator (DAF) and a nutshell filter (FCN), which are directed to the discard after treatment.

In turn, in the ETDI of oily effluents, after the separation of the oily fraction in the SAO, in the dissolved air floater and in the nutshell filters, they go to a biological reactor with membranes (MBR, Membrane Bioreactor, in English), where the removal of biodegradable contaminants occurs through the action of microorganisms (DROSTE, 1997). In the MBR, the biological solids separation step is carried out using ultrafiltration membranes, which guarantee an excellent quality of the treated water in terms of suspended solids, being able to even remove viruses and bacteria, but which is not capable of reducing salinity. of this effluent (CAVALCANTI, 2012). After treatment, the effluent is suitable for release into a receiving water body according to applicable legislation. However, for reuse purposes, this effluent is excessively saline,

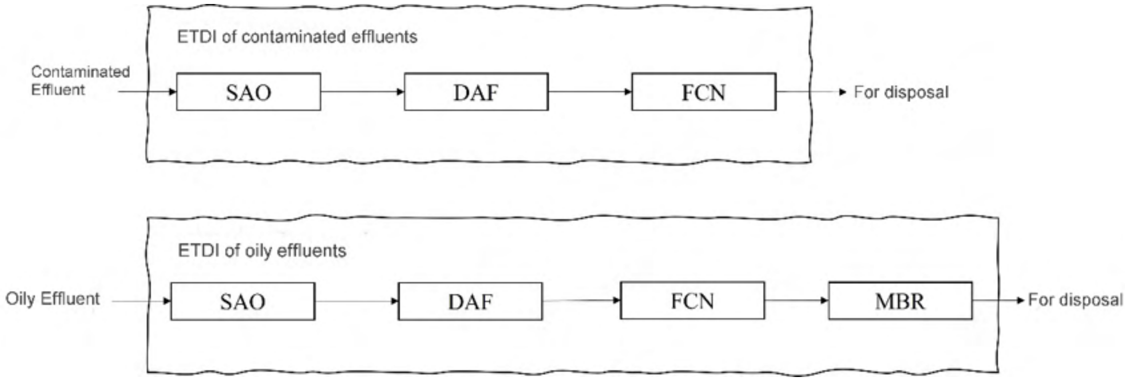

Figure 1 – Effluent treatment scheme for the refinery under study. Source: prepared by the authors.

and it is essential to remove these salts before sending them to the refinery's consumers. With this objective, the project proposes the use of Reverse Osmosis (RO) technology, in order to fit this reuse current to salinity characteristics similar to those of water currently captured in surface water sources.

The philosophy of this project aims to maximize the reuse of final effluents, combining the treated effluents from both ETDIs, allowing the replacement of water in 6 (six) cooling towers of the refinery and other smaller reuses, such as water to combat emergencies and water for the decoking process in a Delayed Coking unit. Figure 2 shows the proposed scheme for the reuse of effluents, where the thick lines represent the new systems, the thin lines, the existing ones, while the dashed lines indicate the main discharges.

In this study, four operating scenarios were considered in the global reuse assessment:

- normal refinery operation;
- operation in the post-rain period;
- operation in a situation of partial unavailability of the reverse osmosis system;
- operation in a situation of partial unavailability of the reverse osmosis system in the post-rain period.

Initially, the water balance of the refinery in normal operation was prepared, in order to determine the flows available for reuse in each of the ETDIs, as well as the demands of potential consumers of this water.

The tertiary treatment route was inserted in the water balance, to reduce the salinity of the oily effluent, considering the treatment by reverse osmosis, with a typical hydraulic efficiency of 70% for water reuse systems. In the normal operating scenario, the reverse osmosis unit will be fed by the MBR effluent at a flow rate of 800 m^3/h, producing 560 m^3/h of permeate continuously. The reverse osmosis permeate will be mixed with the low salinity effluent treated in the contaminated effluent ETDI and the reuse water will be directed to the cooling towers.

Then, for each evaluated scenario, by water and ion balance, the reuse water flows, after tertiary treatment and mixing with the contaminated effluent, destined for the cooling towers, respecting the quality required for the operation of the towers. cooling, as recommended by manufacturers and processing companies. For each of the scenarios, balances were evaluated with the concentration cycles of the optimized and non-optimized cooling towers.

In the post-rain scenario, the refinery will

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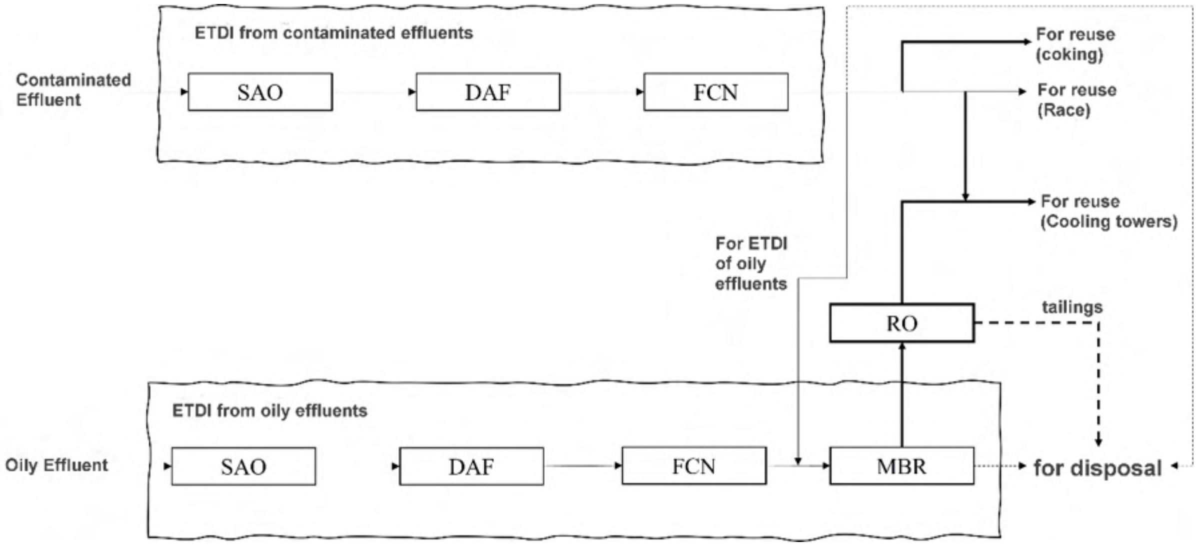

Figure 2 – Scheme with tertiary treatment for reuse. Source: prepared by the authors.

have to treat, in addition to its typical effluents, a portion of rainwater collected in the process units, with potential contamination by oil. In this way, the characterization of the oily ETDI load, as well as the salinity of the treated effluent, is altered, impacting the ionic balance and the amounts of reused water that each cooling tower can absorb.

RESULTS OBTAINED AND EXPECTED

Currently, the refinery already has the possibility of reusing approximately 550 m^3/h of treated contaminated effluent, with up to 70 m^3/h directly into the Emergency Water Network (RACE). The other reuse actions carried out by the refinery, which total 480 m^3/h, involve the reuse of acidic water rectified in the desalters, the return of tailings from the ultrafiltration membranes (UF) to the inlet of the ETA clarifiers and the recovery of water from cooling of machines in one of its Thermoelectric Power Plants.

The rest of the industrial effluent generated at the refinery, whose estimated flow varies from 1,327 m^3/h to 1,793 m^3/h in dry weather and from 1,477 m^3/h to 1,943 m^3/h in the rainy season, is discharged into a receiving body.

The design philosophy described in this work will allow the refinery to expand its capacity to reuse final effluents, with the main expected result being a significant reduction in water abstraction from surface springs, whose water resource can be prioritized for public supply. Table 2 shows the water balance for the evaluated scenarios.

The results of the water and ionic balances carried out show that the reuse water flows may vary from about 900 m^3/h to 1,700 m^3/h, depending on the refinery's operating scenario, as can be seen in Table 2. It is estimated although the reduction in abstraction varies from 1,125 m^3/h to 2,125 m^3/h, considering that the water captured in a spring would have to undergo a clarification process, whose hydraulic efficiency is currently estimated at 80%. This means a reduction of 43% to 82% in relation to the current flow of capture, which is around 2,600 m^3/h. In this way, it will be possible for the refinery to operate with a reduced catchment grant flow, imposed by the state environmental agency.

In addition, as a positive impact for

the environment, a significant reduction in the discharge of effluents is expected in another surface water source, which will be preserved, since it will no longer receive such a large amount of industrial effluents. In the scenarios evaluated in this study, the discharge rates of industrial effluents with reuse ranged from 240 m^3/h to 468 m^3/h, in different compositions, since they consider either only the saline tailings stream from reverse osmosis, or a mixture of saline tailings from reverse osmosis, final effluent from oily ETDI and contaminated ETDI, depending on the refinery's operational scenario.

Among other expected results, mention must be made of the operation of the ETDI of oily effluents at its maximum capacity (800 m^3/h) at all times, aiming at the generation of water for reuse, taking advantage of the full potential of the installed unit for the treatment of effluents. oil, as well as the possibility of providing 350 m^3/h of clarified water from the refinery for the operation of another undertaking in the Brazilian refining park.

DISCUSSION OF RESULTS

Reverse Osmosis technology has been widely applied in seawater desalination processes, both for industrial purposes and for public supply around the world, and brackish water (IPIECA, 2010; SUEZ, 2017; SUEZ, 2020), such as such as the oily effluents from this refinery, which have a conductivity of 4,900 µS/cm and a chloride content of around 1,600 mg/L.

In addition, due to its high performance for removing salts, as it is a dense membrane, acting as a physical barrier to ions and other contaminants (TCHOBANOGLOUS; BURTON; STENSEL, 2004; CRITTENDEN et al., 2005), osmosis technology inversa has wide application in the water treatment systems of the refining park in Brazil, being a known and mastered technology in this area. In addition, it has a wide network of suppliers in the national market, making the replacement of membranes and parts, as well as technical assistance, more agile. The diffusion of the technology around the world has also gradually made it more affordable in terms of installation costs. All these factors were decisive for the choice of treatment technology for reuse in this project.

In order to guarantee greater reliability of the reverse osmosis unit, it is proposed to divide its capacity into three treatment trains, with the same flow, that is, 267 m^3/h each train. In the scenarios of operation in a situation of partial unavailability (a train stopped), the reverse osmosis system will operate with reduced flow, impacting both the water and ion balance, changing the distribution of reuse water between the eligible cooling towers, as well as the discharges of industrial effluent from the refinery and of clarified water produced at the WTP. On the other hand, the stoppage of one of the production trains for maintenance, replacement of membranes, among other services, which are part of the operational life of the system, will not imply a total stop of the reuse of the refinery, guaranteeing the fulfillment of the new grant of capture.

CONCLUSIONS

As main conclusions for this work, the following can be cited:

1. The reuse of final oil refinery effluents through treatment for desalination with reverse osmosis technology proves to be a valuable solution in the search for reducing the consumption of water from surface or underground springs, preserving them as a water resource for priority for public supply (JUDD, 2003);

2. The treatment of final effluents by reverse osmosis for reuse is possible due to the existence of biological treatment of oily

Services	Evaluated scenarios			
	Normal Operation	**Post-Rain Operation**	**Operation with a stopped RO train**	**Operation with a stationary RO train, post-rain**
Reuse water consumption for cooling towers (optimized cycles)	1.012	1.133	824	934
Reuse water consumption for cooling towers (non-optimized cycles)	1.478	1.628	1.290	1.440
Reuse water for Delayed Coking unit	15	15	15	15
Reuse water for RACE	60	60	60	60
RO power	800	800	532	532
RO permeate	560	560	372	372
RO reject	240	240	160	160
ETDI reuse water from contaminated effluent (optimized cycles)	452	573	452	562
ETDI reuse water from contaminated effluent (non-optimized cycles)	918	1.068	918	1.068
Sending effluent from the contaminated ETDI's FCN to the oily ETDI's MBR inlet	150	0	150	0
Oily ETDI feed rate	650	800	650	800
Contaminated ETDI feed flow (optimized cycles)	677	677	677	677
Contaminated ETDI feed flow (non-optimized cycles)	1.143	1.143	1.143	1.143
Final effluent for disposal (optimized cycles)	240	269	428	468
Final effluent for disposal (non-optimized cycles)	240	240	428	428

Table 2 - Water balance of the refinery under study, flows in m^3/h.

effluents with membrane bioreactor (MBR) technology in the refinery, which produces excellent quality water for feeding of Reverse Osmosis, in addition to providing a great reduction in treatment costs for reuse, when compared to other refineries that do not have MBR as secondary treatment technology (JUDD; JEFFERSON, 2003);

3. Reuse will allow, as a benefit to the community, a significant reduction in the disposal of industrial effluents in the receiving water body;

4. Consumers of reuse water, produced from the treatment of final effluents from the refinery, must be listed considering the quality of water required for the service, the level of treatment available for adequacy, the metallurgy of the equipment involved, and any other limitations that these consumers have in terms of specific contaminants. In this context, the cooling towers proved to be the most suitable units to receive the reused water produced, having been selected 6 (six) cooling towers to operate, some totally and some partially, with reused water;

5. The water and ionic balances must consider the different operational scenarios of the refinery expected for the systems that consume reused water, in order to maintain safety and operational continuity at all times, guaranteeing the sustainability of the business. To this end, the project must provide for redundancies aimed at guaranteeing operational continuity, even if partially.

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