Monitoring of the water’s quality of Moulouya River: main tributary of Hassan II dam (Province of Midelt, Morocco)

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Abstract

The Watershed of Hassan II dam contains a fairly well developed river system, including the Moulouya River and Ansegmir River whose flows are almost permanent. This watershed drains an area of 3300Km² and it is subject to anthropogenic disturbances that can have a negative effect on the quality of water supplied to the dam whose health is affected by the intrinsic characteristics of the watershed. Indeed, Moulouya receives throughout its headwaters domestic discharges from local populations and pollutants from agriculture developed throughout the valley of the upstream part of the wadi. The objective of this work, spread over the period from September 2011 to August 2012, is to monitor the physico-chemical quality of the water of Moulouya river at a station situated just in upstream of the confluence river-lake of the dam, eventually leading to an estimate of the quantity and quality of pollution injected by this River in the Hassan II dam. It shows that the average concentrations of total suspended solids, total phosphorus and nitrate (expressed as nitrate ion) in water injected into the dam, were in the range of 39.21 mg/L, 212.83 mg/L and 6.23 mg/L respectively.

Keywords: Moulouya River, Watershed, Water, Hassan II dam, Morocco.

1. Introduction

Moroccan’s water resources are both limited and under pressure accompanied by increasing quality degradation [1]. Increased human activities developed upstream of the lake of Hassan II dam [2], combined with the phenomenon of erosion [3], could contribute to siltation and eutrophication of this ecosystem. In order to characterize and quantify the pollutant loadings injected by the Moulouya River in the lake of the dam, we followed the physico-chemical quality of the water during an annual hydrological cycle: from September 2011 to August 2012, in a station located just in upstream of the confluence river-lake of the dam.

2. Materials and methods

2.1. Presentation of the study area
The Hassan II dam is located in the south-eastern of Meknes-Tafilalet region, in central Morocco; it is installed on the Moulouya river in northwest of the Midelt town. It is from this city about 12 km as the crow flies (Figure 1). The sub-watershed drained by the Moulouya River above the Hassan II dam is subject to human disturbance. This stretch of the river of Moulouya receives domestic agglomeration discharges riparian, as well as waste and residues resulting from abandoned mining district of Zaida and agriculture developed throughout the valley of this River. The study area is included in the high Moulouya characterized by an arid climate with cold mountain trend [4]. The soils in the study area are divided between soils on granite, soils on arkosic Triassic forms, and soils on Jurassic carbonate formations [5]. The vegetation, scattered, 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 [6].

![Figure 1](http://earth.google.fr) Location of the Hassan II dam and the sampling station (Source map: http://earth.google.fr, with modifications).

2.2. Choice of station and sampling frequency
In order to quantify the pollutant loadings injected by the Moulouya River into the lake of the dam, we chose a station so that it is as close to the mouth of the river into the lake of the dam, while remaining outside of its zone of influence. This station is named (M) (Figure 1), its coordinates are: 32° 51,585 N; 004° 53208 O; Altitude: 1466.4 m. The sampling campaigns were conducted once per month for a year, from September 2011 to August 2012. So, 12 campaigns. However the Moulouya River was dry during the 11th (July) and the 12th campaign (August).

2.3. Sampling and analytical methods
The samples are collected and transported using standardized techniques. The physico-chemical analyzes are conducted at the Faculty of Sciences of Meknes, in the Laboratory of Environment and Health, Team of Management and valorization of Natural Resources. Some parameters are measured in situ, namely the temperature of the water and air, the electrical conductivity (EC) and pH. The analyzes of the other parameters (Sulfates (SO$_4^{2-}$), total nitrogen (N tot), nitrates (N-NO$_3^-$), Ammonium (N-NH$_4^+$), Total
Phosphorus (TP), total suspended solids (TSS) and total hardness (TH) are performed using the methods described by Rodier [7].

3. Results

3.1. Flow of Moulouya River

The average monthly flow of the Moulouya River at the hydrological station of Zaida, located in upstream of the dam, was provided by the hydrological agency of Moulouya basin. The maximum average flow (3.43 m$^3$/s) is recorded in November then it lowered and stabilized at about 1m$^3$/s in the months December, January and February. The flow resumed the increase in April and then decreased gradually to cancel in August (Figure 2).

![Figure 2](image)

**Figure 2.** Variations of the mean monthly flow at the hydrological station of Zaida during the 2011-2012 hydrological cycle.

3.2. Water and air temperatures

The evolution of the water temperature follows the temperature of the air (Figure 3). The measurement results showed a gradual lowering of the water temperature from September to December, then, a slight increase was observed in January followed by a lowering to achieve the minimum temperature in February (3.3°C). Then temperatures have risen gradually to reach the maximum temperature in June (24.3°C) (Figure 3).

![Figure 3](image)

**Figure 3.** Temporal variations of the temperatures of the air and water of the Moulouya river in upstream of the Hassan II dam.
3.3. Electrical conductivity (EC) and total hardness (TH)

The evolution of the electrical conductivity (EC) of the water showed approximately two plates: the first plate from November to February (EC average was around 702 µS/cm) and the second from March to October (average EC was around 1393 µS/cm) (Figure 4). Total hardness was almost stable from November (29.5°f) to February (34.5°f) and then it became more important from March (62.5°f) (Figure 4).

![Figure 4](image)

**Figure 4.** Temporal variations of the electrical conductivity and total hardness of water of the Moulouya River in upstream of the Hassan II dam.

3.4. Total nitrogen (N tot), ammonium (NH₄⁺) and nitrates (N-NO₃⁻)

The concentration of total nitrogen decreased gradually from September to February, and then it resumed the increase in March, then afterwards it decreased slightly in April, then it increased progressively over the following months (Figure 5).

![Figure 5](image)

**Figure 5.** Temporal variations of contents of total nitrogen (N tot), nitrates (N-NO₃⁻) and ammonium (NH₄⁺) in the waters of the Moulouya River in upstream of the Hassan II dam.

Regarding the ammonium, a first peak is reported in October (5.46 mg/L), and then the concentration decreased until February (0.78 mg/L). A second peak is recorded in months March (6.14 mg/L) and the content was lowered to almost vanish in June (Figure 5).
(N-NO$_3^-$) increased gradually from September to November (2.57 mg/L), then it stabilized slightly until March (1.78 mg/L), then it decreased to the lowest levels in the months of May (0.11 mg/L) and June (0.14 mg/L) (Figure 5)

3.5. Sulfate (SO$_4^{2-}$) and total suspended solids (TSS)

The sulfate concentration decreased gradually from September to December, and then it increased and reached the maximum level in March (160.49 mg/L) (Figure 6). The highest levels of total suspended solids (TSS) are observed in the months of December, April, May (110 mg/L) and June. However, the minimum value is reported at March (3.33 mg/L) (Figure 6).

![Temporal variations of sulfate and total suspended solids](image)

**Figure 6.** Temporal variations of contents of sulfates (SO$_4^{2-}$) and total suspended solids (TSS) in the waters of the Moulouya River in upstream of the Hassan II dam.

3.6. Total phosphorus (TP) and pH

The pH of the water is slightly alkaline. The maximum value is recorded in June (pH 7.9), and the minimum in December (pH 7.3) (Figure 7).

![Temporal variations of total phosphorus and pH](image)

**Figure 6.** Temporal variations of total phosphorus and pH in the waters of Moulouya River in upstream of the Hassan II dam.
The content of total phosphorus (TP) decreased gradually from September to November. And then it decreased brutally to reach a low concentration in February. The Increasing of the content has been taken in March, and then it decreased gradually to a level of 12.62 µg/L in June (Figure 7).

3.7. Incoming flows of different matters

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. Inflows are summarized in Table 1.

\[
\text{Incoming flow (T/\text{year})} = \sum_{n=1}^{12} (N \cdot 86400 \cdot \text{Qmoy} \cdot C) \cdot 10^{-9} \quad (*)
\]

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 River in Lake of Hassan II dam during the hydrological cycle: 2011-2012.

<table>
<thead>
<tr>
<th>Total nitrogen (Tons)</th>
<th>N-NO₃ (Tons)</th>
<th>NH₄⁺ (Tons)</th>
<th>Total phosphorus (Tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>141.6</td>
<td>44.44</td>
<td>77.69</td>
<td>5.35</td>
</tr>
</tbody>
</table>

4. Discussions

Liquid flows injected by the Moulouya River in Lake of Hassan II dam are constituted mainly by rainfall that received the watershed drained by the River. The high flow rates were observed during the winter period. During the study period, the water's temperature follows that of air, low temperatures are a feature of river's water in winter. The waters of Moulouya River showed significant mineralization during the period of high flow. Whereas, they showed a high mineralization (conductivity is greater than 1000 μS/cm) [7] during the low water period. During the winter period, the lowering of the conductivity seems to be related to the phenomenon of dilution. Waters of Moulouya River are rich in sulfates. This water can be classified as more or less selenitic or polluted or selenitic to very highly polluted water [8]. The pH of the water of the Moulouya River remained slightly alkaline. This could be related to the carbonate nature of the geological outcrops in the study region [9]. According to the classification given by Nisbet & Verneaux [8], the pH values, during the period of high water class this water in the fourth class corresponding to water with close neutrality. However, during the low water period, pH of water corresponded to the fifth class characterized by low alkalinity [8]. 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 Moulouya River. The ammonium ions are the most significant fraction of the total nitrogen. The presence of this ion in water is abnormal [10]. Indeed, this element exists only in waters rich in decaying organic matter, when oxygen levels are insufficient to assure oxidation [8]. This high content of ammonium may be related to 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 [2]. The high levels of nitrate recorded during the period of high water suppose the agricultural origin of this element which would be in relation to agricultural soil runoff in the drained watershed. The large annual flux of total phosphorus, considered, with other nutrients, a major component responsible of the eutrophication of aquatic ecosystems [11, 12], would likely have negative consequences on the dam.

5. Conclusion
Waters of Moulouya River injected into the Hassan II dam were slightly alkaline, highly mineralized and rich in sulfates. In addition to the positive impact of Moulouya River on the dam Hassan II represented by high intakes of water. Inward flows nutrient injected by this wadi in lake of the dam would result in a contribution to the eutrophication of the waters of the dam.

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References