Hydrology and water quality of a semi-arid intermittent river: Oued Fez (Morocco)

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INTRODUCTION
Intermittent rivers have a specific hydrological behaviour resulting in long drought periods interrupted by high intensity floods. This behaviour influences water quality dynamics, as during low flow periods pollutants accumulate in the river bed and are flushed away by the first floods (Walling et al., 2003). Some research programmes have investigated the hydrological and pollution transfer mechanisms of intermittent rivers located in Europe. However, little information is available on their African counterparts and thus efficient water management schemes cannot be established. The objective of this work is to understand and quantify water and pollutant dynamics in Oued Fez (Morocco) taking into account its hydrological behaviour. The analysis is based on field data collected from June 2009 to December 2009.

MATERIALS AND METHODS

The study site
Oued Fez is the main water body crossing the city of Fez in Morocco. It is a tributary of the Sebou River (Fig. 1). The river flows in an easterly direction from the springs of “Ras el Ma” in the upper Sebou (420 m.a.s.l) into the Sebou 4 km downstream of the city of Fez (210 m.a.s.l). Its main course has a length of 33 km and its catchment area is of 615 km². Oued Fez has an urban catchment in its downstream part and the Medina (old city) is a densely populated handicraft centre. This generates both industrial and domestic wastewater. The city represents 40% of the total water quality impact on Oued Sebou (ABHS, 2006): all of Fez’s sewage is flushed directly into nearby watercourses. The catchment has a continental semi-arid climate with cold winters and hot summers. Precipitation data shows a high inter- and intra-annual variation of rainfall. Since September 2008 a gauging station has been installed at the outlet of Oued Fez, upstream of the National Electricity Office’s water intake (Fig. 1). Water level measurements are recorded at 5-min intervals by a pressure-transducer and converted to discharge through a rating curve. Rainfall data is available for this catchment through a tipping-bucket raingauge installed on the FST roof by the University’s Physics department. An additional rainfall gauge has been installed on the catchment in spring 2010.

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Water quality measurements
One-day field campaigns that are conducted in steady-state flow conditions at 8 locations. Three stations are located on the Oued Fez (1) and its tributaries before their entries in the Medina (2,3). Two other stations are located on Oued Fez, just downstream of the urban zones (4) and just before the confluence with the Sebou River (6). The three last stations are located on the Sebou River: before the confluence with Oued Fez (5), 100 m after the confluence (7) and 10 km downstream (8). Water discharge is gauged by velocity field exploration, using a current meter. Water samples are taken manually from the middle of the flow section, kept in a cool box and carried back to the laboratory within less than four hours. The samples are immediately treated and preserved until the analysis.

Analytical methods
Water samples are analysed, among other components, for total phosphorus (TP), total nitrogen (TN), and total chromium (TCr) using HACH LANGE DR 2800 VIS-photometer and appropriate cuvette tests.

RESULTS AND DISCUSSION

Hydrology
Figure 2 presents the rainfall data recorded by the FST raingauge during the 2008–2009 hydrological year. By comparison with previous decades, 2008–2009 appears to be an extremely wet year, with an annual rainfall of 842 mm and monthly rainfall values that are systematically higher than the long term averages. 2008–2009 is an exceptional hydrologic year. Two distinct rainfall periods can be observed. The first corresponds to the autumn–winter period, with high rainfall values over consecutive days while the second corresponds to the spring showers with sporadic spells of lower intensity.
The catchment’s response to the rainfall spells is in the order of hours rather than days, as each rainfall peak has a corresponding spike on the hydrograph (Fig. 2). The analysis of the hydrograph’s shape indicates a high flow period in the river starting in November 2008 and ending in May 2009 when the mean daily discharge settles down to its initial value of 1 m$^3$ s$^{-1}$, corresponding to the average base flow value corresponding to urban wastewater. The general bell-like shape of the hydrograph during the high flow period suggests higher groundwater and subsurface flow contribution.

**Water quality**

The pollution levels in the river are very high in the reaches under the influence of wastewater inputs (points 3, 4 and 6): TN > 40 mgN L$^{-1}$; TP > 6 mgP L$^{-1}$. At the other locations (1, 2 and 5), pollution levels are low, although they are sufficient to generate eutrophication phenomena: TN < 6 mgN L$^{-1}$; TP < 1.5 mgP L$^{-1}$. In terms of chromium, if the concentrations in the most polluted sites are very high (TCr > 0.14 mgCr L$^{-1}$ up to 0.8 mgCr L$^{-1}$), those of the less polluted sites are also very significant (TCr > 0.03 mgCr L$^{-1}$). Downstream of Oued Fez’s confluence with the Sebou River (locations 7 and 8), dilution effects are observed although pollution levels remain high (TN > 20 mgN L$^{-1}$; TP > 4 mgP L$^{-1}$; TCr > 0.06 mgCr L$^{-1}$).

In the Sebou River, downstream of its confluence with Oued Fez, TN loads range between 300 and 800 kgN h$^{-1}$, TP between 45 and 100 kgP h$^{-1}$ and TCr between 1 and 8 kgCr h$^{-1}$ (Fig. 3). The pollutant fluxes registered at the entries of the system (locations 1, 2 and 3) are negligible compared to the fluxes observed at the exit of the Old Medina (locations 4 and 6).

**Fig. 2 Daily discharge and rainfall values recorded during the 2008–2009 hydrological year.**

**Fig. 3 Daily TN and TC loads TP concentrations for the 2009 campaigns.**
CONCLUSIONS AND PERSPECTIVES

The results obtained during the first year of the study highlight the particularities of Oued Fez’s hydrological behaviour and its impact on the water quality. Oued Fez and the Sebou River are characterized by severe pollution downstream of the city of Fez. The most polluted sites are those directly under the influence of domestic and industrial wastewater inputs, in particular, tannery effluents. As mentioned by numerous authors (Fekhaoui & Pattee, 1993; Khamar et al., 2000; Koukal et al., 2004), continuous pollution has completely destroyed the aquatic ecosystems of these water bodies. Our results, and those of the other authors, emphasize the urgent need for remediation plans to improve the water quality of the Sebou River, which is the primary water supply source in Morocco.

REFERENCES


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