Modelling river hydraulics and water quality with limited available data, the case of Sebou River (Morocco)

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Abstract

In this study, a first attempt is performed to study and to model the hydraulic regime and water quality of Sebou River in the Gharb agricultural zone. A 90 km long reach situated upstream a reservoir dam is studied during the base flow period. During this period, water resources are scarce and much solicited by agriculture while water quality is very problematic. The dynamic water quality model WASP5 is used. Results give more information about the hydraulic regime which is influenced by a variable morphology. Water depth, flow and velocity evolutions along the river and the water reserve available in the dam reservoir are simulated. In the water quality modelling, scenarios of excessive salinity propagation were first simulated. The time of arriving and the amplitude of the salinity were estimated at agricultural pumping stations. This model can play the role of an alert system against this natural phenomenon. Dissolved oxygen (DO) and biological oxygen demand (BOD) were then simulated. The impact on the oxygen depletion of each plant wastewater was estimated. This information gives more suggestions for the envisaged waste load treatment programmes.

Key words

Dam, modelling, Sebou River, hydraulic, water quality

INTRODUCTION

The Sebou River (600 km) is the main stream of the Sebou basin (40 000 km^2). Its waters are solicited for different usage. The studied area is situated between Mechraa Belksiri town and Lalla Aicha dam (Figure 1). River waters are used intensively for agricultural activity and many land-use changes are planned. Flow regime is influenced by considerable natural variations (morphology and climate) and by the presence of many dams constructed upstream of the study area for electricity production (Figure 2). During base flow periods, the Lalla Aicha dam whish is situated at the downstream part is partially closed in order to facilitate pumping water for agriculture inside the river reach via 10 pumping stations and to avoid salt intrusion from the estuary. At the same time, two sugar production plants situated near Belksiri town and the third near Sidi Allal Tazi village start dumping their non treated biodegradable wastewater into the river. The combination of plants wastewater and the dam close affect a lot the water quality along the studied reach. DO concentrations below the minimum necessary for fish (5 mg l^{-1}) are sometimes measured (Figure 3), which upsets the natural equilibrium of the river and kills a lot of fish. A few modelling studies have already been developed in the Sebou River (Igouzal et al., 1997). In this context, mathematical modelling approach was needed for more precise answers to many problems. The WASP5 model (Ambrose & Martin, 1993) is applied here to help to understand the hydraulic regime and water quality for 1997. Hydraulic simulations provide flows, depths, water level and the water reserve available in the whole area.

Despite the poor water quality observed in the studied zone, many key-water constituents are not measured because the purpose of data collection is a general survey of water-quality conditions in the stream system and not the development of a water-quality model. Also, there is a tendency to sample certain water-quality constituents because they are easy to sample, not because they increase knowledge of key water-quality process. In other hand, the frequency of data collection is usually insufficient. These inadequacies force water-quality modellers to make weakly supported assumptions regarding model parameters or inputs, thus increasing model-prediction uncertainty and adversely affecting decision making for water-pollution control. So as we said in the paragraphs above, only dissolved oxygen and the biological oxygen demand are simulated in this study in order to study the system tendencies and to have a whole view of it. The influence of the dam downstream and the impact of each sugar production plant were analysed.

In many periods, high salinity concentrations were measured. This affects agriculture and forces some important pumping stations to stop their activities for many weeks each year (Zeraouli & Chakor, 1998, ONEP, 1994). The mean salinity of Sebou waters is 1.15 g l^{-1}. Salinity comes from some specific high-salt soils areas at the upstream zones of Sebou basin. In this contest, model simulations can help for the prevention against this natural phenomenon.

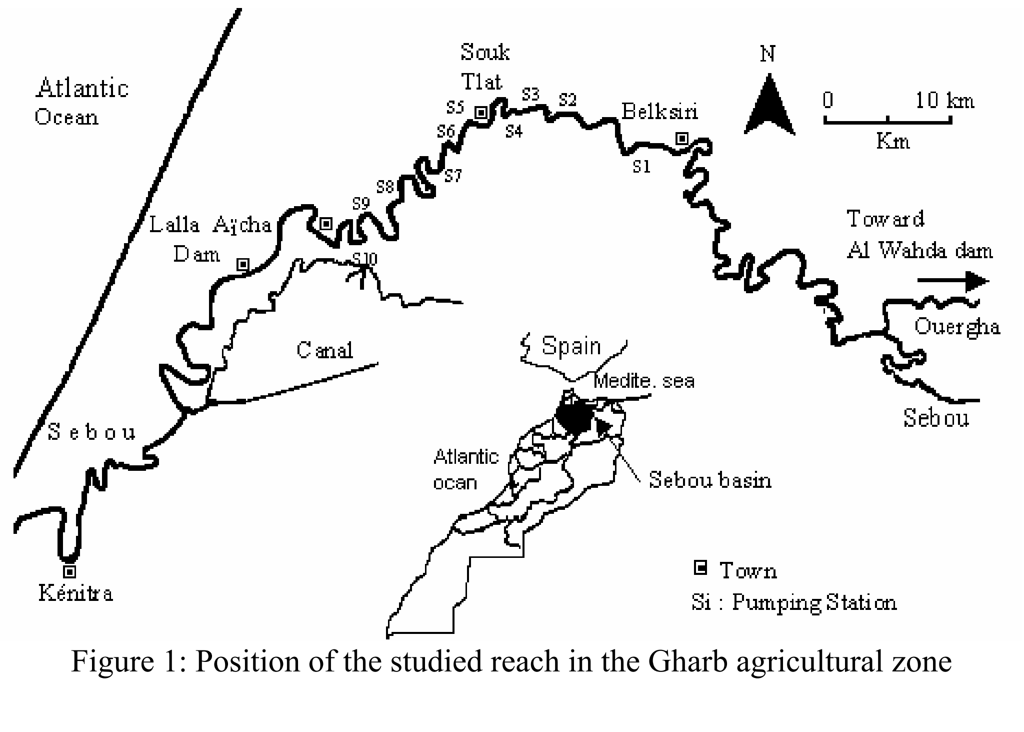

Figure 1: Position of the studied reach in the Gharb agricultural zone

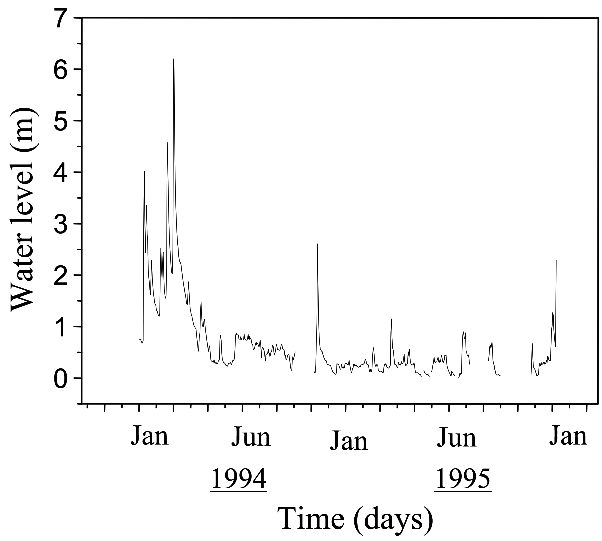

Figure 2: Stage evolution at Belksiri hydrological station during 1994 and 1995

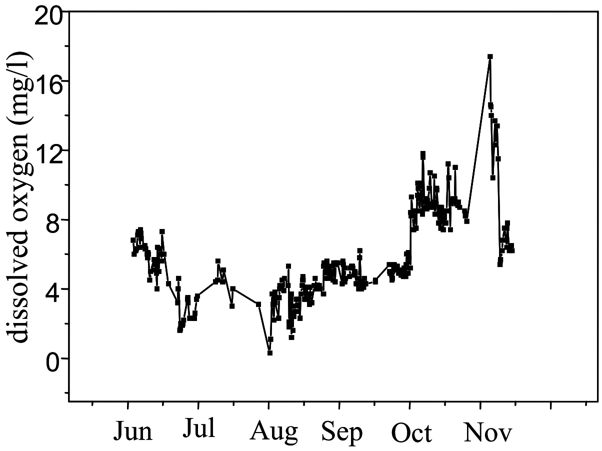

Figure 3: dissolved oxygen measurements during 1996 summer

MODEL DESCRIPTION

In this study, we are interested in a reach of several kilometres. The near field problems have minor interest, justifying our one dimensional approach. The one-dimensional (1-D) hydraulic submodel called DYNHYD5 was modified in order to get a better morphologic representation of the river (Igouzal & Maslouhi, 2003). DYNHYD5 uses the two Saint-Venant continuity and movement equations. Flow resistance is quantified using the Manning friction coefficient, which depends on the nature of the river bed and on the river morphology. It was initially evaluated by Chow's formula (Chow, 1973). Sebou morphology varies a lot along the studied area, so a variable Manning friction coefficient is used along the river. It ranges from 0.02 to 0.04, with a mean value of 0.037. The discretization of the studied reach was performed using aerial photographs taken during a dry period when the river was nearly dry. A total of 528 grid meshes were adopted. River morphology was evaluated using data available from limited cross sectional areas. Near Souk Tlat village, morphology was quantified using "Numeral photogrammetry" (Igouzal *et al.*, 2003). River photos of a 1/20 000 scale taken in 1983 during a very base flow period were used. Then, the RESTIT.2 Photogrammetry's software (Ejels,

1999) permits the morphology's stereoscopic measurements on aerial photos to be scanned and calibrated. A correlation coefficient of 0.96 was obtained between measured and calculated cross section areas. The intensive pumping of waters along the river via 10 principal stations (Figure 1) and many smaller stations is considered in the model. The total pumped flow ranges from 10 to 25 $m^3 s^{-1}$. Also, boundaries and initials time step conditions were needed for the simulations. The upstream boundary is given as values of water level as function of time. The downstream boundary is a discharge as a function of time. Hydraulic model outputs are given as values of discharge and water level at all the locations in the river, especially at pumping stations.

The water quality model used is called EUTRO5, based on the advection–dispersion equation. It represents the biochemical water quality submodel of WASP5. The longitudinal dispersion coefficient can be the most important processes diluting peak concentrations that may result from unsteady loads and it is one of the unknowns of the problem.The longitudinal dispersion coefficient used in the model (13 $m^2 s^{-1}$) was calculated using salinity propagation measurements realised by the agriculturale ministry (Zeraouli & Chakor, 1998).

RESULTS AND DISCUSSION

Calibration of the hydraulic model is achieved by varying the Manning coefficient (with the same magnitude along the river) in order to minimize the difference between measured and simulated water level. The only available measured water level was at S2 station and at the Lalla Aicha dam. The months of July and June 1997 were used for the calibration and validation, respectively. Figure 4 shows a good agreement between measurements and predictions near the dam. The hydraulic model also calculates the spatial and temporal evolution of velocity and water depth. Water reserve available in the whole reach is also simulated (Figure 5). This information can allow rapid interventions when this variable begins to decrease dramatically.

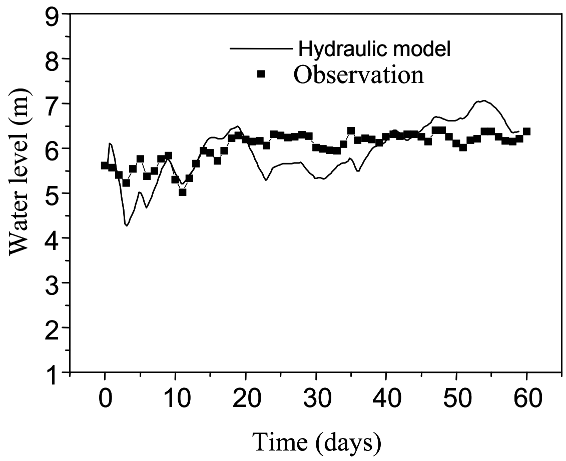

Figure 4: Calibration of the hydraulic model, the Lalla Aicha dam, Jun-July 1997

The fate of salinity intrusion with an amplitude similar to that measured during high salinity periods (Zeraouli & Chakor, 1998) was simulated. Figure 6 gives its theoretical evolution at five locations: Belksiri, S2, S7 and S10 pumping stations and at the dam, for a water flow of 10 $m^3\ s^{-1}$. Salinity arrives more dispersed to the stations downstream and with lower peak values. When the flow is increased to 25 $m^3\ s^{-1}$, salinity arrives quickly downstream, but with large amplitude (Figure 7). The S2 station (the most important regarding the quantity of water pumped) is more affected by the salinity because it is situated at the upstream part. Salinity arrives quickly to this station and with high amplitude. Thus, to increase the time of alert against high salinity intrusion for this station, the upstream condition for the model must be moved more upstream of Belksiri hydrological station. Such a coupled model (hydraulics plus salt transport) could prove extremely useful for an improved management of the pumping stations.

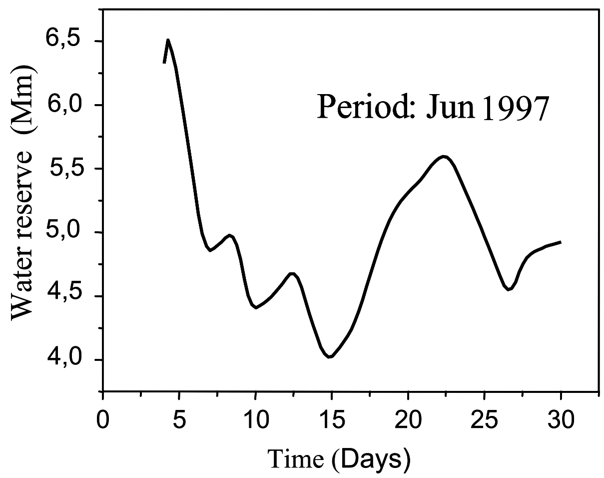

Figure 5: Evolution of the water reserve, June 1997.

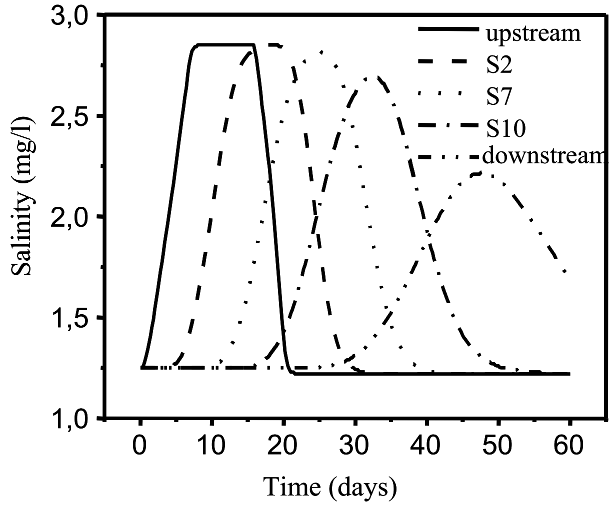

Figure 6: Evolution of a salinity intrusion at different stations for a 10 $m^3\ s^{-1}$

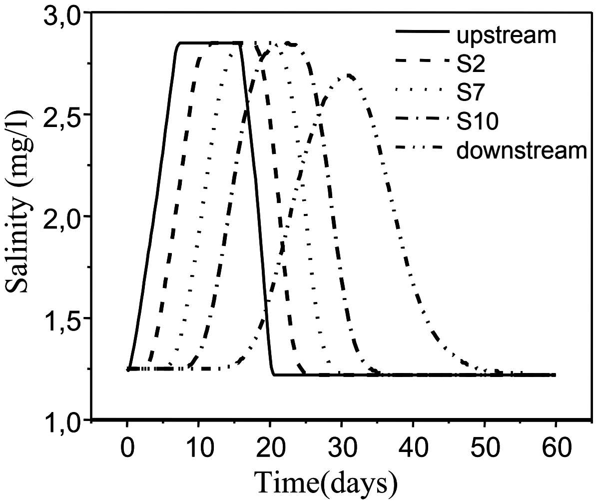

Figure 7: Evolution of a salinity intrusion at different stations for a 25 m^3 s^{-1}

In biochemical modelling, the reacting terms in EUTRO5 are reaeration and oxidation for dissolved oxygen and oxidation for the BOD. Information about oxidation coefficient for the sugar wastewater was not available. A mean oxidation coefficient of 0.2 day^{-1} was used. Also, continuous measurements of DO and BOD were not found to calibrate the water quality model. The existing data have been collected on an occasional basis. So, different scenarios were simulated to estimate the influence of the dam downstream and the impact of each sugar plant. First, simulations without the presence of wastewater were elaborated to quantify the effect of the dam closure. It showed that even when no industrial wastewater is dumped into the river, the dam closure can contribute to the water quality degradation by reducing the natural reaeration (Figure 8). With the presence of the dam downstream, velocity decreases downstream and the depth increases, so reaeration must decrease downstream which reduce the DO concentration.

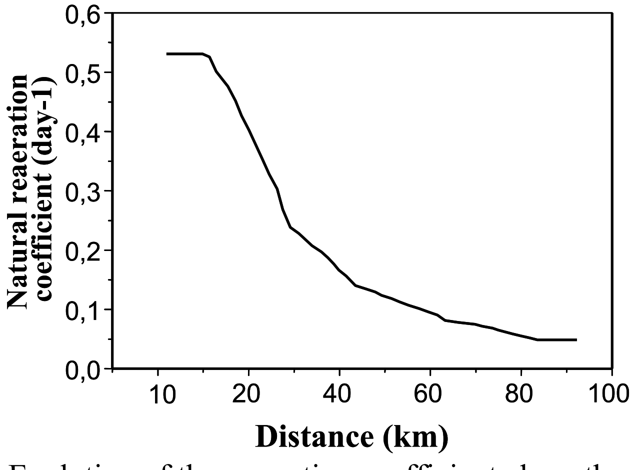

Figure 8: Evolution of the reaeration coefficient along the river

Other simulations considered only the Belksiri wastewater (upstream), only the Tazi wastewater (downstream) and both the Belksiri and Tazi wastewater. These simulations show first that the Belksiri wastewater has the greatest impact on water quality because it increases the BOD and decreases the DO concentrations so much in waters. However, simulations show that the conjunction of the two wastewaters increase the negative influence on the water quality of the river (Figures 9 and 10). Thus, if a treatment must be done, we think that Belksiri wastewater must be treated first. This wastewater is the most important and its travel time along the reach is the longest.

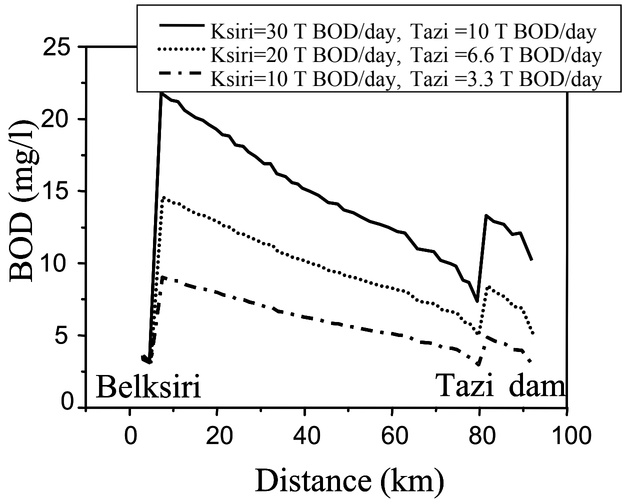

Figure 9: BOD evolution for tree outflows in T day^{-1}

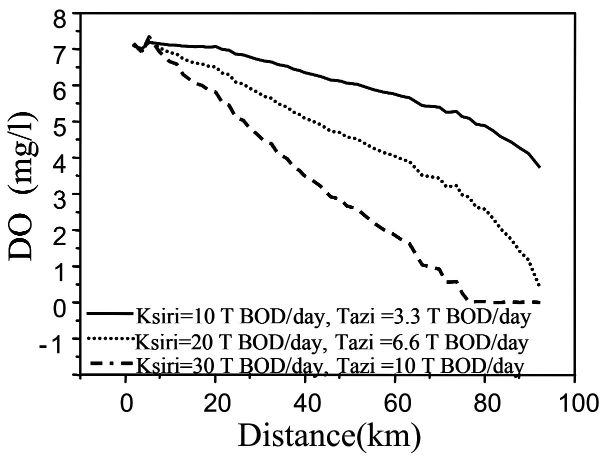

Figure 10: DO evolution for tree outflows in T day^{-1}

CONCLUSIONS

In this study, a first attempt was performed to study and model the Sebou River waters in a 90 km long reach characterized by human quantitative and qualitative impacts. A base flow period is studied, during which waters are very scarce and many water standards are violated. Results permit a good understanding of the hydraulic regime. Despite the lack of adequate field data, salinity and water quality simulations give a lot about the element of response. The time alert against high salinity concentration will be more increased using this mathematical model. Also, simulation of DO and BOD variables provides a lot of suggestions if a waste water treatment is envisaged. These results are not recommended as a substitute for field studies, but are believed to provide reasonable estimates of water quality variables in a short time to help with many environmental and health safety considerations.

REFERENCES

Ambrose R. B. and Martin J. L. (1993) WASP5, a hydrodynamic and water quality model. Model theory, user's manual guide and programmer's guide. *US EPA, Georgia 30613.*

Chow V.T. (1973) Open-Channel Hydraulics, *Mc Graw-Hill International Editions, Civil Engineering Series.*

Egels Y. (1999) *Le logiciel de photogrammétrie RESTIT, Version 5*. Manuel d'utilisation. l'IGN, L'ENSG, France, 12 p.

Igouzal M. and Maslouhi A. (2003) Contribution à la gestion de la retenue d'un barrage réservoir sur la rivière Sebou (Maroc) à l'aide d'un modèle hydraulique. *Rev. Sci. Eau* 16(4), 443–458.

Igouzal M., Maslouhi A., Schelstraete D. and Chan J. (2003) Reconstitution de la morphologie d'une rivière à méandres (le Sebou, Maroc) par l'utilisation de la photogrammétrie numérique. *Bull. Soc. Fr. de Photogramm. et de Télédétec.* 171(3), 16–21.

Igouzal M., Maslouhi A., Lahlou F. and Daniane M. (1997) Modélisation de la qualité des eaux de l'oued Sebou à l'aval d'un rejet industriel, In: Fresh Water Contamination, B. B. Web (ed.), IAHS Publ. 243. IAHS Press, Wallingford, UK, pp. 349-356.

ONEP. (1994) Etude de la qualité des eaux de la rivière Sebou. ONEP, Rabat, Morocco.

Zeraouli M. and Chakor B. (1998) Les sources salées: causes de la salinisation de l'Oued Sebou même en périodes pluvieuses. ORMVAG. Ministère of Agriculture, Kénitra, Morocco.