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Research Article

Physicochemical characterization of university campus' wastewater for internal treatment system installation (Casablanca, Morocco)

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ABSTRACT

Today, protecting water resources and their sustainable use has become an obligation of people and organizations. Wastewater management and reclamation are the most important solutions to protect these resources. This study aims to determine the wastewater physicochemical quality of the Faculty of Sciences Ben M'Sick (FSBM) (Casablanca, Morocco) to establish the appropriate system for their treatment and internal reclamation. The results show that averages of FSBM's wastewater temperature vary between 17.64 and 19.55 °C, 7.18 and 8.18 for pH, and 2.47 and 3.98 $mS.cm^{-1}$ for electrical conductivity. The COD, BOD_5, and TSS average values oscillate respectively between 967.44–1.151.08 $mg.L^{-1}$, 70.5–119.05 $mg.L^{-1}$, and 223.64–1.659.74 $mg.L^{-1}$, and those of total phosphorus between 2 and 3.99 $mg.L^{-1}$. The determination of the biodegradability degree of the discharge, through the calculation of COD/BOD_5, BOD_5/COD, TSS/BOD_5, COD/TP, COD/NH_4^+ ratios, and oxidizable matters (OM,) reveals that the FSBM's wastewater has a heterogeneous character with a high load of oxidizable matter difficult to biodegrade. Despite its low biodegradability, the FSBM's wastewater could be treated using a biological treatment system, preceded by a physicochemical treatment to eliminate non-biodegradable chemical substances. Such a choice of wastewater treatment system requires prior experimental investigations and laboratory tests.

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INTRODUCTION

Water is an essential natural resource, and the assurance of sufficient quantity and quality of this material for each of us has become one of the significant challenges of the 21st century. Water scarcity is a real threat to many nations, and they are being made worse by population increase, excessive water resource use, and the escalating consequences of climate change. In the Mediterranean region, water resources are highly vulnerable to climate change [1], notably impacting the integrity of aquatic ecosystems and the water availability for agricultural irrigation and domestic and industrial activities [2, 3].

Morocco, known for its semi-arid Mediterranean climate, is no exception to water stress in the Middle East and North Africa (MENA) region. Indeed, the country is facing a significant water shortage due to increased water demand and reduced rainfall induced by climate change. This reduction in water resources intensely conditions the country's socioeconomic development ambition. It limits the activities of different sectors of the national economy [4, 5], which could reduce Morocco's GDP by up to 6.7 billion US dollars per year [6]. Thus, investing in water efficiency practices and developing non-conventional resources can mitigate this water stress situation.

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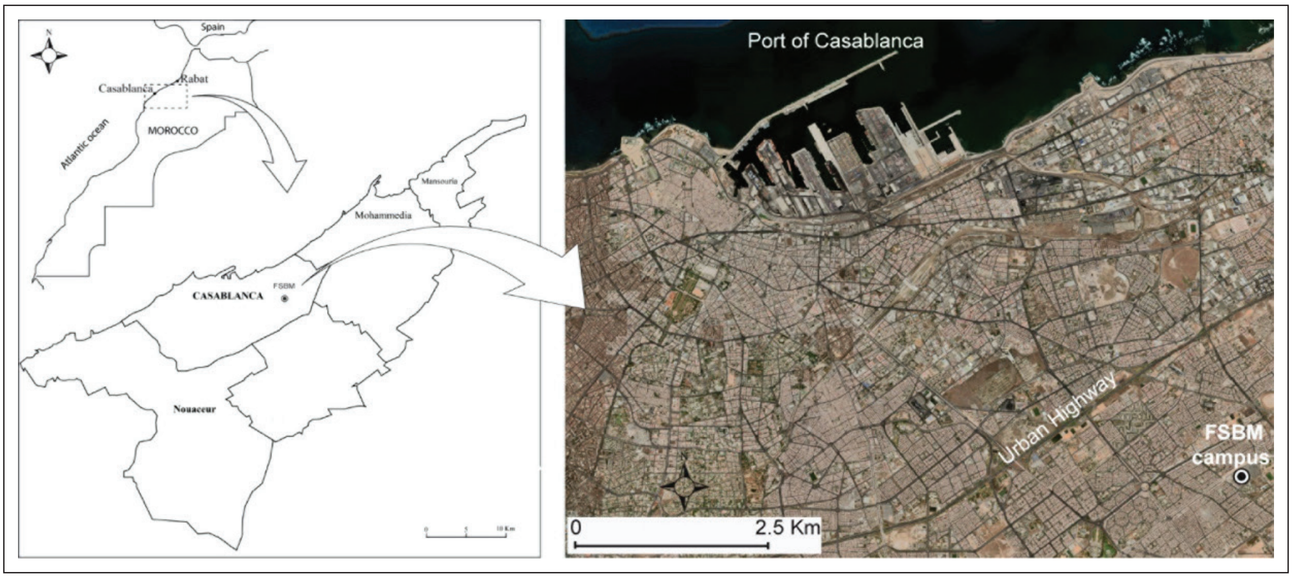

Figure 1. Geographical location of the study area (Faculty of Sciences Ben M'Sick campus).

For this purpose, Morocco adopted a National Water Strategy (NWS) in 2009 [7], which focuses on managing, preserving, and developing water resources, reducing vulnerability to water-related risks, and adaptation to climate change. In addition, the country has developed the National Strategy for Sustainable Development to 2030 (NSSD) to include all the country's development sectors and activities in sustainable exploitation and production, integrating social, economic, and environmental components [8].

This NSSD's application in the higher education sector has resulted in implementing the 2030 education and training strategy through framework law 17.51 [9]. This law stipulates that university campuses must accommodate and train students in socially, economically, and environmentally sustainable sites. Thus, university institutions must be environmentally and energetically resilient and rehabilitated to adapt to the requirements and imperatives of sustainable management of their resources (water, energy, etc.) and waste (liquid effluents, solid waste, etc.).

Thus, the treatment and reuse of wastewater (WW) is a requirement for the sustainable development of university campus activities. However, university campus teaching and research activities generate rather heterogeneous and complex wastewater [10]. Although limited in number, studies on the characterization of university campus effluents have shown that the WW produced by restrooms, dormitories, and restaurants is generally domestic and biodegradable [11–13]. However, the effluents produced by laboratories and practical rooms are heterogeneous and typically of an industrial nature and are biodegradable only to a limited extent [10–13]. This physicochemical profile makes this wastewater treatment quite difficult, to comply with the discharge standards into the city sewerage system or their reuse and recycling.

The main objective of this work is to contribute to the establishment of the Ben M'Sick Faculty of Sciences/ Hassan II University of Casablanca (Morocco) in a sustainable water management approach and to apply a "Zero discharge" approach by installing an internal treatment and reuse system for treated wastewater. Before that, the physicochemical characteristics of these WW were assessed, including temperature "T", pH, electrical conductivity "EC", turbidity "Tur", total phosphorus "TP", orthophosphate, chemical oxygen demand "COD", biological oxygen demand in five days "BOD_5", total suspended solids "TSS", ammonium ion, nitrate, and nitrite, as well as total and calcic hardness "TH/CH", chloride, and sulfate. More precisely, it is a question of determining the WW's load in nutrients and oxidizable matters and their biodegradability degree to propose adequate treatment.

MATERIALS AND METHODS

Study Site

The Faculty of Sciences Ben M'Sick is an institution of higher education attached to the University Hassan II of Casablanca (Central West Morocco). It is built on a four (4) hectares site northeast of this city (Fig. 1), on sandy-clay soil and a groundwater table at 60–70 m depth.

The area's climate is semi-arid with temperate winters, and the institution has, in 2022, about 9,700 students and 280 teachers, researchers, and administrative staff [14]. This institution's consumption of drinking water varied globally between 12,000 and 15,000 m^3 for 2019–2022. The average volume of wastewater produced by the various pedagogical and scientific activities (research laboratories and practical work rooms) in the various premises of the institution can be estimated within a range of 9,600 and 12,000 m^3 year-1, according to a return rate of 80% of consumption water (i.e., 12,000–15,000 m^3 $year^{-1}$). This wastewater is evacuated through a unified network directly into the urban sewerage system of the city of Casablanca.

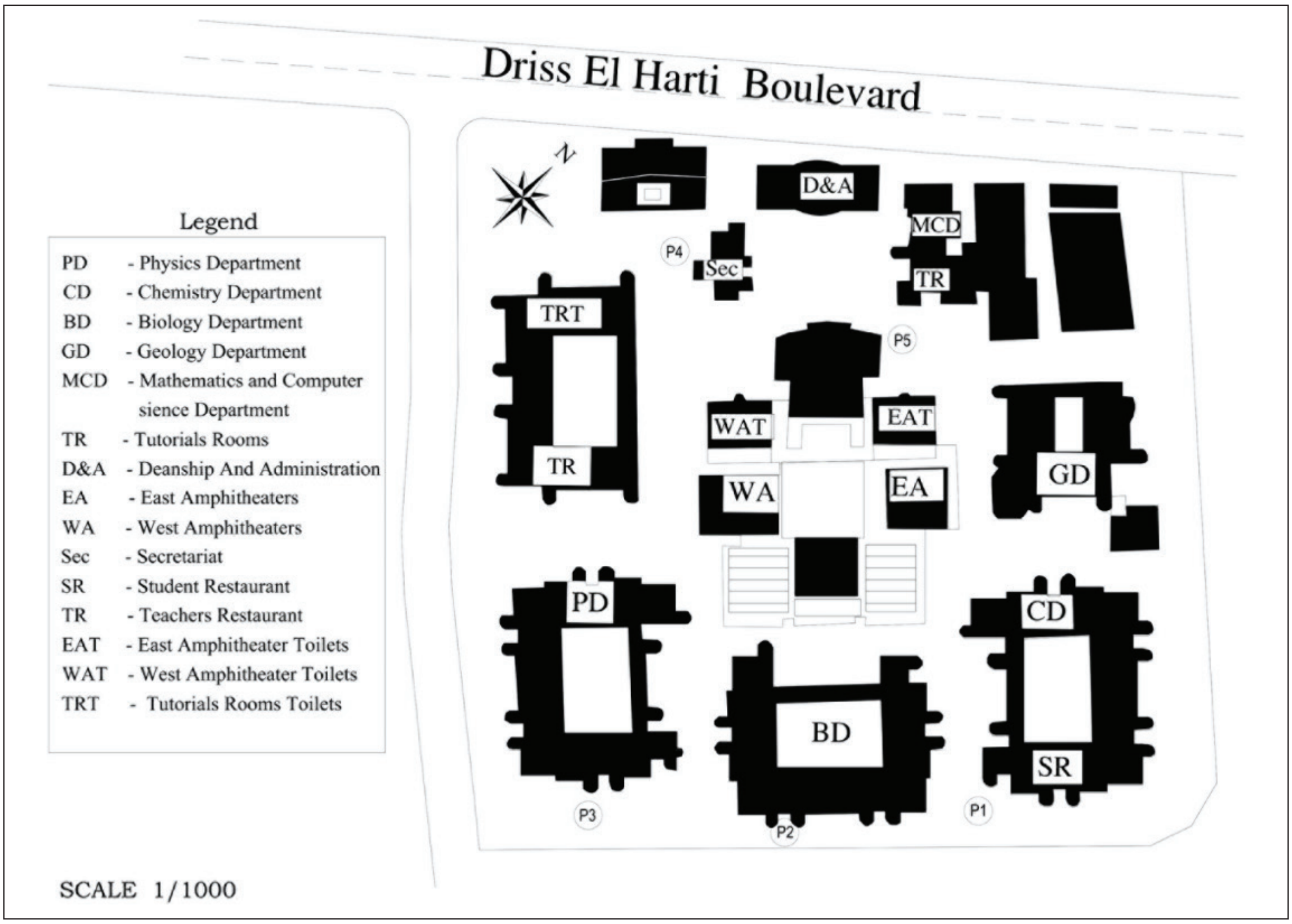

Figure 2. Location of wastewater sampling points (P1, P2, P3, P4, and P5).

Wastewater Sampling and Analysis Methods

The wastewater samples are taken weekly from November 2021 to June 2022 at five maintenance holes of the establishment's wastewater network. These sampling points, chosen according to their location and the wastewater's origin, include (Fig. 2): Point P1: Department of Chemistry and student restaurant; P2: Department of Biology; P3: Department of Physics; P4: toilets of the tutorial's rooms and "West" Amphitheaters; P5: toilets of "East" Amphitheaters and teacher's restaurant.

The wastewater, collected in rinsed 500 ml polyethylene bottles, is transported directly to the laboratory to be analyzed according to AFNOR's standardized methods [15]. In parallel, in situ temperature, pH, and electrical conductivity measurements are performed. Table 1 presents the characteristics of the equipment and the methods used for physicochemical analyses.

Based on the results of the WW analyses, pollution ratios and the oxidizable matter (OM) contents were calculated to better appreciate the nature of these effluents and guide the treatment process choice. These different ratios calculated are:

- BOD_5/COD ratio: indicates the pollution's origin of the WW and the possibilities of their treatment. It characterizes industrial pollution [16].
- COD/BOD_5 ratio: accounts for a fraction of readily biodegradable matter concerning all oxidizable matter. Biological treatment of WW can be considered if the ratio is low. Conversely, a high value of this ratio indicates that a large part of the organic matter is not biodegradable. In this case, it is preferable to consider a physicochemical treatment. This ratio can also indicate that the WW discharged is domestic if it is less than 3 [17].
- TSS/BOD_5 ratio: provides information on the degree of sedimentation of suspended solids to the organic load of the WW. The greater the ratio, the slower TSS sedimentation.
- COD/TP (C/P) ratio: provides information on the relative mix of the effluent and the potential and effectiveness of biological phosphorus treatment [18]. The lower the C/P ratio, the greater the phosphorus removal in biological treatment systems [19].
- COD/NH_4^+ ratio (C/N): indicates the relative mix of the effluent, which influences denitrification and the advantage of having a dissociated anoxic zone in the aeration tank [18]. According to Chiu et al. [20], the C/N ratio regulates the co-occurrence of nitrification and denitrification. The greater the C/N ratio (greater than three), the more nitrogen is removed [21].
- The amount of oxidizable matter (OM) in the WW was calculated according to the equation [15]:

$$OM = \frac{(COD + 2\ BOD5)}{3} \quad (1)$$

Table 1. References of the equipment and methods used for the physicochemical analyses

Parameter	Unit	Material and method	Reference
Temperature (T)	°C	Multi parameters type VW	–
Hydrogen potential (pH)		pH meter type WTW SenTix 51	–
Electrical conductivity (EC)	mS cm^{-1}	Multi parameters type VWR	–
Turbidity (Tur)	NTU	Turbidimeter type BANTE, TB100	–
Biochemical oxygen demand in 5 days (BOD_5)	mg L^{-1}	BOD-mètre type VELP SCIENTIFICA	–
Chemical oxygen demand (COD)	mg L^{-1}	Oxidation with potassium dichromate using a COD meter type VELP SCIENTIFICA, ECO 6 Thermoreactor	NF T 90-101
Total suspended solids (TSS)	mg L^{-1}	Filtration on a Wattman GFC filter	NF EN 872
Ammonium (NH_4^+)	mg L^{-1}	Indophenol blue spectrophotometric method NFT 90-015	NFT 90-015
Nitrite (NO_2^-)	mg L^{-1}	Sulfanilamide diazotization in acid medium	NFT 90-013
Nitrate (NO_3^-)	mg L^{-1}	Sodium salicylate method	NF T 90-012
Total phosphorus (TP)	mg L^{-1}	Oxidation with peroxodisulfate	NF EN 1189
Orthophosphate (PO_4^{2-})	mg L^{-1}	Reduction with ascorbic acid	NF EN 1189
Calcium Hardness (CH)	mmol L^{-1}	The method by complexometry (EDTA)	NF T90-016
Total Hardness (TH)	mmol L^{-1}	The method by complexometry (EDTA)	NFT 90-003
Chloride (Cl^-)	mg L^{-1}	Determination by silver nitrate	NF T 90-014
Sulphate (SO_4^{2-})	mg L^{-1}	Precipitation of sulfate ions in the presence of barium chloride	NFT 90-040

To determine the typology of the FSBM's effluents, a principal component analysis (PCA) was applied to the physicochemical results of a log-transformed matrix (log X+1) consisting of 92 samples and 11 parameters of wastewater physicochemical quality after a Varimax rotation. Furthermore, the Kruskal-Wallis test is used to conduct a statistical analysis of the spatial variability of the physicochemical characteristics of the effluents in the sampling points. The various calculations (e.g., Means, standard deviations, ratios, etc.) and statistical data analyses were performed using the Xlstat Software, version 2016.

RESULTS

Physicochemical Quality of Wastewater

Monitoring the physicochemical quality of the FSBM's effluents shows that the pH averages vary between 7.18 (P5) and 8.18 (P4). The WW's temperature averages are relatively homogeneous and vary between 17.64 and 19.94 °C, respectively noted at P5 and P1, while the extreme values fluctuate in a variable interval from 16.2 (P1) to 25 °C (P2). As for the degree of mineralization, the effluent physicochemical analysis reveals that the EC averages range within an interval of 2.47 (P5) and 3.97 ms cm^{-1} (P4). This WW's strong mineralization is enhanced by the relatively high sulfate contents, which fluctuate between averages of 51.89 and 94.85 mg L^{-1}, respectively noted at P3 and P1, and the chloride concentrations, which vary between averages of 766.57 (P5) and 894.51 mg L^{-1} (P3). Regarding the wastewater hardness, the TH contents oscillate between averages of 508.38 (P5) and 584.52 mmol L^{-1} (P2), while the CH averages range between 146.89 (P4) and 235.88 mmol L^{-1} (P2) (Fig. 3).

The FSBM's effluent has a relatively high particulate load, where the TSS contents range in an interval of 6.66 and 1,277.28 mg L^{-1}, noted at P1, with averages of 192.14 and 694.15 mg L^{-1}, and turbidity ranging from 156.24 (P5) to 224.74 NTU (P3). Regarding the oxidizable and organic load, the physicochemical results show that the COD averages range between 934 and 1,151.08 mg L^{-1} with extreme values of 56 and 2112 mg L^{-1} noted, respectively, at P1 and P5 sampling points. As for BOD_5, the values fluctuate between 0 and 534 mg L^{-1}, with an average range of 59.6 (P5) and 115.78 mg L^{-1} (P2) (Fig. 4).

The nutrient load of the FSBM's wastewater is characterized by total phosphorus contents varying between averages of 2 (P5) and 3.21 mg L^{-1} (P4), with extreme values of 0.08 (P1, P3, and P5) and 7.6 mg L^{-1} (P3). For orthophosphate, the average contents range between 0.74 (P5) and 2.23 mg L^{-1} (P1), whereas ammonium ion concentrations vary between 0.08 and 32.8 mg/L, with an average range of 3.50 (P5) and 16.19 mg/L (P3). At the same time, the nitrite and nitrate concentrations reveal variations within an average range of 0.17–0.71 mg L^{-1} (P1) and 0.51–1.20 mg L^{-1} (P2), respectively (Fig. 4).

Compared to the main wastewater references in Morocco (Table 2), the effluents generated by this university campus have a physicochemical quality globally comparable to that

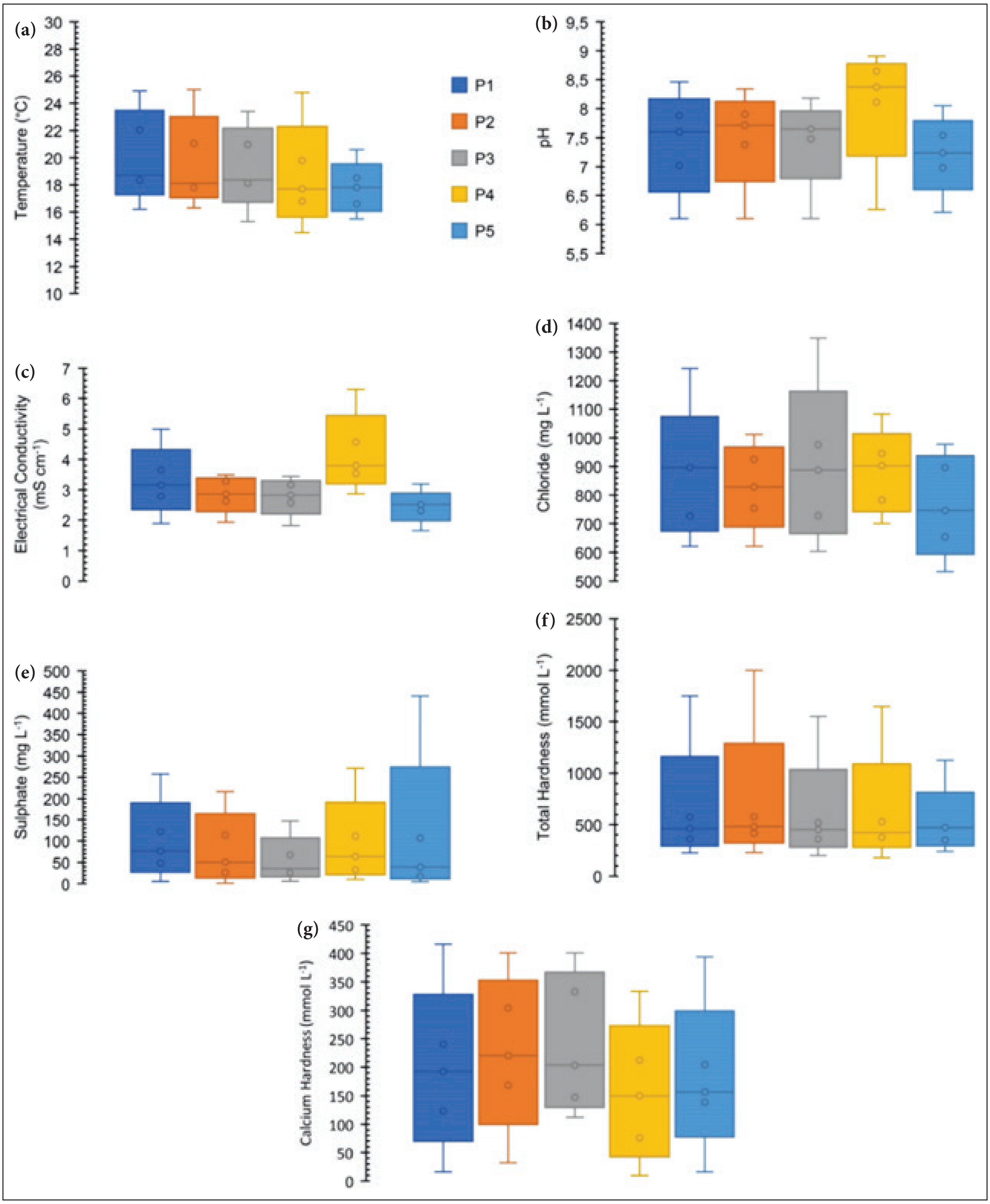

Figure 3. Variations **(a)** in temperature, **(b)** pH, **(c)** EC, **(d)** Cl^-, **(e)** SO_4^{2-}, **(f)** total hardness, and **(g)** calcium hardness at the sampling points. P1: Department of Chemistry and student's restaurant (n=19), P2: Department of Biology (n=19), P3: Department of Physics (n=18), P4: toilets of tutorial rooms and "West" Amphitheaters (n=21); P5: "East" Amphitheaters toilets and teachers' restaurant (n=13).

reported at the national level [22]. However, they remain non-compliant with the indirect discharge limits stipulated by Moroccan standards [23], particularly concerning pH, COD, and TSS.

Furthermore, the application of the Kruskal-Wallis test to the physicochemical data recorded at the different sampling points showed that only the parameters pH, EC, NH_4^+, and PO_4^{3-} present a statistically significant spatial variability (Table 3).

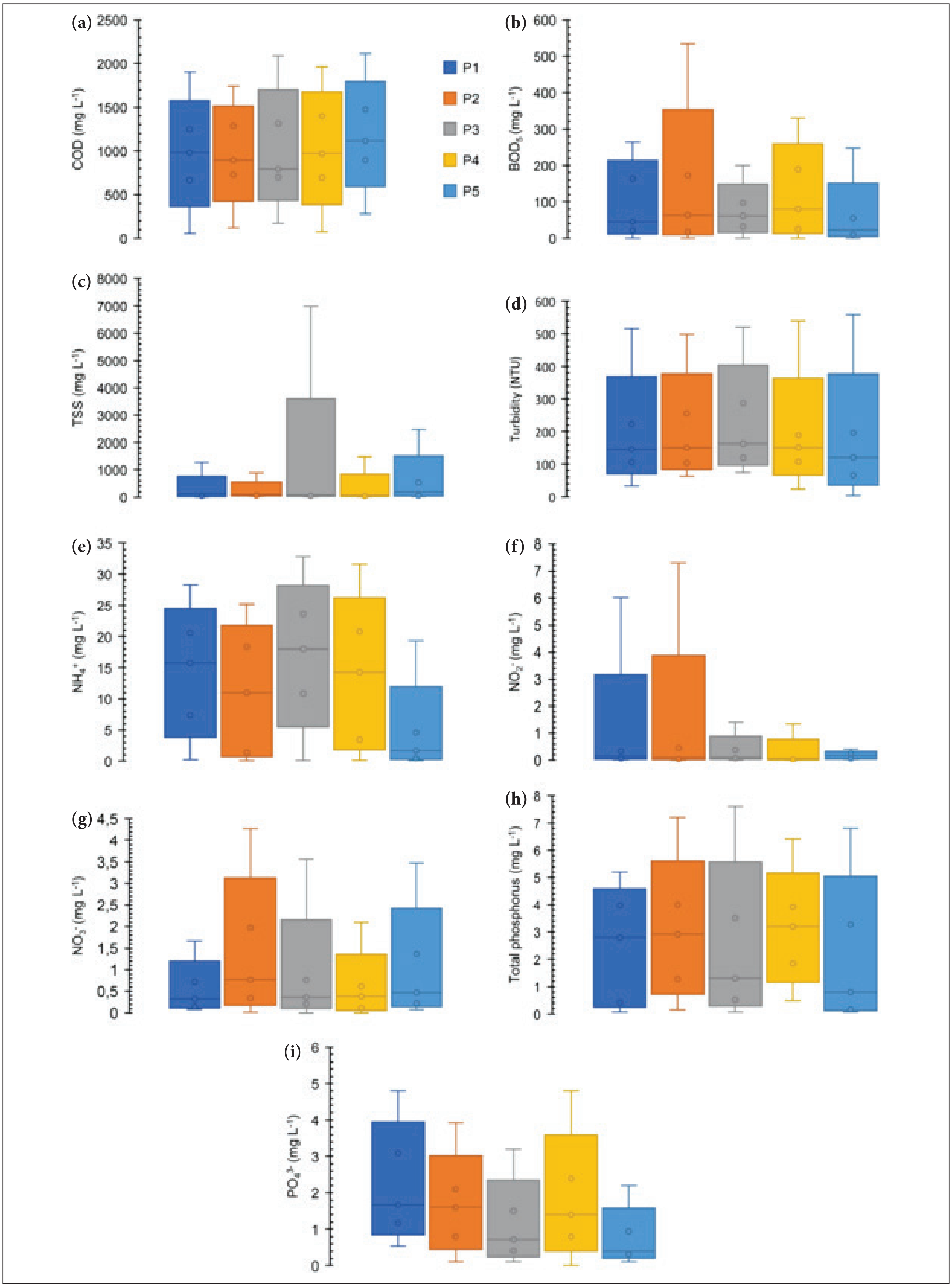

Figure 4. Variations in **(a)** COD, **(b)** BOD_5, **(c)** TSS, **(d)** turbidity, **(e)** NH_4^+, **(f)** NO_2^-, **(g)** NO_3^-, **(h)** total phosphorus, and **(i)** PO_4^{3-} at the sampling points P1: Department of Chemistry and student's restaurant (n =19), P2: Department of Biology (n=19), P3: Department of Physics (n=18), P4: toilets of tutorial rooms and "West" Amphitheater (n=21); P5: "East" amphitheater toilets and teachers' restaurant (n=13).

Table 2. Comparison of physicochemical parameters data obtained with reference values for wastewater in Morocco

Parameter	Unit	Range of variation	Usual range [22]	Indirect release limit values [23]
T	°C	17.64–19.55		35
pH	–	7.18–8.18		6.5–8.5
EC	mS cm^{-1}	2.47–3.98		
Tur	NTU	156.24–224.74		
BOD_5	mg L^{-1}	70.5–119.05	200–400	500
COD	mg L^{-1}	967.44–1,151.08	1,000	1,000
TSS	mg L^{-1}	223.64–1,659.74	250–500	600
NH_4^+	mg L^{-1}	3.50–17.55	20–80	
NO_{2-}	mg L^{-1}	0.17–3.65	<1	
NO_3^-	mg L^{-1}	0.69–1.48	<1	
TP	mg L^{-1}	2.002–3.99	8–16	10
PO_4^+	mg L^{-1}	0.74–2.75		
CH	mmol L^{-1}	171.48–239.91		
TH	mmol L^{-1}	631.76–790.94		
Cl^-	mg L^{-1}	766.57–1,232.25		
SO_4^{2-}	mg L^{-1}	51.89–94.85		400

Table 3. Variability of physicochemical parameters at different sampling points (Kruskal-Wallis test, significance level=0.05)

	T	pH	EC	TSS	Tur	BOD5	COD	NH_4^+
p-value	0.077	<**0.0001**	<**0.0001**	0.643	0.595	0.738	0.784	**0.004**
	NO_3^-	NO_2^-	TP	PO_4^{3-}	SO_4^{2-}	Cl^-	CH	TH
p-value	0.261	0.594	0.225	**0.008**	0.461	0.444	0.130	0.939

Table 4. Mean values and standard deviations (Mean±SD) of different organic pollution ratios of FSBM's wastewater

	P1	P2	P3	P4	P5
COD/BOD_5	11.57 (±12.02)	18.03 (±19.68)	16.51 (±14.8)	31.09 (±39.61)	88.74 (±99.65)
BOD_5/COD	0.23 (±0.24)	0.13 (±0.12)	0.08 (±0.06)	0.18 (±0.18)	0.07 (±0.08)
TSS/BOD_5	3.67 (±4.30)	3.78 (±4.25)	6.23 (±8.01)	6.81 (±8.06)	9.64 (±8.96)
C/P	1,695.09 (±2,240.87)	899.65 (±866.77)	2,769.59 (±3,539.46)	461.30 (±302.93)	3,652.47 (±2,963.22)
C/N	472.74 (±637.09)	958.70 (±1,325.15)	575.12 (±775.83)	741.69 (±100.16)	1,939.40 (±1,968.68)
OM	338.31 (±95.44)	346.25 (±193.58)	314 (±175.36)	406.12 (±151.03)	398.08 (±119.57)

Organic Pollution of Wastewater

According to the results of the FSBM's computation of the various organic pollution ratios (Table 4), the COD/BOD_5 ratio is high and largely exceeds 3, with average values fluctuating between 11.57 (±12.02) and 88.74 (±99.65) calculated, respectively, for P1 and P5 sampling points. Conversely, the BOD_5/COD ratio averages are very low and vary between 0.07 (±0.08) and 0.23 (±0.24) noted at P5 and P1, respectively. As for the TSS/BOD_5 ratio, the average values are between 3.67 (±4.30) calculated for P1 and 9.64 (±8.96) noted in P5. The C/P ratio remains relatively high, especially at P1, P3, and P5 sampling points, and varies between averages of 461.30 (±302.93) and 3,652.47 (±2,963.22), reported at P4 and P5, respectively. Regarding the C/N ratio, the average values vary between 472.74 (±637.09) and 1,939.4 (±1968.68) noted respectively at P1 and P5. The average oxidizable matter (OM) load of the wastewater ranges between 314.83 (±175.36) and 406.12 mg L^{-1} (±151.03).

Wastewater Typology

The multivariate analysis of the FSBM's wastewater physicochemical data by PCA, with Varimax rotation, shows that the first two axes (D1 and D2) explain 36.92% of the data's ordination (Fig. 5). On the same D1*D2 factorial plane, the sampling points are distributed into three groups: The first group consists of sampling points P2, P3, and P4, which are distinguished by relatively warm (i.e., T), highly mineralized (i.e., EC), and highly oxidizable (i.e., TSS, COD, BOD_5)

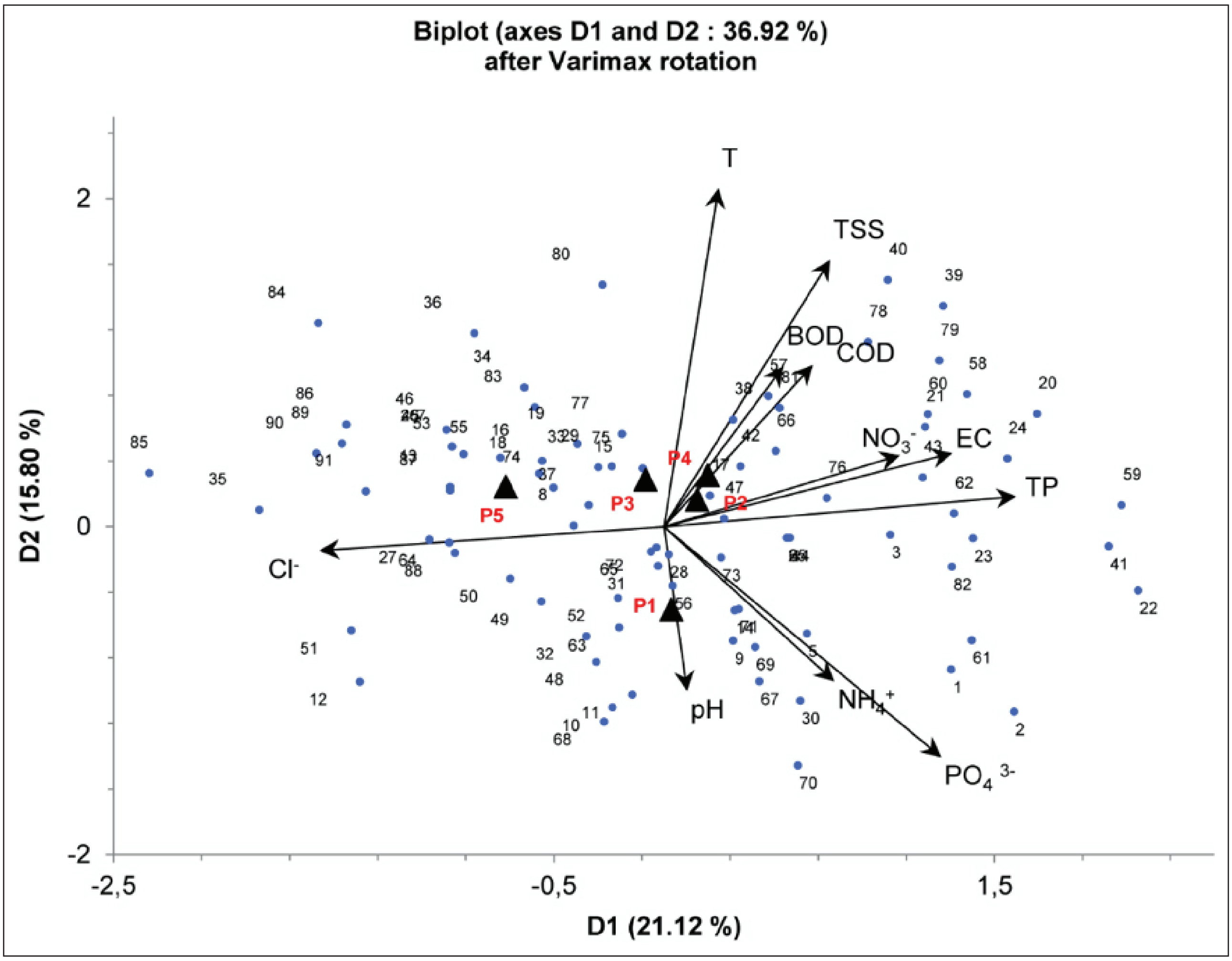

Figure 5. Representation of the ACP analysis after Varimax rotation based on physicochemical data from FSBM campus's wastewater (the dots and numbers represent to the 92 samples carried out at points P1, P2, P3, P4, and P5).

water. The second group is essentially formed by the wastewater samples from the point P5 characterized by high chloride content (i.e., Cl^-) and relatively low particulate (i.e., TSS), oxidizable (i.e., COD), and nutrient loads (i.e., TP, NH_4^+, NO_3^-). The third group is formed by the wastewater samples from the point P1, which are slightly alkaline and characterized by a relatively high load of nitrogen and phosphorus elements (i.e., NH_4^+, PO_4^{3-}).

DISCUSSION

Monitoring the physicochemical quality of the FSBM's effluents shows that their characteristics change globally according to their origin, which is linked to the activities in the various establishment's premises. Thus, several physicochemical parameters show a relatively significant variability (Table 4) at the same sampling point and during any study period. This variability may be associated with the release of high-complexity effluents due to the different use of water according to the practical teaching and research activities carried out within the campus's laboratories. However, rainwater contributes to the dilution of the wastewater collected by the unitary sanitation system and would thus explain the pollutant's load decrease during rainy periods [24]. Thus, the pH of the FSBM's effluent remains relatively neutral to alkaline for all sampling points. This alkaline trend of the WW would be related to their organic nitrogenous contents (i.e., NH_4^+: 3.50–16.19) with generally alkaline characteristics (i.e., P4) [24, 25] and to their low content of nitrite (0.17–0.71) and nitrate (0.56–1.20). This effluent's alkalinity would also be caused by the discharge of chemical solutions, especially alkaline ones, used in the different research and practical teaching activities in the laboratories (i.e., P1, P2, and P3). The effect of these chemical solutions on the laboratory effluents' pH was underlined by Novita et al. [26] (Table 5), who showed that the wastewater's high acidity of the Faculty of Agricultural Technology in Indonesia (i.e. pH=4.28) is related to the use of acidic solutions (i.e., H_2SO_4). These large fluctuations in effluent's acidity or alkalinity can impact the sewage system, equipment, and treatment processes, especially the biological treatment of WW [27]. Nonetheless, the pH values recorded for FSBM's effluent are still suitable for most WW treatment processes. The relatively high temperatures and mineralization (i.e., EC, SO_4^{2-}, and Cl^-) of the FSBM's effluents (i.e., P1, P2, and P3) would be associated with the liquid effluents' nature pro-

Table 5. Comparison of physicochemical characteristics of wastewater from some university campuses

University campus and reference of the study	Origin of wastewater	T (°C)	pH	EC (mS/cm)	TSS (mg/L)	BOD_5 (mg/L)	COD (mg/L)	NH_4^+ (mg/L)	TP (mg/L)	NO_3^- (mg/L)	NO_2^- (mg/L)	PO_4^+ (mg/L)
Las Palmas de Gran Canaria (Spain) [28]	Wastewater from the entire campus				158 201.3–264.8	314 230.7–328.5	416 315.1–365.6	139				
Al-Hussein bin Talal (Jordan) [13]	Wastewater from the entire campus											
Al Bayt (Jordan) [36]	Wastewater from the entire campus		6.87						18.80	7.7		
XYZ (Indonesia) [26]	Wastewater from the laboratories of the Faculty of Agricultural Technology and the Faculty of Pharmacy	26–27	4.28–7.02		542.5–13.6	84.18–58.28	251.6–148.2					
Greece [40]	Typical domestic wastewater (dormitories, student dining, laundry rooms, offices, etc.)	19.1	7.5	1.267		241.6	350.2		9.8			
Higher Polytechnic School of the Coast (ESPOL) (Ecuador) [58]	Typical domestic wastewater				236	350	594					
Pereira (Colombia) [42]	Wastewater from the entire campus					177.5–460.5	395.5–971.0		13.3–11.8	0.5–4.5		11.3–9.5
Occidente (Colombia) [29]	Wastewater from the entire campus	22.20–27.80	8.04–9.20		14–202	200–609	372–1512	45.00–108.50	12.70–113.00	15–46	0.80–3.80	
Guilin (China) [12]	Wastewater from student dormitories and public-use water	11–28	6.34–7.56			113.6–241.1	167.5–521.0		3.6–11.3			
Santa Cruz do (Brezil) [59]	Campus wastewater, except for teaching labs and restaurants.	19.27	6.75	1192.96		142.56	377.3		0.90			
Ouro Preto University (Brazil) [11]	Wastewater from the entire campus		7.35–8.23	0. 53–0.758		171–300	403–670		4.8–6.7			
Faculty of Sciences Ain Chock (Morocco) [38]	Wastewater from university toilets				415	285	541	45.45		0.01	0.73	3
Faculty of Sciences Ben M'Sick (Morocco) (the present study)	Wastewater from the entire campus	17.64–19.55	7.18–8.18	2.47–3.98	223.64-1,659.74	70.5–119.05	967.44–1,151.08	3.50–17.55	2.002–3.99	0.69–1.48	0.17–3.65	0.74–2.75

duced by the research and practical teaching laboratories, which are generally formed of warm water (i.e., Distillation apparatus cooling) and loaded with ionic salts. This high salt load is associated with using reagents and chemicals in laboratories, which are sometimes hazardous or toxic.

At point P4, the high ammonium load can be due to the urea content of wastewater from student toilets. Moreover, this ammoniacal nitrogen load is less important at point P5, which has relatively low pH values compared to those noted at point P4. Thus, it shows a significant relationship between wastewater pH and ammoniacal nitrogen load. In addition, this wastewater's alkalinity could influence the nitrogen removal process during treatment. The pH of the FSBM's effluents varies globally between 6.1 and 8.91, indicating that nitrogen removal during treatment is primarily accomplished through bacterial transformations (i.e., nitrification and denitrification) [28]. Indeed, some bacterial nitrogen transformations in the WW treatment systems depend on energy derived from organic carbon degradation. However, others release energy used by microorganisms for their growth and survival. Therefore, nitrogen removal in these treatment systems is directly influenced by the C/N ratio; the greater the ratio, the higher the nitrogen removal. Chiu et al. [20] showed that a low C/N ratio of the effluent leads to a rapid carbon deficit and simultaneous nitrification-denitrification process at a sequential biological treatment system, which disrupts the complete removal of NH_4^+ and COD. In this regard, the high average C/N ratio values (i.e., 472.74–1939.40) recorded at the FSBM's effluents suggest that biological treatment would be suitable for removing this nitrogenous element.

The load of calcium and magnesium in the FSBM's effluents, although relatively high, is similar to the results reported by Sarria et al. [29] for the Universidad Autonoma de Occidente (Colombia) campus's wastewater (Table 5). This high hardness of the FSBM's wastewater would favor biofilm development in the sewerage network and treatment systems [30, 31]. Indeed, in biological treatment systems, divalent cations (e.g., Ca^{2+} and Mg^{2+}) can enhance the cross-linking effect of soluble extracellular polymers (EPSs) matrix [32, 33] and even improve them. Thus, this hardness would be one of the factors influencing the formation, stability, and settling of purifying biomass during biological treatment of FSBM's effluents [34, 35].

The load of the phosphorus compounds (TP and PO_4^{3-}) in the FSBM's effluents, whose characterization is essential for the good progress of the WW treatment process (i.e., their role in the biomass growth), remains relatively lower than that noted in several studies on the effluents of university campuses including the work of Ziadat et al. [36] for the WW of the university campus Al Bayt in Jordan, and Beyene and Redaie [37] for the WW of the university of Hawassa's reference hospital (Ethiopia) (Table 5). However, Chakri et al. [38] revealed a comparable phosphorus element load (i.e., 3 mg L^{-1}) to this study's findings (Table 5) on effluent from the toilets of the Faculty of Science Ain Chock-Casablanca (Morocco). Phosphorus removal from WW is strongly related to the organic load, and the C/P ratio plays a central role in treating this nutrient, which is highly removed when this ratio is low. In the FSBM's effluents, the high values of the C/P ratio (i.e., 461.30–3652.47) indicate that a specific treatment is necessary for phosphorus removal. Indeed, several studies have shown that a high C/P ratio (e.g., C/P>50 mg) in the liquid effluent does not allow good development of the organisms accumulating phosphorus, responsible for its elimination, during treatment [39].

The particulate load of FSBM's effluent is generally high despite the low flow rate at the sampling points. These high TSS contents, comparable to those of Moroccan urban WW [22], are associated with the nature of the activities that generate these liquid effluents. Indeed, this TSS load is very high at points P1 and P5, which receive the WW from the students' (P1) and teachers' restaurant (P5), particularly loaded with organic particles, in addition to the research and practical work laboratories wastewater. Moreover, the leaching of organic and mineral solid particles during the rainy period (the maximum extreme values are recorded during the rainy period of November 2021 and January 2022) contributes to this TSS's enrichment. In addition, the high TSS levels are a risk factor for clogging and limited wastewater disinfection in several treatment systems [40]. Thus, treating the high TSS load of FSBM's Wastewater requires a combination of physical (e.g., decantation and filtration) [41] and biological processes to be implemented in the planned treatment system. A priori, providing a stilling tank for these effluents before any treatment is necessary for the early reduction of their particulate load and, at the same time, improve the efficiency of their treatment.

The high oxidizable matter (COD) and organic matter (BOD_5) loads recorded at the sampling points P1, P3, P4, and P5 for the first parameter and at P2 and P4 for the second would be associated with the FSBM's effluents richness in chemicals carried notably by laboratory effluents and organic matter from typical domestic activities (e.g., toilets, restaurants) [11]. These COD and BOD_5 values are comparable to those reported in similar studies [29–42] (Table 5). The high recorded values of oxidizable matters (OM) and COD/BOD_5 ratio indicate that the FSBM's effluents contain a significant fraction of poorly biodegradable matters that would be related to the chemical solutions and reagents discharged by the different FSBM's laboratories. In addition, the low BOD_5/COD ratio (i.e., $BOD_5/COD<0.5$) confirms this low biodegradability of FSBM's effluents and the presence of probably toxic chemicals that may slow down or delay the biological process of their treatment [43]. The high TSS/BOD_5 ratio values, compared with those of Moroccan urban WW (i.e., 1.2–1.5) [18], could be explained by the low sedimentation of solid matter in the FSBM's wastewater. These TSS/BOD_5 ratio values indicate that the effluent's particulate load is formed essentially by organic matter flakes that are difficult to settle, unlike sand, silt, and other solid matter particles.

Based on this study's findings, considering the regulatory compliance context related to the respect of discharge standards, and considering the impacts of water stress that Morocco has been undergoing in recent years, it is judicious to equip the FSBM's campus with a compact wastewater treatment system, with low economic cost and effective to produce reusable purified water. For this purpose, biological treatment processes, often used for the purification of a wide range of WW, may constitute an option because of their adaptation to the treatment of several types of effluents and their economic advantages in comparison to other treatment processes (e.g., thermal processes, chemical oxidation) [44]. Moreover, membrane bioreactors (MBR) are highly efficient in treating complex industrial effluents [45–48]. In addition to their compact size, shape and low energy consumption, MBR systems produce good quality treated water [49–51] that can be reused, especially in watering green spaces [52–57]. However, in the case of FSBM's effluents, variability in organic, nitrogen, and phosphorus load could negatively impact the performance of any proposed biological treatment system, especially during the rainy season and possibly during the summer vacation due to a lack of substrate for biomass feeding. Thus, homogenization and feed flow regulation are essential before the biological treatment phase.

CONCLUSION

The physicochemical characterization of the FSBM's effluents carried out to apply the "zero discharge" approach via their internal treatment and reuse revealed that they are globally alkaline, with homogeneous average temperatures and strong mineralization linked to high concentrations of sulfate, chloride, Ca^{2+} and Mg^{2+}. These WW also contain high levels of TSS and oxidizable (COD) and organic matters (BOD_5) exceeding the limit values recommended by Moroccan standards of indirect discharge, unlike nutrients (i.e., total phosphorus, orthophosphate, ammonium ion, nitrite, and nitrate).

The multivariate analysis performed by PCA on the effluents' physicochemical data revealed that their heterogeneous nature is linked to their origin. The effluents from the Biology (P2) and Physics (P3) departments, the tutorial room's toilets, and the "West" Amphitheatre (P4) are relatively warm, alkaline, highly mineralized and loaded with oxidizable matters. The WW coming from the "East" Amphitheatre's toilets and the teachers' restaurant (P5) is characterized by high chloride contents, relatively low particulate and oxidizable loads, and nutrients. At the same time, the wastewater generated by the department of Chemistry and by the student's restaurant (P1) is slightly alkaline and has a relatively high nitrogen and phosphorus load.

The pollution ratios (COD/BOD_5, BOD_5/COD, TSS/BOD_5, COD/TP, and COD/NH_4^+) show that the FSBM's effluent would be loaded with poorly biodegradable substances with a heterogeneous character. This character would be linked to chemical products from the research laboratories' effluents and the departments' practical work. Despite this profile and their organic loads, the FSBM's effluents could be treated using a biological purification system. However, this must be preceded by a physicochemical treatment to eliminate non-biodegradable chemical substances. Such a choice of WW treatment system requires prior experimental investigations and laboratory tests.

DATA AVAILABILITY STATEMENT

The author confirm that the data that supports the findings of this study are available within the article. Raw data that support the finding of this study are available from the corresponding author, upon reasonable request.

CONFLICT OF INTEREST

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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