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Assessment of drinking water quality based on trace elements concentrations in the semi-arid region, Morocco

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Abstract. Human health and sustainable socio-economic growth are closely linked to water quality. Due to increasingly intense human activity, pollutants, and in particular trace elements, are entering the aquatic system and harming humans. The main objective of this study is to analyse and compare the impact of the trace elements on the water quality of natural springs. The concentrations of ten trace elements in 12 spring water samples collected in 2022 were analyzed using ICP-MS to determine the spatial variability of natural water quality in the Ouislane watershed. Nine major trace elements (boron, cobalt, chromium, copper, manganese, nickel, lead, zinc, and vanadium) were measured using the inductively coupled plasma mass spectrometry (ICP-MS) technique. The average values of these elements followed the descending trend: B > Ni > Cr > Co > Zn > Mn > V > Cu > Pb in spring water samples. Some trace elements measured in certain water samples exceed the upper limits set by Moroccan drinking water quality standards (NM) and the World Health Organization (WHO). From the principal components analysis (PCA), 83% of the variation is explained by the first three main components. B, Co, Cr and Ni have a strongly impact on water quality explain by their strong correlation with CP1 ($R^2 > 0.70$). The calculated water quality index (WQI) values ranged from 61.18 to 95.11, with an average of 78.47. Approximately 17% of the water samples were categorized as excellent quality water (WQI < 50), with the remaining 83% classified as good quality water (50 < WQI < 100). According to the

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WQI index, all the natural spring waters investigated are deemed suitable for human consumption.

Keywords: Water quality; trace elements; springs; Ouislane watershed; water quality index

1 Introduction

Water is considered the most crucial component among all natural resources **[1,2]**, For ecological health, sustainable development, and human survival, water resources' availability and quality are essential **[3,4]**. Groundwater, springs serve as the primary water sources for the people of Morocco. However, their quality is compromised due to various pollutant emissions, including those from domestic, agricultural, and industrial wastewater **[5]**. Several analyses can be used as references to identify the suitability of water for different uses, such as physical, chemical, biological analyses **[6]**. Indeed, the water quality is highly sensitive to climate change , flow water in geological facies or faults, and anthropogenic contributions **[4,7,8]**. Currently, there is growing worried over the quantity and variety of toxins in the environment. Trace elements have a major impact on aquatic pollution and have attracted a significant attention in the world **[9]**. pose the greatest danger owing to their environmental toxicity, persistence, and carcinogenicity **[10,11]**. Trace elements are present in the atmosphere, hydrosphere, lithosphere and biosphere, while anthropogenic activities increase their input through overexploitation of resources and waste disposal **[12]**. The existence of trace metals in soluble, exchangeable, included in mineral, complexed or precipitated form defines the pollutant potential and its impact on water quality **[13]**. A number of these metals are non-degradable, persistent and toxic **[14]**, which would have adverse health and environmental impacts, and their accumulation in water **[15,16]**. The original quality and suitability of water for human consumption are compromised by the high concentration of trace elements. From water quality index (WQI), five different classifications were determined as follows: when WQI < 50 (excellent water quality); 50 ≤ WQI < 100 (good water quality); 100 ≤ WQI < 200 (poor water quality) ; 200 ≤ WQI < 300 (very poor water quality); WQI ≥ 300 (deemed undrinkable water) **[17,18]**. This study aims to identify trace elements characteristics and their impact on drinking water, then assess the spatial distribution of water quality at all investigated sites. The water quality can be evaluated by integrating the water quality model to a GIS environmental **[19]**, .

2 Study Area and sampling stations

The Ouislane sub-basin is located in northern Morocco and is home to an urban and rural population. It is located on a plateau in north-western part of Middle Atlas mountains with a Mediterranean climate and covering and area of 315.4 km². Regarding the topography of the selected area, the elevation values are range between 1,434 m (south) m and 5 m (north). The Ouislane river is a part of R'Dom watershed [20], flows from the south to the north and the major water springs discharged in the river. Twelve springs stations were selected to assess their quality evolution. These sampling points are taken from upstream to downstream (Figure 1). The principal crops in the Ouislane area are cereals, olive trees, and vegetables, along with pasture and forest lands. Agriculture constitutes the primary economic activity in this project area [20].

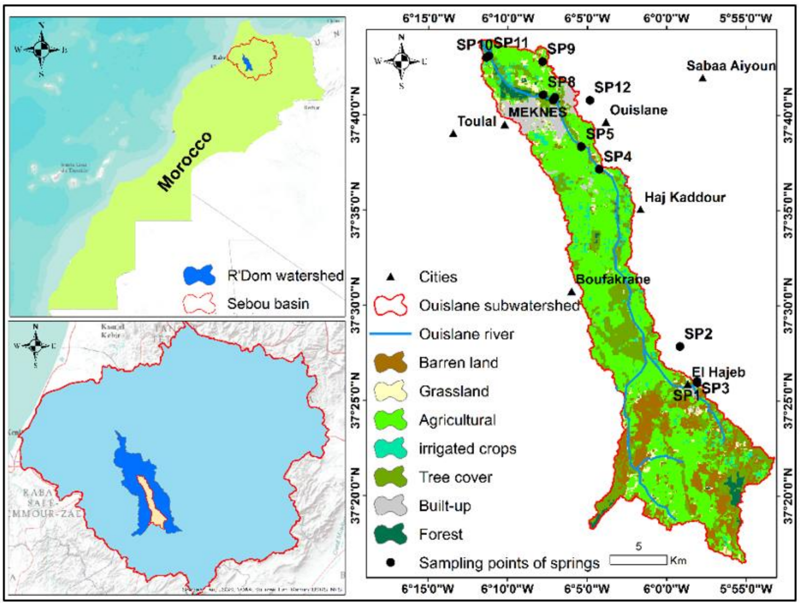

Fig 1. Study Area location

3 Methodology

In order to characterise the hydro-geochemistry of springs water, twelve samples were gathered on field trips in May 2022. Because, in recent decades, water quality has been a major concern for human beings, as it is the most important natural resource, but water is being polluted by population growth, industrial and agricultural activities. In this study, water samples were collected from springs, and nine trace elements (B, Co, Cr, Cu, Mn, Ni, Pb, Zn, and V) were analysed using the ICP-MS technique. The results were utilized to calculate the water quality index, determining the suitability of the water for consumption. PCA was performed on trace elements data. Without distinguishing between common and unique variants, PCA reduces the data into a large number of variables using a set of weighted linear combinations of all these variables. The adopted methodology in this research project is composed of five steps, as shown in the figure 2.

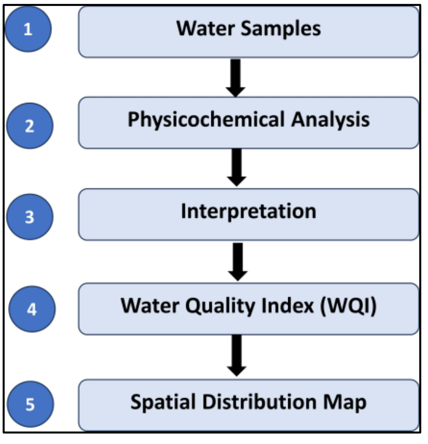

Fig 2. Adopted methodology

4 Results and discussion

4.1 Descriptive statistics of trace elements

The figure 3 shows the evolution of the trace elements concentration in the visited spring stations. The boron concentrations obtained from the analysis range between 0.012 mg/l and 0.134 mg/l, with an average of 0.049 mg/l. Cobalt concentrations remain almost stable at all investigated stations, averaging around 0.054 mg/l. Chromium contents vary from 0.035 to 0.082 mg/l, with an average of 0.066 mg/l. Chromium is thus one of the most prevalent elements measured in water samples, exceeding the upper limit of 0.05 g/l set by the Moroccan standard on allowable doses in some investigated stations. Excessive chromium can be harmful, particularly in its hexavalent form, leading to various disorders such as stomach upsets, ulcers, and damage to the kidneys, liver, and even death [18]. Copper and lead concentrations are the lowest among all elements at all stations (<0.02 mg/l). Nickel is the most abundant element in all waters, ranging from 0.062 to 0.125 mg/l, with an average of 0.096 mg/l. The quantified values exceeded the maximum allowable doses set by the Moroccan standard, which is 0.02 mg/l. Manganese concentrations are only measured at stations S1, S2 and S10, and are null at the other stations. Generally, the difference between water samples was more marked in the B, Cr and Ni case (Figure 2).

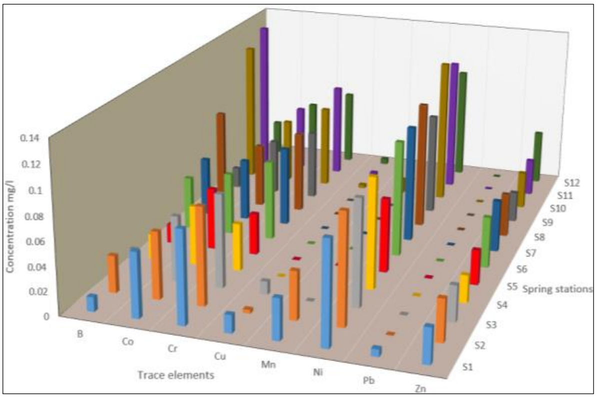

Fig 3. Trace elements concentration in the investigated stations.

The Moroccan standard (NM) and World Health Organization (WHO) drinking water standards were chosen for this study. Table 1 displayed the statistical analysed parameters and maximum acceptable standard values.

Table 1. Trace Elements statistics.

Parameters	Min	Max	Avg.	SD	NM	WHO
B (mg/l)	0.012	0.134	0.049	0.040	0.5	0.5
Co (mg/l)	0.048	0.058	0.054	0.003	50	50
Cr (mg/l)	0.035	0.082	0.066	0.014	0.05	0.05
Cu (mg/l)	0	0.015	0.003	0.005	2	2
Mn (mg/l)	0	0.04	0.007	0.014	0.5	0.04
Ni (mg/l)	0.062	0.125	0.096	0.015	0.02	0.07
Pb (mg/l)	0	0.006	0.001	0.002	0.01	0.01
Zn (mg/l)	0.023	0.047	0.034	0.007	3	3

4.2 Correlation matrix analysis

The Pearson correlation matrix is generated in this research to find possible sources, origin and correlation of trace elements in source samples [21]. A correlation matrix describes inter-element relationships and new associations between trace elements. The trace elements exhibit a significant positive correlation (r > 0.5) and negative correlation (-0.5 > r). They also show a weak, significant positive correlation (r < 0.5) and negative correlation (r > -0.5), as well as an insignificant correlation when r is close to zero (Table 1).

Table 2. Pearson correlation matrix for springs trace elements.

Parameters	B	Co	Cr	Cu	Mn	Ni	Pb	Zn	V
B	1.000								
Co	**.670**	1.000							
Cr	.414	**.703**	1.000						
Cu	-.224	.300	.483	1.000					
Mn	-.147	.339	.426	.486	1.000				
Ni	**.856**	**.530**	**.556**	-.112	-.062	1.000			
Pb	-.275	.057	.222	**.749**	**.583**	-.216	1.000		
Zn	.145	.198	.329	-.147	-.125	.276	-.206	1.000	
V	**.679**	**.949**	**.620**	.264	.314	**.526**	-.003	-.064	1.000

4.3 Principal Components Analysis

Based on eigenvalue (Figure 3a), three first components of the PCA were performed form 12 samples and account for over 82.96% of the total variance. Principal components C1, C2 and C3 contributed 42.01, 28.99 and 11.96% from the total variance, respectively (Figure 3b). From the water samples, elements B, Co, Cr, Ni, and V exhibited high loadings in PC1, then, Cu, Mn, and Pb demonstrated high loadings in PC2, while, Zn displayed high loadings in PC3 (table 3).

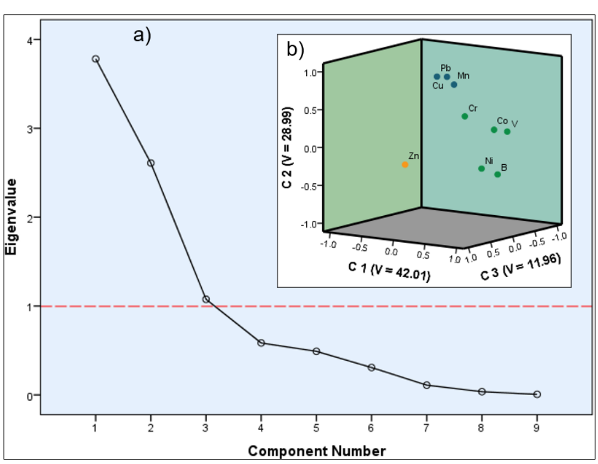

Fig 4. Principal Component Analysis (PCA) for dissolved trace elements in drinking water involves two key visualizations: a) a screen plot, and b) a component plot in rotated space.

Table 3. Rotated Component Matrix

	Component		
	C1	C2	C3
B	**.897**	-.308	-
Co	**.887**	.290	.101
Cr	**.654**	.492	.430
Cu	-	**.890**	-
Mn	.140	**.788**	-
Ni	**.804**	-.207	.265
Pb	-.151	**.860**	-
Zn	-	-.128	**.961**
V	**.915**	.232	-.157

4.4 Water Quality Index (WQI)

The WQI defines the suitability of water for drinking based on the content trace elements. It is calculated using the following equation [15]:

$$WQI = \sum [W_i \times (\frac{C_i}{S_i}) \times 100]$$

Where
Wi = wi/Σwi represents the relative weight,
wi is the weight attributed to the target element based on its relative apperceptive effects on human health and significance in terms of potability. Ci represents the measured trace element concentrations, and Si is the Moroccan standard (NM) for drinking water [22].
Based on WQI classification (figure 5a) and GIS environment (figure 5a), the investigated stations were classified in an excellent quality (WQI<50) and a good quality (50<WQI< 100).

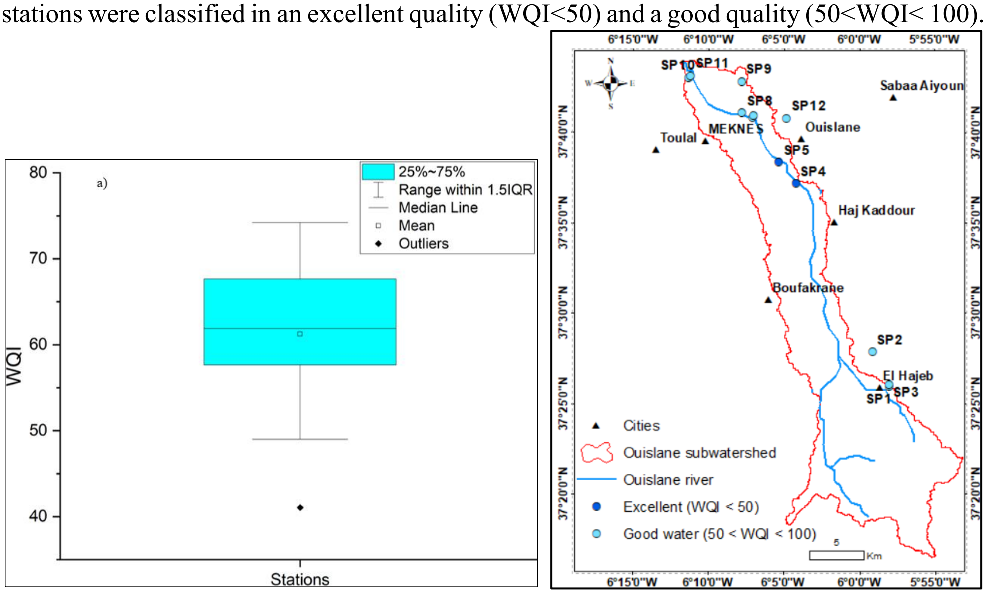

Fig 5. a) Box plots of WQI and b) spatial distribution of WQI

5 Conclusion

This research presented high-precision ICP-MS trace element data for spring water. Based on the concentrations obtained for the analyzed trace elements and their impact on water quality, chromium (Cr) received the highest weighting (5). This decision was made due to the potential adverse effects of these elements on water quality, including toxicity. Manganese (Mn) was assigned a weight of 4 due to its significant impact on water quality. Boron (B) received a weight of 3 because it contributes to the improvement of water quality. Copper (Cu) was assigned a weight of 2. Zinc (Zn), Cobalt (Co), and Nickel (Ni) were each given a weight of 1, indicating their relatively lower impact on water quality. High concentrations of chromium (Cr) in SP1, SP2, SP3, SP6, SP7, SP8, SP9, SP10, SP11, and SP12 contribute to a degradation of water quality in the mentioned stations. However, the water quality in the investigated stations was classified as good to excellent water.

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