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Statistical evaluation ff physical and chemical characteristics of effluent at a university

Avaliação estatística das características físicas e químicas do efluente em uma universidade

Evaluación estadística de características físicas y químicas del efluente en una universidad

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Abstract
The aim of this study is to characterize the physic-chemical aspects of the effluent generated at a university campus and statistically analysing how the effluent characteristics are affected by campus activities. Effluent samples were done along one year. Parameters analysed were: COD, total solids, suspended solids, dissolved solids, chloride, pH, ammoniacal nitrogen, conductivity and flow rate of the effluent based on water consumption. Statistical studies were carried out in order to analyse the impacts of campus activities on effluent quality parameters. It was observed that chemical oxygen demand (COD) and dissolved solids vary according to the days of the week, whereas pH, chloride and conductivity do not. However, none of these parameters have statistically different average values throughout the hours of the day. Furthermore, there are no differences between the average pH values of the term and pH of the vacation period; instead, COD, chloride and conductivity have statistically lower average values in the vacation period. Correlation tests have shown that the academic population does not directly influence pH and concentrations of COD, total solids and suspended solids. In addition, it was concluded that the number of served meals can influence effluent characteristics. This work shows that campus effluent has unique characteristics. All data and analysis of this work can support better projects and management of sewage treatment systems in educational institutions. Studies on the broad characterization of university effluents are scarce in the literature. This work aims to complement the literature on this topic.
Keywords: Wastewater characterisation; Effluent per capita loading; University campus effluent; Sustainable universities; Statistical analyses.

Resumo
O objetivo deste estudo é caracterizar os aspectos físico-químicos do efluente gerado em um campus universitário e analisar estatisticamente como as características do efluente são afetadas pelas atividades do campus. Amostras de efluentes foram feitas ao longo de um ano. Os parâmetros analisados foram: DQO, sólidos totais, sólidos suspensos, sólidos dissolvidos, cloreto, pH, nitrogênio amoniacal, condutividade e vazão do efluente com base no consumo de água. Estudos estatísticos foram realizados para analisar os impactos das atividades do campus nos parâmetros de qualidade do efluente. Observou-se que a demanda química de oxigênio (DQO) e os sólidos dissolvidos variam de acordo com os dias da semana, enquanto o pH, o cloreto e a condutividade não variam. No entanto, nenhum desses parâmetros tem valores médios estatisticamente diferentes ao longo das horas do dia. Além disso, não há diferenças entre os valores médios de pH do termo e o pH do período de férias; em vez disso, COD, cloreto e condutividade têm valores médios estatisticamente mais baixos no período de férias. Os testes de correlação mostraram que a população acadêmica não influencia diretamente o pH e as concentrações de DQO, sólidos totais e sólidos suspensos. Além disso, concluiu-se que o número de refeições servidas pode influenciar as características do efluente. Este trabalho mostra que o efluente do campus possui características únicas. Todos os dados e análises deste trabalho podem subsidiar melhores projetos e gestão de sistemas de tratamento de esgoto em instituições de ensino. Estudos sobre a ampla caracterização de efluentes universitários são escassos na literatura. Este trabalho visa complementar a literatura sobre o tema.
Palavras-chave: Caracterização de águas residuais; Carregamento de efluentes per capita; Efluente do campus universitário; Universidades sustentáveis; Análise estatística.

Resumen
El objetivo de este estudio es caracterizar los aspectos físico-químicos del efluente generado en un campus universitario y analizar estadísticamente cómo las características del efluente se ven afectadas por las actividades del campus. Las muestras de efluentes se realizaron a lo largo de un año. Los parámetros analizados fueron: DQO, sólidos totales, sólidos en suspensión, sólidos disueltos, cloruro, pH, nitrógeno amoniacal, conductividad y caudal del efluente en función del consumo de agua. Se realizaron estudios estadísticos para analizar los impactos de las actividades del campus sobre los parámetros de calidad de los efluentes. Se observó que la demanda química de oxígeno (DQO) y los sólidos disueltos varían según los días de la semana, mientras que el pH, el cloruro y la conductividad no. Sin embargo, ninguno de estos parámetros tiene valores promedio estadísticamente diferentes a lo largo de las horas del día. Además, no existen diferencias entre los valores de pH promedio del término y el pH del período vacacional; en cambio, DQO, cloruro y conductividad tienen valores promedio estadísticamente más bajos en el período de vacaciones. Las pruebas de correlación han demostrado que la población académica no influye directamente en el pH y las concentraciones de DQO, sólidos totales y sólidos en suspensión. Además, se concluyó que el número de comidas servidas puede influir en las características del efluente. Este trabajo muestra que el efluente del campus tiene características únicas. Todos los datos y análisis de este trabajo pueden apoyar mejores proyectos y gestión de sistemas de tratamiento de aguas residuales en instituciones educativas. Los estudios sobre la caracterización amplia de los efluentes universitarios son escasos en la literatura. Este trabajo tiene como objetivo complementar la literatura sobre este tema.
Palabras clave: Caracterización de aguas residuales; Carga de efluentes per cápita; Efluente del campus universitario; Universidades sostenibles; Análisis estadístico.

1. Introduction

Untreated effluent discharged in the waterbody is one of most significant ways of degrading water resources, causing changes to the water quality. Treating the effluent before discharging it into the waterbody is necessary to reduce environmental impacts; however, there are different treatment procedures for effluents with different characteristics.

The characteristics of the effluent are very diverse depending on how the water is used. In the case of industries, these characteristics are related to the manufactured products, the manufacturing processes and the materials used in those processes. In the case of domestic sewage, there is a typical characterisation inherent to domestic activities. Similarly, educational institutions will have a characteristic effluent related to their activities. This lack of standard makes it important for each generating source to characterise its effluent before choosing a treatment process.

Metcalf & Eddy, et al. (2003) said that sanitary sewage can be divided into weak, medium and strong, with values of COD of 250 mg/l, 430 mg/l and 800 mg/l, respectively. The same authors present classifications for other parameters, obtaining values according to the wastewater flow rate - the flow rate is a fundamental parameter in determining a pollutant load (von Sperling, 2005). On the other hand, the per capita loadings are important parameters because they represent the contribution of each individual, expressed as a mass of pollutant per unit of time - in general, a unit of g/inhab.day is used. Typical values in domestic sewage are: 180 g/inhab.day for total solids (TS), 10 g/inhab.day for fixed suspended solids (FSS), 50 g/inhab.day for volatile suspended solids (VSS), 100 g/inhab.day for COD, 4.5 g/inhab.day for ammoniacal nitrogen (ammonia) and 6 g/inhab.day for chlorides (von Sperling, 2005). However, these values do not necessarily apply to sites with particular routines and activities such as universities, hospitals, and in different communities with different cultural habits (Graham et al., 2015).

Different cities can present different sewage characteristics. In a study carried out in two different cities in Palestine, the per capita COD load ranged from 166 to 418g/inhab.day in one city, and from 155 to 202 g/inhab.day in another city. The conclusion obtained by the author is that these values of per capita loadings are higher than the values found in the literature. These observed differences can be related to diverse cultural habits in these two cities, including water consumption (Mahmoud et al., 2003). Another study carried out in Tehran showed values of 49.25 ± 2.49 g/inhab.day for COD, 20.76 ± 2.44 g/inhab.day for Total Suspended Solids (TSS), 92.23 ± 5.68 g/inhab.day for Total Dissolved Solids (TDS) and 128.96 ± 6.69 g/inhab.day for TS. The obtained results have different values from those recommended as reference values for treatment plant projects in that region; showing that more reliable data is needed for designing more reliable sewage treatment plants (Mesdaghinia et al., 2015).

Likewise, educational institutions may have particular activities, which suggests that their effluent can have different characteristics. A floating population comprising students, staff and teachers; having restaurants or not; diverse types of laboratories are examples of inherent operation characteristics of a university that make the effluent characteristics different from domestic or industrial ones.

Wastewater treatment plants at universities would contribute to mitigating environmental impacts, and would serve as important study and research environments. The characterisation of the effluent is the first step in determining the basic parameters required for treatment plant projects such as the concentration of solids and organic matter, pH, temperature and flow. These data allow the determination of maximum, minimum and average pollutant loads, as well as the determination of the per capita loading rate for each parameter. This characterisation makes it possible to predict how the effluent characteristics would change in a scenario where the academic population increased, for example.

As far as we know, there are few studies on characterisation of university wastewater. In this paper, we present some of them which were conducted in Brazil and other countries. Ciner and Sarioglu (2006) determined the inert COD fraction of Cumhuriyet University (Turkey) wastewater. A preliminary characterisation of wastewater samples taken from the equalisation tank of the treatment plant had mean values of conventional wastewater parameters as follows: total COD of 272 mg/l, total soluble COD of 124 mg/l, total suspended solids of 117 mg/l, ammonia of 31.2 mg/l and pH of 7.4.

Coskuner and Ozdemir (2006) studied the operational effects of the parameter and raw wastewater characteristics on the biological nitrification process and the overall performance of the treatment plant at Cumhuriyet University. Fifteen samples were collected from different locations of domestic wastewater treatment plants every month starting from October 2003 – samples were collected from 9 a.m. to 10 a.m. As the result of an annual raw wastewater characterisation, a biological oxygen demand range was observed which varied between 60 mg/l and 200 mg/l, ammonia range varied between 3.5 mg/l and 21 mg/l, and the total suspended solids range varied between 28 mg/l and 146 mg/l.

In Brazil, some institutions carried out studies on the characterisation and treatment of their effluent, such as the Federal University of Ouro Preto (UFOP- Brazil), which found Biological Oxygen Demand (BOD) and COD values of 280 and 670 mg/l, respectively (Bertolino et al., 2008). At the Campo Mourão campus at the Federal Technological University of Paraná (UTFPR – Brazil), the average COD value found was 648 ± 46 mg/l and pH 7 ± 0.60. An analysis of total solids had an average value of 637 ± 64 mg/l. The average values for the total fixed and volatile solids were 184 ± 44 mg/l and 463 ± 76 mg/l, respectively (Martins, 2012). In another example, the effluent of a university campus was used in an anaerobic-aerobic fixed bed reactor in a study at the University of São Paulo in São Carlos (USP-Brazil). During the various stages of the study, the characteristics of the raw sewage presented average COD from 93 ± 31 mg/l to 214 ± 30 mg/l from one phase to another - average concentration of volatile suspended solids from 10 ± 4 mg/l to 54 ± 34 mg/l - pH average value from 7.5 ± 0.75 to 7.7 ± 0.19 between phases (Sarti et al., 2007). In particular, it can be observed that these universities have very similar effluent characteristics, with typical concentrations of domestic sewage (Bertolino, 2007).

Some other studies were conducted at universities focusing on specific wastewater sources or specific contaminants. Nkansah et al., (2016) characterised beauty salon wastewater from Kwame Nkrumah University surroundings. The results showed a mean COD of 60.04±1.82 mg/L, BOD of 30.03±9.11 mg/L, dissolved oxygen of 3.00±0.53 mg/L, pH of 9.55± 0.42, nitrate of 5.42±0.36 mg/L, and total dissolved solids of 1150.25±262.10 mg/L in the salon waste. In conclusion, results showed that the physicochemical parameters were above the WHO regulatory limits for discharged wastewater with isolated cases of low BOD, DO, TDS, and COD levels, characterising salon wastewater as only having slightly more industrial strength than typical domestic and house wastewater.

Vatovec et al., (2016) investigated the effect of the demographic change that occurs each spring during the end-of-semester Vermont University move-out period, which results in a loss of approximately 25% of a city's population, primarily in the age range of 18 to 22 years old. They collected a series of samples for a ten-day period from May 1–10, 2014, that corresponded to the end of the academic year student move-out period. Results showed that in general, concentrations of most pharmaceuticals increased over the 10-day period when students left Burlington at the end of the semester. They conjecture that among this population of university students, flushing unused medication is not a common behaviour; and that the demographic shift leaves less diluted wastewater of the generally older year-round residential community, which uses a larger quantity and different types of pharmaceuticals compared to the student population.

Sundari and Erdawati (2016) studied metal distribution in campus wastewater at the State University of Jakarta and also studied the effects of metal ions (Cu, Zn, Pb, Mn, And Ni) on the water quality of campus wastewater applying backward stepwise multiple linear regression (Sundari et al., 2014). The results showed Cu yields the most metal ion effect on the TSS of campus wastewater among other given metals, and Cu and Pb ions yielded a strong effect on pH.

Most recently, Gao et al. (2022) have studied the occurrence and characteristics of microplastics (MPs) in a secondary wastewater treatment plant (WWTP) at the University of Mississippi. In the influent, the highest MP concentration occurred after a football game on campus (62.3±7.6 particles/L) and the lowest (19.7±2.1 particles/L) during the summer with little activity on campus.

In the last few years however, most research on wastewater analysis have focused on surveillance for SARS-CoV-2. At the epicentre of the coronavirus crisis, Deng et al. (2022) reported a use case of intensified sewage surveillance to initiate public health action to thwart a looming Delta variant outbreak in Hong Kong. This kind of research has also been held in university campus. Wartell et al. (2022) have tested and concluded that “wastewater monitoring is a doable process that can be implemented across colleges or other campuses to detect SARS-CoV-2. The logistical infrastructure is present to survey a large population of people to obtain a representative sample for early detection and quick response time.”. Likewise et al. (2022) came to the same conclusion; additionally however, they have also studied the impact of wastewater parameters on SARS-CoV-2 detection, showing that SARS-CoV-2 detection based on the centrifugation concentration method was more sensitive for wastewater with high solids content and that the ultrafiltration concentration method was more sensitive for wastewater with low solids content. This last research reinforces that no matter the specific purpose, the wastewater characteristic can affect the results.

Therefore, the aim of this study is to characterise the effluent from the Federal University of Alfenas, Poços de Caldas campus determining effluent parameters related to the activities of the university, and comparing the results with those existing in the literature. The parameters analysed are COD, total solids (fixed and volatile), suspended solid (fixed and volatile), dissolved solids, chloride, pH, ammoniacal nitrogen, conductivity and flow rate of the effluent based on water consumption. Various statistical studies were carried out in order to analyse the impacts of campus activities on effluent quality parameters. Statistical analyses were done in order to determine the behaviour of these parameters on weekdays and throughout the day. In addition, statistical analyses were done in order to verify differences between effluent quality during the vacation and term periods. Correlation tests were carried out to determine whether effluent characteristics change according to the variation of the campus population or the numbers of meals served in the local restaurant. Finally, considering all the analysis results and water consumption data, we were able to define reference values of campus per capita loading rates.

2. Materials and Methods

This is a quali-quanti research tha starts in the field with sewage sampling, followed by laboratory analysis, generating data for statistical analysis that support qualitative classification of the sewage (Pereira et al., 2018). In the following, all the research steps are detailed.

Study Area

The study area is the Poços de Caldas campus at the Federal University of Alfenas, which has four undergraduate courses and four post-graduate courses. The academic population on the campus varied from 1366 in 2015 to 1337 in 2016 – it includes 83 faculty members and 68 other employees including secretaries, technicians, cleaning staff, etc.

The physical structure of the campus currently has 11 buildings, which are the following: 1) a library; 2) a university restaurant; 3) a 150-seat amphitheatre; 4) a sports complex; 5) a building with 18 classrooms, an audiovisual room, and 3 computer labs; 6) a basic science laboratory building with 2 physics laboratories and 7 chemistry and biology laboratories; 7) a building where there are multidisciplinary engineering laboratories; 8) a building comprising post-graduate materials engineering laboratories; 9) a building with approximately 90 faculty members' offices; 10) a general services building; 11) an administration services building.

Effluent Sampling

The collection point chosen was the observation point just before the wastewater pumping station, where sewage from the whole campus merges. Samplings were performed using a plastic bucket, transferred to a polyethylene flask and then stored under refrigeration until the analyses were performed.

Seventeen samples of the effluent were taken from 8 p.m. to 10 p.m. from 26/10/2015 to 21/01/2016; three samples for each day of the week (excluding Saturday and Sunday) and 2 samples for the vacation period. This first campaign was called Campaign I. The vacation periods and terms were determined according to the university's academic calendar.

Furthermore, 7 effluent profiles were made: one for each day of the week (excluding Sunday) during the term; and another profile for the vacation period. The samplings for each profile were carried out every 2 hours, from 9:00 a.m. to 11:00 p.m. from 19/11/2015 to 03/02/2016, making a total of 49 samples. This campaign was called Campaign II.

During Campaign I, we registered whether it rained or not in the preceding 24 hours of sampling time. For Campaign II, we registered whether it rained or not at the sampling time.

Characterisation of the Effluent

The parameters analysed during Campaign I were COD, dissolved solids, pH, chloride and conductivity. The parameters analysed during the Campaign II were COD, pH, total solids (fixed and volatile), suspended solids (fixed and volatile). Campaign I and Campaign II samples were analysed in different laboratories, which is the reason why the parameters are not the same.

The analyses of dissolved solids were made using an Orion 115 model conductivity meter. The other parameter analyses were performed according to the Standard Methods for the Examination of Water and Wastewater (2012) using the following methodologies: 4500-H + B (potentiometric pH); 2540 G (Total Solids); 2540 D (Total Suspended Solids), 2540 E (Fixed and Volatile Solids); 5220 D (COD - colorimetric); 4500 Cl-E (Chloride) and 4500 - NH 3-C (ammoniacal nitrogen).

Quantification of Generated Effluent Volume

The volume of generated effluent was estimated based on the water consumption. Measurements were made by reading the water meters on each sampling day of Campaign II at 8:00 a.m., and 24 hours later. Thus, it was possible to estimate 24h water consumption. The adopted value of return coefficient was 80% (Von Sperling, 2005).

Campus Population Survey

The number of people on the campus was estimated for each day of effluent sampling, and the day before it. In the case of Campaign II, the campus population was estimated for each sampling time, and for the last class period of the day before. The number of students was estimated based on the roll call regarding the subjects taught on the days and times considered.

The number of permanent employees that were on campus each day and the collection time was estimated by deducting the number of employees who were not there on each occasion (according to administrative records). The estimation of the number of laboratory technicians present on each day and time considered was carried out based on the work schedule. The administrative staff has a work day from 8:00 a.m. to 5:00 p.m. and the number of permanent administrative staff was provided by campus management. The number of outsourced staff members was provided by campus management, which also provided an outsourced staff work schedule.

The estimation of the campus population during the evening considered that teachers who taught lessons in the evening started their work day at 1:30 p.m. Teachers who had classes until 9 p.m. did not stay on campus after that time, and teachers who had morning and evening classes on the same day were not present on campus between 12 a.m. and 7p.m. Moreover, during lunch time, from 12:15 p.m. to 2 p.m., the population was estimated to be equal to the number of served meals.

Statistical Analysis

The averages and standard deviations of Campaign I effluent parameters were calculated with data grouped by days of the week; and for Campaign II with data grouped by sampling time. Analysis of variance (ANOVA) with 5% significance and the Scott-Knott mean comparison test were used to investigate the possible impacts of academic activities on effluent quality: a) impact of the day of the week in Campaign I; b) impact of the time of the collection in Campaign II; c) impact of the rain in Campaign I; d) impact of the campus population for different days of the week and class periods. Residue analyses concerning normality, independence and homogeneity (Shapiro-Wilk, Durbin-Watson and Bartlett tests, respectively) were also done. The software R was used to perform the analyses.

In the cases in which residue analyses indicated inconclusive ANOVA results, variable transformation was needed - Johnson Transformation was used. When results remained inconclusive, Per-mutational Multivariate Analysis of Variance using Distance Matrices (PERMANOVA) analyses were performed.

In Campaign I, for the cases in which the mean comparison tests showed separate groups among the days of the week for the analysed effluent parameters, T-tests were performed to identifying whether there are differences among the average values of the campus population for those groups.

Furthermore, in Campaign I, a T-test was performed comparing parameter average values for school and vacation periods to identify differences in effluent parameters between school and vacation periods.

Correlation tests were performed between the campus population and the effluent parameters in two ways: a) first considering that the population present on campus during a class time could impact effluent characteristics at that moment; b) second, considering that the population present on campus during a class time could impact effluent characteristics 2 hours later.

Correlation tests were performed between: a) the number of meals served on campus during dinner and the parameters of the effluent sample collected at 11:00 p.m.; b) the number of meals served during lunch and the parameters of the effluent sample collected at 3:00 p.m. A correlation test was also performed between the volume of consumed water and the average population attending the campus on each considered day.

For the correlation tests that presented results greater than 0.70, the data were graphically represented, as well as the trend line.

Definition of Load and Per Capita Loadings

The load and the per capita load of COD, total solids (fixed and volatile), suspended solids (fixed and volatile), dissolved solids, ammoniacal nitrogen and chloride were calculated by the methodology described by Von Sperling (2005).

3. Results and Discussion

Descriptive Statistics

Using all the generated data (Campaign I and II), descriptive statistics were made for each effluent parameter analysed. Considering all the analyses, the average values found were (in mg/l): COD value of 625.38 ± 347.30, total solids of 507.60 ± 207.30, total volatile solids of 311.90 ± 161.10, total fixed solids of 205.00 ± 120.50, volatile suspended solids of 102.80 ± 82.90, fixed suspended solids of 24.60 ± 0.43, ammoniacal nitrogen of 9.30 ± 4.99, dissolved solids of 399,05 ± 172.13, chloride of 189.41 ± 78.09. The pH average value was 7.07 ± 0.59 and conductivity 787.89 ± 307.58 µS/cm. An overview of the results is presented using the box-plot in Figure 1 – the box plot allows one to visually observe that some parameters present high standard deviantion, see for instance Figure 1(i,j,l) . In Table 1, we summarise the average values of some wastewater parameters presented in the literature in order to compare them with the results given here.

Table 1 - University wastewater quality comparison table.

Parameters	**This study**	**Ciner & Sarioglu (2006)**	**Coskuner & Ozdemir (2006)**		**Bertolino (2008)**	**Sarti (2007)**	**Martins (2012)**
	average	average	min	max	average	average	average
pH	7.07	7.4	6.48	7.98	7.78	7.2	7
COD (mg/l)	625.38	372	-	-	670	536	648
BOD mg/l)	-	-	60	200	300	-	-
Total suspended solids (mg/l)	507.6	117	28	146	300	250	637
Ammonia mg/l)	9.30	31.2	3.5	21.5	56	-	-

Source: Authors.

The average value found for the COD parameter in the present study (625.38 ± 347.30 mg/l) is similar to the average value found by Bertolino et al. (2008), 670 ± 94 mg/l (in the sampling point with the highest average) at the Federal University of Ouro Preto (UFOP – Brazil) – it does not consider the vacation periods. The average COD, however, is almost double the average COD characterised by Ciner and Sarioglu (2006). Neverhtheless, the average COD values presented in all the cited researchs are considered medium values for sanitary sewage classification. The fact that average total suspended solids value are slightly lower than the value presented by Martins (2012) should also be considered.

The maximum value found for the COD parameter was higher than the value found by Martins (2012) in the characterisation of the Mourão campus at the Federal Technological University of Paraná, which was 712 ± 46 mg/l. Higher values were obtained for total solids and total fixed solids parameters, whose maximum values in the study of Martins (2012) were 767 ± 64 mg/l and 226 ± 44 mg/l, respectively. Moreover, for total volatile solids and pH, the maximum values found in this study were higher than those found by Martins (2012): 584 ± 76 mg/l and 7.80 ± 0.6, respectively.

Regarding the minimum values of COD, total solids, total fixed solids and total volatile solids, they are all lower than those found by Martins (2012), which is probably because we also performed analyses during the vacation period, which were not carried out in the cited reserachs.

Anova: Variation of Effluent Characteristics in Each Weekday and Sampling Time

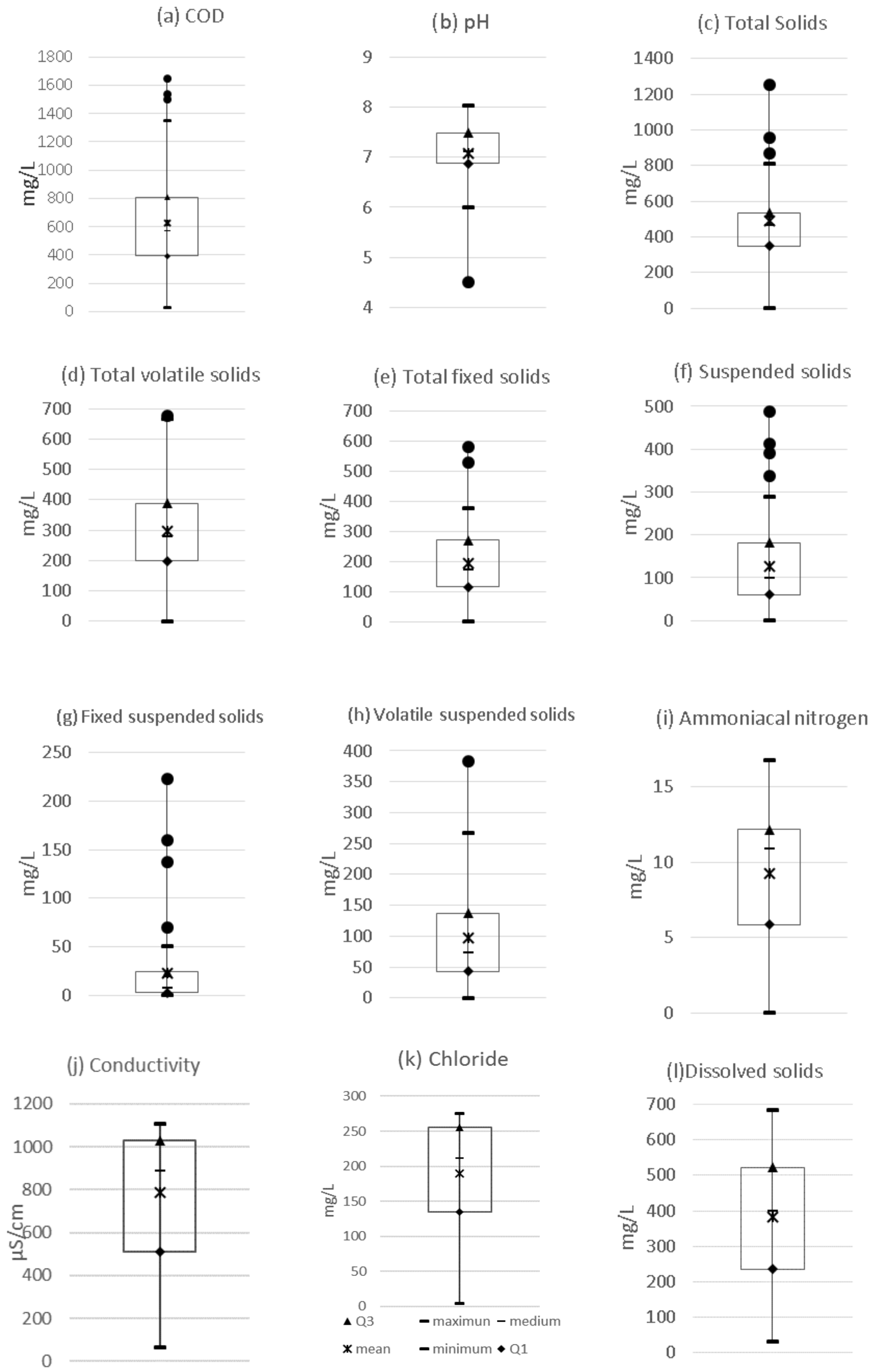
Table 3 shows the ANOVA results in Campaign I. The ANOVA showed that, on average, parameters pH, chloride and conductivity do not statistically vary among the days of the week. For COD, the analysis showed that the group comprising Monday, Tuesday and Thursday has a higher average value of COD than the average value of COD for Wednesday and Friday. For dissolved solids, the analysis showed that the group consisting of Monday, Tuesday, Thursday and Friday has a higher average value than the average value found on Wednesday. In all these ANOVA, the statistical residues were found to be homogeneous, independent and normal.

A PERMANOVA test considering Campaign II data was made to verify if there were any differences among the average values of effluent parameters throughout the day. The results showed that the average values of pH, COD, total solids, total fixed solids, total volatile solids, suspended solids, fixed suspended solid and volatile suspended solids do not statistically vary throughout the day.

T-Tests: Investigation of Possible Influence of Population, Restaurant Meals, Vacation Period And Rain on Effluent Characteristics

The average campus population during term oscillates from 24 to 665 people as can be seen in Table 2. The average value of the campus population in each class period = 434 (considering both campaigns). Particularly, on Saturdays, the average population is 98 people, and in the vacation period, the average population is 77 people.

Figure 1 - Box plot showing an overview of all analysed parameters of the effluent collected at UNIFAL-MG, Poços de Caldas campus.



Source: Authors.

Table 2 - The average campus population during term time.

Time	Academic Population		
	Average	Min	Max
8-10a.m	470	382	535
10-12a.m.	471	304	535
12-14p.m.	150	**24**	248
14-16p.m.	344	146	591
16-19p.m.	446	347	**665**
19-21p.m.	556	334	644
21-23p.m.	481	248	630

Source: Authors.

A T-test was made between the average campus population found on Monday, Tuesday and Thursday versus the population on Wednesday and Friday to verify if the population could be the cause of the variation of the COD average value in these two different groups. A T-test was also carried out considering the average campus population on Monday, Tuesday, Thursday, Friday versus the campus population on Wednesday to verify if the campus population could be responsible for these two different groups found in ANOVA for dissolved solids concentration. Both T-tests showed that the average campus population of the different groups of days of the week could not be considered statistically different. Therefore, the campus population itself cannot be directly responsible for the variation of COD and dissolved solids concentration on weekdays. Further tests must be performed to better understand the formation of these groups.

A second T-test was made to identify if the average values of served meals at the restaurant are statistically different between the two groups of weekdays. The results showed that there is no statistically significant difference between the average value of served meals on Monday, Tuesday, Thursday and the average value on Wednesday and Friday. The same test was made for the group consisting of Monday, Tuesday, Thursday and Friday versus Wednesday. In this case, there is no statistically significant difference between the average numbers of served meals either.

A third T-test was made to verify if there is a statistical difference between each effluent parameter average value during school or the vacation period. The results showed that pH values in the school period were not different from the pH during the vacation period. Chloride, conductivity, COD and dissolved solids presented higher average values during the school periods.

Another T-test and PERMANOVA test were made to evaluate if there is a statistical difference between the average value of chloride, conductivity, dissolved solids and pH on rainy days and not rainy days. The results showed that the rain does not interfere with the average value of the parameters. In fact, it shows that the campus rainwater drainage system works effectively.

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Table 3 - Results found from analyses of variance of effluent parameters considering the days of the week. Significance = 5%, number of data (n = 15), where there were 3 observations for each day of the week.

Parameters n = 15	**ANOVA**	**Test of normality (Shapiro-Wilk)**	**Test of independence (Durbin-Watson)**	**Test of homogeneity of variance (Bartlett)**	**Groups (Days of the week)**
	p-value	p-value	p-value	p-value	
pH	0.6055	0.8946	0.6774	0.2892	-
COD	0.0056	0.7644	0.5668	0.0824	a (Mon, Tue, Thu) b (Wed, Fri)
Dissolved solids	0.0253	0.7647	0.2242	0.4321	a (Mon, Tue, Thu, Fri) b(Wed)
Chloride	0.1701	0.5081	0,.081	0.2407	-
Conductivity	0.1351	0.3888	0.3103	0.3400	-

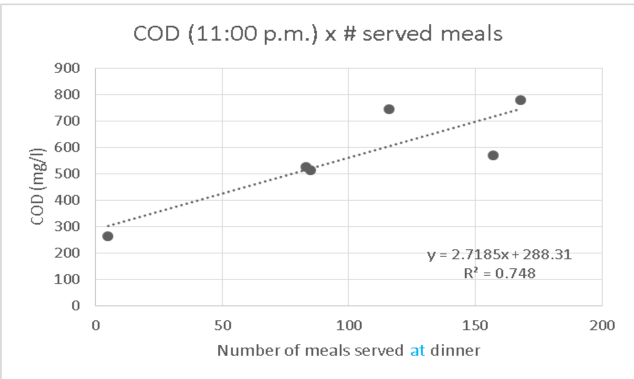
Source: Authors.

Correlation Analyses

The correlation tests between the campus population and the concentration of COD, total solids, total fixed solids, total volatile solids, suspended solids, fixed suspended solid volatile suspend solids and pH for each sampling time in Campaign II showed that there is no correlation between the campus population and the concentration of any of these parameters. Considering the campus population two hours before each sampling time, the correlation test also showed there is no correlation between the campus population and the concentration of the parameters. These results show that the average campus population throughout the day does not directly impact the concentration of the effluent parameters.

The correlation tests made considering the served meals and the concentration of the analysed parameters in Campaign II showed that there is a strong correlation (absolute value higher than 0.7) between: a) the pH at 11a.m. and the number of breakfasts served; b) total suspended solids at 3p.m. and the number of lunches served; c) suspended volatile solids at 3p.m. and the number of lunches served; d) COD at 11p.m. and the number of dinners served – the most significant correlation found - for this case, data and linear regression adjustment can be seen in Figure 2. In the case of pH and COD, the correlation is positive; and for the case of total suspended solid and suspended volatile solids, the correlation is negative. These results showed that the activities of the campus restaurant can impact the characteristics of the effluent.

Figure 2 - Linear regression of the behaviour of COD at 11:00 p.m. and number of meals served at dinner at the campus restaurant.



Source: Authors.

This negative correlation between served meals and total suspended solid/suspended volatile solids can be explained due to an increase in the use of water for food preparation and restaurant cleaning during meal hours.

Effluent Load

The measurement of the water consumption on campus showed a daily average water consumption of 12.28 m³. This consumption is lower than that found by Bertolino (2007) on another university campus in Brazil (290 m³/day). Even if we consider 4 times this value of daily average water consumption (since the campus studied by Bertolino is larger, with a campus population almost four-fold), we still have a lower water consumption.

Metcalf and Eddy (2003) show that the water consumption in a school with a cafeteria can be estimated at 60 litres per student per day. The campus of this study has almost 1,300 students, which is 60 l/student.day; therefore, a water consumption of 78m³/day would be expected, which is higher than the measured consumption. The result shows that the water consumption is lower than expected (considering literature values), and therefore the effluent flow will also be lower.

A correlation test between the campus population and the water consumption was made and the result showed a positive and strong correlation. Thus, the number of people present on campus directly impacts the water consumption and effluent generation – an expected result.

Considering that 80% of the consumed water turns into effluent, the generated volume of effluent is 9.82 m³/day. Based on this value, the per capita loadings were calculated, see Table 4.

According to von Sperling (2005), typical values of per capita sewage loading are: 180 g/inhab.day for total solids; 10 g/inhab.day for fixed suspended solids; 50 g/inhab.day for volatile suspensions; 100 g/inhab.day for COD; 4.5 g/inhab.day for ammoniacal nitrogen (ammonia); and 6 g/inhab.day for chlorides.

These results show that the values found for the UNIFAL-MG campus in Poços de Caldas fell far lower than the literature values for raw domestic sewage parameters. A Wastewater Treatment Plant designed for the campus following domestic sewage parameters would not be adequate for our reality, which could affect the treatment process. As shown in this study, the disparity between the results found in the Poços de Caldas campus at the UNIFAL-MG and literature can be related to a particular water consumption characteristic and effluent volume, which are much lower than those values used to determine the reference values for domestic sewage parameters.

4. Conclusion

In this study, we characterised the effluent generated at the Poços de Caldas campus at UNIFAL-MG and defined reference values of per capita loadings. The effluent parameters analysed were COD, total solids (fixed and volatile), suspended solid (fixed and volatile), dissolved solids, chloride, pH, ammoniacal nitrogen, conductivity and flow rate of the effluent based on water consumption.

Two different sampling campaigns were carried out: Campaign I with 3 samples of each weekday and 3 samples for the vacation period; and Campaign II, with samplings carried out every 2 hours, from 8:00 a.m. to 11:00 p.m, for each weekday.

Statistical analyses reveal that there are no statistical differences for the average values of effluent parameters among sampling times in Campaign II. However, COD and dissolved solids have statistical different average values between the groups comprising Monday/Tuesday/Thursday and Wednesday/Friday.

Besides some differences in effluent parameters throughout the days of the week, it can be concluded that the campus population does not directly influence the concentration of effluent parameters. However, it can be observed (as expected) that the variation of the campus population directly influences the water consumption of the institution, and thus the volume of generated effluent.

An important conclusion was that the number of meals served by the university restaurant is correlated with the pH and concentration of total suspended solids, volatile suspended solids and COD at various times. This shows that the restaurant's activities impacts the final characteristics of the campus effluent. In particular, the higher the number of served meals, the higher the pH and COD, but the lower the total suspended solids and suspended volatile solids.

Table 4 - Load and per capita load of each effluent parameter analysed for the studied site.

Average volume of effluent per day = 9.82 m³			**Average value of campus population in each class period = 434**		
Parameter	**Data size**	**Average (mg/l)**	**Standard Deviation**	**Load (kg/day)**	**Per capita load (g/inhab.day)**
COD	66	625.38	347.30	3.410	7.86
Total solids	49**	507.60	207.30	2.036	4.69
Total volatile solids	42**	311.90	161.10	1.582	3.65
Total fixed solids	40**	205.00	120.50	1.183	2.73
Suspended Solids	48**	134.50	106.86	1.049	2.42
Volatile suspended solids	46**	102.80	82.90	0.814	1.88
Fixed suspended solids	49**	24.60	43.86	0.431	0.99
Ammoniacal nitrogen	16*	9.30	4.99	0.049	0.11
Dissolved solids	17*	399.05	172.13	1.690	3.89
Chloride	17*	189.41	78.09	0.767	1.77
Parameter	**Data size**	**Average (uS/cm)**	**Standard Deviation**		
Conductivity	17*	787.89	307.58		
Parameter	**Data size**	**Mean**	**Standard Deviation**		
pH	66	7.07	0.59		

*Campaign I has a total of 17 samples – Ammoniacal nitrogen, Dissolved solids, Chloride and Conductivity were analysed only in Campaign I. **Campaign II has a total of 49 samples – Total solids, Total volatile solids, Total fixed solids, Suspended solids, Volatile suspended solids and Fixed suspended solids were analysed only in Campaign I. COD and pH were analysed in both campaigns. Due to several laboratory problems, some parameters could not be analysed for all samples.

The results of the per capita loading of the analysed parameters are much lower than those found in the literature on sanitary sewage, which may be related to the lower consumption of water by the institution and, consequently, to the low generation of sewage. The Poços de Caldas campus effluent does not even have similar characteristics to the effluent of campuses from other Brazilian universities. Thus, it can be observed that the use of reference values of domestic sewage for the university would lead to failures in the design of a Water and Sewage Treatment Plant.

Finally, it can be concluded that it is necessary to characterise the different sources of effluent, whether they are industries, educational institutions or urban regions with different habits, to obtain reference values that consider the particularities of each effluent generator. This study is the basing for a future work: the characterisation presented in this study would make Wastewater Treatment Plant designs more reliable and efficient. Also, based on this work, one can define most relevant parameters for a long term characterization – one purpose is to perform a one year sample schedule to improve sewage characterization also determining seasonalities. Finally, In the campus is also in course a sewage study for SARS-CoV-2 surveillance.

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