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Contribution to comparative study of the physico-chemical quality of waters of Moulouya and Ansegmir rivers in upstream of Hassan II dam (Province of Midelt, Morocco)

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Abstract

The hydrographic network of the watershed of lake of Hassan II Dam (Midelt, Morocco) is fairly well developed. This latter is mainly represented by rivers Moulouya and Ansegmir, whose flows are virtually permanent. With an area of 3300 km² approximately, catchment of the dam is subject to the phenomenon of erosion and anthropogenic disturbances that can have a negative effect on the quality of water injected into the dam. The aim of this work is to evaluate the impact of the waters of Moulouya and Ansegmir rivers on the Hassan II dam. To do so, we started a comparative study of the physico-chemical quality of water injected by these two wadis in the lake of the dam during the period from September 2011 to August 2012. The results obtained showed that the waters of the Moulouya river were characterized by a high organic and mineral pollution; they were hard, rich in total phosphorus, sulfates, chlorides and ammonium compared to the Ansegmir river which the load of suspended matter and nitrates was very important. Comparison of flow of total phosphorus and suspended matter brought by the wadis in lake of the dam showed that Moulouya seems to have an eutrophying impact and the Ansegmir river seems to have a silting effect.

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Introduction

Morocco has long been committed to a proactive policy to provide the country with a large infrastructure of large dams. However, it remains that these works constructed are constantly threatened by siltation and eutrophication phenomena (Niazi *et al.*, 2005). These two phenomena are mainly favored by the current climate increasingly drier and the intrinsic characteristics of watersheds. However, the spatio-temporal variability of rainfall is considerable and is a characteristic of the climate of Morocco. It causes the periods of drought that can last more than two years, and floods caused by the violent storms or to widespread weather disruptions (Bouaicha and Benabdelfadel, 2010), supporting the natural process of soil erosion in the watersheds, and inducing, thereby, an alteration of water quality by providing different pollutants (El Ghachtoul *et al.*, 2005).

The Hassan II dam currently ranks, viewpoint capacity, as the largest dam in the Moulouya basin with a maximum storage capacity of about 400 million cubic meters. It is a wealth of varied economic potentialities. This is an important reserve of water for the production of drinking water and irrigation. The dam also contributes to the protection of downstream areas against flooding, and it participates in the alleviation of the siltation of Mohammed V dam, located downstream (DHA, 2008). This lake is an attractive tourist environment for practitioners of sport fishing, emanating from the surrounding regions, and a refuge for migratory birds. The watershed of the dam is subject to the phenomenon of water erosion (Ahamrouni, 1996 and Naslhaj, 2009) and anthropogenic disturbances that can have a negative effect on the quality of water injected into the dam by the two main tributaries: Moulouya and Ansegmir.

The study of the water quality of the Moulouya river has attracted interest from a number of researchers, including Makhoukh (2012), Lamri and Belghiti (2011), Berrahou *et al.*, (2001). Although these studies have focused on the whole Moulouya river, they were, however, fractionated in time and no study of them has a special interest in the study of the tributaries of the dam Hassan II. The present work fills this gap and complete the study had focused on the physico-chemical water quality of the Hassan II dam (Chahboune *et al.*, 2013). It aims to assess the potential impacts of the wadis Moulouya and Ansegmir on the Hassan II dam; this through monitoring, during an annual cycle: from September 2011 to August 2012, of the physico-chemical quality of the water injected by these two tributaries in the lake of the dam. Indeed, the understanding of these impacts may facilitate the nature of the preventive measures that should start actors of the sector of water in upstream of the dam for to ensure its durability and utility.

Materials and methods

Presentation of the study area

The catchment of the dam is drained by two main tributaries: Moulouya and Ansegmir. These latter drains an area of 991 km² upstream the hydrological station of Ansegmir, however the Moulouya drains a sub-basin of 1840 km² upstream the hydrological station of Zaida (Riad, 2003). Both rivers receive, throughout their upper streams, domestic discharges of agglomerations. They also receive waste from agriculture developed in the valleys of the two wadis. In addition, the Moulouya drains water from the abandoned mining district of Zaida. This dam is situated in Midelt plain (South-East Region Meknes-Tafilalt in the center of Morocco) (Fig. 1).

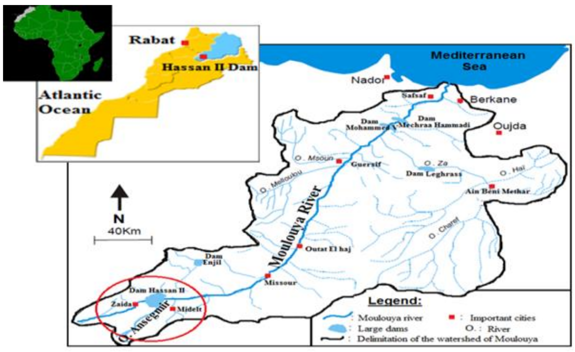

Fig. 1. Geographical situation of the Hassan II dam in the watershed of Moulouya. (Dakki *et al.,* 2003.) (With modifications).

The soils of the study area is distributed between soil on granite, soil on arkosic Triassic forms, and soils on Jurassic carbonate formations (Amrani *et al.*, 2006). The scattered vegetation is represented mainly by tufts of alfa (*Stipa tenacissima L.*) and wormwood (*Artemisia herba alba*), which undergo the action of a constant and prolonged overgrazing (Rhanem, 2009).

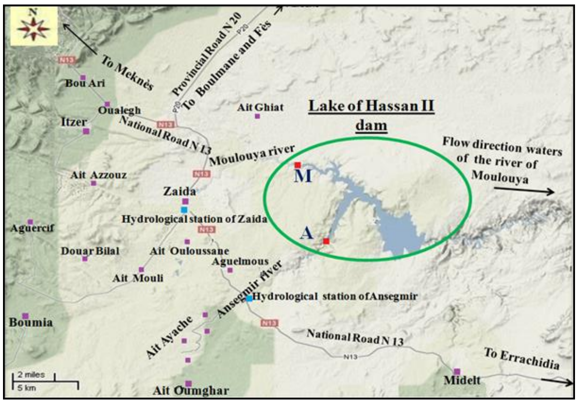

Fig. 2. Localization of the sampling sites in Moulouya and Ansegmir rivers.

(Source map: http://earth.google.fr) (With modifications).

Choice of stations and sampling frequency

In order to quantify the inputs of pollutants injected by the two wadis Moulouya and Ansegmir in the lake of the dam, prospecting the terrain has allowed us to determine the location of the two sampling stations (Fig. 2):

- Station M (32 ° N 51585; 53208 004 ° W; Altitude: 1466.4 m) was chosen on the river of Moulouya.
- Station A (32 ° 46.022 N, 004 ° 52 882 O; Altitude: 1421 m) was located on the river of Ansegmir.

These two stations were selected so that they are as close as possible to the mouth of the river into the lake of the dam, but staying outside the area of its influence.

The sampling campaigns were conducted during the period from September 2011 to August 2012 with a monthly frequency. However the Moulouya was dry during the 11th (July) and the 12th campaign (August), but, Ansegmir was dry at the 12th campaign.

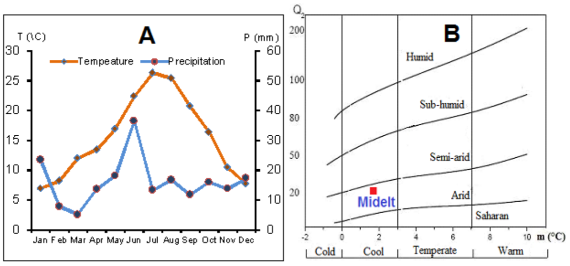

Fig. 3. Ombrothermic diagram of Gaussen of the study area (A), and positioning of station of Midelt in Emberger climagramme (B).

Climatic characteristics and Flows at the two stations

The use of climate data over a period of 10 years (2001-2010), provided by the Meteorological park of Midelt showed that the study area has an alternation of two periods: a dry, longest, from February to November and a wet, short lasted two months (December and January) (Fig. 3A). The pluviometric quotient of Emberger (Q_2) showed that the area belongs to the arid bioclimatic floor with a cool winter (Fig. 3B). Both ombrothermic diagrams of the two stations surveyed during the study period are almost identical (Fig. 4), precipitation was characterized by significant variability from one month to another, they have intensified in November. The wet period is represented by the month November and January. Comparing ombrothermic diagrams derived from climatic data of the study period with those established over a longer period (Fig. 3A) shows that there is an interruption of the wet period (November and January) by one dry month (December).

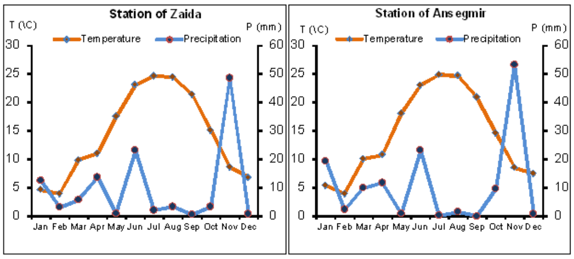

Fig. 4. Ombrothermic diagrams of Gaussen of the stations studied: Zaida and Ansegmir during the study period.

Average flows of the two wadis during the study period, provided by the Agency Water of Basin Moulouya, showed that the hydrological regime of the Moulouya evolved in much the same way as that of the Ansegmir wadi (Fig. 5). However, with the exception of November, the average flow of the Ansegmir river were more important than the Moulouya river. The latter had a maximum average flow of about 3.43 m3/s in November against an average flow of 3.88 m3/s in April for Ansegmir Wadi.

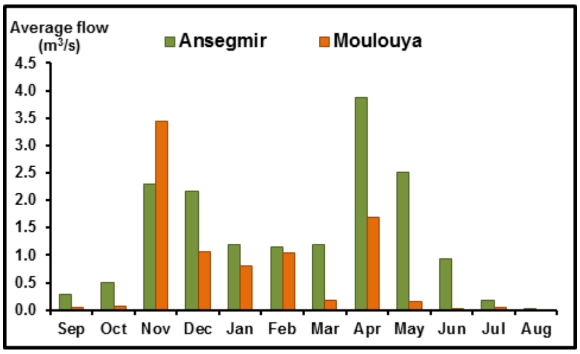

Fig. 5. Changes in monthly average flow at the two hydrological stations: Zaida and Ansegmir during the study period.

Sampling and analytical methods

The samples were taken according to standardized techniques (Rodier *et al.,* 2009). Some parameters were measured in situ, namely, the water temperature, the hydrogen potential (pH), dissolved oxygen and the electrical conductivity.

The samples were stored at ±4°C in cold boxes, and they were transported to the, Laboratory of Team of Management and valorization of Natural Resources, Faculty of Sciences of Meknes in which we have made the physico-chemical analyzes using the methods described by Rodier (Rodier *et al*, 2009.): suspended matters (membrane filtration), nitrates (molecular absorption spectrometry), ammonium (indophenol blue method), total nitrogen (mineralization peroxodisulfate), total phosphorus (mineralization sodium persulfate), total hardness (titration EDTA), sulfates (nephelometric method), chlorides (Mohr's method), biological oxygen demand in five days (method for undiluted samples), chemical oxygen demand (reflux method in an open system).

Results

Water temperature, pH, electric conductivity, sulfates, chlorides and total hardness

During the entire study period, the waters of the Moulouya were colder than those of the Ansegmir wadi (Fig. 6A). The water temperature is gradually lowered from September to February. The lowest values were recorded during this month (Moulouya: 3.3 ° C *vs.* 5 ° C: Ansegmir). Then the water is warmed gradually to the maximum values in June (Moulouya: 23.3 ° C *vs.* 28.6 ° C: Ansegmir).

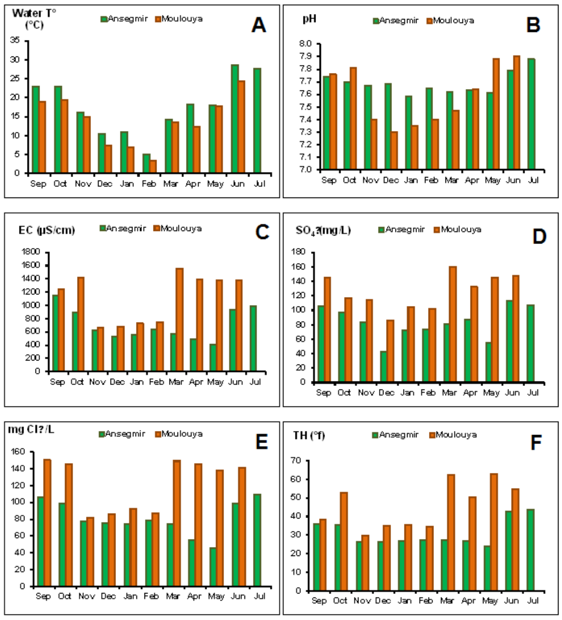

Fig. 6. the spatiotemporal evolution of water temperature (A), the pH (B), the electrical conductivity (C), sulfates (D), chlorides (E) and total hardness (F) at two stations: Moulouya and Ansegmir during the study period.

The waters of the two wadis were slightly alkaline (Fig. 6B). From November to March the waters of the Ansegmir river were more alkaline than those of the Moulouya river and vice versa during the other months of the study cycle.

Waters of Moulouya river were more mineralized than those of Ansegmir wadi (Fig. 6C). The evolution of water's electric conductivity in Moulouya showed important values for the months September and October, and the conductivity decreased and evolved almost shelf from November to February, then she resumed increase in March. The lowest values of the conductivity of the water of Ansegmir river were recorded during the period extending from November to May and the largest in the other months of the study period. However, the minimum value was reported in the month of May and maximum in the month of September.

Waters of Moulouya river were richer in sulfates than those of Ansegmir wadi (Fig. 6D). At the two wadis, concentrations of water sulfates decreased gradually from September to December, then they increased from January to March for Moulouya river, and they continued to increase until April at Ansegmir wadi.
Waters of Moulouya river were more loaded with chlorides than those of Ansegmir wadi (Fig. 6E). Low concentrations were reported from November to February at Moulouya and from November to May at Ansegmir.

During the entire period of the hydrological cycle, waters of Moulouya were harder than those of the Ansegmir wadi (Fig. 6F). Important values of total hardness of water at both wadis were reported to the extremities of hydrological cycle. The maximum total hardness at Moulouya and Ansegmir were 63 °f (May) and 43.5 °f (July) respectively.

Dissolved oxygen, biological oxygen demand of 5 days (BOD), chemical oxygen demand (COD), suspended matters, total phosphorus and nitrogen compounds
Total intakes of suspended matters (SM) were rather provided by the Ansegmir river than by the Moulouya wadi (Fig. 7A). The maximum concentration at Ansegmir wadi was recorded in the month of April. However, in the Moulouya the high content of suspended matters was recorded at May. At both stations, the minimum concentrations were reported at March (Ansegmir 12.2 mg/L vs. 3.33 mg/L Moulouya).

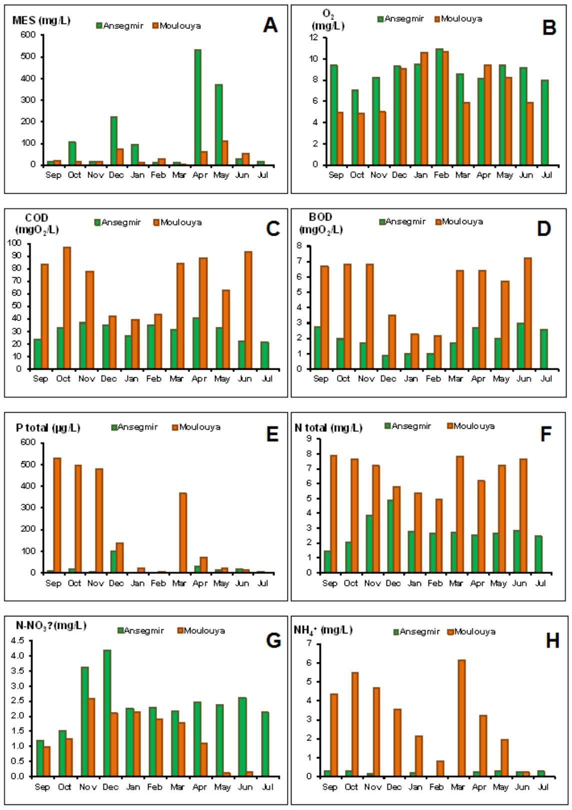

Fig. 7. Spatiotemporal evolution of suspended matter (A), dissolved oxygen (B), COD (C), BOD (D), total phosphorus (E), the total nitrogen (F) , nitrates (G) and ammonium (H) at the two stations: Moulouya and Ansegmir during the study period.

Generally the waters of Ansegmir wadi were more oxygenated than those of Moulouya (Fig. 7B). The oxygenation of the water was higher in the two wadis at February.

Organic pollution was more important in Moulouya manifested by higher values of COD and BOD reported in this wadi compared to those found at Ansegmir. Organic pollution was increasing at the extremities of the cycle of study (Fig. 7C and 7D).

Important intakes of total phosphorus (total P) were provided by the Moulouya whose high concentration was reported at September (526.54 mg/L). As for the Ansegmir river, the important content was noticed at December (97.57 mg/L). During the other months the supply was much lower (Fig. 7E).

Waters of Moulouya were loaded by total nitrogen than the Ansegmir wadi (Fig. 7F). The high content of this element was reported at December for the Ansegmir wadi (4.86 mg/L) and at September for Moulouya (7.85 mg/L). However, the low concentrations measured in the Ansegmir and Moulouya corresponded to September (1.45 mg/L) and February (4.95 mg/L) respectively.

The waters of the Ansegmir river were richer in nitrates (Fig. 7G), concentrations were between 4.17 mg/L (December) and 1.19 mg/L (September). At the Moulouya nitrate content increased progressively from September (0.97 mg/L) to November (2.57 mg/L) and then gradually decreased to record low levels at May (0.11 mg/L).

Waters of Moulouya were richer in ammonium (Fig. 7H). Concentrations of this element provided by this wadi were progressively decreased in October (5.46 mg/L) to February (0.78 mg/L) and a peak was pointed at March (6.14 mg/L), then content declined to reach the lowest concentration at June (0.23 mg/L). Ammonium amount at Ansegmir wadi remained low during the study period, and the maximum concentration was noticed at October (0.3 mg/L) and the content is canceled at December.

Flows of elements injected into the dam

The calculation of incoming flows is estimated that since we have only one monthly and punctual measure per element. By neglecting the contributions of other smaller streams that flow only during floods, the overall estimate of incoming flows is performed by calculating annual loadings on the basis of monthly flows (Equation (*)). Monthly flows are determined by multiplying the concentrations of the elements studied and monthly average flows of river concerned. Inflows are summarized in Table 1. Ansegmir river was the main supplier of nitrates and suspended matters, however the Moulouya wadi was the primordial provider of total phosphorus, total nitrogen and ammonium.

$$\text{Incaming flows (Tons/year)} = \sum_{n=1}^{12} (N * 86400 * Qmoy * C) * 10^{-9} \quad (*)$$

With:

Qmoy: average flow in liters/second in the month in question; C: concentration of desired element in mg/L in the month concerned; N: number of days in the month in question; 86400: number of seconds per 24 hours.

Table 1. Estimates of quantities of different elements injected by Moulouya and Ansegmir rivers in Lake of Hassan II dam during the hydrological cycle: 2011-2012.

	Suspended matters (Tons)	**total nitrogen (Tons)**	**Nitrates (Tons)**	**Ammonium (Tons)**	**total phosphorus (Tons)**
Ansegmir	9805	118,60	107,91	6,96	1,03
Moulouya	764,69	141,6	44,44	77,69	5,35

Typology of physico-chemical water quality of the two wadis

The principal component analysis is performed on an array of data from 21 individuals (stations at different months) and 15 variables: water temperature (T° water), flow, electrical conductivity (EC), total hardness (TH), sulfate (SO4), pH, suspended matters (SM), total nitrogen (TN), nitrate (NO3), ammonium (NH4), total phosphorus (TP), chemical oxygen demand (COD), biochemical oxygen demand (BOD), chloride (Cl) and dissolved Oxygen (O2). The F1-F2 factorial plane allowed us to explain 72.68% of the total variability.

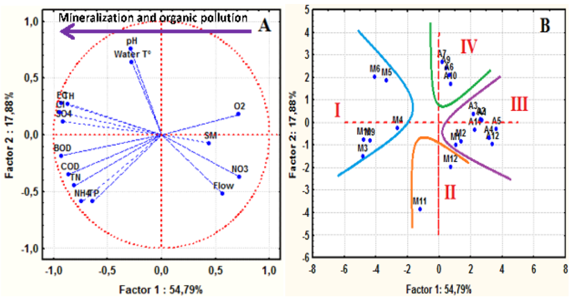

Fig. 8. Principal Component Analysis (A): Physico-chemical variables collected in the two wadis Moulouya and Ansegmir. (B) factorial map of individuals (stations). The different letters associated with the numbers distinguished sampling points (stations), the number corresponds to the month of sampling, the months are numbered by number from 1 to 12, with: number 1 is January and so on until 12, which designates the month of December.

The circle of correlation variables (Fig. 8A) showed that:

The flow, nitrates, dissolved oxygen and suspended matters were positively correlated with F1, unlike the electric conductivity, chlorides, total hardness, sulfates, total nitrogen, ammonium, total phosphorus, BOD and COD which were negatively associated with this axis. So, this latter opposes water loaded in suspended matters and nitrate to water characterized by high mineral and organic pollution. The temperature and the pH of water were positively correlated with the axis F2.

The factorial map of individuals (F1xF2) (Fig. 8B), showed that the waters of the two wadis presented different physico-chemical characteristics and secondly the water quality differed at the same wadi that according it is a sample taken during low flow (low water) or high flow (high water).

The overall analysis allows to define a typology dominated by the individualization of four groups of stations (Fig. 8A and 8B).

- The first group (I) is represented by the station of Moulouya during the low water period (March to June, September and October), the waters were characterized by their high mineral and organic pollution;
- The second (II) is formed by the station of Moulouya during the high water period (November and December), they were characterized by cold and near neutrality waters;
- The third group (III) is formed by the station of Ansegmir during the high flow period (November to May), and the station of Moulouya during the period following the period of high waters, the waters were well oxygenated, characterized by their high flow rates and their high load of suspended matters and nitrate;
- The fourth (IV) is represented by the station of Ansegmir during the low flow period (September, October, June and July); the waters were more alkaline and characterized by high temperatures.

Discussion

At the two tributaries, water inputs is influenced by rainfall had received the watershed of the dam. Snowmelt, ensured a continued flow in April, May and June. However, water inflows are largely insured by the wadi Ansegmir. The flow peak at April in Ansegmir seems to be generated by rainfall associated with snowmelt accumulated during the winter on the famous Jebel Ayachi. This last culminating at 3751 meters (Blache, 1920). Depletion in reserves of snow, stopping precipitation and accentuation of the withdrawals for irrigation of agricultural parcels developed throughout the two valleys, are all factors which significantly influenced the flow rates that were lowered from the month June and July at the two wadis Moulouya and Ansegmir respectively.

Sub-basin drained by the Ansegmir river compared to that drained by the Moulouya appears to be the most exposed to water erosion manifested by enormous quantities of suspended matters injected by this wadi in the dam and that were estimated at 9805 tons.

During the study period waters of Moulouya river were colder than those of Ansegmir wadi. This result could be explained by the high load of suspended

matters in water of Ansegmir wadi compared to those of Moulouya. Such higher levels of suspended matters could cause warming of the water through the phenomenon of absorption of solar energy as it has been demonstrated by Hébert and Légaré (2000).
The pH of the water in two wadis remained slightly alkaline, this could be related to the carbonate nature of the geological outcrops of watershed drained (Igmoullan *et al.*, 2001). According to the classification given by Nisbet and Verneaux, the pH values of the waters of the river Ansegmir during the entire study periodas well as those of Moulouya during the dry period were classified waters of these tributaries in the fifth class characterized by low alkalinity waters. However, the pH values of the waters of Moulouya during the period of high water class this waters in the 4th class which corresponded to water with close neutrality. These classes of pH characterized piscicultural waters and limestone regions (Nisbet and Verneaux, 1970) and this is the reason, presumably, among others, to explain high hardness of waters in the two wadis.

In addition to the wastewater discharged by the waterfront communities in the Moulouya river, the important mineralization waters of this wadi compared to those of Ansegmir wadi could also be explained by the fact that the Moulouya river drains Zaida abandoned mine site. According to the classification given by Rodier (Rodier *et al.*, 2009), the waters of the Moulouya showed an important mineralization during periods of high flow, while they were shown a high mineralization during the low water period. However, the waters of the Ansegmir river had presented mineralization moderately accentuated during the period of high flow, whereas they were characterized by a significant high mineralization during the low water period.

Waters of Moulouya river were less oxygenated than those of Ansegmir wadi, this low oxygen content could be explained by organic pollution characterizing the waters of this river due to wastewater discharged by cities located upstream of the dam, thus, agglomerations Boumia, Zaida, Tounfite and Itzer poured approximately 404000 m^3 of wastewater and about 458 tons/year of BOD_5 in Moulouya (AWBM, 2009). These spills were the likely source of significant levels of ammonium recorded in this wadi, this element exists only in waters rich in decaying organic matter, when oxygen levels are insufficient to assure oxidation (Nisbet and Verneaux, 1970).

The waters of the Ansegmir river were richer in nitrate than those of Moulouya, but the content at the two wadis was far from being close to the guideline value set by the World Health Organization for that water is drinkable (WHO, 2011). Nitrates constitute the largest fraction of the total nitrogen in the waters of the river Ansegmir, this suggests an agricultural origin of the nitrogen supplied by this river as it showed by Martinelli in his work on the effects of wastewater on the chemical composition of the Piracicaba River in Brazil (Martinelli *et al.*, 1999).

The role of phosphorus in the eutrophication was highlighted since several years (Schindler and Fee 1974, Hecky and Kilham, 1988), the total annual flow of total phosphorus injected into the dam Hassan II by both wadis is estimated at 6.38 tons. Majore part of this quantity (83.85%) was provided by the Moulouya river. For comparison this quantity remains minimal to the quantity injected by Oum Errbia river in Al Massira dam (Mhamedi Alaoui *et al.,* 1994).

The principal component analysis corroborated the results of spatio-temporal variations of physico-chemical parameters and showed an opposition of the flow to the organic and mineral pollution characterizing waters of Moulouya river, suggesting a point source of origin of these two types of pollution from wastewater discharges and not to soil leaching.

Conclusion

Following this study, the results obtained revealed that the waters of the Moulouya river were characterized by an important mineral and organic pollution, they were hard, rich in total phosphorus, sulfates, chloride and ammonium compared to those of Ansegmir wadi whose load of suspended matters and nitrate was very important.

Besides the positive impacts, represented by the large quantities of water introduced by the Ansegmir wadi on the Hassan II dam, high intakes of suspended matters and nitrates associated with large flows of total phosphorus and ammonium assumed by Moulouya river would result in a contribution to the eutrophication and siltation of this artificial lake. To ensure its durability and utility, corrective interventions ensuring a reduction in incoming flows in these pollutants are being required, we recommend as follows:

- Establishment of a depollution program in agglomerations located upstream of the dam through the adequate treatment of wastewater before being discharged into the Moulouya river, and the establishment of a common controlled discharge between all commons;
- The sensitization of farmers from Ansegmir and Moulouya valleys on the interest of soil analysis to determine their wealth of nutrients and taken into account before begin fertilization;
- The strengthening of soil conservation interventions initiated at the sub-watershed drained by the river Ansegmir.

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