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Spatio-temporal evolution of the physico-chemical parameters of the Inaouen wadi and its tributaries

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Abstract

In order to assess the water quality of the Inaouen Wadi and its main tributaries, a monitoring of the physico-chemical parameters of twelve stations has been carried out during an entire annual cycle (year 2019). We measured ten parameters (T°, pH, electrical conductivity, total hardness, sulphates, ortho-phosphates, dissolved oxygen and nitrogen compounds) and five heavy metals were determined (iron, zinc, copper, lead, silver). The upstream stations (S1, S3, S4, S5 and S6) are the most polluted. These stations have the highest sulphate, ortho-phosphate, biological oxygen demand and nitrogen compounds. This pollution is a consequence of the solid and liquid wild discharges brought by the S1 and S5 tributaries and the urban agglomerations installed on the Inaouen river banks, which have a direct and important impact on the quality of water in the whole wadi. In addition, heavy metals (Zn, Iron, Ag and Cu) present high levels upstream of the Inaouen while passing downstream. A statistical multi-variate study using PCA (Principal Component Analysis) revealed that the content of these parameters remains low downstream of this river (S11) and the tributaries S10, S9 and S7 compared to upstream (S5). This pollution generated upstream is mainly caused by human actions (wastewater discharges, agricultural and industrial activities) without prior treatment. The main factors that reduce the pollution load downstream of the Inaouen wadi are self-purification and the tributaries leaving the Middle Atlas characterized by good water quality.

Keywords: *water quality, pollution, anthropic activity.*

1. Introduction

Water resources, especially surface water, play a vital role in various sectors of the economy such as agriculture, industry, livestock and forestry. Knowledge of a country's water resources and their availability for different uses is a prerequisite for land-use planning and sustainable development, especially when water resources continue to decline due to rainfall deficits [2,3]. In addition, its pollution by human activities such as population growth, industrialization, urbanization, etc. , wastage and overexploitation could make water more scarce, thus threatening the quantity and quality of water, and hence the water supply and associated food production [4–7] . In Morocco, several international and national works have been carried out to assess the physico-chemical quality of rivers in different regions and in particular at the level of Taza [8], north-eastern Morocco [1], Eastern High Atlas, Morocco [5], Sebou Basin [6], El Haouz of Marrakech [9] and Eastern Morocco [10]. This work has revealed real risks that arise with the acceleration of pollution problems and their impact on the quality of surface and ground water. Indeed, the important demographic growth, the extension of agricultural land and the intensification of agriculture, as well as the development of industry are the main factors which are the origin of various pollutions affecting the air, the soil, the ground water resources but also and especially the surface water. The Wadi Inaouen is the second major tributary of Sebou. It is located at the level of the southern furrow rifain Fez-Taza corridor and drains a watershed with an area of 3396 km2 at the level of which located two dams Driss 1er and bab louta. It receives on its right bank the flows of the wadis; Larbaa, Lahdar, and Amlil. These tributaries collect runoff from the pre-rifaine hills. On its left bank, the Wadi Inaouen receives tributaries fed, in part, by the primary massif of Tazekka and by the Middle Atlas limestones, often karstic in this region: Zerg, Bouhlou, Matmata and Bouzemlane [8]. The future of the economy of the Taza region is strongly conditioned by the quality of water resources and the way they are exploited. Located in a semi-arid climate, this region has experienced significant agricultural development and a significant population growth in recent decades. Consequently, the demand for water has increased significantly, mainly in large cities, such as Taza, wadi Amlil, Tahla etc. [11]. Inaouen's water is used for the irrigation of various organic crops, the industrial activities of the urban agglomerations installed along the Wadi [8]. The present work proposes to establish a diagnosis of the water quality of the Inaouen wadi in order to know the real state of water quality and to determine the type and origin of pollution.

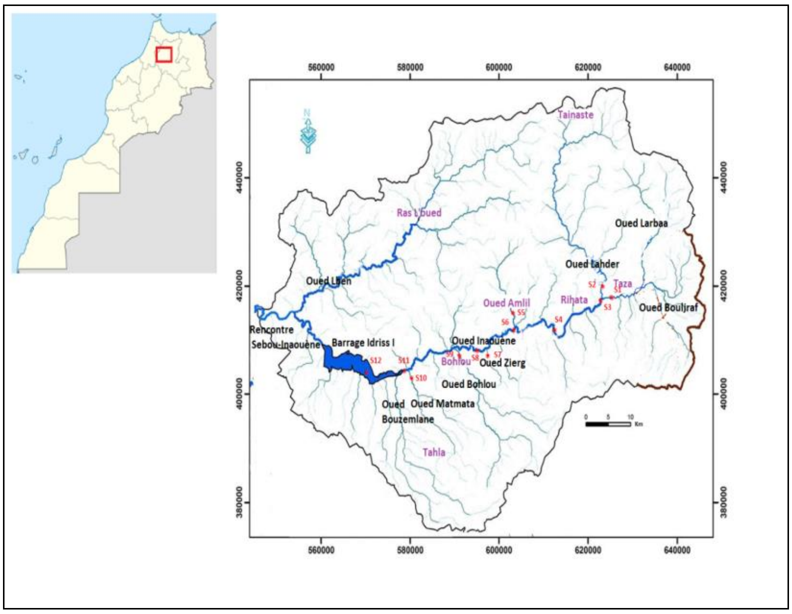

Fig 1. The watershed of Inaoune wadi and its tributaries

1. Materials and methods

*1.1. **Description of the study area and studied watercourses***

The Wadi Inaouène watershed (Fig 1) is a sub-basin of the great Sebou basin, located in northeastern Morocco; it covers an area of 3320 km2. Wadi Inaouen has its source at Bab Merzoka (Taza) downstream where it meets Sebou at the rural commune of Al Ouadayne (Molay Yaacoub), it is the second main tributary of Wadi Sebou after Wadi Ouargha.

*1.2. **Sampling and hydrochemical analysis***

During 2019, the water samples from Wadi Inaouen were collected in 500 ml opaque worm bottles. The water samples were sent directly to the laboratory within 8 hours and at a temperature of 4°c for analysis. Twelve stations were explored along the wadi (Fig. 1, Table 1), taking into account different criteria such as source of pollution, direction of flow, accessibility, and others.

Table 1: ***Description of sampling sites***

	Station Name and Address	Geographical coordinates		Altitude (m)	Human pressure
		Latitude N	Longitude W		
S1	The Wadi Larbaâ located at RN6, 35000 Bab Marzouka	34°13’58.841"	4°3’42.36"	483	Urban /agricultural
S2	The Wadi Lahdar situe à RN6, 35000 Bab Marzouka	34°14’3.659"	4°3’50.099"	483	agricultural
S3	Amon d’Inaouen situé à 35000 Bab Marzouka,	34°13’40.942"	4° 4’7.528"	483	Urban /agricultural
575 **S4**	Inaouen Amon located in Ghiata Al Gharbia	34° 11’57.611"	4°12’24.865"	479	forest/agricultural
S5	Wadi amlil situé à RN6, 35252 Wadi Amlil	34° 11’17.293"	4°16’39.879"	304	Urban /agricultural
S6	Wadi Amlil located at RN6, 35252 Wadi Amlil	34°11’16.967"	4°16’39.88"	304	Urban /agricultural
575 **S7**	Wadi Zireg located in Caïdat de Bouhlou	34°09'54.2"	4°20'24.5"	367	agricultural
S8	Middle of Inaouen located at caïdat de Bouhlou	34°09'54.5"	4°20'24.4"	367	agricultural
S9	Wadi Bouhlou located in Caïdat de Bouhlou	34°07'56.4"	4°24'33.8"	266	agricultural
S10	Wadi matmata located at RN6, 35203 Matmata	34°07'00.6"	4°32'17.4"	279	agricultural
S11	Inaouen Downstream located at RP5418, Matmata	34°08'16.2"	4°30'09.6"	273	agricultural
S12	Dam Idriss 1st located in Oulad Ayyad, caïdat of Ouled Riab	34°7’31.989’’	4°39’50.032’’	277	agricultural

The parameters analyzed are Temperature (T°C), Hydrogen Potential (pH), Electrical Conductivity (EC), Dissolved Oxygen (DO), directly measured in situ using a multi-parameter (appropriate C931 Consort laptop) Sulfates (SO42-), Ortho-phosphates (PO4) and Biological Oxygen Demand (BOD5) were determined according to the Rodier protocol [12]. Thus the Total Hardness (F°) of the water was determined by volumetric titration with 0.2N EDTA, Nitrates (NO3-) and Ammonium (NH4+) were determined by spectrophotometry. The determination of metallic trace elements (Mg, Co, Cu, Fe, Ni, Pb, Cr, and Zn), were carried out using Inductively Coupled Plasma Emission Spectrometry (ICP-AES) at the CNRST laboratory in Rabat.

1.3. ***Statistical analysis***

Statistical analyses were performed on the data for both single-variable (correlation tests) and multivariate (similarity tests and principal component analysis) to determine the different correlations between these parameters.

2. Results & Discussion

The physicochemical indicators of water quality are often subject to spatio-temporal variations induced by anthropogenic activities which modify the characteristics of the water and affect its quality [13], Thus, the pollution degree measurements of this biotope. The average temperature does not show large variations from one station to another. The recorded minimum is 15.7°C (station S1) and the maximum is 22.74°C (station S11). These values fluctuate between 9.52°C and 29.5°C (Table 2) and show a slightly increasing gradient both upstream and downstream. The highest temperature was recorded during the summer season in station S11 and the lowest during the automn season in station S3 (Table 2). Water temperature is strongly influenced by environmental conditions related to the geographical location of the locality, the geology of the terrain crossed, the hydrology of the ecosystem and especially the prevailing climate [14]. The pH values measured are generally alkaline to moderately neutral and range from 7.33 to 8.02. A slight gradient decreasing from upstream to downstream was recorded. Seasonal variations are well expressed and follow the same direction as temperature (Table 2). The pH is a factor dependent on natural environmental conditions, such as vegetation cover, the nature of the rocks and soil substrate, and human activities such as pollution [15,16]. It decreases in the presence of high levels of organic matter and increases during periods of low water levels, when evaporation is fairly high [17]. Conductivity is one of the physical parameters that makes it possible to verify the quantity of salts dissolved in water [12] and the existence of pollution in water [18]. It represents a better parameter for geochemical differentiation of water [19]. The conductivity of the waters of the Inaouen wadi and its main tributaries presents significant values which vary very strongly between the two banks of the Inaouen wadi, in the tributaries of the right bank the conductivity is maximum 2258µs / cm at S2 and 2155 µs / cm at S5 on the other hand, the left bank records minimum conductivity of 180, 202 and 360 µs / cm at S7, S10 and S9 respectively. Seasonal variations show that the highest values are recorded in the summer and autumn. The increase in conductivity during the warm period can be linked on the one hand to the low flow of the Wadi, which leads to an increase in the concentrations of mineral salts, and on the other hand to strong atmospheric evaporation [20]. On the other hand, the minimum values recorded in the rainy return period could be attributed to the rainfall that led to a phenomenon of water dilution due essentially to the subterranean water sources, coming from the mountains of the Middle Eastern Atlas and the pre rif. The average oxygen content of the wadi increases from upstream to downstream and goes from 3.17 mg/l (S3) to 5.98 mg/l (S11). This significant deficit in dissolved oxygen upstream of inaouen is probably linked to the high organic loads generated by the liquid effluents of the region's urban agglomerations loaded with high concentrations of polluting substances. BOD5 is an indicator of biodegradable organic pollution and is also evaluated to determine the oxygen demand to stabilize domestic and industrial waste [21,22]. The upstream of Inaouen (S3, S4 and S6) and the tributaries S1 and S5 record very high concentrations of BOD5 during the summer season reaching a

maximum value of 597 mg O2/l at S5, these concentrations decrease significantly downstream reaching a minimum value of 2.06 mg O2/l recorded at S10 during the spring. These values are higher than the Moroccan standards (10-25 mg O2/l) of surface water quality and consequently these waters are classified respectively of poor quality along inaouen (S3, S4, S6, S8 and S11), downstream of wadi Larbaa S1 and downstream of wadi amlil S5. For the others, wadi lahdar S2, wadi zireg S7, wadi Bouhlou S9 and wadi Matmata S10 are considered of good quality. Bn Abbou [8] recorded average values between 437 mg O2/l and 207 mg O2/l from upstream which receives discharges from the city of Taza via the wadi larbaa as well as discharges from the agglomerations of Makansa, wadi amlil and ghiyata lgharbia downstream which receives unpolluted tributaries of the wadis Matmata, bouhlou, zireg and bouzemlane. The evolution of the sulphate content (SO_4^{2-}) shows very important values upstream of the Inaouen wadi and tributaries S1 and S5, these values decrease significantly as they progress downstream of Inaouen and tributaries S7, S9 and S10. (Table 2), maximum sulphate concentrations decreased gradually in winter and then increased to reach its maximum level (910 mg/L) in summer at S1 (Table 2). This shows that the anthropogenic contribution is not negligible, because of the evacuation of domestic water in this element, generally the high content of sulphates is linked to the abundance of secondary evaporitic formations mainly gypsum ($CaSO_4$, $2H_2O$) and anhydrite ($CaSO_4$). The levels of orthophosphates (PO_4^{3-}) found upstream of Inaouen are generally high, the annual concentrations of PO_4^{3-} in the waters of the different stations vary between 0.48 mg/l and 8.14 mg/l (Table 2), the highest values are found at station S1, S3 and S5 during winter and autumn. These levels are the consequences of wastewater discharges from many municipalities near the stations (Taza, wadi Amlil, mkanssa and ghyata lgharbiya). The increase in these grades during the winter period could be related to increase soil leaching. Average nitrate (NO3-) values in the Inaouen water and its tributaries range from 22.93 mg/l to 1.29 mg/l. The stations S3, S6 and S11 show high nitrate levels exceeding the WHO (world health organization) recommended limit for drinking water (50 mg/l). This situation can be explained by the high use of chemical fertilizers and pesticides related to the agricultural activities developed in the study area. The station of the idriss 1 S12 dam has a minimum nitrate content of 0.4 mg/l. Bn Abbou [8] reports that the Inaouen basin records high nitrate levels in winter (142.52 mg/l) that may be caused by fertilizer application. In general, the nitrate content increases during the low water period and decrease during the rainy period. In unpolluted waters, it varies between 2 and 3 mg (<20mg/l), its increase is attributed to anthropogenic origin (fertilizer use in agriculture). The presence of ammonium (NH4+) in water remains a criterion of pollution [16]. The highest concentration of ammonium is recorded at S1 during autumn (0.91 mg/l) (Table 2). Waters S2, S7, S9, S10, and S12 are classified as of good quality (0.1-0.5 mg/l) according to Moroccan surface water quality standards.

Table 2: ***Spatial and temporal evolution of the physico-chemical parameters of the different stations***

		T°C	pH	EC	Dissolved O_2	Sulphates	$PO_4{}^{3-}$	Nitratres NO_{3-}	Ammoniacal nitrogen	DBO5	F°
S1	**Went**	11,02±0,67^{a}	7,9±0,1^{a}	1333±19^{a}	2,17±0,07^{a}	890±9,5^{a}	8,81±0,11^{a}	22,8±0,5^{a}	0,95±0,11^{a}	491 ±22,5^{a}	155±2,67^{a}
	Spri	16,1±0,2^{b}	7,95±0,2^{a}	1689±22^{b}	1,95±0,08^{a}	895±11,15^{a}	7,85±0,13^{b}	23± 0,61^{a}	0,59±0,14^{b}	501,7± 25^{a}	90,29±3,7 ^{b}
	Summ	23,1±0,1^{c}	8,2±0,1^{b}	2000±24^{b}	3,02±0,09^{b}	910±11,37^{b}	7,8± 0,06 ^{b}	22,7± 0,25^{a}	0,79±0,1^{c}	520,9 ±9,95^{a}	108,76±2,3^{b}
	Autm	12,5±0,38^{a}	7,65±0,1^{c}	1310±20^{a}	2,17±0,07^{a}	885±10,3^{a}	8,07±0,07 ^{b}	22±0,42^{b}	0,91±0,14^{a}	386,5±31,11^{b}	180±4^{a}
Annual M.V.		15,7±5.4^{A}	7,9±0.2^{A}	1583±327^{A}	2.33±0,47^{A}	895±10^{A}	8,14±0,46^{A}	22,93±0,29^{A}	0.81±0.16	475±60^{A}	133,5±41^{A}
S2	**Went**	11,96±0,1^{a}	7,88±0,1^{a}	1534±21^{a}	5,07±0,2^{a}	272,1±14,9^{a}	1,3± 0,04^{a}	7± 0,08^{a}	0,09 ±0,05^{a}	16,74 ±2,39^{a}	155,2±3,5^{a}
	Spri	19,2±0,1^{b}	7,91±0,1^{a}	1967±21^{b}	8,11±0,06^{b}	260,8± 12,2^{a}	1,3± 0,03^{a}	7,4±0,05^{a}	0,11±0,07^{ab}	6,46 ±3,55^{a}	200,1±3,2 ^{b}
	Summ	26,9±0,1^{c}	8,1± 0,1^{a}	2894±19^{c}	5±0,09^{a}	488± 10,45^{b}	1,02±0,03^{a}	7,6± 0,09^{a}	0,18 ±0,07^{b}	17,38±4,92^{a}	145,3±3,9 ^{a}
	Autm	11,15±0,1^{a}	7,9± 0,2^{a}	2641±20^{d}	7,08±0,06^{c}	288,7±10,5^{c}	1,4± 0,05^{a}	7,39± 0,06^{a}	0,16 ±0,04^{b}	13,72±2,32^{a}	120,2±1,5^{ab}
Annual M.V.		17,3±7,4^{AB}	7,95±0,1^{A}	2258±691^{B}	6,32±1,54^{B}	327±107^{B}	1,28±0,18^{B}	7,46±0.12^{B}	0,14±0.04	13,56±5^{B}	155,2±33^{A}
S3	**Went**	11,17±0,1^{a}	7,8± 0,2 ^{a}	1555±18^{a}	3,39±0,07^{a}	425,2±12,9^{a}	7,21± 0,04^{a}	18±0,26^{a}	0,87 ±0,1^{a}	373,6 ±6,38^{a}	95,8±4 ^{a}
	Spri	18±0,04^{b}	7,91±0,2^{a}	1768±18^{b}	4,40±0,08^{b}	462,66±10^{b}	6,05± 0,13^{b}	21± 0,51^{b}	0,59 ±0,08^{b}	420,77±15,6^{b}	144,7±3,5^{b}
	Summ	26±0,2^{c}	8,05±0,1^{a}	2099±19^{c}	2,23±0,06^{c}	875± 10,01^{c}	6,45±0,08^{b}	21±0,43^{b}	0,65 ±0,04^{b}	516,76±22,2^{c}	159,7±3,1^{b}
	Autm	9,52±0,4^{a}	7±0,13^{b}	1809±17^{b}	2,67±0,06^{ac}	784,8±11,4^{d}	7,46± 0,12^{a}	22,01±0,59^{b}	0,8 ±0,12^{a}	390,79±12,5^{a}	191,4±5,7^{c}
Annual M.V.		16,2±7,5^{A}	7,7±0,48^{B}	1808±224^{A}	3,17±0,95^{AC}	636±226^{C}	6,8±0,66^{C}	20,58±1,72^{C}	0,73±0,13	425±63^{A}	147,88±39,89^{A}
S4	**Went**	12,7±0,03^{a}	7,7± 0,1^{a}	1136±22,5^{a}	3,02±0,07^{a}	308,8±10,8^{a}	5,37± 0,06^{a}	17,7±0,69^{a}	0,65 ±0,15^{a}	278,6±16,4^{a}	187,06±2 ^{ab}
	Spri	18,15±0,2^{b}	7,72±0,1^{a}	1408±23^{b}	6,5±0,07^{b}	374,8±12,7^{b}	3,4±0,09 ^{b}	18± 0,63 ^{a}	0,51±0,07^{b}	401,3±21,38^{b}	180±3,3 ^{a}
	Summ	26,3±0,19^{c}	7,9± 0,04^{a}	1859±22^{c}	3,02±0,08^{a}	580,6± 14,2^{c}	4,89± 0,06^{a}	21,21±0,24^{b}	0,75 ±0,1^{c}	447,27±31,2^{c}	102±7,98 ^{ab}
	Autm	10,5±0,03^{a}	7,1±0,04^{b}	1328±20^{b}	4,02±0,05^{c}	510,13± 9,2^{d}	3,4± 0,09^{b}	18,9± 0,8^{c}	0,78±0,04^{c}	340,07±24,9^{d}	110±2,6^{ab}
Annual M.V.		16,9±7^{AB}	7,6±0,32^{B}	1433±306^{AD}	4,14±1,64^{C}	443±123^{D}	4,27±1^{D}	19±1,54^{D}	0,67±0,12	366±73^{C}	144,77±45^{A}
S5	**Went**	14,3±0,06^{a}	7,35± 0,1^{a}	1678±21^{a}	3,81±0,06^{a}	633,2±9,3^{a}	6,6± 0,06^{a}	20,28±0,97^{a}	0,92±0,04^{a}	390,45±9,18^{a}	99,6±2,4^{a}
	Spri	25±0,65^{b}	7,61±0,1^{a}	2009±19^{b}	4,49±0,04^{a}	690,3± 14,5^{b}	6,13±0,1^{a}	20,36± 0,1^{a}	0,55 ±0,22^{b}	491±9,54^{b}	50,02±2^{b}
	Summ	25,27±0,1^{b}	7,90± 0,1^{b}	2495±19,5^{c}	4,39±0,08^{a}	879,9±15,15^{c}	4± 0,08 ^{b}	20,23±1^{a}	0,82±0,19^{c}	597,88±18,3^{c}	65,4±1,9^{b}
	Autm	15,94±0,1^{a}	7,45± 0,1^{a}	2440±20 ^{c}	3,92±0,07^{a}	785±14,45^{d}	7,67±0,06 ^{c}	20± 0,7^{a}	0,85 ±0,16^{c}	356,1±17,46^{d}	90,12±1,5^{ab}
Annual M.V.		20,1±5,8^{B}	7,58±0,2^{B}	2155±385^{B}	4,16±0,34^{C}	747±108 ^{E}	6,2±1,39^{C}	20,23±0,14^{DC}	0,79±0,16	458±108^{A}	76,28±22,77^{B}
S6	**Went**	12±0,29^{a}	7,2± 0,1^{a}	1145±18,5^{a}	3,22±0,05^{a}	315±13^{a}	4,6±0,04^{a}	17,4± 0,74^{a}	0,62±0,04^{a}	282,9 ±7,27^{a}	145±3,66^{a}
	Spri	23,06±0,2^{c}	7,49± 0,1^{b}	1398±18^{b}	5,43±0,06^{b}	446±10,5^{b}	4,13±0,05^{a}	17,1± 0,56^{ab}	0,68 ±0,1^{ab}	338,34±12,6^{b}	120±1,2^{b}
	Summ	25,2±0,03^{d}	7,8±0,1^{c}	1590±20,5^{c}	3,84±0,07^{ac}	646,8±10,4^{c}	4,95±0,09^{ac}	16,59±0,64^{b}	0,72±0,03^{b}	405,9±15,45^{c}	87,5±2,33^{c}
	Autm	16,4±0,05^{b}	6,9±0,1^{c}	1277±19^{a}	4,12±0,05^{c}	508,3±9,17^{d}	3,1± 0,07 ^{b}	17,8± 0,25^{a}	0,67±0,05^{ab}	351,99±10,15^{b}	100,13±2,8^{bc}
Annual M.V.		19,1±6,2^{AB}	7,33±0,38^{C}	1352±189^{AD}	4,16±0,93^{C}	478±137^{D}	4,22±0,8^{D}	17,23±0,53^{E}	0,67±0.04	344±5^{C}	113±25,2^{A}
S7	**Went**	15,26±0,19^{a}	7,94±0,1^{a}	110,23±9,55^{a}	6± 0,06^{a}	145±8,3^{a}	1,22±0,03^{a}	3,97± 0,04^{a}	0,07± 0,04^{a}	29,1 ±3^{a}	150,87±2,84^{a}
	Spri	25,11±0,12^{b}	8,03±0,1^{a}	210,92±8,78^{a}	7,95±0,04^{b}	202,7±11,5^{b}	1,4±0,05^{a}	6,4±0,05^{b}	0,1 ±0,08^{a}	57,2±5,68^{a}	129±2,5^{a}
	Summ	27,4±0,09^{b}	8,1± 0,03^{a}	214,3±11,59^{a}	5,01±0,09^{c}	301±11^{c}	1,68±0,04^{a}	7,04± 0,03^{b}	0,1±0,04^{a}	59,1 ±1,99^{a}	129,2±3,86^{a}
	Autm	16,5±0,02^{a}	7,98± 0,03^{a}	184,8±9,30^{a}	5±0,09^{c}	285±14^{c}	1,39± 0,07^{a}	6,8± 0,12^{b}	0,11±0,03^{a}	16,8 ±2,68^{a}	131,38±2,4^{a}
Annual M.V.		21,1±6,1^{B}	8,02±0.08^{A}	180±48,4^{C}	5,99±1,39^{B}	233±72,98^{F}	1,42±0,19^{E}	6,08±1,42^{F}	0,1±0,02	40,5±20,95^{B}	135,13±10,63^{A}
S8	**Went**	13,31±0,1^{a}	7,44± 0,1^{a}	819,4±7,67^{a}	4,12±0,04^{a}	389,8±11,6^{a}	3,82±0,23^{a}	15,15±0,54^{a}	0,45±0,09^{a}	244,9±15,8^{a}	139,83±3,2^{a}
	Spri	15±0,19^{b}	7,57±0,1^{a}	1052±7,9^{b}	6,69±0,06^{b}	411,1±10,2^{b}	3,74±0,09^{a}	17,24± 0,09^{b}	0,51±0,03^{a}	231,7±14,2^{a}	105,33±2,6^{b}
	Summ	19,4±0,48^{c}	7,64±0,1^{a}	1493±10,5^{c}	3,36± 0,09^{c}	597,85±14^{c}	3,41±0,06^{a}	17,01±0,09^{b}	0,71 ±0,05^{b}	337 ±15,5^{b}	75,5±3,33^{c}
	Autm	18,9±0,1^{c}	7,07±0,1^{b}	1236±10,86^{d}	4,81±0,07^{a}	420±9,13^{b}	3,11± 0,01^{a}	17,5± 0,67^{b}	0,61 ±0,03^{c}	257,3± 12,8^{b}	109,97±1,4^{b}
Annual M.V.		16,7±3^{A}	7,43±0,3^{C}	1150±285^{D}	4,75±1,42^{CB}	454,96^{D}	3,5±0,32^{DE}	16,74±1,09^{G}	0,57±0,12	267±48^{D}	107,66±26,4^{A}

S9	**Went**	15,1±0,04^{a}	7,31± 0,1^{a}	298,6±9^{a}	6,02± 0,07^{a}	141,2±15,8^{a}	1,45± 0,06^{a}	2,4± 0,045^{a}	0,1 ±0,02^{a}	14,02 ±2,75^{a}	182,17±2,88^{a}
	Spri	19,3±0,17^{b}	7,59± 0,1^{b}	416,2±10^{a}	8,09±0,06^{b}	151± 10^{a}	1,09±0,16^{a}	1,7± 0,04^{a}	0,1 ±0,04^{a}	11,82±2,47^{a}	250,13±2,58^{b}
	Summ	22,8±0,15^{c}	7,89±0,1^{c}	425,8±9,75^{a}	7,99± 0,07^{b}	276± 10,6^{b}	1,4± 0,08^{a}	1,4± 0,04^{b}	0,11±0,04^{a}	16,8 ±2,90^{a}	255±3,33^{b}
	Autm	19,5±0,05^{b}	7,75±0,1^{bc}	301±8,50^{a}	8± 0,05^{a}	156,05±3^{a}	1,12±0,15^{a}	2,35± 0,6^{a}	0,08±0,05^{a}	14,9 ±3,99^{a}	254,7±0,5^{b}
Annual M.V.		19,2±3,2^{A}	7,64±0,25^{B}	360±69^{CE}	7,53±1^{BD}	181±63^{G}	1,28±0,19^{E}	1,99±0,47^{H}	0.1±0,01	14,43±2,11^{B}	235,4±35,7^{C}
S10	**Went**	15,7±0,1^{a}	7,14±0,03^{a}	172±8,02^{a}	7,08±0,05^{a}	60,95±6,9^{a}	0,84±0,21^{a}	1,34± 0,02^{a}	0,07 ±0,06^{a}	2,33±0,66^{a}	155,2±2,9^{a}
	Spri	20,6± 0,2^{c}	7,19±0,01^{a}	220,11±7^{a}	7,36± 0,04^{a}	75,16±5,24^{ab}	0,8± 0,08^{a}	1,03±0,05^{a}	0,14±0,06^{b}	2,06 ±0,09^{a}	200,1±3,24^{b}
	Summ	22,9±0,2^{d}	7,36±0,01^{a}	229±8,4^{a}	7,24±0,05^{a}	89,09±5,9^{b}	1,01± 0,1^{a}	1,11±0,09^{a}	0,12±0,08^{ab}	3,11±0,19^{a}	220±3,28^{bc}
	Autm	18,23±0,2^{b}	7,24±0,01^{a}	189±7,35^{a}	7,69± 0,04^{a}	67,16±5,47^{a}	0,69± 0,03^{a}	1,69±0,16^{a}	0,11±0,07^{ab}	3,27 ±0,52^{a}	240,23±3,17^{c}
Annual M.V.		19,4±3,1^{B}	7,23±0,09^{D}	202±26^{C}	7,34±0,26^{BD}	73,09±12^{H}	0,86±0,13^{EG}	1,29±0,3^{H}	0,12±0,03	2,69±0,59^{B}	203,9±36,4^{C}
S11	**Went**	19,1±0,2^{a}	7,24± 0,1^{a}	673±9,5^{a}	4,40± 0,04^{a}	590± 8,7^{a}	3,35± 0,06^{a}	12,67±0,09^{a}	0,63 ±0,11^{a}	135,4±24,6^{a}	159,13±4^{a}
	Spri	22,10±1,1^{b}	7,36±0,01^{a}	944±7,54^{b}	8,08±0,07^{b}	609± 5,1^{b}	2,68±0,04^{b}	14,7± 0,06^{b}	0,62 ±0,06^{a}	108,8± 12,3^{a}	145,53±3^{a}
	Summ	29,5±0,91^{c}	7,9± 0,01^{b}	1308±11^{c}	7,40± 0,05^{b}	689± 10,75^{c}	2,5±0,05^{a}	15,23±0,12^{b}	0,71 ±0,1^{b}	289 ±14,64^{b}	180±1,95^{a}
	Autm	20,25±0,2^{ab}	7,44±0,1^{a}	1090,2±11^{b}	4,02±0,1^{a}	610± 10,9^{b}	2,56±0,21	15,2± 0,05^{b}	0,72 ±0,05^{b}	195,19±10,8^{c}	101,39±4,54^{b}
Annual M.V.		22,74±4,7^{B}	7,49±0,3^{C}	1004±269^{D}	5,98±2,1^{B}	624±43^{C}	2,8±0,37^{F}	14,46±1,22^{I}	0,67±0,05	182,1±79,9^{D}	146,52±33,49^{A}
S12	**Went**	18± 0,23^{a}	7,3±0,04^{a}	461±6,95^{a}	8,01±0,05^{a}	56± 4,9^{a}	0,5±0,11	0,4±0,2^{a}	0,12±0,04^{a}	2,12±1,04^{a}	255,46±2,56^{a}
	Spri	24,9±0,4^{c}	7,4±0,03^{a}	508±10,31^{a}	9± 0,08^{b}	51,57± 5^{a}	0,42±0,06	0,44± 0,02^{a}	0,07 ±0,03^{a}	2,55 ±1,38^{a}	250±3^{a}
	Summ	26,12± 1^{c}	7,8± 0,04^{b}	596±10,5^{a}	7,08± 0,06^{c}	57±6^{a}	0,6± 0,06	0,55± 0,02^{a}	0,08 ±0,02^{a}	2,9±0,06^{a}	200,48±2,94^{b}
	Autm	20,3±0,18^{b}	7,53±0,1^{a}	420±10,5^{a}	8± 0,04^{a}	52,78±3,5^{a}	0,38± 0,05	0,37± 0,05^{a}	0,09 ±0,04^{a}	1,94±0,49^{a}	200±1,94^{b}
Annual M.V.		22,3±3,8^{B}	7,49±0,2^{C}	496±75^{E}	8,03±0,78^{D}	54,37±2,6^{H}	0,48±0,11^{G}	0,44±0,08^{H}	0,09±0,02	2,38±0,43^{B}	226,5±30,36^{C}

Means followed by different letters are significantly different . The LSD0.05 test was used as a post-hoc comparison.

The values followed by the same letters are not significant (lower case letters for saisons and upper case letters for stations).

In this study, we investigated the existence of five essential trace elements (Ag, Fe, Pb, Cu, and Zn) (Table 3). Cu, Zn, and Fe which are essential metals in the human body, but if the body takes these elements excessively from the external environment, they will damage health. [23] Pb is potentially dangerous for various life forms because of its toxicity [24]. Annual mean concentrations range from 0.091-0.05, 0.64-0.02, 0.091 -0.05, 1.90-0.005 and 0.009-0.094 mg/L, respectively, seasonal variations are significant for Ag, Fe and Pb concentrations ($p < 0.05$) whereas Zn and Cu concentrations are unaffected ($P > 0.05$). The average concentration s of iron, silver and lead in the autumn are higher than the average values determined for the other seasons. The content of heavy metals, particularly Fe, Pb, Cu and Mn, is higher than the relative standards, which is explained by the artisanal activities of the city of Taza than by the city's domestic liquid discharges. On the other hand, heavy metals, in addition to their possible origins from anthropogenic activities, they may also have a geological origin and, have reached the river system through hydro-climatic erosion.

Table 3: ***Heavy Metals at different stations***

		Ag	Fe	Pb	Zn	Cu
S1	**Went**	0,051 ±0,006^{a}	0,53±0,03 ^{a}	0,051 ±0,003 ^{a}	1,95±0,03 ^{a}	0,013 ±0,003 ^{a}
	Spri	0,05±0,001^{a}	0,51 ±0,02 ^{a}	0,05±0,003 ^{a}	1,88 ±0,066 ^{a}	0,011 ±0,002 ^{a}
	Summ	0,092± 0,007^{b}	0,72±0,07 ^{b}	0,09 ±0,02 ^{b}	1,88 ±0,038 ^{a}	0,012 ±0,002 ^{a}
	Autm	0,17±0,0248^{c}	0,78±0,03 ^{c}	0,17 ±0,03 ^{c}	1,89±0,02 ^{a}	0,002 ±0,0012 ^{a}
Annual M.V.		0,091±0,05 ^{A}	0,64±0,13 ^{A}	0,091 ±0,06 ^{A}	1,90±0,03 ^{A}	0,009±0,005 ^{A}
S2	**Went**	0,046± 0,003^{a}	0,018±0,005 ^{a}	0,046±0,002^{a}	0,005±0,001 ^{a}	0,009 ±0,001 ^{a}
	Spri	0,049 ±0,004^{a}	0,02±0,006 ^{a}	0,049±0,008 ^{a}	0,0055±0,001 ^{a}	0,011 ±0,003 ^{a}
	Summ	0,049±0,003^{a}	0,05±0,001 ^{a}	0,049±0,003 ^{a}	0,0053±0,001 ^{a}	0,013 ±0,025 ^{a}
	Autm	0,091 ±0,001^{b}	0,02 ±0,008 ^{a}	0,087±0,01 ^{b}	0,005±0,001 ^{a}	0,012 ±0,003 ^{a}
Annual M.V.		0,058±0,02 ^{A}	0,027 ±0,01 ^{B}	0,057 ±0,02 ^{A}	0,005±0,0004^{B}	0,094±0,16 ^{A}
S3	**Went**	0,052 ±0,006^{a}	0,46±0,03 ^{a}	0,051±0,002 ^{a}	1,81±0,02 ^{a}	0,01 ±0,002 ^{a}
	Spri	0,049 ±0,003^{a}	0,49 ±0,025 ^{a}	0,052±0,01 ^{a}	1,09 ±0,045 ^{b}	0,012 ±0,003 ^{a}
	Summ	0,06 ±0,04^{a}	0,49 ±0,015 ^{a}	0,045±0,04 ^{b}	1,13±0,03 ^{b}	0,01 ±0,001 ^{a}
	Autm	0,16±0,06^{b}	0,56±0,03 ^{b}	0,16 ±0,031 ^{c}	1,8 ±0,07 ^{a}	0,012 ±0,002 ^{a}
Annual M.V.		0,08 ±0,05 ^{A}	0,5 ±0,042 ^{C}	0,079±0,06 ^{A}	1,46±0,4 ^{C}	0,011 ±0,0009 ^{A}
S4	**Went**	0,048± 0,008 ^{a}	0,36 ±0,015 ^{a}	0,049±0,004 ^{a}	0,405±0,005 ^{a}	0,01 ±0,0005 ^{a}
	Spri	0,05 ±0,003 ^{a}	0,39 ±0,03 ^{a}	0,05±0,001 ^{a}	0,99±0,07 ^{a}	0,01 ±0,002 ^{a}
	Summ	0,093±0,015 ^{b}	0,42±0,04 ^{ba}	0,08±0,004 ^{ab}	1,08±0,05 ^{a}	0,011 ±0,001 ^{a}
	Autm	0,14±0,035 ^{c}	0,44 ±0,02 ^{b}	0,13 ±0,03 ^{b}	0,86±0,03 ^{a}	0,011 ±0,003 ^{a}
Annual M.V.		0,082±0,042 ^{A}	0,41±0,034 ^{D}	0,079±0,041 ^{A}	0,83 ±0,29 ^{D}	0,011±0,0007 ^{A}
S5	**Went**	0,046±0,004 ^{a}	0,485±0,03 ^{a}	0,046 ±0,003 ^{a}	1,87 ±0,025 ^{a}	0,011 ±0,0011 ^{a}
	Spri	0,093±0,04 ^{b}	0,57 ±0,07 ^{b}	0,09±0,03 ^{b}	1,89±0,02 ^{a}	0,023 ±0,001 ^{a}
	Summ	0,049 ±0,002 ^{a}	0,51±0,06 ^{a}	0,049± 0,003 ^{a}	1,09±0,02 ^{a}	0,012 ±0,003 ^{a}
	Autm	0,11 ±0,045 ^{b}	0,57 ±0,03 ^{b}	0,11±0,03 ^{b}	1,57±0,03 ^{a}	0,01 ±0,001 ^{a}
Annual M.V.		0,075 ±0,03 ^{A}	0,54±0,045 ^{C}	0,074±0,03 ^{A}	1,61±0,37 ^{CA}	0,014 ±0,006 ^{A}
S6	**Went**	0,036 ±0,014 ^{a}	0,31 ±0,02 ^{a}	0,04 ±0,002 ^{a}	0,7 ±0,035 ^{a}	0,008 ±0,001 ^{a}
	Spri	0,052±0,008 ^{a}	0,34±0,02 ^{ba}	0,051 ±0,005^{a}	0,83±0,02 ^{a}	0,01 ±0,001 ^{a}
	Summ	0,1±0,04 ^{b}	0,36 ±0,04 ^{b}	0,101 ±0,008 ^{b}	0,9 ±0,025 ^{a}	0,01 ±0,001 ^{a}
	Autm	0,11±0,08 ^{b}	0,39 ±0,05 ^{cb}	0,11±0,04 ^{b}	0,926± 0,035 ^{a}	0,01 ±0,001 ^{a}
Annual M.V.		0,074 ±0,04 ^{A}	0,35 ±0,034 ^{D}	0,076±0,03 ^{A}	0,84 ±0,1 ^{D}	0,01±0,001 ^{A}
S7	**Went**	0,037± 0,006 ^{a}	0,014±0,002^{a}	0,039± 0,003 ^{a}	0,0045±0,0015 ^{a}	0,01 ±0,0003 ^{a}
	Spri	0,05 ±0,013 ^{a}	0,024±0,002^{b}	0,049 ±0,003 ^{a}	0,005 ±0,002 ^{a}	0,01 ±0,001 ^{a}
	Summ	0,049±0,005 ^{a}	0,025±0,004^{b}	0,05±0,001 ^{a}	0,005±0,001 ^{a}	0,011 ±0,002 ^{a}
	Autm	0,051 ±0,001 ^{a}	0,026±0,003^{c}	0,05 ±0,002 ^{a}	0,004 ±0,001 ^{a}	0,011 ±0,001 ^{a}
Annual M.V.		0,047±0,007 ^{B}	0,02 ±0,006 ^{E}	0,05±0,005 ^{A}	0,005±0,0005 ^{B}	0,01 ±0,001 ^{A}
S8	**Went**	0,038±0,004 ^{a}	0,15 ±0,03 ^{a}	0,038±0,002 ^{a}	0,75 ±0,03 ^{a}	0,008 ±0,0004 ^{a}
	Spri	0,045 ±0,002 ^{a}	0,19 ±0,04 ^{b}	0,043 ±0,003 ^{a}	0,8 ±0,025 ^{a}	0,01 ±0,0014 ^{a}
	Summ	0,09±0,03 ^{b}	0,2 ±0,03 ^{b}	0,09±0,01 ^{b}	0,98 ±0,095 ^{a}	0,011 ±0,003 ^{a}
	Autm	0,11 ±0,04 ^{b}	0,28 ±0,05 ^{c}	0,095±0,004 ^{b}	0,9±0,03 ^{a}	0,01 ±0,002 ^{a}
Annual M.V.		0,07 ±0,03 ^{A}	0,22±0,06 ^{BE}	0,07±0,03 ^{A}	0,9±0,1 ^{D}	0,01 ±0,001 ^{A}
S9	**Went**	0,033±0,007 ^{a}	0,011± 0,002 ^{a}	0,031 ±0,002 ^{a}	0,005±0,001 ^{a}	0,0077 ±0,002 ^{a}
	Spri	0,052±0,003 ^{a}	0,021 ±0,003 ^{b}	0,049 ±0,002 ^{a}	0,005±0,002 ^{a}	0,011 ±0,002 ^{a}
	Summ	0,051±0,008 ^{a}	0,023 ±0,003 ^{bc}	0,05±0,003 ^{a}	0,0051± 0,001 ^{a}	0,01 ±0,001 ^{a}
	Autm	0,05±0,02 ^{a}	0,025 ±0,002 ^{c}	0,05±0,006 ^{a}	0,0056 ±0,0007 ^{a}	0,0107 ±0,001 ^{a}
Annual M.V.		0,05±0,01 ^{B}	0,02 ±0,006 ^{E}	0,045 ±0,009 ^{A}	0,005 ±0,0003 ^{B}	0,01 ±0,002 ^{A}
S10	**Went**	0,051±0,01 ^{a}	0,023 ±0,02 ^{a}	0,052± 0,004 ^{a}	0,005 ±0,001 ^{a}	0,011 ±0,002 ^{a}
	Spri	0,05 ±0,002 ^{a}	0,024±0,002 ^{ab}	0,05±0,001 ^{a}	0,0051 ±0,0007 ^{a}	0,01 ±0,002 ^{a}
	Summ	0,049±0,01 ^{a}	0,025±0,004 ^{ab}	0,049± 0,001 ^{a}	0,0053±0,002 ^{a}	0,011 ±0,002 ^{a}
	Autm	0,052 ±0,002 ^{a}	0,026±0,002 ^{b}	0,05 ±0,003 ^{a}	0,005±0,001 ^{a}	0,011 ±0,002 ^{a}
Annual M.V.		0,05 ± 0,001 ^{B}	0,024 ±0,001 ^{BE}	0,051±0,001 ^{A}	0,0052±0,0001 ^{B}	0,011±0,0006 ^{A}
S11	**Went**	0,055 ±0,03 ^{a}	0,12±0,02 ^{a}	0,049±0,002 ^{a}	0,65±0,04 ^{a}	0,01 ±0,001 ^{a}
	Spri	0,052±0,004 ^{a}	0,19 ±0,05 ^{b}	0,051±0,001 ^{a}	0,75 ±0,03 ^{a}	0,012 ±0,002 ^{a}
	Summ	0,05±0,004 ^{a}	0,24±0,03 ^{c}	0,05±0,002 ^{a}	0,98 ±0,11 ^{a}	0,012 ±0,002 ^{a}
	Autm	0,091±0,05 ^{b}	0,26 ±0,04 ^{c}	0,099± 0,01 ^{b}	0,9±0,07 ^{a}	0,011 ±0,001 ^{a}

Annual M.V.		0,062±0,02 ^{A}	0,2 ±0,06 ^{E}	0,05±0,025 ^{A}	0,8 ±0,15 ^{D}	0,011 ±0,0008 ^{A}
S12	**Went**	0,052±0,013 ^{a}	0,023 ±0,01 ^{a}	0,051±0,002 ^{a}	0,005±0,001 ^{a}	0,011 ±0,001 ^{a}
	Spri	0,053±0,026 ^{a}	0,023 ±0,005 ^{a}	0,051±0,001 ^{a}	0,005 ±0,001 ^{a}	0,011 ±0,002 ^{a}
	Summ	0,051±0,005 ^{a}	0,02 ±0,002 ^{a}	0,051±0,003 ^{a}	0,005 ±0,001 ^{a}	0,011 ±0,002 ^{a}
	Autm	0,05±0,001 ^{a}	0,021±0,003 ^{a}	0,05±0,001 ^{a}	0,0051±0,001 ^{a}	0,011 ±0,001 ^{a}
Annual M.V.		0,051 ±0,001 ^{B}	0,022±0,002 ^{BE}	0,05 ±0,0006 ^{A}	0,005 ±0,09 ^{B}	0,011±0,0002 ^{A}

Means followed by different letters are significantly different . The LSD0.05 test was used as a post-hoc comparison.

The values followed by the same letters are not significant (lower case letters for saisons and upper case letters for stations).

3. Data analysis

Principal Component Analysis (PCA) was carried out to identify trends, correlations and phenomena that may influence the distribution of chemical elements in the waters of Inaouen and its tributaries. To study the correlations between the physico-chemical variables we perform a principal component analysis. PCA was applied to data including twelve water samples and ten variables (Table 4).

4. Choice of eigenvalues (number of selectable factors)

The treatment of these physico-chemical data by PCA gives several results which are presented in Tables 4 and 5. Table 4 shows the eigenvalues, variability and accumulation, the contributions of the different parameters whose expression on the first two factorial axes F1 and F2 respectively are 70.99% and 12% or 82.99% of the information explained.

Table 4: ***Eigenvalues with an inertia of 82.99%***

Component	Initial eigenvalues		
	Total	% of variance	cumulative%
1	7,100	70,995	70,995
2	1,200	12,002	82,997
3	0,744	7,439	90,436
4	0,492	4,925	95,360
5	0,314	3,142	98,503
6	0,079	0,792	99,295
7	0,052	0,522	99,817
8	0,017	0,169	99,985
9	0,001	0,012	99,997
10	0,000	0,003	100,00

5. Analysis of the distribution of the parameters in the F1xF2 plane

Examination of the correlation matrix between the variables shows a significant correlation between NO_3^-*BOD5 (0.964); PO_4^{3-}*BOD5 (0.962); NO_3^-*NH_4^+ (0.966); NO_3^-*SO_3 (0.926); PO_4^{3-}*SO_3 (0.919); DO*NO_3^- (-0.973) and DO*BOD5 (-0.942). There is also a lower degree of correlation between variables such as NH_4^+*PO_4^{3-}(0.898); SO_3*DBO5 (0.887); F° *DBO5 (-0.736); F° *NH_4^+ (-0.736) and F°*SO_3 (-0.727). These different correlations reflect the influence of each parameter on the mineralization of the waters of the Wadi Inaouen and its tributaries (Table 5).

Table 5: ***The Correlation Matrix***

	DBO5	SO_3	NH_4^+	NO_3^-	EC	pH	T	DO	PO_4^{3-}	F°
DBO5	1,000									

SO_3	0,887	1,000								
NH_4^+	0,957	0,914	1,000							
NO_3^-	0,964	0,926	0,966	1,000						
EC	0,647	0,699	0,631	0,707	1,000					
Ph	0,044	0,260	-0,063	0,130	0,278	1,000				
T	-0,467	-0,368	-0,349	-0,492	-0,487	-0,256	1,000			
DO	-0,942	-0,916	-0,914	-0,973	-0,650	-0,246	0,556	1,000		
PO_4^{3-}	0,962	0,919	0,898	0,923	0,641	0,210	-0,537	-0,947	1,000	
F°	-0,736	-0,727	-0,736	-0,813	-0,629	-0,132	0,243	0,768	-0,646	1,000

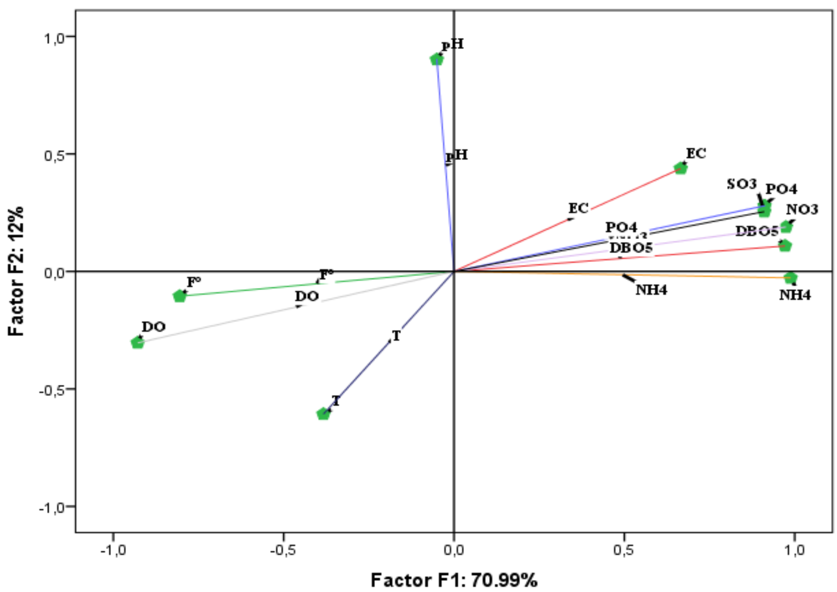

Fig 2: Graphical presentation of one's own factorial design F1 x F2 (82.99%)

In the figure formed by the F1 and F2 axes (Fig. 2), there is a range of variables such as EC, SO_3, NO_3^-, PO_4^{3-}, BOD5 and NH_4^+ that are positively correlated on the F1 axis with a variability of 70.99%. Inversely, there is a negative correlation between the variables F°, DO, T and pH On the F2 axis, with a variability of 12%, there is a positive correlation between the variability of pH, EC, PO_4^{3-}, NO_3^-, $SO_3$and BOD5, inversely to the variable F°, DO, T and NH_4^+.The graph in Fig.3 illustrates the distribution of the different sampling stations studied (12 stations) on the factorial plane F1 x F2, which will be automatically unhooked with that of the variables (chemical elements) to give an idea of the groups according to their quality. The projection of the sampling stations on the factorial plane F1xF2, confirms the existence of four more or less distinct zones (GI, GII, GIII, and GIV) (Fig 3): Group I: represented by stations S1, S3 and S4, the water in this zone is characterized by anthropogenic, industrial and agricultural pollution resulting in high levels of BOD5, NO_3^-, SO_3 and PO_4^{3-}. This significant load of chemical elements and organic matter seems to be mainly due to human activity (wastewater from the city of Taza). Group II: This group occupies the positive parts of F1 and the negative part of F2. It is represented by stations S5, S6, S8 and S11. This area, in addition to their anthropogenic pollution caused by domestic and agricultural discharges, is characterized by a high load of NH_4^+, which could be related to the anaerobic conditions of the ecosystems. Group III: occupies the negative part of F1 and the positive part of F2 and is represented by stations S2, S7 and S9 which present less polluted waters from a mineralization point of view, the waters of the stations S7 and S9 come out of the Middle Atlas characterized by an excellent water quality and which is far from the agglomerations with high Ca^{2+} and Mg^{2+} contents, for S2, the waters are strongly influenced by the presence of $CaSo_4$ gypsum and NaCl halite in the marly-limestone geological

substrates of the preriff. The group IV represented by S12, Idriss I dam which receives water from Inaouen and other tributaries of the middle atlas (matmata gallery and wadi Bouzemlane) and S10 wadi matmata which a compensation gallery of the two dams, the water in these two stations are of very good quality characterized by a high hardness, temperature and dissolved oxygen content this is mainly due to the inflow of water out of the middle atlas at the self-purification of the wadi Inaouen.

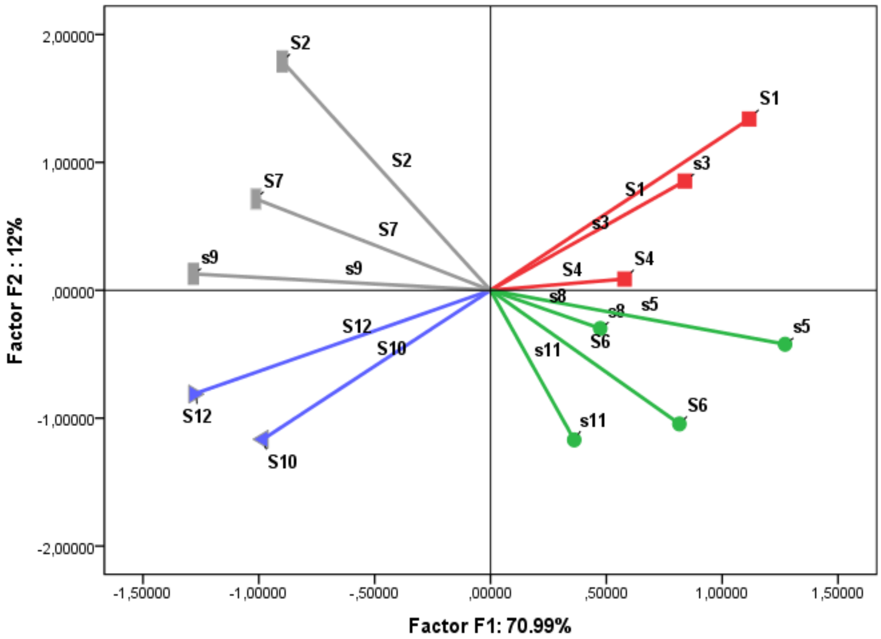

Fig 3: representation of the stations in the factorial plane F1 × F2.

6. Conclusion

Several parameters such as physico-chemical parameters and heavy metals are taken into account in our study on the water of the wadi Inaouen and its main tributaries. Ten water quality parameters and five heavy metals were considered to assess the water quality of the rivers.

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