

Smart water: An innovative approach to integrated water management at the Faculty of Sciences Ben M'sick (Casablanca, Morocco) in the face of water stress

Khaoula Grimah ^{1}, Abdelmottalib Nahli ¹, and Mohamed Chlaida. ¹*

¹Laboratory of Ecology and Environment, Hassan II University of Casablanca, Ben M'sik Faculty of Science, Casablanca, Morocco.

Abstract: The integrated management of water resources at the level of various human activities is today imperative for individuals and organizations. This study investigates the possibilities of applying a responsible and sustainable water management approach at the Ben M'sik Faculty of Sciences (FSBM) in Casablanca through rainwater collection/reclamation, groundwater exploitation and decentralized treatment/internal wastewater reuse. To this end, physicochemical characterization of these three types of water was carried out, with preliminary results showing that the wastewater quality complied with the discharge limits recommended by Lydec for all the parameters determined, except for Chemical Oxygen Demand (COD) and Total suspended solids (TSS), with average values for COD, BOD₅, and TSS of around 1010.12 mg L⁻¹, 87.27 mg L⁻¹ and 370.48 mg L⁻¹ respectively. In parallel, average values for COD/BOD₅ (33.19), TSS/BOD₅ (6.03) and oxidizable matter (360.72 mg L⁻¹) revealed that these wastewaters are heterogeneous and poorly biodegradable. As for rainwater and groundwater, the results show that they comply with the quality grid for water intended for irrigation, except for chloride (715.23 to 884.72 mg L⁻¹) and nitrate for groundwater (61.45).

1 Introduction

Water is one of our planet's most vital and precious natural resources, and its importance is crucial to the survival and well-being of all forms of life (human beings, animals and plants) [1] and all human activities. At a time of global warming, this satisfaction of water demand is confronted with water stress resulting from the drought affecting several countries worldwide. As a result, water shortages threaten many regions where the water demand exceeds the capacity of water resources to renew themselves [2].

* Corresponding author: khaoula.grimah-etu@etu.univh2c.ma

This situation is particularly marked in Mediterranean areas, where water resources are highly vulnerable, affecting the integrity of aquatic ecosystems and the availability of water for agricultural, domestic and industrial needs [3].

Morocco, a country in this region, faces increasing water stress due to rising water demand, falling rainfall and dwindling freshwater resources [4]. According to the Food and Agriculture Organization of the United Nations (FAO), the country is considered a low-water-resource country, with water availability of less than 1,000 m³ capita⁻¹ year⁻¹ [5]. This reduction in water resources intensely conditions the ambition of the country's socio-economic development, and adopting water efficiency practices and developing non-conventional water resources are proving essential to mitigate water stress.

In this context, Morocco launched the National Water Strategy (NWS) in 2009, which aims to manage, preserve and develop water resources, reduce vulnerability to water-related risks and adapt to climate change. Subsequently, the National Sustainable Development Strategy 2030 (NSDS) was drawn up in 2017 to integrate social, economic and environmental aspects into all the country's development sectors. Thus, in the higher education sector, and following framework law 17.51 [6], university campuses must be socially, economically and ecologically sustainable, and they must be rehabilitated for sustainable management of resources (water, energy, etc.) and waste (liquid effluents, solid waste, etc.).

Integrated water resource management is crucial to promoting the sustainable development of activities on university campuses. It is a strategic approach that aims to ensure sustainable and efficient water use, considering different needs and environmental constraints. With this in mind, wastewater treatment and reclamation, as well as rainwater collection and reclamation, play an essential role in optimizing the management of water resources.

Several studies and projects have already demonstrated the potential benefits of this approach in different parts of the world. For example, Lyu et al. [7] evaluated the effectiveness of wastewater treatment in reusing water for agricultural irrigation in China. The results showed that this practice helped improve agricultural productivity while preserving freshwater resources. In addition, projects such as Singapore's rainwater harvesting and reclamation program have demonstrated the feasibility and benefits of this approach to meeting the water needs of a densely populated city facing water shortages [8].

This study investigates the possibilities of applying a sustainable water management approach to the Faculty of Science Ben M'sik (FSBM) university campus in Casablanca through rainwater collection and reclamation, groundwater exploitation, and decentralized wastewater treatment for internal reuse. To this purpose, physicochemical characterization of these three types of water is required.

2 Materials and methods

2.1 Study site

The Faculty of Science Ben M'sick is a higher education establishment attached to Hassan II University in Casablanca (Central western Morocco). It occupies a four (4) hectare site northeast of the city (Figure 1) on sandy-clay soil with an underground water table 60-70 m deep.

The area's climate is semi-arid with temperate winters [9] and, in 2022, the institution had around 9696 students and 280 teachers, researchers and administrative staff [10]. In 2021, the institution's drinking water consumption reached almost 15462 m³. The volume of wastewater produced by the various teaching and scientific activities (practical work rooms and research laboratories) and domestic activities (refreshment rooms and toilets) can be

estimated at $12,369\text{ m}^3\text{ year}^{-1}$, based on a return rate of 80% of consumption water (i.e. $15462\text{ m}^3\text{ year}^{-1}$, not including watering of green spaces). This wastewater is evacuated via a combined sewer system, directly into the Casablanca city sewer system. In addition, the faculty has an operational well (20 m deep) which is sometimes used for drip irrigation of shrubs adjacent to the enclosure wall.

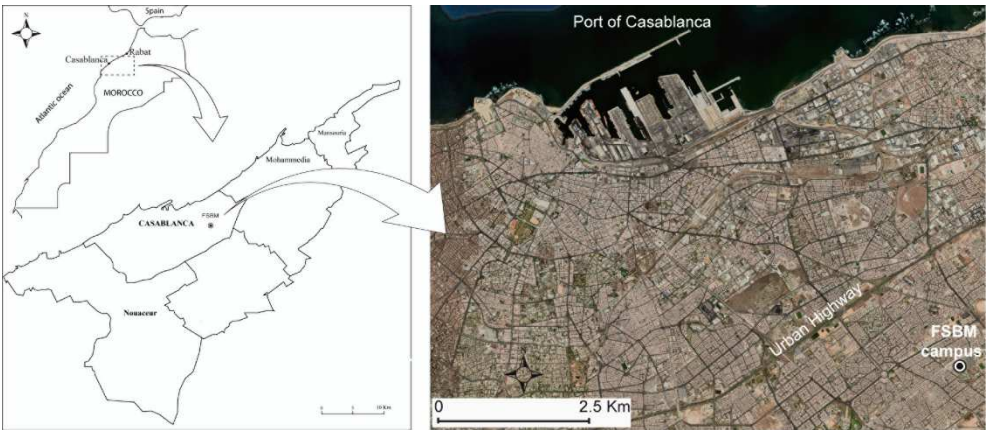


Fig. 1. Geographical location of the study area (The Faculty of Sciences Ben M'Sick campus)

2.2. Wastewater sampling and analysis methods

Wastewater samples are taken every week from November 2021 to June 2022 at 5 manholes in the faculty’s wastewater network. These sampling points are chosen according to their location and the origin of the wastewater (Figure 2). Rainwater was collected from the roofs of the faculty's departments on rainy days, and groundwater was pumped and drawn fortnightly from a functional well on the site.

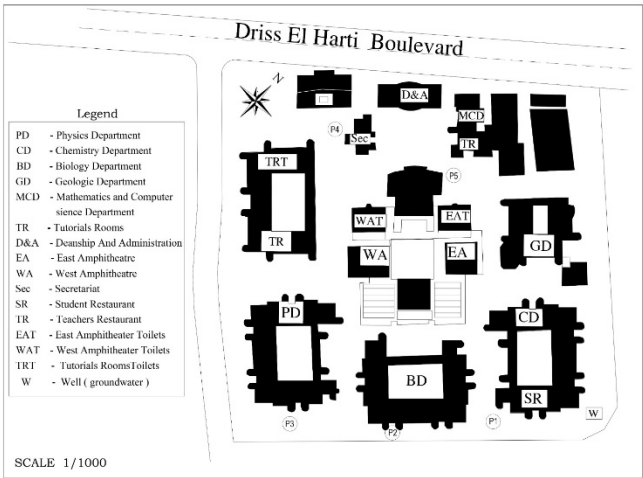


Fig. 2. Location of wastewater (P1, P2, P3, P4 and P5) and groundwater (well) sampling points.

The three types of water were sampled in rinsed 500 ml polyethylene bottles and then transported directly to the laboratory for analysis using AFNOR standardized methods [11]

(Total Suspended Solids, Chloride, Nitrate, Bicarbonate, COD, BOD₅, Total Phosphorus, and Sulphate). In parallel, in situ temperature (T), pH, and electrical conductivity (EC) measurements were carried out in each sampling point.

3 Results and discussion

3.1 Wastewater physicochemical quality

The results for the various physicochemical parameters are expressed as the range of variation of the mean values calculated for each sampling point. The monitoring of FSBM's wastewater physicochemical quality (Table 1) shows that the average pH varies between 7.18 and 8.18 and remains relatively neutral to basic. This profile can be attributed to the release of chemical solutions, particularly basic one, used in various research and practical teaching activities at the facility. Novita et al [12] studied the impact of these chemical solutions from study and research laboratories on the pH of effluents from the Faculty of Agricultural Technology in Indonesia. They reported that the high acidity of effluents (pH=4.28) is directly linked to the use of acidic solutions such as sulfuric acid (H₂SO₄).

For wastewater temperatures, mean values are globally uniform, ranging from 17.64 to 19.94°C, while the degree of mineralization remains relatively high, with electrical conductivity (EC) varying between 2.47 and 3.98 mS cm⁻¹. This high level of effluent mineralization is strengthened by sulfate contents, fluctuating between averages of 51.89 and 94.85 mg L⁻¹, and total phosphorus between 2 and 3.99 mg L⁻¹. In fact, this high mineralization would be linked to the presence of laboratory wastewater containing a high load of ionic salts from the reagents and chemicals used in the various experiments.

The FSBM's wastewater also have a relatively high particulate load, with TSS contents varying between 223.64 and 1659.74 mg L⁻¹ which are thought to be linked to the solid organic and mineral particles leaching. Concerning the wastewater's oxidizable and organic load, COD averages remain between 967.44 and 1151.08 mg L⁻¹, while BOD₅ averages fluctuate within 70.5 to 119.05 mg L⁻¹. These oxidizable and organic matter contents would be associated to the high chemical content in FSBM's wastewater, carried by laboratory effluent and organic matter from internal domestic activities (e.g., toilets, refreshment areas) [13]. Compared with the indirect discharge values set by Moroccan standards in 2005 [14], FSBM's effluent quality is generally compliant, except COD, and TSS (Table 1).

According to the obtained data following analysis of the organic pollution indicators (Table 2), the DCO/DBO₅ ratio is significantly high (average range: 11.57 - 88.74), clearly exceeding the value of 3. As for the TSS/DBO₅ ratio, the mean values range from 3.67 to 9.64. In addition, the average oxidizable load (OM) of FSBM's wastewater varies between 314.83 and 406.12 mg L⁻¹ (Table 2).

The high COD/BOD₅ ratio and oxidizable load suggest that the FSBM's effluent contains a significant fraction of poorly biodegradable materials. These substances could be associated with chemicals and reagents discharged by the various FSBM's laboratories. The high TSS/BOD₅ ratio could be attributed to limited sedimentation of solid particles present in FSBM's wastewater. This low TSS/DBO₅ ratio suggests that the wastewater particulate load is mainly composed of organic matter flakes, which are difficult to settle (Table 2).

Table 1 : Average values and variation range of the wastewater physicochemical parameters at the FSBM Faculty.

Parameter	Unit	Variation range (Min.-Max.)	Average (±SD)	Limit values for indirect discharges [14]
Electrical conductivity (EC)	mS cm ⁻¹	2.7-3.98	3. 08 (±0.42)	-
Temperature (T)	°C	17.64-19.55	18.90 (±0.69)	35
pH	-	7.18-8.18	7. 57 (±0.24)	6.5-8.5
Total suspended solids (TSS)	mg L ⁻¹	223.64-1659.74	370 (±195.19)	600
Chemical oxygen demand (COD)	mg L ⁻¹	967.44-1151.08	1010 (±60.23)	1000
Biochemical oxygen demand (BOD ₅)	mg L ⁻¹	70.5-119.05	87. 27 (±18.23)	500
Total phosphorus (TP)	mg L ⁻¹	2-3.99	2. 62 (±0.35)	10
Sulphate	mg L ⁻¹	51.89-94.85	77. 21 (±12.03)	400

Table 2 : Average values and range variation of the pollution ratios.

Ratio	Range (Min.-Max.)	Average (±SD)
COD/BOD5	11. 57-88.74	33. 19 (±22.22)
TSS/BOD5	3. 67-9.64	6. 03 (±1.83)
OM (mg L ⁻¹)	314. 83-406.12	360. 72 (±33.106)

3.2 Rainwater and groundwater physicochemical quality

Physicochemical characterization of the rainwater collected at the FSBM site (Table 3) revealed EC variation range of 0.06 and 0.71 mS cm⁻¹, with an average of 0.3±0.16 mS cm⁻¹, and temperatures range of 14.4 and 17.5°C, with an average of 15.71±0.95°C. In parallel, the rainwater pH remains slightly basic, and ranges between 7.09 and 8.14 with an average of 7.39±0.19. TSS concentrations range from 2 to 94 mg L⁻¹, with an average of 28.21 mg L⁻¹, while chloride concentrations vary from 71 to 2307.5 mg L⁻¹, averaging 736.24±532.73 mg L⁻¹. Nitrate contents range from 0 to 3.18 mg L⁻¹, with an average of 1.02±0.88 mg L⁻¹, while bicarbonate contents range from 0.16 to 2 mg L⁻¹, with an average of 0.76±0.34 mg L⁻¹.

Overall, these results remain comparable to those reported by Hebabaze et al. [15] for roof water from the same study site. They indicate that the chemical constituents measured in the sampled runoff water mainly relate to the dissolution of particles accumulated on the roof surface and derived from the building materials used for their covering [16]. Compared with the quality grid for water intended for irrigation [17], collected rainwater is generally compliant, except for chloride.

Concerning groundwater, temperatures range from 15.7 to 25°C with an average of 19.73, while pH is between 6.9 and 8.31 with an average of 7.27 (Table 3). EC values range from 2.53 to 2.98 mS cm⁻¹, with an average value of 2.85 mS cm⁻¹. This relatively high conductivity is due to dissolved mineral contents, notably chloride (32.66 to 2130 mg L⁻¹) and bicarbonate (2.46 to 5.92 mg L⁻¹). Nitrate (0.5 - 203.35 mg L⁻¹) also contributes to the high mineralization of groundwater, although these essential plant nutrients are naturally present in the environment [18].

TSS concentrations range from 2 to 172 mg L⁻¹, averaging 36.71 mg L⁻¹. This particulate load would be linked to interactions between dissolved minerals, notably calcium, chloride, carbonate, bicarbonate, magnesium, silica and sodium [19]. Compared with water quality standards for irrigation, pumped groundwater is generally acceptable, except for chloride and nitrate.

Table 3 : Physicochemical quality profile of reclaimed rainwater and groundwater pumped from the FSBM site.

Parameter	Rainwater		Groundwater		Irrigation water quality table [17]
	Range (Min.-Max.)	Average (±SD)	Range (Min.-Max.)	Average (±SD)	
Electrical conductivity (mS cm ⁻¹)	0.07-0.71	0.30 (±0.16)	2. 53-2.98	2.85 (±0.07)	12
Temperature (°C)	14. 4-17.5	15.71 (±0.95)	15.7-25	19.73 (±2.15)	35
pH	7. 09-8.14	7.39 (±0.19)	6.9-8.31	7.27 (±0.18)	6. 5-8.4
Total suspended solids (mg L ⁻¹)	2-94	28.21 (±25.04)	2-172	36.71 (±37.26)	2000: Gravity irrigation 100: Sprinkler and localized irrigation
Chloride (mg L ⁻¹)	71-2307.5	736.24 (±532.73)	32.66-2130	884.72 (±463.48)	350: Surface irrigation 105: Sprinkler irrigation
Nitrate (mg L ⁻¹)	0-3.18	1.02 (±0.88)	0. 5-203.35	61.45 (±49.65)	30
Bicharbonate (mg L ⁻¹)	0.16-2	0.76 (±0.34)	2.46-5.92	4.69 (±1.06)	518

4 Conclusion

This physicochemical characterization of water (wastewater, rainwater and groundwater) on the FSBM campus was carried out to adopt an innovative approach to integrated water management. We found that wastewater is generally alkaline, with uniform temperatures and high mineralization due to high concentrations of minerals such as sulphate, which present relatively high concentrations, as well as high contents of partical (i.e., TSS) and oxidable matter (i.e., COD, OM), which sometimes exceed the limit values recommended by Moroccan standards for indirect discharges.

In the case of rainwater collected from roofs, the physicochemical quality profile reveals a generally neutral pH and low mineralization. At the same time, well water (groundwater) is characterized by high electrical conductivity, a slightly basic pH and variable mineral concentrations (Chloride, bicarbonate and nitrate).

Overall, the physicochemical quality of the collected rainwater and groundwater complies with the quality criteria for irrigation water in Morocco, except for groundwater’s chloride and nitrate.

Based on this physicochemical characterization, it is possible to propose an effective wastewater treatment approach for this university establishment that could combine upstream physicochemical pre-treatment to eliminate non-biodegradable chemical substances, followed by a biological purification process.

As regards rainwater and groundwater, various methods can be envisaged to reduce nitrate and chloride concentration by biological treatment (using denitrifying bacteria in biological processes), adsorption, evaporation/distillation, electrodialysis or ion exchange columns.

However, choosing any suitable purification system requires prior investigation, laboratory tests and in-depth experimental studies.

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