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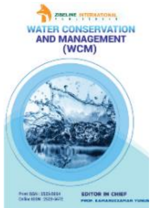

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RESEARCH ARTICLE

EVALUATION AND STATISTICAL ANALYSIS OF SURFACE WATER QUALITY IN OUED ASSAKA IN THE PROVINCE OF GUELMIME, MOROCCO

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ABSTRACT

One of the main environmental problems in Morocco is the water issue, due to the health and economic consequences of water pollution and inadequate sanitation, as well as the pressure on resources caused by increasing water demand. Water pollution is a scourge that threatens Morocco and other African countries. Morocco has one of the smallest natural water reserves in the world. In this respect, the Guelmim province region has seen an increase in critical points in terms of problems linked to the water system, which is defined by a fertile depression that threatens to flood, as well as problems linked to the scarcity of water resources and erosion. There are even environmental threats. In this study, we analyzed the water quality of the Oued d'Assaka basin in the Guelmim province. The results obtained showed that the alkalinity level of the water was stable, as the hydrogen potential was stable between 6.5 and 8.5. The electrical conductivity of the Assaka basin showed an increase in values exceeding standards by 2140 $\mu s.cm^{-1}$ on point 4 and 4830 $\mu s.cm^{-1}$ on point 2 of the sampling. Statistical analyses based on Pearson correlation were carried out for some of the physicochemical parameters analyzed in this study, notably pH, temperature, turbidity, and water hardness.

KEYWORDS

Assaka; Pollution; water quality; Pearson correlation; statistical analysis (SPSS).

1. INTRODUCTION

The main reasons for wastewater treatment before its possible reuse are Morocco's drought, the demands of economic development, the generalization of access to drinking water for all citizens, and the protection of receiving environments. It is crucial for socio-economic development at local, regional, and national levels (Bhateria and Jain, 2016; Noureddine et al 2024; El Mahmouhi et al., 2016). Consequently, water resource management remains a major challenge, particularly in countries with arid or semi-arid climates, where these resources are crucial to the development of human, economic, and social activities (Taleb et al., 2021). Water is a natural resource vital to the survival of any ecosystem. For a society faced with growing water needs, preserving its quality remains an absolute priority (Afi et al., 2022). It is crucial to socio-economic development at local, regional, and national levels (El-Moustaqim et al., 2024; El-Moustaqim et al., 2023; Lesley et al., 2023). Consequently, water resource management remains a major challenge, particularly in countries with arid or semi-arid climates, where these resources are crucial to the development of human, economic, and social activities (mondiale de la Santé, 2019). One of the main environmental problems in Morocco is the water issue, due to the health and economic consequences of water pollution and inadequate sanitation, as well as the pressure exerted on resources by increasing water demand (Mabrouki et al., 2019; Mabrouki et al., 2022; Mabrouki et al., 2022, Mabrouki et al., 2023, Mabrouki et al., 2022). Water resources remain a major challenge to be preserved and used efficiently, particularly in countries with arid or semi-arid climates (Hem, 1959; Kijjanapanich, 2013). These reserves have a significant impact on human, economic, and social activities. Natural and human constraints, as well as water management and conservation, can affect the quality of natural surface water. In the province of Guelmim, numerous springs are frequently found in wadi beds (Kouassi et al., 2013). They are used in construction, play a role in the development of the agricultural sector, and are a major tourist attraction and place of relaxation (Oumara and El Youssfi, 2022). The water table exploited in the Guelmim Plain is the most important aquifer recognized in the southern Anti-Atlas. The rapid expansion of the region's population centers and the growing development of agricultural activity have led to overexploitation of the aquifer, resulting in a significant drop in water levels (Taleb, 2021; Lesley et al, 2023). In recent years, periods of drought have become increasingly common, resulting in an extremely large deficit that affects almost the entire country (Kouassi et al., 2013; Oumara and El Youssfi, 2022; Mahmouhi, 2016). The watershed appears to be a static unit of the landscape, but it is a dynamic and changing area hydrologically. Thus, the watershed is generally delimited on the surface by ridgelines, whose slopes divide the water between the different catchment areas (El Attaoui et al., 2023; Vecchio and Kuper, 2022; ATTOU, 2014). With the world's

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population growth and economic development, water consumption has almost doubled over the last fifty years. A great deal of work has already been done on the issue of water in Africa, and in particular on drinking water in large African cities located in arid or semi-arid environments (Lenntech, 2024; Boulal, 2017). In the Assaka area, domestic wastewater is discharged directly into public spaces. Rainwater from the internal basins of the town of Guelmim is considerable and poses a flooding risk for houses along the Assif Ouzro and Targa Oufella rivers (Agence du Bassin Hydraulique de Draa Oued Noun, 2024; El Blidi, 2006; Agoumi and Debbarh, 2005). In the absence of a sewage treatment plant or controlled landfill to stabilize it, the product of the cleaning of cesspools is discharged directly into the natural environment (Bergier, 2009; du Maroc, n.d.). This is a problem of road communication between the two banks and, consequently, of the equipment department. Existing constructions on the bed of the chaâbats and hermetic obstacles erected in the path of the runoff increase the risk of flooding (Bergier, 2009 ; Gharbi, 1986).

This work aims to provide a clear picture of the state of water quality in Oued Assaka de Guelmim, and to determine some of the origins of water pollution, within the limits of the analyses carried out at the various water quality monitoring network points, based on Moroccan water quality standards and the hydrogeological study of the region.

2. Materials And Methods

2.1 Presentation of the study area

The province of Guelmim, which was created by decree no. 2.79.123 of 01-01-1979, is located in the southeast of the Kingdom and is part of the Guelmim Oued Noun region. Assaka or the center of Targa-Wassay lies to the east-west of the town of Guelmime, some twenty kilometers away, and is served by the RP1300 provincial road (Chouafa Nesrine, 2022; Mohammed and Anas, 2021). Housing and cultivated land are concentrated on the left bank of Oued Assaka. Average annual rainfall is around 120 mm, but there is considerable random variability between 15 mm and 300 mm. At its mouth, the Oued Assaka basin, which drains the Guelmim basin, covers an area of 6,840 km² (du Maroc, n.d.; Humbert, 2013). The Oued Assaka, which crosses the coastal relief via a gorge, collects the residual floodwaters from these basins and from a complementary basin of 410 km², after spreading out over the plain (Mohammed and Anas, 2021; Mekki et al., 2021).

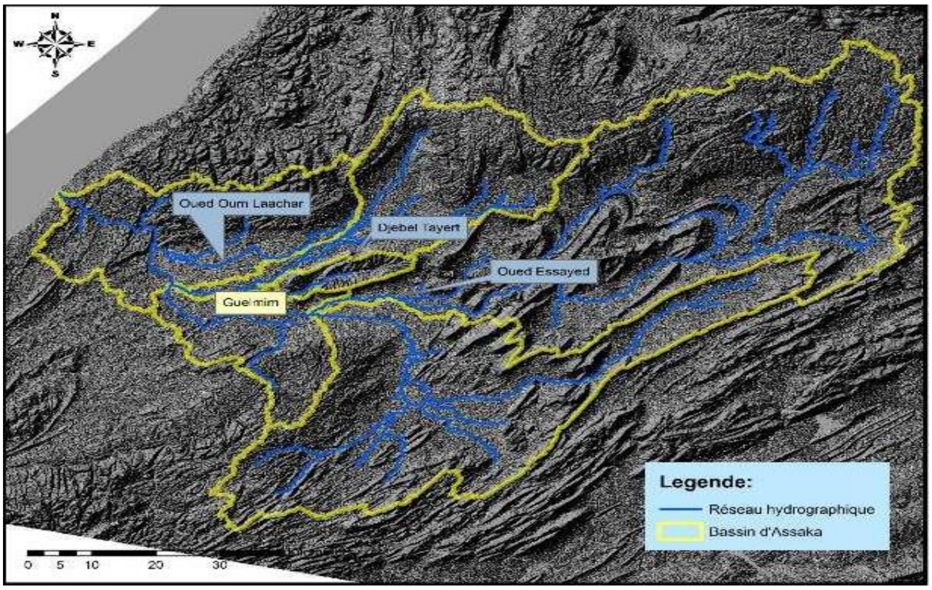

Figure 1: Presentation of the study area.

The Guelmim basin (Figure 1) is structured as a syncline, centered on the Jbel Tayert, crowned by the quartzite bars of the terminal Acadian. The fill on either side of these reliefs consists of plio-quaternary blanket deposits overlying the bedrock Acadian shales. In these areas, domestic wastewater is discharged directly into public spaces (Gharbi, 2024; Albab et al., 2013). Rainwater from the city's internal basins is considerable and poses a flooding risk for houses along the Assif Ouzro and Targa Oufella rivers. In the absence of a sewage treatment plant or controlled landfill to stabilize it, the sewage from cesspools is discharged directly into the natural environment. Wastewater from the municipal abattoir and slaughterhouse residues are also affected (Moussa et al., 2012; El Arabi, 2021).

2.2 Climate conditions

The study area is characterized by an arid climate (Figure 2), with very frequent winds causing sand accumulation (Brouyère et al., 2022; Ouhamdouch et al., 2018). The study area is characterized by a pre-Saharan climate where temperatures benefit from oceanic influence in the Guelmim basin to very arid Saharan conditions with harsh winters (between -7°C and -1°C) and hot summers (44°C) in the Drâa basin (Bekkar et al., 2023). Despite its latitude, the Atlantic Ocean more or less mitigates the effect of the Saharan continental climate. Average annual rainfall is around 120 mm but with considerable random irregularity, ranging from 15 mm to 300 mm (Bouaicha and Benabdelfadel, 2010; SIREDD Guelmim-Oued Noun, 2024).

Figure 2: Presentation of the Assaka wadi in Guelmim province.

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2.3 Sampling method and Physical-chemical analysis

The water samples used for analysis in this study were taken during the period February 2021 to January 2022, of which four points were logically selected to sample the waters of the Oued d'Assaka basin in the Guelmim province and to carry out the physicochemical and other quality assessment analyses. Water flow velocities at survey points at the time of sampling the water body itself, current velocity is approximated by following a dropped object along a 10 m path.

To assess the basin's quality parameters and to identify the most polluting tributary or Oued in the feeder network, thus calling on the relevant departments to take action to reduce the level of pollution. The sampling campaign took into account the lithological diversity of the basin, as well as the distribution of activities at four points over twelve months, with sampling carried out successively over the months from February 30, 2021, to January 17, 2022.

Physical-chemical parameters include pH, electrical conductivity EC, and temperature T°C, measured (in situ) in the field, and turbidity analyzed in the laboratory. These parameters were determined according to the analysis methods recommended by AFNOR standards. Results were evaluated and visualized using Excel 2016 software.

2.4 Statistical analysis

Principal component analysis was performed on the mean annual values of the physico-chemical parameters characterizing the four sampling points. This analysis highlighted the correlations between the various water parameters. Statistical analysis of the data was carried out using Microsoft Excel 2016 (Microsoft Corp) and SPSS Statistics (SPSS Inc.). Mean values and standard deviations were determined. Pearson correlation coefficients were calculated.

3. Result And Discussion

3.1 Physical and chemical characterization

Detailed results of physico-chemical analyses of Guelmim province waters used in the Oued d'Assaka watershed are shown in Figure 3.

3.1.1 pH

The pH is also influenced by acid precipitation, biological activity, and certain industrial discharges. The quality criterion values for raw water supply are between 6.5 and 8.5, and between 6.5 and 9.0, to protect aquatic life. The pH values of the Assaka watershed show visible stability (Figure 3 (a)). The stable neutrality of the waters in the basin could be the result of an equilibrium between the high levels of carbon dioxide and dissolved calcium bicarbonates, stabilized by the buffering effect resulting from the high mineralization of the waters (Savean, 2014; Ouyang, 2005).

3.1.2 Temperature

Temperature variation in the Assaka basin of Guelmim province (Figure 3 (b**)**) displays distinct seasonal characteristics, reflecting regional climatic fluctuations. Data collected over several months reveal trends that highlight thermal differences between seasons. During the summer months, temperatures tend to reach higher levels, with peaks generally observed between months 9 and 12, due to increased sunshine and warmer weather conditions. In contrast, spring months show lower temperatures, with minimum values recorded between March and May, attributable to reduced sunshine and cooler climatic influences.

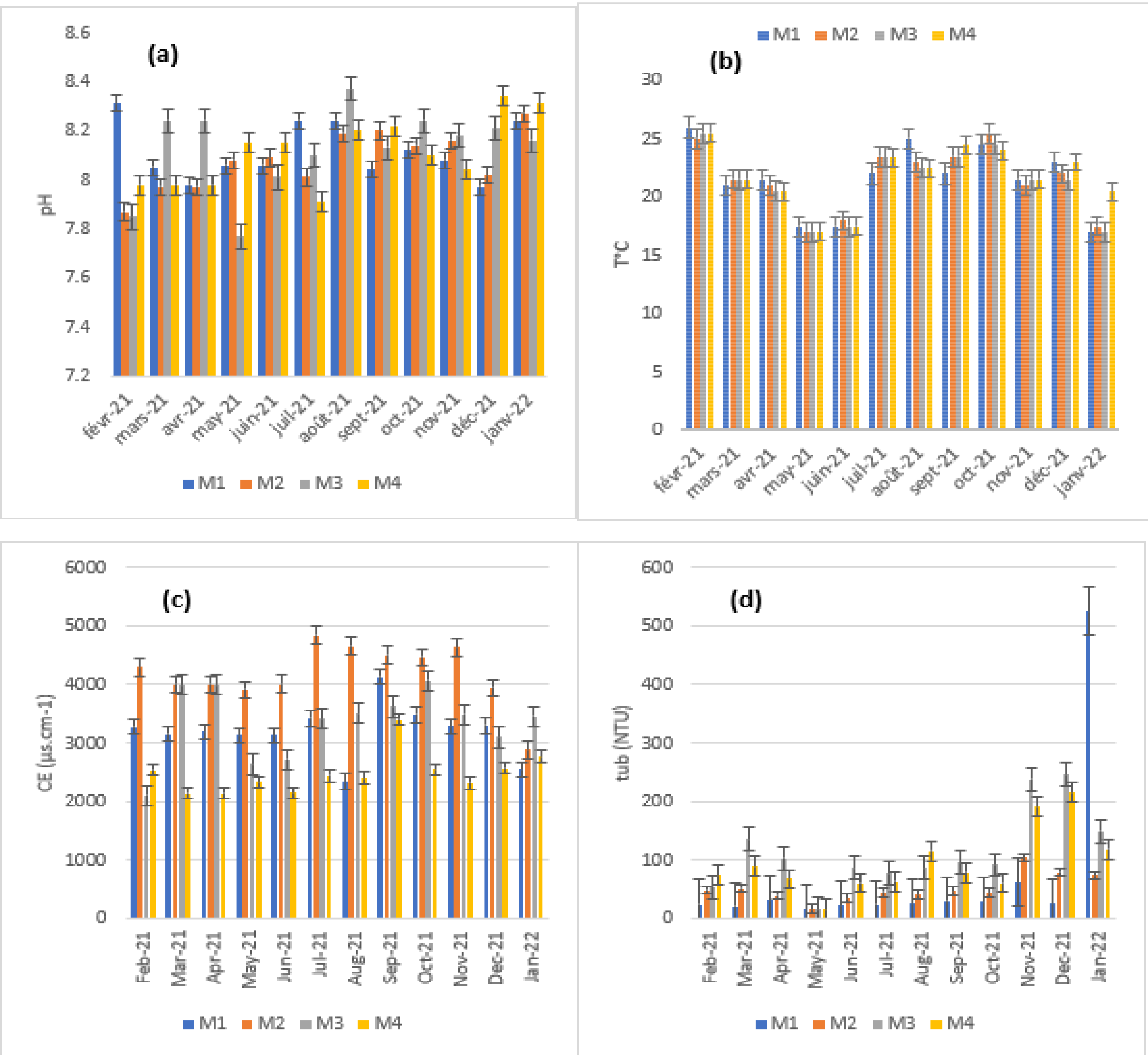

Figure 3: (a): Changes in pH at four points in the Assaka basin during the sampling period. (b): Variation in temperature during the sampling period. (c): Electrical conductivity differences at four locations. (d): Turbidity evolution.

3.1.3 Electrical Conductivity

The electrical conductivity of water expresses its overall mineralization and reflects its ionic charge. It is proportional to the concentration of ionizable salts, which in turn depends in part on water temperature. It is an index of the abundance of ions in water (Yehya, 2015). The Assaka basin waters analyzed show generally high conductivity values (Figure 3 (c)), well above the Guide Value set by European standards (100 µs.cm^{-1}). They generally range from 2140 µs.cm^{-1} at sampling point 4 to 4830 µs.cm^{-1} at sampling point 2. The high mineralization of the water at this point may be due either to the existence of a local saline geological formation or to the particularly marked impact of discharges (Quarouch et al., 2014).

3.1.4 Turbidity

Turbidity refers to the content of turbid matter in a liquid. In watercourses, it is generally caused by colloidal particles that absorb, scatter, and/or reflect light. It is measured by various methods of photometry of turbid media, such as nephelometry, opacimeter, and turbidimetry. It is expressed in NTU (Nephelometric Turbidity Unit) (Chouafa Nesrine, 2022). Calibration is performed using solid controls. Turbidity data collected from four different sampling points reveal a significant variation in water clarity in the Assaka basin at Guelmim (Ouzanni et al., 2023). Turbidity values range from 16.80 NTU to 150 NTU (Figure 3 (d)), indicating a range from slightly turbid to very turbid water.

3.2 Statistical physicochemical study of the water in study point in doued Assaka

Water samples from the Assaka basin showed alkaline pH values ranging from 8 to 8.1, with an average of 8.075. Seasonal mean pH values ranged from 8 in spring to 8.1 in summer, and remained constant for the rest of the seasons (Table 1), indicating that there was no discernible change in pH concentration.

Table 1: Physico-chemical characteristics of Assaka basin water by season.

Season	T water °C	PH	EC µs/cm	BOD5 mg/l	COD mg/l	SS mg/l	Ca 2+ meq/l	Mg2+ mg/l	Cl- mg/l	SO42- mg/l	NO32- mg/l
Spring	19,8	8	3219,2	65,4	153,1	114,5	234,6	91,4	245,8	457,1	130,7
Summer	21,3	8,1	3250	87,1	262,4	139	259,9	92,3	241,1	413	94,4
Autumn	21,3	8,1	3659,2	114,5	234,9	102,8	238,5	102,7	263,6	522,8	97,7
Winter	22	8,1	3065	85	264,8	172	262,8	66,5	189,4	444,3	130,4

The values observed were, however, within the WHO safe limits for consumption. A similar trend was also observed for conductivity. Conductivity values ranged from 3219.2 µs/cm to 3065 µs/cm, with an overall mean value of 3298.35 µs/cm. Table 2 shows the seasonal mean values for conductivity. The highest conductivity at the Assaka basin sampling points may be due to the degree of dissolved ions, pollutants, organic matter, and water temperature (Mekki et al., 2021).

Table 2: Concentration statistics for physical-chemical parameters in the Assaka basin.

Physical and chemical parameter	Average	Standard deviation
Temperature °C	21,100	0,9274
pH	8,075	0,0500
Electrical Conductivity µs/cm	3298,350	253,8158
BOD5 mg/l	88,000	20,1893
COD mg/l	228,800	52,2579
SS mg/l	132,075	30,5934
Ca^{2+} meq/l	248,950	14,4551
Mg^{2+} mg/l	88,225	15,3643
Cl^- mg/l	234,975	31,8913
SO_4^{2-} mg/l	459,300	46,2089
NO_3^- mg/l	113,300	19,9645

Table 3: Pearson correlation of physicochemical characteristics of Assaka basin water.

	Temperature water °C	pH	Electrical conductivity µs/cm	BOD5 mg/l	COD mg/l	SS mg/l	Ca^{2+} meq/l	Mg^{2+} mg/l	Cl^- mg/l	SO_4^{2+} mg/l	NO_3^- mg/l
Temperature water °C	1										
pH	0,934	1									
Electrical conductivity µs/cm	-0,063	0,208	1								
BOD5 mg/l	0,566	0,746	0,787	1							
COD mg/l	0,954*	0,966*	-0,046	0,548	1						
SS mg/l	0,638	0,383	-0,808	-0,272	0,588	1					
Ca^{2+} meq/l	0,776	0,662	-0,581	-0,005	0,834	0,895	1				
Mg^{2+} mg/l	-0,467	-0,138	0,841	0,401	-0,331	-0,935	-0,680	1			
Cl^- mg/l	-0,543	-0,226	0,816	0,334	-0,416	-0,958*	-0,737	0,996**	1		
SO_4^{2+} mg/l	-0,056	0,032	0,819	0,650	-0,213	-0,646	-0,672	0,493	0,496	1	
NO_3^- mg/l	-0,254	-0,581	-0,663	-0,695	-0,457	0,384	-0,066	-0,673	-0,604	-0,148	1

*. Correlation is significant at the 0.05 level (two-tailed).

**. Correlation is significant at the 0.01 level (two-tailed).

Pearson's analysis was used to establish the matrix shown in **Table 3**. According to the data in the correlation table, there is a strong correlation between pH and COD, with a positive and significant value (r = 0.966*). This is due to several factors, notably biological activity such as the decomposition of matter, which can lead to a decrease in pH due to the production of organic acids, resulting in a strong significant correlation between pH and COD. As well as chemical substances present in the water that can influence both pH and COD. Certain compounds present in water can react with others to form acids or bases, influencing pH and COD. This analysis reveals a strong correlation between temperature and COD, with a value of (r = 0.954), a positive and significant correlation. Similarly for chloride and magnesium ions, with a value of (r = 0.996), the explanation for this strong correlation can be traced back to the contents of the basin, in particular the minerals rich in chloride and magnesium. As the water flows through these materials, the ions are dissolved, increasing the concentration in the water. Water sources in the Assaka basin, such as aquifers and rivers, can be influenced by the same geological processes that favour materials. Anthropogenic activities such as agricultural irrigation, industry and the use of de-icing salts can increase ion concentrations, leading to a strong correlation (Hem, 1959; Chen et al., 2022; Lin et al., 2019; Elassassi et al., 2022).

4. Conclusion

Organic pollutants and heavy metals are the main pollutants. High loads and complex effluents render the water's assimilative capacity ineffective in most cases. It is therefore essential to find effective and accessible treatments. In this study, we analyzed the water quality of the Oued d'Assaka basin in Guelmim province. Statistical analyses based on Pearson correlation were carried out for some of the physicochemical parameters analyzed in this study, notably pH, temperature, electrical conductivity, COD, suspended solids, chloride, magnesium, sulfate and nitrate ions, turbidity, water hardness, and others. The results obtained for these analyses in the Assaka catchment studied showed a stable or alkalinity level of the water, as the Hydrogen potential and takes its stability between the interval of 6.5 and 8.5 by mean values oscillating between (7.77 and 8.34) indicating a satisfactory balance of notable acidity. The temperature at the study site varies seasonally according to regional chemical changes. Physico-chemical parameters showed a strong correlation between temperature and COD with a value of (r = 0.954), while chloride and magnesium ions showed a value of (r = 0.996) according to statistical analysis of the data using Pearson's correlation.

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