*Desalination and Water Treatment*
www.deswater.com

doi:10.5004/dwt.2021.27222

225 (2021) 86–93
June

# Differences between sewage effluent parameters for dry and rainy periods in tropical climate area

Diogo Botelho Correa de Oliveira*, Marco Aurélio Calixto Ribeiro de Holanda, Willames de Albuquerque Soares

*University of Pernambuco, Civil Engineering at the Polytechnic School of Pernambuco (POLI), Recife, Pernambuco, Brazil, emails: diogobotelhocorrea@gmail.com (D.B.C. de Oliveira), holandamacr@yahoo.com.br (M.A.C.R. de Holanda), was@poli.br (W. de Albuquerque Soares)*

Received 27 November 2020; Accepted 11 March 2021

## ABSTRACT

Communication between urban drainage and sewage collection systems can cause various damages to the effluent treatment, such as changing its initial characteristics, overloading the sewage system and its treatment performance. During the 3 y period, for a large sewage treatment plant (345,600 $m^3$ $d^{-1}$), of the type of activated sludge, the work proposed to identify and evaluate changes in the parameters of inlet flow, pH, temperature, total chlorine, biochemical oxygen demand (BOD), chemical oxygen demand (COD), sedimentable solids, total suspended solids, oil and greases, nitrate, nitrite ammoniacal nitrogen and efficiency of treatment in two distinct periods: those with the interference of rainwater (rainy season from April to August) and without its influence. From the confidence interval test, in general, the sewage treatment plant showed on rainy days an increase in flow rate (16.5%), dilution in chlorine, BOD, COD, ammoniacal nitrogen and oils and greases, higher acidity on dry days and increased concentration in total suspended solids and nitrite. Therefore, despite the increase in the sewage flow, there was no change in the treatment efficiency in the activated sludge system. Despite the changes, according to European Union, World Health Organization and national legislation (Brazil) recommendations, there were disapprovals in the indicators of oils and greases and ammoniacal nitrogen on days without rain (European Union and Brazil).

*Keywords:* Wastewater treatment; Absolute separator system; Activated sludge

## 1. Introduction

Sanitation services are essential for the well-being and development of the population. In developing countries, an estimated 2 billion people do not have access to sanitation facilities, including transport and wastewater treatment. This is directly related to the lack of investment in infrastructure through public development policies [1–3].

In Brazil, the costs of implementing a complete sanitation system can vary from US$170 to US$770 per inhabitant, considering variables such as terrain, pipe diameter, capacity and type of the STP (sewage treatment plant), roofing sidewalks, among others [2].

There are different sewage collection systems, which are mainly influenced by the rainfall regime, the geographical position and the local socio-economic situation. These systems can be divided into units, mixed separators and absolute separators. The former perform better and are more common in more economically developed subtropical regions, such as in some European countries, where rainwater and sewage are conducted in a single pipeline network and directed to the same treatment system. In tropical areas, it is preferable to use absolute or mixed separator systems (which transport rainwater and sewage through separate piping networks), since annual precipitation averages are higher. This use also

---

* Corresponding author.

depends on the type of implantation or project adopted, combining the needs and benefits of each system [3].

Although the use of absolute separator systems in effluent collection systems and urban drainage galleries is common in tropical countries, it is quite common to find several unwanted interferences (communication between drainage galleries and sewage collection pipes) between them, impairing the performance and proper use of these sanitation aspects. There are some relations between the effluent flows that enter the treatment plants and the rainy periods of a certain region, increasing considerably the amount of liquid volume that enters the plants, besides altering their original characteristics, such as concentrations of organic loads, suspended solids, turbidity, among others [4,5].

In some cases, the interference of rainwater in sewage systems can be beneficial, provided they are designed and sized for this purpose, reducing the gross biochemical and chemical demands, promoting an increase in the flow inside the pipes and consequent self-cleaning and helping in their cleaning and reducing the production of gases resulting from anaerobic processes [6,7]. When the communication between these networks is not foreseen, it causes undesirable effects, such as the overload of the pipes, lifting and treatment stations, dragging of solid materials, increase of costs and reduction of intervals in the maintenance not foreseen and changes in the performance of the sewage treatment [3,5].

Among the various types of systems for STPs, the activated sludge, which uses one of the most modern systems in operation and efficiency in wastewater, stands out. In this case, the costs of operation and maintenance of a large sewage treatment plant are among the largest available, due to its implementation, acquisition of equipment, energy performance and specialized workforce [2,3].

Some authors have shown that increases in the sewage system in rainy events can alter the composition of wastewater, depending on the size of the sanitary sewage system (SES) in which it is inserted, the intensity and characteristics of the incident rainfall and the type of sewage treatment system, causing changes in flow rates in the order of 10% to 400%, reduction in the acidity of the effluent and interfering in the performance of organic load removal [3,5].

Quantifying variations between the characteristics of the effluent and increasing the volume of treated sewage is of great relevance for studies in the area to predict and correct problems within the operation of treatment systems. This paper aims to analyze the different properties and changes that occur in the sewage and its treatment process in a large sewage treatment plant using activated sludge.

## 2. Methodology

The STP studied is located in the Metropolitan Region of Recife, in the city of Paulista, with a project capacity of 34,560 $m^3 d^{-1}$ (mcd – $m^3 d^{-1}$), is designed to serve about 452,000 inhabitants. This station uses the activated sludge type treatment system with secondary decantation. The SES basin (collection network) of Janga is inserted in the municipalities of Olinda and Paulista. It should be noted that not all areas included in the basin have a sewage and/or water supply system. Its internal structure is subdivided into two sub-basins (Janga and Olinda), which have approximately 2,206 and 2,101 $km^2$ of area, respectively. After treatment, the effluent is directed to the receiving waterbody, Timbó River [8].

The flow in the STP starts through the entry of the sewage into the preliminary treatment system (railing and sandbox). Soon after, the material is sent to the aeration tanks, where the effluent is oxygenated. Then, the effluent is directed to the tank where the denser material of the effluent is decanted to form the sludge, which is used in the recirculation in the aeration tanks, while the treated effluent is directed to the water body. After 24 h of the treatment cycle, the sludge is renewed.

The study area registers an average annual rainfall of 2,050 mm, being the area with the highest rainfall of the northeast coast, where the months of September to March are very dry and the rainy period begins in April. In the month of June, the maximum rainfall is generally recorded with an average of more than 600 mm accumulated [3].

The period studied is from January 2017 to March 2020, which refers to the subsequent phase of the STP recovery works, which occurred until 2016 [3]. This interstice totals 39 daily records (in which each one is representative for the respective month), which were divided into two populations: the days on which rainfall is considered significant for changes in the patterns of the affluent rainy days (RD) and the insignificant dry days (DD).

The effective precipitation was limited to values equal to or greater than 10 mm, where lower values fit dry days [3]. To obtain these data, two rainfall stations were used (Olinda and Paulista), one for each sub-basin. The operation of the stations and the availability of records is the responsibility of APAC (Water and Climate Agency of Pernambuco).

In addition to this information provided by [9], analytical data of effluent quality are also used, which was provided by Companhia Pernambucana de Saneamento (Sanitation Company of Pernambuco), COMPESA, currently responsible for sewage treatment and collection services in the State of Pernambuco, through the Request for Access to Information, registered under N° 202019869. These data are collected once a month to verify compliance with legislation and other environmental agencies. For greater accuracy, daily or even weekly data would be necessary, but due to the costs, both of tests and operations (necessary for collection, analysis and compilation) these less spaced measurements become unfeasible for the concessionaire.

The parameters analyzed were, as followed: (1) flow, at the entrance of the STP, (2) pH, (3) temperature, (4) total chlorine, (5) biochemical oxygen demand (BOD), (6) chemical oxygen demand (COD), (7) sedimentable solids (SS), (8) total suspended solids (TSS), (9) oil and grease, (10) nitrate, (11) nitrite, (12) ammoniacal nitrogen (AN), all in and out of the process, and treatment efficiency based on organic load removal.

For gauging and testing the parameters, the methods and equipment are defined as shown in Table 1. The procedures used for the tests were performed according to the Standard Methods for the Examination of Water and Wastewater [10]. The efficiency of the treatment is measured through the BOD concentrations at the beginning and end of the treatment, indicating the rate of organic load removal.

Table 1
Methods and equipment for measurement tests of study parameters

| Parameter | Method used | Equipment |
|---|---|---|
| Flow | Direct measuring | Electromagnetic meter and Parshall Gutter |
| pH | Direct measuring | Thermo Scientific Orion Star A22 (Thermo Fisher Scientific Inc., Waltham, Massachusetts, EUA) |
| Temperature | Direct measuring | Thermo Scientific Orion Star A22 |
| Total chlorine | DPD Colorimetric Method | Pocket Colorimeter II, HACH (Loveland, Colorado, EUA) |
| BOD | OxiTop Method | Method Compliant |
| COD | SMEWW | DR3900 HACH Spectrophotometer |
| Sedimentable solids | Volumetric (Imhoff Cone) | Method Compliant |
| Total suspended solids | Gravimetric | Method Compliant |
| Oil and grease | Extraction (Soxhlet) | MA044850 and MA044550 |
| Nitrate | Colorimetric Method | DR3900 HACH Spectrophotometer |
| Nitrite | Colorimetric Method | DR3900 HACH Spectrophotometer |
| Ammoniacal nitrogen | Titrimetric Distillation | Method Compliant |

SMEWW – Standard Methods for the Examination of Water and Wastewater

Table 2
Treated effluent discharge standards

| Parameter | CONAMA (430/2011) | CPRH | EU | WHO |
|---|---|---|---|---|
| pH | Between 5 and 9 | Between 5 and 9 | Between 6 and 9 | Between 6 and 9 |
| Temperature | Less than 313.15 K | Less than 313.15 K | Less than 308.5 K | – |
| Total chlorine | – | – | – | Up to 350 mg L$^{-1}$ |
| BOD | 60% removal or up to 120 mg L$^{-1}$ | 90% removal or up to 60 mg L$^{-1}$ | 70% removal or up to 25 mg L$^{-1}$ | Up to 60 mg L$^{-1}$ |
| COD | – | – | 75% of or 125 mg L$^{-1}$ | Up to 150 mg L$^{-1}$ |
| Sedimentable solids | Up to 1 mL L$^{-1}$ | Up to 1 mL L$^{-1}$ | – | – |
| Total suspended solids | – | – | 90% removal or 35 mg L$^{-1}$ | Up to 60 mg L$^{-1}$ |
| Oil and grease | Up to 100 mg L$^{-1}$ | Up to 20 mg L$^{-1}$ | Up to 10 mg L$^{-1}$ | Up to 8 mg L$^{-1}$ |
| Nitrate | – | – | 50 mg L$^{-1}$ | Up to 45 mg L$^{-1}$ |
| Ammoniacal nitrogen/total | 20 mg L$^{-1}$ | 20 mg L$^{-1}$ | 10 mg L$^{-1}$ | Up to 60 mg L$^{-1}$ |

For statistical analysis, the confidence interval (CI) was used for: input flow, treatment efficiency, total chlorine, COD, TSS, nitrate and nitrite. The CI was structured with a 90% tolerance level of significance (um-sigma), due to the amount of sample data [11]. For the other parameters analysis was used through boxplots.

The Brazilian parameters for discharging treated effluents are governed by national and state legislation. The state impositions of the State of Pernambuco are more restrictive than the national ones and are governed by the State Environment Agency of Pernambuco (CPRH). The European Union (EU) shares its restrictions on discharges into water bodies (case of this study) and the ocean, and may vary for specific cases, such as region and population of care. The World Health Organization (WHO) also has international parameterizations (Eastern Mediterranean) as to the discharge in hydric bodies, recharge in the soil and use in the irrigation of agricultural soils, also depending on the region in which it fits. Table 2 shows the restrictive parameters of four different regulatory entities for discharges into rivers and lakes [12–16].

## 3. Results and discussion

Fig. 1 presents the flow and precipitation history for the study period, including their means for both populations. It is important to highlight the records of June and August (2017) and April 2018, which presented the largest inflows for the rainy period, where the values were beyond the average obtained (415.22 L s$^{-1}$). For this population, only the record of November 2018 was close to the average of the dry period. Despite the influence of rainfall on the volume of entry into the STP, this does not happen in a directly proportional way [5], since the highest flow recorded may not occur on the day of higher precipitation and vice versa. The correlation made in a linear way presents low coefficients of

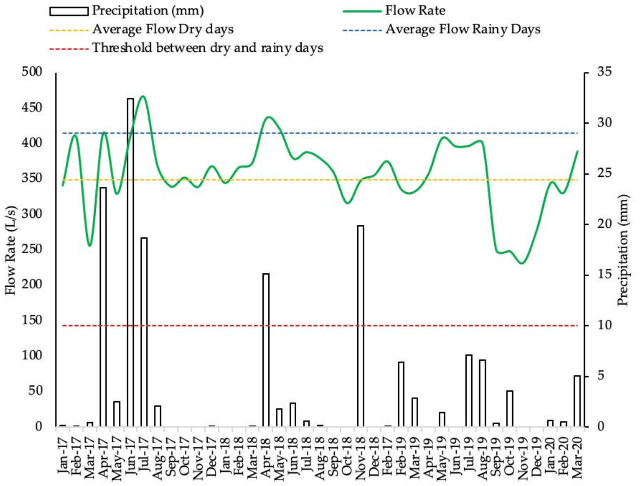

Fig. 1. Graph of rainfall indexes, input flow and their averages for rainy days (RD) and dry days (DD).

determination ($R^2$), it can reach values between 0.4 and 0.7 for monthly averages of precipitation and flow. In occasional analyses, this correlation can be even smaller (Fig. 2), reaching 0.21 or lower [17].

This is mainly due to three factors: The first is in relation to the SES contribution basin, because of the difference in interference density between the rain drainage system and sewage collection net, where in some localities, mainly where there are low-income communities, they have a higher number of connections per km² than others, depending also on the cultural issue of the micro-region. The second refers to the intensity of the rains, where the large amount of rainfall in the arrivals of the pumping and treatment stations can demand stoppages in the pump system, in order not to overload the downstream treatment system, and finally, there is the variability of demand that enters the STP, where in dry periods (where there is no interference from the rains) the input flow already has $R^2$ of low numerical coefficient [3,5,17–19].

The coefficient of determination at Janga STP's was approximately 0.15 between precipitation and instantaneous input flow. This is very dependent on factors such as the specific contribution of the population, transport capacity of the pipes, obstructions and physical conditions of the collecting networks [6], causing the dispersion graph to show low linear correlation, normally varying between 0.21 and 0.85 depending on the SES in which it is inserted [17].

In percentage terms, this increase in flow may vary from 10 to 400% compared to occasions without rain, depending on factors such as the extent of the collection basin and the potential volume treated by the STP [19]. The input flow has significant differences between averages (days with and without rain) of 66.12 L $s^{-1}$ (16.53% of the project flow). This means that about 5713 $m^3$ of volume are treated daily without necessity due to the communication of the collection systems (improper links between the two collection systems). This is very relevant for the activated sludge process, which has a high operational cost, due to the use and maintenance of equipment, pumps and chemicals [20].

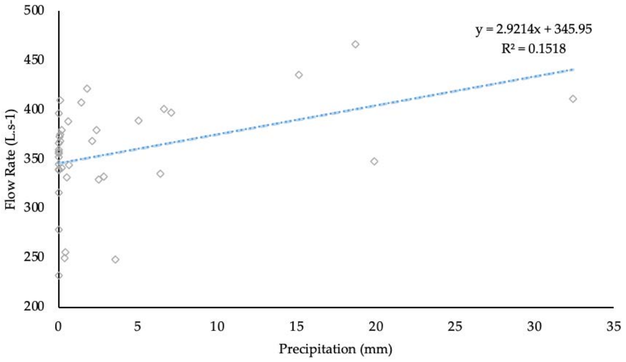

Fig. 2. Dispersion between the registers of instantaneous flows and daily precipitations.

The results of effluent parameters can be consulted in Table 3. For rainy days, the chlorine present in the effluent presents reductions, on average, of 33% in the entrance and 36% in the exit of the treatment in relation to dry days, presenting significant differences among themselves. The concentration reductions during the treatment are very sensitive, not reaching 10 mg $L^{-1}$, also due to the lack of tertiary treatment (disinfection) in the system. For the entry of the process, on rainy days, this change is positive, because the reduction of this component in the water helps in the proliferation and maintenance of purification bacteria [21]. The same happens with the total suspended solids, because although they present a slight increase in the upper limits on rainy days, no significant changes were noted, including in the treatment itself (in relation to the upstream and downstream STP).

In the treatment process of activated sludge, nitrites and nitrates are usually of great relevance, as they are responsible for a good part of the biological removal of ammoniacal nitrogen, through nitrification and denitrification. There were no considerable variations between the two situations studied, with the growth of these concentrations in the direction of entry to exit the process and on dry days for rainy ones. The increase of the first refers to the anaerobic and aerobic cycle of the treatment itself, while the second is influenced by factors such as the alkalinization of the effluent and the drop in temperature (shown in Figs. 3a and b). All concentrations are in accordance with the environmental standards cited in this study and are suitable for release into the water bodies [21–24]. On rainy days, the COD present in the treatment plant decreases resulting in a decrease in bacterial activity, causing it to increase nitrite and nitrate levels, corroborating with what was observed by other authors in the monitoring of bacterial activity in an activated sludge system present in the city of Campina Grande, located in northeastern Brazil [25].

Rashid and Liu [5] highlight that parameters such as BOD, COD, TSS, AN and flow are directly influenced by the intercommunication of absolute separator systems. The COD showed at the entry of the STP average reduction of concentration on rainy days of approximately 30% (304.76 and 214.00 mg $O_2$ $L^{-1}$), 55% (258.25 and 114.03 mg $O_2$ $L^{-1}$) in the lower limits and 10% (351.28 and 313.97 mg $O_2$ $L^{-1}$) in the upper limits of the confidence interval. Although there are no significant differences in this test, the reductions are quite considerable, since the BOD/COD ratio is directly linked to

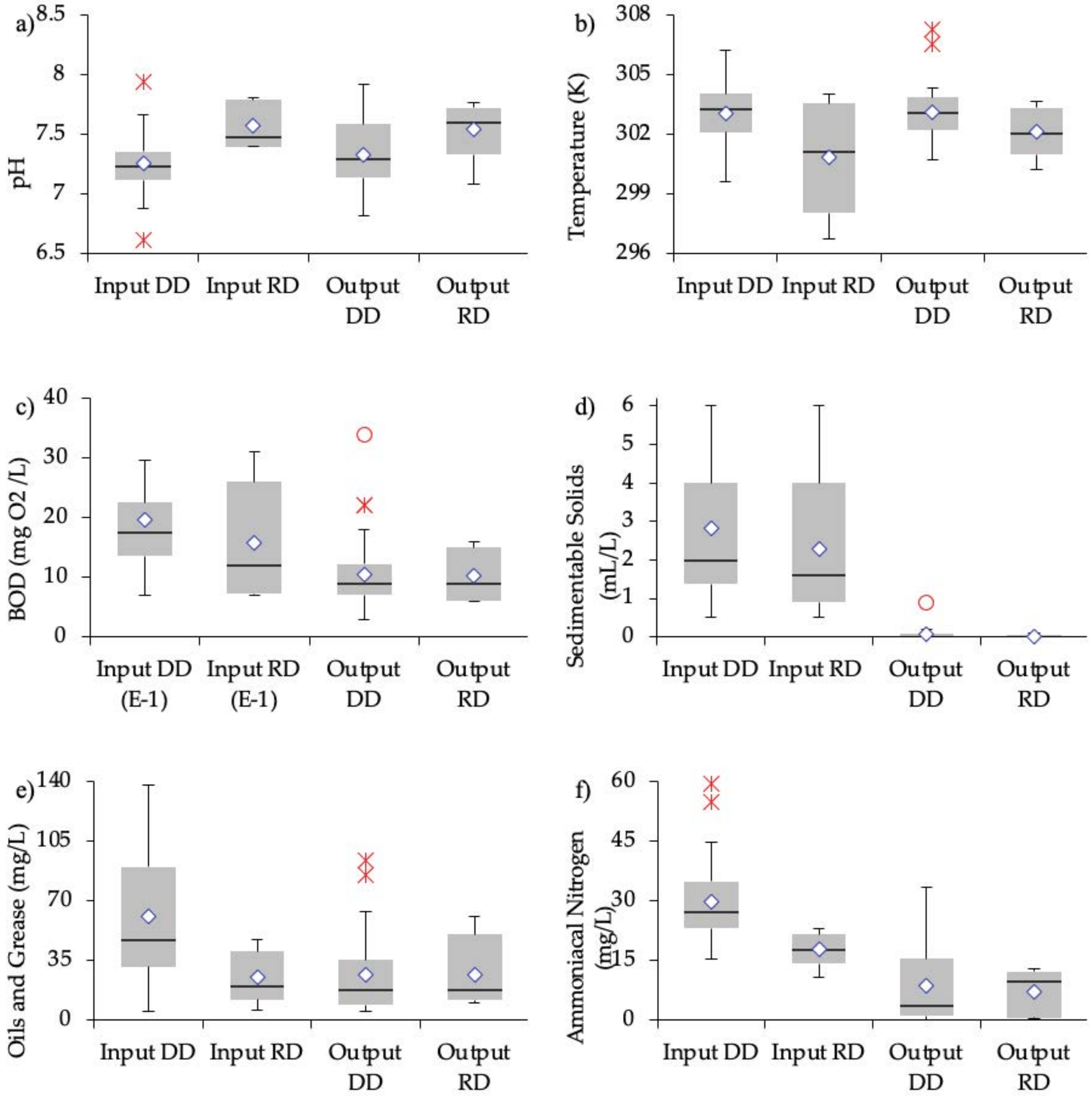

Fig. 3. Boxplot for the parameters analyzed, at the entrance and exit of the process, for dry days (DD) and rainy days (RD).

sewage biodegradability [26]. At the outlet the results are quite close, which causes loss of efficiency in removing the oxygen available in the effluent [5], since the outlets have averages close to 32 mg $O_2$ $L^{-1}$, both for dry and rainy days. This behavior is similar to the BOD, considering their respective proportions [27].

The efficiency of the treatment (directly related to BOD) obtained a performance higher than 90% in the two averages, but it was below CPRH on two rainy occasions. Despite not presenting significant differences in relation to the CI, there was a reduction in the percentages of organic matter removal in the effluent on rainy days, with average reductions of 2.11%. This indicates that, despite the dilution of organic matter (Fig. 3c), the sludge recirculation process does not allow a drop in the effluent purification. Nevertheless, throughout the period this parameter has been meeting EU and WHO specifications.

The pH has a direct influence on various aspects of treatment in activated sludge. Intervals with higher alkalinity and/or closer to neutrality (7 to 10) have greater ease of anaerobic fermentation and consequent disintegration of organic matter. Ma et al. [28] and Liu et al. [29] states that range from 8 to 11 are significantly better than those close to neutrality to improve COD dissolved in sewage.

In this respect, the rains are beneficial for the treatment because at the entrance they present alkalinization of the pH in 0.4 (average) and 0.2 at the exit (average). This also contributes to the preservation of the treatment structures themselves (aeration tanks, which in Brazil are usually made of reinforced concrete), which are more susceptible to developing pathological manifestations at lower pHs [20].

The pH variations at the exit of the treatment on rainy days are greater, from 6.8 to 8, while on dry days it is 7 to 7.8. The amplitudes, both in and out of STP normally vary

Table 3
Confidence interval (CI) for rainy days (RD) and dry days (DD), at the entrance and exit of the treatment process

| | Dry days | | | Rainy days | | |
|---|---|---|---|---|---|---|
| | Lower limit | Average | Upper limit | Lower limit | Average | Upper limit |
| Input flow (L $s^{-1}$) | 335.49 | 349.10 | 362.71 | 373.94 | 415.22 | 456.49 |
| Total chlorine – input (mg $L^{-1}$) | 110.46 | 124.56 | 138.65 | 70.62 | 83.00 | 95.38 |
| Total chlorine – output (mg $L^{-1}$) | 104.31 | 116.47 | 128.63 | 60.30 | 74.20 | 88.10 |
| TSS – input (mg $L^{-1}$) | 15.76 | 19.75 | 23.74 | 2.51 | 19.62 | 36.73 |
| TSS – output (mg $L^{-1}$) | 9.45 | 15.68 | 21.90 | 13.56 | 22.50 | 31.44 |
| Nitrate – input (mg $L^{-1}$) | 0.87 | 1.35 | 1.83 | 0.56 | 1.76 | 2.96 |
| Nitrate – output (mg $L^{-1}$) | 2.19 | 2.96 | 3.73 | 0.09 | 3.60 | 7.11 |
| Nitrite – input (mg $L^{-1}$) | 0.61 | 1.76 | 2.91 | 0.37 | 3.68 | 7.00 |
| Nitrite – output (mg $L^{-1}$) | 0.70 | 1.31 | 1.92 | 0.00 | 6.46 | 15.09 |
| COD – input (mg $O_2$ $L^{-1}$) | 258.25 | 304.76 | 351.28 | 114.03 | 214.00 | 313.97 |
| COD – output (mg $O_2$ $L^{-1}$) | 25.82 | 30.50 | 35.18 | 15.27 | 33.80 | 52.33 |
| Efficacy (%) | 92.72 | 93.85 | 94.98 | 88.39 | 91.74 | 95.10 |

from 6.5 to 8. Despite the sensible increase of alkalinity in the effluent in rainy periods, it is customary that there is a slight acidification in this parameter, but being of particular characteristic of the liquid entering the season [30–32].

At the entrance of the STP, the temperature reduced to 3 K and occasionally increased up to 8 K, at the entrance of the process, in relation to the dry days. In the periods in which there is interference from the rains, there was an average reduction of 8 K. For the end of the treatment this difference is more sensitive, reaching 2 K. This occurs because of the lower temperature of the rainwater, due to the external interference of the environment (which has lower temperature) on rainy days. Although higher temperatures accelerate the sewage purification process, the variations identified are not sufficient to interfere with this type of treatment [33]. Although the environmental conditions are very different (Brazil and the countries forming the European Union), this indicator met international environmental requirements.

With the addition of water volume on rainy days, there was a reduction of the average BOD of approximately 90 mg $O_2$ $L^{-1}$ in relation to the dry at the entrance of the treatment process, although the total amplitudes of the boxplot are similar for the entrance of the treatment, varying from 65 to 300 mg $O_2$ $L^{-1}$, characteristic of domestic effluents. This BOD amplitude is similar to that found by the study of Mahapatra et al. [27], which can vary from 29 to 307 mg $O_2$ $L^{-1}$, between dry and rainy periods. Although the average output concentration on rainy days is slightly higher than dry (1.2 mg $O_2$ $L^{-1}$), there were no great differences in the efficiency of organic load removal in STP.

No significant variations were found for sedimentable solids on days with and without rain, although there was sensitive dilution (approximately 0.5 mL $L^{-1}$) for days of high rainfall. The input amplitudes were very close (0.4 to 6 mL $L^{-1}$) and the treatment process eliminated almost all the SS, resulting concentrations of up to 0.07 mL $L^{-1}$, meeting the national and state legislation in Brazil, which requires a maximum of 1 mL $L^{-1}$.

For oil and grease, it is common that their concentration is reduced in rainy periods, due to the increase in liquid volume in the ducts. Because they are not biodegradable and more common in industrial waste, the STP for the treatment of domestic sewage does not have high efficiency in removing these compounds. From Fig. 3e it is possible to see that there are no big differences for the entrance in rainy days and for the exit of rainy and dry. There is a reduction of concentration in the entry of dry days because of the secondary decantation process, which eliminates some supernatant compounds in its treatment [34].

Regarding the averages of the output values of this parameter, the national (CONAMA) and state (CPRH) resolution are met, but not the WHO and the EU, which require a maximum concentration of 10 and 8 mg $L^{-1}$. This occurs due to the increase in direct disposal of compounds such as cooking oils in the sewage collection system. To reduce these concentrations would require the use of fat boxes by primary users or insertion of a specific anaerobic digestion system of these compounds in the treatment station, the latter being much more expensive to implement, compared to the first [35].

As for the nitrogen concentrations, there is a reduction in the inlet of rainy days, which does not occur in their outlet, thus reducing the removal efficiency in the treatment. As the EU recommendations are the most restrictive (for this study), there was compliance in 70% of the occasions, and for the recommendations of Brazil in 85% of the times. For the disapproved indicators, which occurred every dry day, there should be greater control in the process of nitrification and denitrification of activated sludge to achieve 100% frequency [36]. As WHO is milder on this indicator, there were no inefficient processes.

## 4. Conclusion

As for the difference between the effluent parameters between dry and rainy days, it can be concluded that:

- There was an increase in the input flow on rainy days, an average increase of 16.53% (66 L $s^{-1}$), with a low coefficient of determination between the daily rainfall and the instantaneous flow measured ($R^2 = 0.15$).

- There was a reduction in the averages of concentration for Total chlorine (input and output), COD (input), temperature (input and output), BOD (input), oil and greases (input) and ammoniacal nitrogen (input) for periods with a significant rainfall.
- Higher acidity was identified in the pH for the days without rain, reducing, on average, 0.4 at the entrance of the process and 0.2 at the exit. In both cases this parameter is neutral or slightly alkaline in the great majority of the registers, varying from 7 to 8.
- There were no big differences for the indicators of TSS (input), nitrate (input and output), COD (output), BOD (output), sedimentable solids (input and output), oils and grease (output) and ammoniacal nitrogen (output).
- Increased concentrations were identified for rainy days in: TSS (output) and nitrite (input and output).
- The treatment efficiency of STP was not altered by the intrusion of rainwater into the sewage collection and treatment system.
- The absolute separator system, in this case, is more interesting, since the increase of the entrance flow through the unitary system raises the costs of operation and maintenance of the STP.

Regarding the compliance with environmental legislation, it was possible to infer that the indicators of pH, temperature, total chlorine, BOD, COD, SS, TSS and nitrate were met at all times. The failures were total for the indicator of oil and greases, since the removal process is more common for STPs of industrial and non-domestic effluents. As for ammoniacal nitrogen, the rainy days met all the recommendations, while for the dry ones there was a disapproval of the criteria adopted by the EU and by Brazilian legislation.

## Acknowledgments

The present work was done thanks to the support of the Coordenação de Aperfeiçoamento de Pessoal de Nível Superior (CAPES, Coordination for the Improvement of Higher Education Personnel).

## References

[1] E.P. Kresch, R. Schneider, Political determinants of investment in water and sanitation: evidence from Brazilian elections, Econ. Lett., 189 (2020) 1–18.

[2] M. von Sperling, B.L. Salazar, Determination of capital costs for conventional sewerage systems (collection, transportation and treatment) in a developing country, J. Water Sanit. Hyg. Dev., 3 (2013) 365–374.

[3] D.B.C. de Oliveira, W. de Albuquerque Soares, M.A.C.R. de Holanda, Effects of rainwater intrusion on an activated sludge sewer treatment system, Rev. Ambient Água, 15 (2020) 1–12.

[4] A.G. El-Din, D.W. Smith, A neural network model to predict the wastewater inflow incorporating rainfall events, Water Res., 36 (2002) 1115–1126.

[5] S.S. Rashid, Y.-Q. Liu, Assessing environmental impacts of large centralized wastewater treatment plants with combined or separate sewer systems in dry/wet seasons by using LCA, Environ. Sci. Pollut. Res., 27 (2020) 15674–15690.

[6] G. Balacco, V. Iacobellis, F. Portincasa, E. Ragno, V. Totaro, A.F. Piccinni, Analysis of a large maintenance journal of the sewer networks of three Apulian Provinces in Southern Italy, Water, 12 (2020) 1–18, doi: 10.3390/w12051417.

[7] J.L. Li, K. Sharma, Y.Q. Liu, G.M. Jiang, Z.G. Yuan, Real-time prediction of rain-impacted sewage flow for on-line control of chemical dosing in sewers, Water Res., 149 (2019) 311–321.

[8] COMPESA, 2020. Available at: https://servicos.COMPESA.com.br/esgotamento-sanitario (Accessed on: 20th May 2020).

[9] APAC – Agência Pernambucana de Águas e Climas [Pernambuco Water and Climate Agency], 2020. Available at: http://www.apac.pe.gov.br/meteorologia/monitoramento-pluvio.php (Accessed on: 31st May 2020).

[10] E.W. Rice, R.B. Baird, A.D. Eaton, L.S. Clesceri, Standard Methods for the Examination of Water and Wastewater, 22nd ed., American Public Health Association, American Water Works Association, Water Environmental Federation, Washington, D.C., 2012.

[11] D.C. Montgomery, G.C. Runger, Estatística aplicada e probabilidade para Engenheiros [Applied Statistics and Probability for Engineers], 5th ed., Rio de Janeiro, 2012.

[12] CONAMA, Resolução n° 430 de 13 de maio de 2011. Dispõe sobre as condições e padrões de lançamentos de efluentes, complementa e altera a Resolução n° 357, de 17 de março de 2005 [Resolution No. 430 of May 13, 2011. Adaptation on the Conditions and Standards of Effluent Discharge, Complements and Amends Resolution No. 357, of March 17, 2005], Diário Oficial da União: seção 1, Brasília, Brazil, 2011.

[13] CPRH, Companhia Pernambucana de Recursos Hídricos, 2018, Instrução normativa CPRH n°003/2018 [Normative instruction CPRH No. 003/2018]. Available at: http://www.cprh.pe.gov.br/ARQUIVOS_ANEXO/INSTRU%C3%87%C3%83O_NORMATIVA_CPRH_N%C2%BA_003-2018;140609;20190313.pdf (Accessed on: 14th Jun 2020).

[14] EHS, Environmental, Health, and Safety Guidelines, 2007. Available at: https:// www.ifc.org/ehsguidelines (Accessed on: 14 de junho de 2020).

[15] EPA, Environmental Protection Agency, Licensing and Permitting, 2014. Available at: http:// www.epa.ie/terminalfour/waste/index.jsp#.VVR2hrlVhHw (Accessed on 14th June 2020).

[16] WHO, World Health Organization, 2006. A Compendium of Standards for Wastewater Reuse in the Eastern Mediterranean Region. Available at: https://apps.who.int/iris/handle/10665/116515 (Accessed on: 14th Jun 2020).

[17] R.O. Mines Jr., L.W. Lackey, G.H. Behrend, The impact of rainfall on flows and loadings at Georgia's wastewater treatment plants, Water Air Soil Pollut., 179 (2007) 135–157.

[18] E. Schramm, B. Ebert, B.X. Wang, M. Winker, M. Zimmermann, Keeping flows separate: good management practices in novel urban water systems derived from error analyses, Water, 11 (2019) 1–15.

[19] P.D. Saliba, M. von Sperling, Performance evaluation of a large sewage treatment plant in Brazil, consisting of a UASB reactor followed by activated sludge, Water Sci. Technol., 76 (2017) 2003–2014.

[20] X. Li, U. Kappler, G.M. Jiang, P.L. Bond, The ecology of acidophilic microorganisms in the corroding concrete sewer environment, Front. Microbiol., 8 (2017) 683–700.

[21] M. McFadden, J. Loconsole, A.J. Schockling, R. Nerenberg, J.P. Pavissich, Comparing peracetic acid and hypochlorite for disinfection of combined sewer overflows: effects of suspended-solids and pH, Sci. Total Environ., 599 (2017) 533–539.

[22] N. Durban, V. Sonois-Mazars, P. Albina, A. Bertron, A. Albrecht, J.-C. Robinet, B. Erable, Nitrate and nitrite reduction activity of activated sludge microcosm in a highly alkaline environment with solid cementitious material, Int. Biodeterior. Biodegrad., 151 (2020) 104971, doi: 10.1016/j.ibiod.2020.104971.

[23] H.H. Cui, L. Zhang, Q. Zhang, X.Y. Li, Y.Z. Peng, Stable partial nitrification of domestic sewage achieved through activated sludge on exposure to nitrite, Bioresour. Technol., 278 (2019) 435–439.

[24] Y.Q. Lu, Y. Xu, B. Dong, X.H. Dai, Effects of free nitrous acid and nitrite on two-phase anaerobic digestion of waste activated sludge: a preliminary study, Sci. Total Environ., 654 (2019) 1064–1071.

[25] A.G. Costa, A.F. Ferreira, A. van Haandel, Monitoramento da atividade bacteriana de um sistema de lodos ativados bardenpho

por meio da respirometria [Control of reaction sludg's system bacterian activity – Bardenpho through respirometry], Eng. Sanit. Ambient., 12 (2007) 17–23.

[26] M.E. Angulo, O.G. Castellar, B.M.M. Cely, S.L. Ibáñez, M.L. Prasca, Discoloration of wastewater from a paint industry by the microalgae *Chlorella* sp., Rev. MVZ Córdoba, 22 (2017) 5706–5717.

[27] D.M. Mahapatra, H.N. Chanakya, T.V. Ramachandra, Treatment efficacy of algae-based sewage treatment plants, Environ. Monit. Assess., 9 (2013) 7145–7164.

[28] H.J. Ma, X.C. Chen, H. Liu, H.B. Liu, B. Fu, Improved volatile fatty acids anaerobic production from waste activated sludge by pH regulation: alkaline or neutral pH?, Waste Manage., 48 (2016) 397–403.

[29] Y. Liu, X. Li, X.R. Kang, Y.X. Yuan, M. Du, Short chain fatty acids accumulation and microbial community succession during ultrasonic-pretreated sludge anaerobic fermentation process: effect of alkaline adjustment, Int. Biodeterior. Biodegrad., 94 (2014) 128–133.

[30] S. Bai, S. Srikantaswamy, D. Shivakumar, Urban wastewater characteristic and its management in urban areas—a case study of Mysore City, Karnataka, India, J. Water Resour. Prot., 2 (2010) 717–726.

[31] L.T. Hadgu, M.O. Nyadawa, J.K. Mwangi, P.M. Kibetu, Assessment of pollution in Ndarugu River due to runoff and agro-industrial wastewater disposal, J. Agric. Sci. Technol., 16 (2014) 109–121.

[32] H.J. Qin, Z.Y. Zhang, M.H. Liu, H.Q. Liu, Y. Wang, X.Z. Wen, Y.Y. Zhang, S.H. Yan, Site test of phytoremediation of an open pond contaminated with domestic sewage using water hyacinth and water lettuce, Ecol. Eng., 95 (2016) 753–762.

[33] S. Ahsan, M.A. Rahman, S. Kaneco, H. Katsumata, T. Suzuki, K. Ohta, Effect of temperature on wastewater treatment with natural and waste materials, Clean Technol. Environ. Policy, 7 (2005) 198–202.

[34] M. Eljaiek-Urzola, N. Romero-Sierra, L. Segrera-Cabarcas, D. Valdelamar-Martínez, E. Quiñones-Bolaños, Oil and grease as a water quality index parameter for the conservation of Marine Biota, Water, 11 (2019) 856, doi: 10.3390/w11040856.

[35] T. Wallace, D. Gibbons, M. O'Dwyer, T.P. Curran, International evolution of fat, oil and grease (FOG) waste management, J. Environ. Manage., 187 (2016) 424–435.

[36] C. Wang, S. Liu, X. Xu, C. Zhang, D. Wang, F. Yang, Achieving mainstream nitrogen removal through simultaneous partial nitrification, anammox and denitrification process in an integrated fixed film activated sludge reactor, Chemosphere, 203 (2018) 457–466.