Assessment of a Sour Water Treatment Unit Using Process Simulation, Parametric Sensitivity, and Exergy Analysis
Rayme Mestre-Escudero, Alejandro Puerta-Arana, and Ángel Darío González-Delgado*

ABSTRACT: In this work, a sour water treatment unit was evaluated combining exergetic analysis and parametric sensitivity analysis. Process simulation was performed using Aspen HYSYS 10.1 following real refinery configurations, and the results were validated with existing data. The parametric sensitivity was evaluated by varying the effect of process variables to identify an alternative case with the best technical performance. The exergy analysis was applied to both base and alternative cases. The outcomes were exergy efficiency, total irreversibilities, and exergy by industrial services. A comparison of both cases was performed to identify opportunities for improvement in real sour water treatment. Results revealed that the overall exergy efficiency for the base case was 44.28%. After improving the technical performance, the overall exergy efficiency decreased to 36.12%; the latter indicated higher irreversibilities due to the increase in the use of industrial services. This finding suggested that those process improvements may affect the performance of this refinery unit from an exergetic point of view.

1. INTRODUCTION
Oil refining always generates sour water coming from numerous processing units. Most refinery sour water systems contain a small amount of CO₂. H₂S content makes sour water "sour", and H₂S levels can become exceedingly high. The capacity of ammonia solutions for H₂S is a direct result of ammonia's ability to accept the proton liberated by H₂S when it enters the solution and dissociates. In principle, and with sufficient H₂S partial pressure, there can be more H₂S than ammonia. This potentially high H₂S content can make sour water extremely foul, and if the H₂S is not recovered, pollution levels would be completely out of control.¹

One of the greatest challenges for mankind is finding ways to increase energy availability and minimize climate impacts.² The drawbacks of testing installed systems in the oil and gas industry led to the use of computer-aided tools to model the process performance and identify opportunities for improvements.³ These tools allow varying operating conditions to observe how they change the technical aspects of any system, also called parametric sensitivity analysis.⁴

For the evaluation of emerging or existing technologies, process simulation is used to analyze them and propose changes that increase their efficiency,⁵ and then these studies can be complemented with parametric sensitivity analysis and exergy analysis, which is a powerful tool that allows identifying stages of a process that require improvements from the point of view of energy use.⁶

2. RESULTS AND DISCUSSION
2.1. Process Simulation. Figure 1 depicts the simulation of the sour water unit whose purpose is to eliminate compounds such as H₂S and NH₃, which come from other units. The stream (101) with 240 353.78 lb/h of water contaminated with sulphydryc acid, ammonia, carbon dioxide, and phenols under operating conditions of 102.3 °F and 24.7 psia enters the drum D-303 that removes acid gases and sent to the contactor T-2303, that removes ammonia from the gas phase (132); and this drum was simulated using a three-phase separator (3-phase separator), the bottom of which is directed toward the stripping tower T-303 modeled as a reflux absorber (refluxed absorber); then, the treated water (114, 115, and 116) is sent back to the units where it is required, and the top stream (123) is sent to a sulfur recovery unit. For this simulation, the NTRL was used as a global model given the nonelectrolytic polar nature of the substances involved;⁷ for the boiler (E-2302) on the side of the tubes, ASME steam was used, which is specific for systems involving steam.⁸

Table 1 presents a comparison between the data gathered from a real industrial sour water treatment unit of a Latin American refinery and the simulation results that were

Received: May 16, 2020
Accepted: September 2, 2020
Published: September 10, 2020
validated by comparing the two sets of data, concluding that they were similar enough to proceed with further analysis. This accuracy in simulation data demonstrates the relevance of the chosen thermodynamic models as well as the simulation strategies implemented.

2.2. Parametric Sensitivity Analysis. For this analysis, we determined the most critical parameters for a sour water treatment plant, which were the fractions of water at the bottom of the tower and the fractions of H$_2$S, NH$_3$, CO$_2$, and phenols leaving the top and the bottom reflux of the column. Following previous work, these variables determine the correct performance of the plant.$^{12}$

The performance of these variables was studied by changing the vapor flow that entered the reboiler at different constant bottom pressures of the stripping tower, which were 40.4 psi (normal operating point), increased pressure of 57.4 psi, and a lower pressure of 25.4 psi, to observe the effect of pressure on the performance of the stripping tower along with the amount of vapor entering the tower.

2.2.1. Effect of Steam Flow on Water Recovery. Figure 2 shows the effect of steam flow on the concentration of water in the bottom reflux, where the parametric sensitivity analysis applied to the stripping tower is shown, in which a variation of the steam flow in the bottom reboiler and the operating pressure of the said column and its effect on the water fraction at the bottom of the column are observed. The results show that higher steam flows favor the stripping of light components present in sour water (H$_2$S and NH$_3$).

For optimal performance of the unit and to accomplish downstream process requirements, H$_2$S and NH$_3$ should not exceed 10 and 100 ppm, respectively, in the stripped water that leaves the bottom of the column.$^{13}$ For this process, these minimum concentration parameters are accomplished because for the base case the contents of H$_2$S and NH$_3$ in the stripped water are 0.48 and 50.14 ppm, respectively, and for the alternative case, they are 0.15 and 29.38 ppm, respectively. This is attributed to the increased energy consumption to

| stream | type | H$_2$O (lbmol/h) | H$_2$S | NH$_3$ | CO$_2$ | phenol |
|--------|------|------------------|-------|--------|--------|--------|
| 101    | real | 13 229.9         | 17.6  | 42.2   | 13.7   | 1.0    |
|        | simulation | 13 229.9 | 17.6  | 42.2   | 13.7   | 1.0    |
| 113    | real | 4152.0           | 0     | 0      | 0      | 0      |
|        | simulation | 4110.9 | 0     | 0      | 0      | 0      |
| 115    | real | 2590.1           | 0     | 0.1    | 0      | 0.2    |
|        | simulation | 2566.7 | 0     | 0      | 0      | 0.2    |
| 116    | real | 7535.0           | 0     | 0.4    | 0      | 0.5    |
|        | simulation | 7465.4 | 0     | 0      | 0      | 0.6    |
| 114    | real | 693.8            | 0     | 0      | 0      | 0.1    |
|        | simulation | 665.9 | 0     | 0      | 0      | 0.1    |
| 123    | real | 2358.9           | 0     | 0.1    | 0      | 0.2    |
|        | simulation | 2358.8 | 0     | 0      | 0      | 0.2    |
| 114    | real | 52.1             | 17.6  | 41.6   | 13.7   | 0      |
|        | simulation | 53.6 | 12.9  | 42.6   | 5.7    | 0      |

Figure 1. Simulation of the sour water treatment plant.

Table 1. Comparison of Real and Simulated Data from the Sour Water Unit

![Figure 2](https://dx.doi.org/10.1021/acsomega.0c02300)
vaporize these components. On the other hand, by lowering the operating pressure of the column, these components volatilize more easily, although they also carry more water vapor, increasing the fraction of water in the bottom reflux.

2.2.2. Effect of Steam Flow on Stripping of H$_2$S, NH$_3$, CO$_2$, and Phenols. In this kind of process technology, the steam has a very important role in the stripping section because it is used as a heating source for the reboiler, thus carrying out the separation. Also, the steam has a strong relationship with the removal of undesired compounds through the top of the tower because when the steam flow is increased, the mass fraction of H$_2$S and NH$_3$ in the overhead vapor is also increased. Such performance is observed in Figures 3−5, where the increase in the flow of steam increases the concentration of these compounds in the top stream, due to the greater energy contribution from steam, which favors the stripping of the aqueous phase. An increase in pressure also allows a higher concentration of ammonia and hydrogen sulfide to the extent that less water vapor will come out of the top of the tower. In the range of 66 500 lb/h and 72 000 lb/h of steam, changes have no significant effects on the concentration of CO$_2$, NH$_3$, and H$_2$S hindering the operation of the control systems. Hence, an advisable range to operate this tower should be between 70 500 and 76 000 lb/h of steam.

Figure 6 shows the relationship between the steam flow and the pressure for the recovery of phenol at the top of the stripping tower, where it exhibits the opposite behavior to those previously shown since CO$_2$, NH$_3$, and H$_2$S are in a higher proportion at the top (253.711 and 441 lb/h, respectively, compared to 0.02013 lb/h of phenol, taking into account that phenol is less volatile than the previous ones); increasing the vapor flow will reduce CO$_2$, NH$_3$, and H$_2$S more easily, in turn decreasing the concentration of phenol at the top.

2.2.3. Effect of the Flow of Steam in the Bottom Reflux. Figure 7 relates the effect of the steam flow and the pressure against the backflow of the stripping tower, where an increase in the backflow of the tower is evidenced as the steam flow increases. This increment provides more energy that allows the bottom stream of the column (121) to be vaporized to a greater extent and thus more steam goes through (122), which is the current that returns to the tower.

2.3. Exergy Analysis. For the exergetic analysis of this unit, two cases were taken into account: an initial or simulated base case under the current conditions and an improved case where the parameters that allowed a better technical
performance of the unit were used. The sensitivity analysis showed that the most influential variable is the steam flow, which was modified to observe how stripping behaves in the tower under different operating conditions.

2.3.1. Base Case for the Sour Water Unit. Table 2 shows the results of chemical, physical, and total mass exergies of the

| stream | chemical exergy (MJ/h) | physical exergy (MJ/h) | total mass exergy (MJ/h) |
|--------|------------------------|------------------------|-------------------------|
| 101    | 19 132.66              | 72.47                  | 19 205.13               |
| clean water | 0.78          | 0.01                   | 0.79                    |
| 132    | 7.93                   |                        | 7.94                    |
| 103    | 17 373.97              | 27.93                  | 17 401.90               |
| 105    | 17 373.97              | 37.65                  | 17 411.62               |
| 108    | 6631.85                | 6954.82                | 13 586.67               |
| 122    | 2 092.57               | 20 962.80              | 23 055.37               |
| 106    | 17 373.97              | 293.76                 | 17 667.73               |
| 121    | 8843.45                | 9054.85                | 17 898.30               |
| 109    | 6631.85                | 5846.23                | 12 478.08               |
| 126    | 17 438.81              | 23 210.69              | 40 649.50               |
| steam  | 113.02                 | 146.49                 | 259.51                  |
| condensate | 1472.49        | 2517.43                | 3944.92                 |
| 123    | 10 978.32              | 221.81                 | 11 200.13               |
| AE     | 23 651.83              | 424.91                 | 24 094.74               |
| AE2    | 12 345.67              | 219.34                 | 12 565.01               |
| 113    | 1 327.15               | 520.09                 | 1847.24                 |
| 115    | 3 860.63               | 241.98                 | 4102.61                 |
| 116    | 344.38                 | 11.05                  | 355.43                  |
| 114    | 1 219.61               | 39.13                  | 1258.74                 |
| AE1    | 23 651.83              | 780.69                 | 24 432.52               |
| AE3    | 12 456.89              | 753.25                 | 13 210.14               |

The exergy balance revealed that the total chemical and physical exergies of the process were 204 278.63 and 72 355.39 MJ/h, respectively. Based on these results, exergetic analysis was performed and resulted in the following figures.

2.3.1.1. Exergy Analysis Per Stage. Figure 8 shows the exergetic analysis by stages of the phenolic sour water treatment unit; it was noted that the exergetic efficiency of the flash separation, storage, and preheating stages exceeded 90%. The stripping stages, bottom circuit, and coolers reached exergy between 55 and 30%; these values, as expressed by Tan et al., denoted loss or degradation of heat or work and directly influenced the overall efficiency of the process. Besides, the stripping section exhibited the lowest exergetic efficiency of the process, around 31.4%. On the other hand, the highest percentages of irreversibilities were found in the bottom circuit, stripping, and cooler stages, which presented a contribution of 59.67, 27.13, and 8.8%, respectively; this reduced exergy was associated with loss of heat, work, or waste.

2.3.1.2. Global Exergy Analysis. Figure 9 shows the global exergy analysis of the sour water treatment unit. The overall efficiency of the process is 44.28%, which is slightly low because the steam consumption in the bottom circuit is high; therefore, there is a large waste of energy, which in turn significantly increases the irreversibilities of the stage, where 74.4% corresponds to the exergy for waste (52 833.36 MJ/h).

2.3.2. Alternative Case for the Sour Water Unit.

Table 3 shows the results of chemical, physical, and total mass exergies of the main process streams. The chemical exergy of a stream was calculated from the sum of this same property for each compound; the physical exergy is reported in the simulation software, and the total mass exergy was estimated.

| stream | chemical exergy (MJ/h) | physical exergy (MJ/h) | total mass exergy (MJ/h) |
|--------|------------------------|------------------------|-------------------------|
| 101    | 19 132.66              | 72.47                  | 19 205.13               |
| clean water | 0.78          | 0.01                   | 0.79                    |
| 132    | 7.93                   |                        | 7.94                    |
| 103    | 17 373.97              | 27.93                  | 17 401.90               |
| 105    | 17 373.97              | 37.65                  | 17 411.62               |
| 108    | 6631.85                | 6954.82                | 13 586.67               |
| 122    | 2 092.57               | 20 962.80              | 23 055.37               |
| 106    | 17 373.97              | 293.76                 | 17 667.73               |
| 121    | 8843.45                | 9054.85                | 17 898.30               |
| 109    | 6631.85                | 5846.23                | 12 478.08               |
| 126    | 17 438.81              | 23 210.69              | 40 649.50               |
| steam  | 113.02                 | 146.49                 | 259.51                  |
| condensate | 1427.49        | 2517.43                | 3944.92                 |
| 123    | 10 978.32              | 221.81                 | 11 200.13               |
| AE     | 23 651.83              | 424.91                 | 24 094.74               |
| AE2    | 12 345.67              | 219.34                 | 12 565.01               |
| 113    | 1 327.15               | 520.09                 | 1847.24                 |
| 115    | 3 860.63               | 241.98                 | 4102.61                 |
| 116    | 344.38                 | 11.05                  | 355.43                  |
| 114    | 1 219.61               | 39.13                  | 1258.74                 |
| AE1    | 23 651.83              | 780.69                 | 24 432.52               |
| AE3    | 12 456.89              | 753.25                 | 13 210.14               |

Figure 8. Exergetic analysis per process stage in the sour water treatment unit.

Table 3. Chemical, Physical, and Total Mass Exergies of the Main Process Streams
the processing unit, and finally, the total mass exergy is the sum of the previous properties.

From the exergy balance, it was determined that the total chemical and physical exergies of the process were 168 131.20 and 68 779.41 MJ/h, respectively. Based on these results, exergetic analysis was performed and resulted in the following figures.

2.3.2.1. Exergy Analysis Per Stage. Figure 10 shows the exergy analysis by stages of the improved phenolic sour water treatment unit. It can be identified that the exergy efficiency of the flash separation, storage, and preheating stages exceeds 90%, whereas the stripping stages, bottom circuit, and coolers have an exergy between 55 and 29.5%. This efficiency is very similar to the exergetic analysis for the original phenolic sour water treatment unit; therefore, the overall efficiency of the process will also be reduced due to the fact that there is a waste of heat or work on the equipment present in the unit.

Also, the stripping section showed the lowest exergetic efficiency of the process, about 29.5%. Those with the highest irreversibilities were found in the bottom circuit, stripping, and cooler stages, which presented a contribution of 61.1, 25.6, and 7.8%, respectively; this reduced exergy is associated with losses of heat, work, or waste. The exergy for residues is presented in Figure 10, which shows that the greatest amount of this is finally the total mass exergy is the sum of the previous properties.

2.3.2.2. Global Exergy Analysis. Figure 11 shows the global exergy analysis of the phenolic sour water treatment unit for the alternative case, where the overall efficiency of the process was 36.12%. This is a low value because the steam consumption in the bottom circuit increases compared with that of the original simulation of sour water where the water output is lower at the top, which increases the steam consumption. This results in a waste of a large amount of energy and irreversibilities of the stage, where 55.2% corresponds to the exergy of residues (42 719 MJ/h). This is related to what was reported by Ruiz-De La Cruz and collaborators for the exergy evaluation of a biodiesel production process from *Euphorbia lathyris*, where they took the exergetic analysis results for quantification of inefficiencies. When comparing the irreversibilities generated by industrial services at the entrance of the process (33 982 MJ/h), it was observed that the first reported value is higher; therefore, it would be appropriate to try to improve this result.

2.3.3. Comparison between the Base Case and the Alternative Case for the Sour Water Unit. The sensitivity analysis showed that a higher steam flow helps significantly in the production of clean process water (free of phenol, carbon dioxide, and ammonia). Lower pressures also facilitate the stripping of these species; for this reason, an increment of the steam flow from 74 057.49 lb/h (normal operation point) to 76 234.73 lb/h leads to purer product obtenion, whereas the pressure, which is decreased from 40.4 psig (normal operation point) to 24.5 psig, helps in the removal of contaminant compounds. Also, the water mass fraction increased from 0.999618 (normal operation point) to 0.999643, which may be a small amount, but it impacts the exergetic performance of the process significantly by removing more H₂S, NH₃, CO₂, and phenols, which causes the global exergetic efficiency to drop from 44.28 to 36.12% (Figure 12).

For the exergy analysis, Figure 12 displays how the exergetic efficiencies of the stages change to produce a purer product. This parameter dropped mainly in the bottom circuit and stripping stages because more wastes compounds were removed from the feed stream, thus increasing the irreversibilities of the process and the contribution of exergy of waste, as shown in Figure 13. The efficiency of the bottom circuit stage decreased from 46.4 to 41.1% due to the additional heat provided as a measure for the technical optimization of the unit.

Figure 13 shows the comparison between the exergies of utilities and waste compounds as well as the irreversibilities of the process for both cases of this study, where the exergy of waste increases from 4204.440 to 4329.212 MJ/h due to the better degree of separation and thus more unwanted compounds are separated and recovered through the top of the column.
3. CONCLUSIONS

This work attempted to analyze the performance of a sour water unit from an exergetic point of view. The process was simulated using Aspen HYSYS showing accuracy with real plant data. From the exergy analysis, it was found that the global exergy efficiency of the base case was 44.28%, and for the alternative case, it was 36.12%. The decrease by 8.16% was attributed to the fact that by improving the technical efficiency of the processes by improving the products at a technical level, the amount of waste at the output of these increased, which in energy terms is represented as a decrease in the usable useful work of a current. According to the sensitivity analysis, the addition of steam at the bottom of the stripping tower leads to better separation of light components present in the sour water (H₂S and NH₃). These results allow oil and gas companies to decide process changes based on technical data from simulated units.

4. MATERIALS AND METHODS

4.1. Methodology. The modeling of the sour water treatment unit was based on the collection of real data from an installed industrial operating plant from a Latin American refinery and scientific literature, as well as on the support of experienced engineers working in this specific field. Then, the process simulation software, Aspen HYSYS version 10.1, was used for the simulation of sour water treatment by introducing the data gathered from the unit into the simulation environment, which yielded results that were validated by comparing them with the base information used, as shown in Table 1.

The substances present in the actual process were selected directly from the Aspen HYSYS database; hence, there was no

Figure 13. Comparison of global exergetic parameters between the base case and the alternative case.

Figure 14. Simplified process flow diagram of the sour water treatment unit.
need to create any hypothetical compounds in the simulation environment. The NRTL fluid package was used as a thermodynamic model given the nonelectrolytic polar nature of the substances involved. Besides, their behavior under different operating conditions was analyzed to determine the best ones. Additionally, exergetic analysis of the processes was carried out, where it was determined in which stages useful energy was wasted, for which improvements were proposed.

4.2. Process Simulation. A process diagram was built for the sour water unit and thus a better scope on regarding the equipment that was implemented in the simulation environment was achieved using the Aspen HYSYS 10.1 software. This plant mainly consists of separation equipment, pumps, heat exchangers, and a steam stripping tower. Following this, all of the data carried by the currents and equipment were entered, such as temperature, pressure, mass or molar flows, processing capacity, etc. Finally, a detailed process was obtained with the flows and composition of all of the process currents, material and energy balances, and thermodynamic properties.

4.3. Process Description. As shown in Figure 14, the sour water from different units of the refinery is collected and sent to a drum that accumulates sour water. When entering the container, most of the light hydrocarbons present in the mainstream are evaporated when the pressures inside the drum are balanced. This stream is brought into contact with the stripped sour water (main product) in an instantaneous contactor to absorb the hydrogen sulfide and ammonia present in the hydrocarbons.

The accumulated sour water in the drum is sucked by the sour water pumps, which discharge into the phenolic sour water storage tank present in the unit. The tank must have a nitrogen blanketing system to keep it free of oxygen; then, the main pumps suck from the tank to send the flow to the stripping tower. But before that, it enters the side of the tubes of the heat exchanger, which is heated with stripped water that enters from the side of the shell. After heating the stream, it is sent to the stripping tower to separate the hydrogen sulfide and ammonia from the sour water using steam heating that enters through the bottom of the column. The stripped sour water comes out of the bottom of the column, which must be cooled and sent to the process as the main product in the unit, and H₂S and NH₃ gases come out from the top to be treated in another unit of the refinery.

4.4. Parametric Sensitivity Analysis. This type of analysis allows us to parametrize a process or system to vary its operating parameters, which provides information about how the process would change if a change is generated within any stage of it. To carry out a sensitivity analysis, different process variables such as temperature, pressure, concentrations, and mass flows must be taken into account, allowing the process to be viewed in various ways and, in that order, it facilitates the analysis of the behavior of the system based on its critical operational variables. To conduct this kind of analysis, the process should be modeled and simulated using simulator software such as Aspen Plus® as it provides extended energy and mass balances.

4.5. Exergy Analysis. This concept was taken from Martínez et al., Toghyani et al., and Leal-Navarro et al. who developed exergetic analysis from the second law of thermodynamics, which provides an alternative to analyze, evaluate, and compare the energy use of complex systems. This analysis is useful to identify the irreversibilities of processes and estimate efficiencies, which allows proposing solutions to these problems. This tool has different advantages among which are the following: it allows finding the most effective way to use an energy resource and it is the best way to direct the impact of an energy resource to the environment and to carry out analysis and design of energy systems. Such an analysis incorporates both principles of energy conservation and the second law of thermodynamics. For a steady-state exergetic balance, the destroyed exergy is related to the net irreversibility of mass transfer, work, and heat using eq 1.

\[
\text{Ex}_{\text{destroyed}} = \text{Ex}_{\text{net-mass}} + \text{Ex}_{\text{net-heat}} + \text{Ex}_{\text{net-work}}
\]

\[
\text{Ex}_{\text{work}} = W
\]

\[
\text{Ex}_{\text{heat}} = \sum_i \left(1 - \frac{T_0}{T_i}\right)Q_i
\]

The exergy associated with work in a system where there is a constant volume is equal to the same work in the system (eq 2). The exergy by heat transfer can be calculated based on the Carnot efficiency using eq 3. On the other hand, the total input of exergy in a system is related to the input currents of the process and/or services required by the system (eq 4), while the total output exergy is associated with the main product streams and/or waste streams, as shown in eq 5.

\[
\text{Ex}_{\text{total-in}} = \sum \text{Ex}_{\text{mass-in}} + \sum \text{Ex}_{\text{utilities-in}}
\]

\[
\text{Ex}_{\text{total-out}} = \sum \text{Ex}_{\text{products-out}} + \sum \text{Ex}_{\text{wastes-out}}
\]

\[
\text{Ex}_{\text{destroyed}} = \sum \text{Ex}_{\text{total-in}} - \sum \text{Ex}_{\text{products-out}}
\]

The irreversibilities in the process can be calculated by subtracting the total exergy of the products from the total exergy input (eq 6). Finally, the exergy efficiency of a process or stage can be calculated based on the irreversibility and the total exergy input of the system, as given by eq 7 and the percentage of total irreversibilities destroyed of the process can be calculated with eq 8.

\[
\eta_{\text{exergy}} = 1 - \left(\frac{\text{Ex}_{\text{destroyed}}}{\sum \text{Ex}_{\text{total-in}}}\right)
\]

\[
\%\text{Ex}_{\text{destroyed,i}} = \left(\frac{\text{Ex}_{\text{destroyed,i}}}{\sum \text{Ex}_{\text{total-destroyed}}}\right) \times 100\%
\]

4.6. Comparison between the Base Case and the Alternative Case for the Sour Water Unit. Once the technical and exergetic information was obtained for both cases, we conducted a comparison to select the case with best results and identity optimum operating conditions for the sour water treatment unit, thus generating recommendations for their optimal performance under the studied criteria.

### AUTHOR INFORMATION

**Corresponding Author**

Angel Dario González-Delgado – Chemical Engineering Department, Nanomaterials and Computer Aided Process Engineering Research Group (NIPAC), University of Cartagena, Cartagena 130014, Colombia; orcid.org/0000-0001-8100-8888; Email: agonzalezd1@unicartagena.edu.co
Authors
Rayme Mestre-Escudero — Chemical Engineering Department, Nanomaterials and Computer Aided Process Engineering Research Group (NIPAC), University of Cartagena, Cartagena 130014, Colombia
Alejandro Puerta-Arana — Chemical Engineering Department, Nanomaterials and Computer Aided Process Engineering Research Group (NIPAC), University of Cartagena, Cartagena 130014, Colombia

Complete contact information is available at: https://pubs.acs.org/10.1021/acsomega.0c02300

Funding
This research was funded by the University of Cartagena, grant number 067-2017.

Notes
The authors declare no competing financial interest.

■ ACKNOWLEDGMENTS
The authors would like to acknowledge the University of Cartagena for providing equipment and software to conduct this work.

■ REFERENCES
(1) Weiland, R. H.; Hatcher, N. A. Sour Water Strippers Exposed, Laurence Reid Gas Conditioning Conference, Norman, Oklahoma, 2012.
(2) Vilarinho, A. N.; Campos, J. B. L. M.; Pinho, C. Energy and exergy analysis of an aromatics plant. Case Stud. Therm. Eng. 2016, 8, 113–127.
(3) Erdmann, E.; Ruiz, L. A.; Martínez, J.; Gutierrez, J. P.; Tarifa, E. Endulzamiento de gas natural con aminas. Simulación del proceso y análisis de sensibilidad paramétrico. Av. Cienc. Ing. 2012, 3, 89–101.
(4) Rangel, H.; Bogoya, D. Análisis de la Sensibilidad Paramétrica en Reactores de Lecho Fijo. Ing. Invest. 1992, 70–80.
(5) Figueroa-Jimenez, S.; Gamarra-Torres, J.; Bonilla-Correa, D.; Peralta-Ruiz, Y. Evaluation of biodiesel production process from palm oil (Elaeis Guineensis) using exergy analysis methodology. Chem. Eng. Trans. 2015, 43, 529–534.
(6) Martínez, D.; Puerta, A.; Mestre, R.; Peralta-Ruiz, Y.; González-Delgado, A. D. Exergy-based evaluation of crude palm oil production in North-Colombia. Aust. J. Basic Appl. Sci. 2016, 48, 1–8.
(7) Carlson, E. C. Don’t Gamble with Physical Properties. Chem. Eng. Prog. 1996, 92, 35–46.
(8) Erdmann, E.; Ruiz, L.; et al. Análisis De Sensibilidad Por Simulación Del Proceso De Deshidratación De Una Planta De Acondicionamiento De Gas Natural. Av. Cienc. Ing. 2012, 3, 119–130.
(9) Toghyani, M.; Rahimi, A. Exergy analysis of an industrial unit of catalyst regeneration based on the results of modeling and simulation. Energy 2015, 91, 1049–1056.
(10) Leal-Navarro, J.; Mestre, R.; Puerta, A.; León, J.; González, Á. D. Evaluating the Exergetic Performance of the Amine Treatment Unit in a Latin-American Refinery. ACS Omega 2019, 4, 21993–21997.
(11) Liu, Z.; Karimi, I. A. Simulation of a combined cycle gas turbine power plant in Aspen HYSYS. Energy Procedia 2019, 158, 3620–3625.
(12) Lee, S.-Y.; Lee, J. M.; Lee, D.; Lee, I. B. Improvement in steam stripping of sour water through an industrial-scale simulation. Korean J. Chem. Eng. 2004, 21, 549–555.
(13) Zahid, U. Techno-economic evaluation and design development of sour water stripping system in the refineries. J. Clean. Prod. 2019, 236, No. 117633.
(14) Tan, H. T.; Lee, K. T.; Mohamed, A. R. Second-generation bioethanol (SGB) from Malaysian palm empty fruit bunch: Energy and exergy analyses. Bioresour. Technol. 2010, 101, 5719–5727.
(15) Morosuk, T. J.; Tsatsaronis, G. Splitting physical exergy: Theory and application. Energy 2019, 167, 698–707.
(16) Ruiz-De La Cruz, I.; Orozco-Muñoz, A.; Bonilla-Correa, D.; Peralta-Ruiz, Y. Exergy evaluation of biodiesel production process from Euphorbia Lathyris. Chem. Eng. Trans. 2015, 43, 535–540.