Assessment of groundwater quality in the region of Hjar Nhal for safe drinking water purposes

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Abstract. This study assesses the groundwater quality in the vicinity of the newly established landfill site in the city of Tangier. A total of 8 wells and 2 water sources within a 2-kilometer radius of the landfill were sampled for analysis. The selection of sampling sites was carefully executed, taking into consideration the flow direction and elevation in the study area to ensure representative results. The study focused on the analysis of 11 physicochemical parameters to evaluate the suitability of the groundwater for drinking and irrigation purposes. Notably, the pH measurements at various points (S1, S2, P4, P7, P8) consistently fell within the WHO's recommended range of 6.5-8.5 for safe drinking water. Conductivity values (µS/cm) were well below the limit of 1000 µS/cm at each location, indicating low levels of dissolved ions. Additionally, the TDS levels (ppm) did not exceed the WHO limit of 500 ppm, further confirming water quality that meets international standards. These findings provide valuable insights into the groundwater quality for safe drinking water and irrigation purposes in the area. The results contribute to informed decision-making and sustainable water resource management practices, ensuring the preservation of local water resources in the context of the landfill's environmental impact.
Keywords: groundwater quality, landfill, wells, contamination, drinking water, environmental impact

1 Introduction

Morocco is often classified as one of the most water scarce nations globally. According to statistics, with an annual water resource total of 22 billion cubic meters (Bm^3), the allocation per individual is around 700 cubic meters (m^3) per year [1]. This allocation is widely acknowledged as the critical threshold, signaling the onset of water scarcity and an impending water crisis. Approximately 20% of the nation's water resource potential in Morocco is attributed to groundwater, which is distributed across 130 aquifers. These aquifers consist of 32 deep and 98 surface aquifers. Based on existing information, the groundwater resources potential is estimated at only 3.9 billion cubic meters (m^3) to a minimum of 22 million cubic meters (m^3). [1].

Evaluating the quality of groundwater from wells, which serves both drinking and irrigation needs, should be a routine practice. However, given the recent establishment of a regulated landfill in the study area, there is an expected significant risk of soil, groundwater, and surface water pollution due to potential leachate leakage [2]. Monitoring the quality of groundwater in nearby wells has now become imperative and a responsibility toward local residents. This not only safeguards the integrity of the resource but also ensures the well-being of the community [3].

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2 Methodology

2.1 Study area and sampling process

2.1.1 Overview

The study area is situated within the Hjar Nhal commune, which falls under the jurisdiction of the Tangier-Asilah prefecture. It is located approximately 30 kilometers to the south of the city of Tangier. The area is bordered by five neighboring communes. To the west and northwest, it is adjacent to the Gzenaya commune, to the northeast lies the Aouama commune, to the east is the Sebt Azzinate commune, and to the south and southeast, it shares borders with the Al Manzla commune. In the south, it is bordered by the Aqouass Briech commune. The new regulated landfill is situated in the central part of the commune, with the Charf El Akab aquifer located just 9 kilometers to the west of its border (Figure 1).

2.1.2 Sampling sites

The commune of Hjar Nhal, particularly the village of Seguedla, has faced a prolonged water scarcity issue. It was only in 2007 that they gained access to drinking water supplied by Amendis, a subsidiary of Veolia, through the installation of several standpipes within the village. Our primary objective was to evaluate the quality of local wells, as many of them are designated for consumption, although concerns exist regarding their water quality. We collected samples from 10 continuously operational wells, with 3 samples taken from each well. The selection of these wells was based on their availability, proximity, and elevation concerning the nearby landfill site.

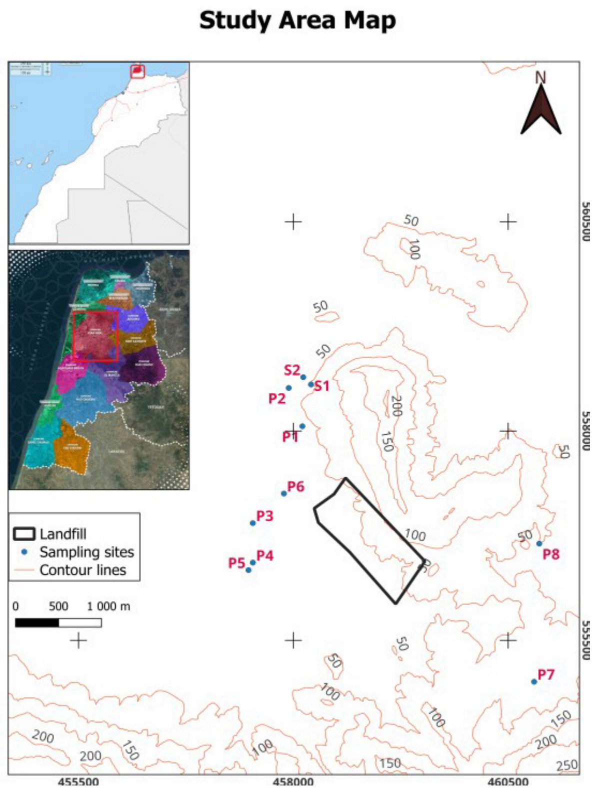

Fig. 1. Study area map

2.1.3 Field sampling:

Groundwater samples were systematically collected from wells located in the vicinity of Seguedla village, within a 2-kilometer radius from the landfill site. This collection took place after the conclusion of the hot season in September 2023. For each sampling site, samples were obtained in 1L plastic bottles that had been properly cleaned and prepared.

Three samples were collected from each of the open wells and water sources. To maintain the integrity of the samples, they were immediately placed in a cooler with ice, ensuring a temperature of 4°C, and subsequently transported to the laboratory.

After arrival to the laboratory, all collected samples underwent comprehensive analysis for essential physico-chemical parameters. These analyses were performed in accordance with internationally recognized protocols and standard methods [4].

Specifically, parameters such as temperature, pH, electrical conductivity (EC), total dissolved solids (TDS), and Dissolved Oxygen (DO) in the groundwater samples were determined using a Multi-parameter detector instrument right at the sampling site (Table 1).

Table 1. Water Quality Parameters and Measurement Methods

	Measurement method	Reference
T, pH, EC, TDS, DO	HANNA HI-98194 MULTIPARA-METER	NF EN 50082-1
TSM	Glass Filter Filtration	Rodier, 1984
BOD	OxiTop Method	NF EN 1899-1998

2.2 Qgis: Groundwater pollutant distribution

The spatial interpolation of pollutants was conducted within a GIS environment, specifically using QGIS 3.30.2. This advanced method offers precise monitoring and evaluation of groundwater quality in the study area. For each pollutant, a distribution map was generated using the Inverse Distance Weighting (IDW) method. This approach was employed to visualize how each pollutant is distributed across the various wells studied.

3 Results and discussion

The results for physico-chemical parameters shown in (Figure 2) will be assessed against the standards set by both Moroccan regulations and international guidelines from the World Health Organization (WHO). This comparison aims to determine whether the observed values fall within the acceptable range for each parameter. The acceptable limits for drinking water, as defined by both Moroccan standards and WHO guidelines, are presented for reference (Table 2).

Table 2. Water quality parameter standards: Moroccan vs. WHO Guidelines

Parameters	**Moroccan Standards**	**WHO**
T	30	NM
pH	6.5-9.2	6.5-8.5
EC	1300	1000
TSM	1000	NM
TDS	NM	600
DO	5	NM
BOD	7	NM

Analyzing the pH levels of the 10 water samples, all of them were found to fall within the acceptable limits set by both Moroccan regulations and WHO standards. The pH values range between 6.56 and 8.43. These results indicate that the groundwater in these samples is generally neutral to slightly alkaline, which is safe for human consumption. This is consistent with previous studies conducted in Varanasi (India), Dar Bouazza and Mohammedia-Benslimane (Morocco) by Mishra et al. [3], Laaouan et al. [5] and Merbouh et al. [6] respectively.These studies also found that the groundwater quality in those regions met the required standards. The fact that the nearby wells do not show signs of increased acidity further suggests that there is no significant leachate leakage. This is important because landfills less than five years old typically produce highly acidic leachate [7]. If there were leachate leakage, we would expect to see more acidic results in the nearby wells. No such hypothesis can be supposed at least for the pH parameter.

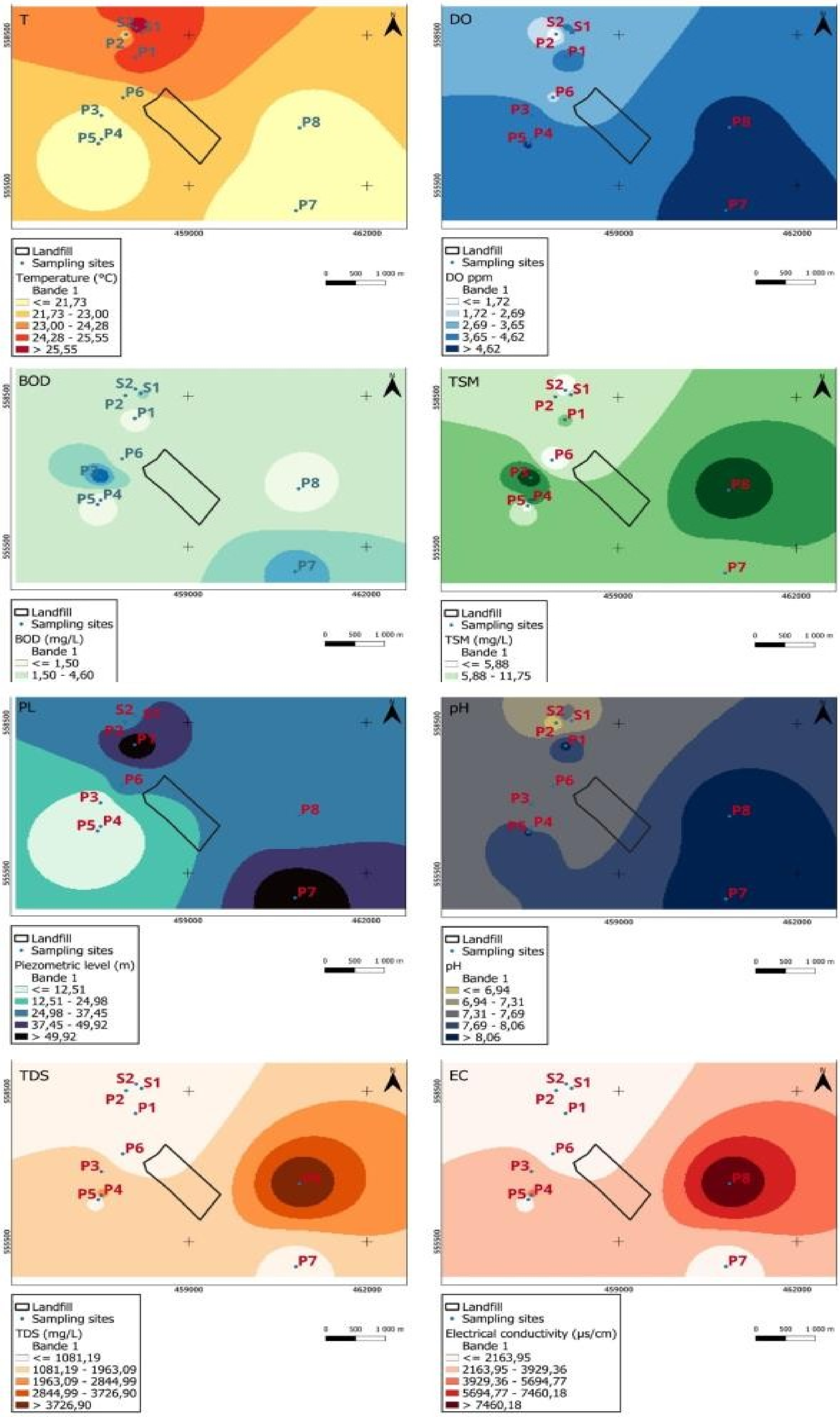

Fig 2. IDW interpolation of DO, BOD, TSM (mg/l), T (°C)PL(m), pH, TDS(mg/l), and EC (µs/cm)

As for temperature, the highest recorded value was 26.8°C, notably lower than the Moroccan regulation [8] limit of 30°C. The WHO Guidelines do not specify a particular temperature limit. It's important to note that elevated water temperatures can lead to increased microorganism growth and may worsen concerns related to taste, odor, and color in the water [9].

In terms of Dissolved Oxygen (DO) levels, the recorded values range between 0.74 and 5.58 mg/L in our groundwater wells. Moroccan standards specify 5 mg/L as the minimum acceptable DO level for potential drinking water, while the World Health Organization (WHO) does not provide a specific guideline for DO in drinking water. Regrettably, only three of our wells (P5, P7, and P8) meet the minimum DO value required for drinking water. This falls well below the findings from Merbouh et al, [6], where DO values ranged from 4.88 to 8.21 mg/L. The reason for this discrepancy can be attributed to the continuous decomposition of organic matter by microorganisms in the groundwater. This decomposition process demands a significant amount of oxygen, which might account for the depletion of DO in the water. The evidence is reinforced when we examine the Biochemical Oxygen Demand (BOD) values. Four of the wells with the lowest DO levels (S1, P2, P3, and P6) also exhibit the highest BOD values, measuring 6.2, 14, and 2 mg/L, respectively. This connection suggests that the source of organic matter may be linked to leachate infiltration, as leachate is known to contain substantial amounts of organic material. In summary, the low DO levels in the groundwater, with only a few wells meeting the minimum standard, can be attributed to the ongoing decomposition of organic matter by microorganisms, which depletes the available oxygen. This is supported by the elevated BOD values in these wells. The potential source of this organic matter could be linked to leachate infiltration, which is known to carry significant quantities of organic material.

The Electrical Conductivity (EC) values measured in our study vary between 398 and 9226 µS/cm. We can categorize these values into two distinct classes. Notably, five of the monitored wells (P1, P3, P4, P7, P8) exceed the guidelines set by both Moroccan regulations (1300 µS/cm) and the World Health Organization (WHO) recommendations (100 µS/cm). These results are in agreement with the EC values reported by Mishra et al. [3] during the post-monsoon period (equivalent to our summer sampling campaign), where values ranged from 600 to 2640 µS/cm. The notable elevation in EC levels in these wells may be associated with the presence of high concentrations of ionic substances stemming from human-related sources [10].

The strong correlation between Total Dissolved Solids (TDS) and EC (0.9998538), along with a p-value below 0.00001 (Figure 4), further confirms that the same wells exceeding the established guidelines persist. Specifically, wells P1, P4, P7, and P8 significantly surpass the WHO limits of 600 mg/L, while P3 is in close proximity to this threshold with a TDS value of 590 mg/L. Given the notable wind patterns in the study area, it is reasonable to suggest that particles containing salts, metals, inorganic ions, and organic matter from the landfill could be carried to surrounding areas. As expected, the wells located closest to the landfill exhibit the highest levels of contamination.

Table 3. Correlation test for Water quality parameters

	EC	***BOD***	***DO***	***TSM***	***PL***	***pH***	***T***	***TDS***
EC	1							
BOD	-0.1219	1						
DO	0.3096	0.1737	1					
TSM	**0.9372**	0.0722	0.3759	1				
PL	-0.3824	0.0881	0.078	-0.451	1			
pH	0.3343	-0.0966	**0.8659**	0.3183	0.0388	1		
T	-0.4421	-0.1617	-0.1865	-0.5044	**0.6686**	-0.2468	1	
TDS	**0.9999**	- 0.1254	0.3079	**0.937**	- 0.3876	0.3287	- 0.4436	1

The concentration of Total Suspended Matter (TSM), also known as Total Suspended Solids (TSS), in our study is ranging from 2.4 to 42.9 mg/L. Notably, these values significantly surpass those observed in a prior study conducted in the R'mel aquifer of Morocco by Er- Raioui et al. (2011) [11], where TSM levels were expected to remain below 1 mg/L. However, our study's samples still align with the water quality standards set by Morocco, which establish 1000 mg/L as the maximum acceptable limit and 50 mg/L for designating water quality as excellent, while the World Health Organization (WHO) has yet to provide specific guidelines for this parameter.

Correlation between TSM and TDS is also to be noted, as it equals 0.93844 (figure 4) with p-value less than 0.05. This can be explained by the following expression as Total solids (TS) is the sum of both the total suspended matter (TSM) and total dissolved solids (TDS) in the process of water.

$$TS = TSS + TDS \quad [12]$$

4 Conclusion

The results obtained from the summer groundwater sampling campaign in the Hjar Nhal region reveal some noteworthy deviations in water quality parameters, particularly in terms of Electrical Conductivity (EC), Total Dissolved Solids (TDS), Biological Oxygen Demand (BOD), and Dissolved Oxygen (DO). Among the sampled wells, P3, P7, and P8 stand out as the most contaminated, with values exceeding the established Moroccan standards of 1300 µs/cm, 500 mg/L, 7 mg/L, and 5 mg/L for EC, TDS, BOD, and DO, respectively. It's crucial to note that only one of these wells, P3, aligns with the groundwater flow direction.

These findings do not conclusively confirm a direct impact of the nearby landfill on the groundwater in the region. This is especially significant considering that the landfill's age is less than 2 years. However, it is imperative to conduct further in-depth chemical analyses, bacterial assessments, and identification of heavy metals to closely monitor any potential impact. Subsequent findings may help to provide a more thorough examination of the area and will also empower decision-makers to make informed choices promptly. This timely and data-driven decision-making will be crucial in addressing any potential environmental concerns and ensuring the long-term sustainability of the region.

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