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Analysis of wastewater discharges to the Wadi Kebir East River by the environmental discharge objectives (EDO) method

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ABSTRACT

The contribution of discharges of urban wastewater to the aquatic environment was evaluated. In Oued Kebir East downstream, several parameters were determined for the discharges of the urban areas. The environmental discharge objectives method (EDO) has been applied to discharges of urban wastewater. The concentration of three parameters (chlorides, nitrates, and phosphates) has been analyzed. Calculations of EDO showed negative values for phosphates, which means that Oued Kebir East River has a strong concentration of these ions, and consequently their discharge in this stream should be forbidden. The concentrations in the effluent of chlorides and nitrates depend on Oued Kebir East rates. They are in the range of 252.64–1,033.33 mg/L for chlorides and 3.26–12.58 mg/L for nitrates.

Keywords: Discharge; Concentration; Environmental objective

1. Introduction

An understanding of the nature of wastewater is important to assess the effects of pollutants on the aquatic life and their impact on the food chain of wildlife, and humans. Other discharges such as nutrients may interfere with the natural balance of ecosystems and furthermore they can affect the taste, odor, or color of the receiving waters [1–3].

In this regard, the Canadian Ministry of Sustainable Development, Environment, and Parks (MSDEP) is responsible for ensuring requirements for the protection of human health and biological resources as preserving, maintaining, and recovering water and aquatic biological resources. The main purpose is to reach the environmental discharge objectives (EDO) for sources of water pollution. These objectives were determined based on the knowledge of the receiving water streams and the desired quality level. This article will address the desired level of quality represented by water quality criteria that reflect the knowledge about the harmful effects of contaminants [4–6].

2. Geographical situation

The study area is part of the Constantine-East Coastal Basin, one of the largest reservoirs of surface and groundwater in northern Algeria with a surface

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area of 2,870 km^2. This basin is drained by a big river in the East, Oued Kebir East, which flows into the sea by a single outlet: Oued Mafragh [7]. Oued El Kebir East is formed by the confluence of two major tributaries, the Oued Ballouta coming from the East and Oued Bougous from the west [8]. From a geological point of view, the study area is part of the geological Tell northeastern Algeria [9], which extends from the region of Constantine to the Algerian–Tunisian border (Fig. 1).

3. Materials and methods

3.1. Sampling sites

In order to monitor the environmental discharges in Oued Kebir East, samples were withdrawn over a period of 6 months (April–September 2011), one sample per month for each station. Seven sampling stations were chosen and the sampling was carried out in the following way: samples were taken from the center of the water stream, facing the stream, and were transported at low temperature (4°C) from the field to the laboratory [10].

3.2. Analytical methods

The water analysis was performed by volumetric and colorimetric techniques following standard protocols as well as the ISO and AFNOR standards. The analysis of phosphates (PO_4^{3-}) was performed by the colorimetric method; chlorides (Cl^-), by volumetric method of Mohr (ISO No 9297), and nitrates (NO_3^-), by the colorimetric method. A UV–visible spectrophotometer (JENWAY 6705) was used for the colorimetric analysis [10,11].

3.3. Data processing method

The data processing is based on the EDO (Fig. 2) in reference [12–14]. For the majority of contaminants,

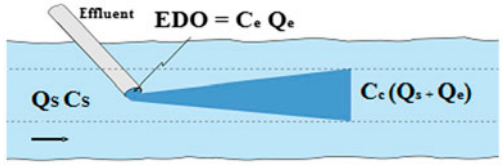

Fig. 2. Elements of the loading mass balance.

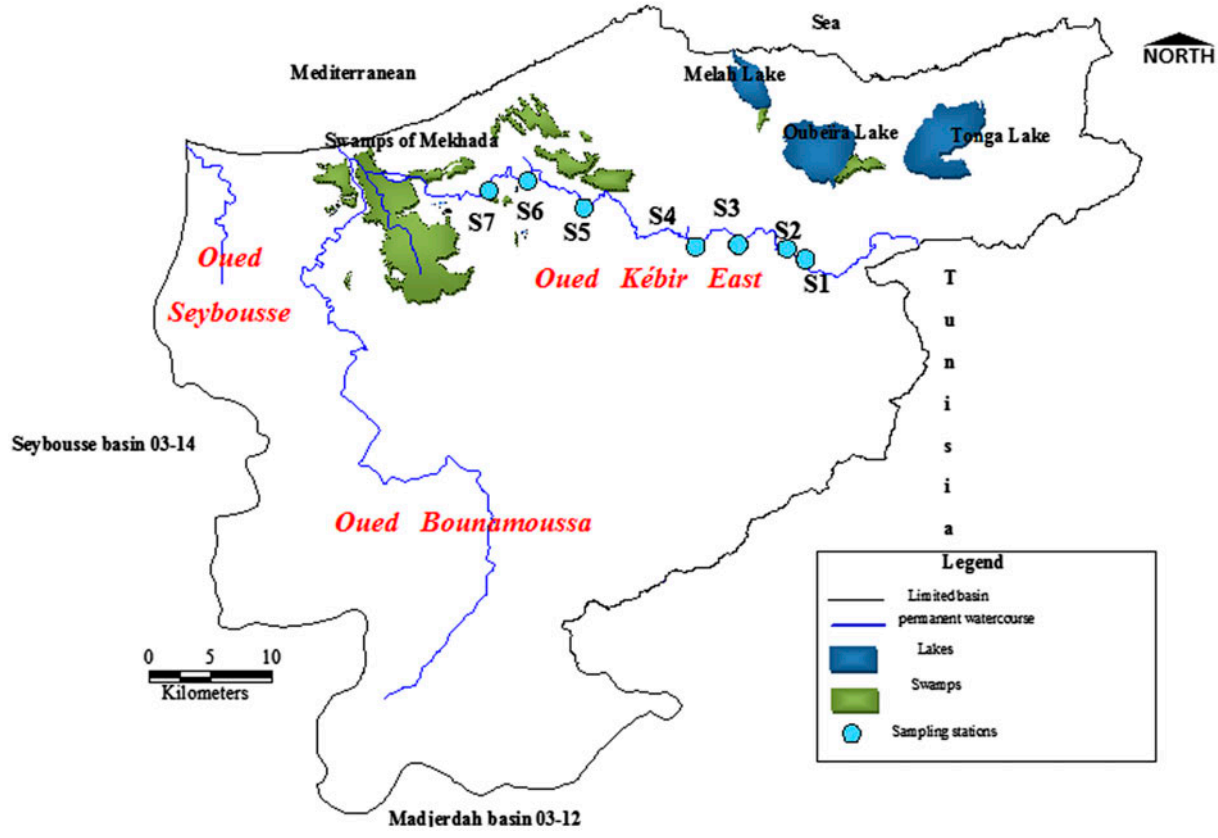

Fig. 1. Geologic situation and draft of the zone of study in the Constantine-East Coastal Basin.

the mass balance is represented by the following equation:

Upstream water load + allocated load on the effluent = maximal tolerable load at the limit of the mixing zone:

$$C_s Q_s + C_e Q_e = C_c (Q_s + Q_e) \quad (1)$$

where C_e (mg/L): the environmental objective of discharge in concentration; C_s (mg/L): median upstream concentration in the Wadi; C_c (mg/L): quality of water criterion; Q_r (L s^{-1}): flow of recurrence; Q_e: effluent flow.

f = fraction of effluent's flow. The f factor has a value of "0" when the water supply is from groundwater. If the water intake is underground or located in another watershed.

The charge in the effluent (C_eQ_e) corresponds to the charge to comply with the water quality criterion (maximum charge permitted at the limit of the mixing zone), from which it is subtracted the charge already present in the stream (upstream charge). These charges are defined as follows:

$$C_eQ_e = C_c(Q_s + Q_e) - C_s Q_s \quad (2)$$

Replacing Q_s by its definition ($Q_r - fQ_e$) in Eq. (2), we get:

$$C_eQ_e = C_c[(Q_r - fQ_e) + Q_e)] - C_s(Q_r - fQ_e) \quad (2a)$$

To determine the concentration of the effluent (C_e) the following equation has to be solved:

$$C_e = [C_c(Q_r - fQ_e + Q_e) - C_s(Q_r - fQ_e)] / Q_e \quad (3)$$

The approach used to determine EDO's for wastewater discharged into the Oued Kebir East takes into account the protection of the aquatic life; EDO's are mainly developed from the protection criterion of chronic aquatic life (CALC) which is usually a good indicator of contaminants effects on medium organisms. The effluent flow rates are from upstream to downstream, respectively: 9.71, 130.45, 152.67, 197.94, and 243.12 l/s.

Regarding the Oued Kebir East environmental protection the lower flow rate used for the calculation of the EDO as a function of water quality criterion was $Q_{2,7}$ = 40 l/s. The calculation of the low flow rate was carried out based on a descriptive statistical analysis that follows a Gumbel's law.

4. Results and discussions

Table 1 shows the results of the calculation of the discharge environmental objectives expressed as concentration and charge of chlorides, nitrates, and phosphates being 230–2.9 and 0.03 mg/L, respectively.

As shown in Figs. 3 and 4, as the urban density increases the discharge flow rates and the upstream concentration in different sampling stations also increase; which leads to a decrease of EDO. It can be noticed also that there is a relationship between the charge (EDO in charge) and the discharge rate; this means that the higher the OER concentration is, the lower the EDO charge, in the range of 5,342.32–769.09 kg/d for chlorides and 69.28–10.47 kg/d for nitrates.

Table 1
EDO in concentration (mg/l) and charge (kg/d) of chlorides, nitrates, and phosphates for the protection of aquatic life (CALC) chronic effect

				Criterion chloride for CALC chronic effect (230 mg/L)			Criterion nitrates for CALC chronic effect (2.9 mg/L)			Criterion phosphates for CALC chronic effect (0.03 mg/L)		
Stations	f	Q_r (l/s)	Q_e (l/s)	C Upstream (mg/L)	EDO (mg/L)	Load (kg/d)	C Upstream (mg/L)	EDO (mg/L)	Load (kg/d)	C Upstream (mg/L)	EDO (mg/L)	Load (kg/d)
S1	0	40	9.71	35.00	1,033.33	866.88	0.55	12.58	10.55	0.05	–0.05	–0.04
S2	0	40	9.71	63.30	916.74	769.09	0.57	12.48	10.47	0.04	–0.01	0.00
S3	0	40	130.45	70.78	278.82	3,142.58	0.67	3.58	40.40	0.14	0.00	–0.03
S4	0	40	152.67	81.70	268.86	3,546.38	0.89	3.43	45.19	0.26	–0.03	–0.39
S5	0	40	197.94	79.25	260.46	4,454.47	0.61	3.36	57.50	0.16	0.00	0.07
S6	0	40	243.12	92.39	252.64	5,306.88	0.64	3.26	68.55	0.18	0.01	0.12
S7	0	40	243.12	82.13	254.33	5,342.32	0.48	3.30	69.28	0.12	0.02	0.33

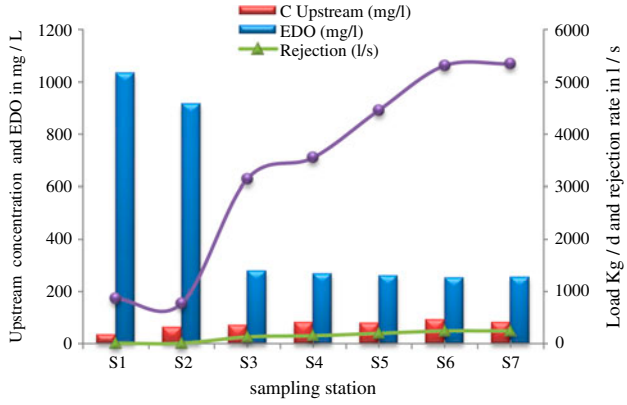

Fig. 3. EDO in concentration and charge of chlorides for the protection of aquatic life chronic effect.

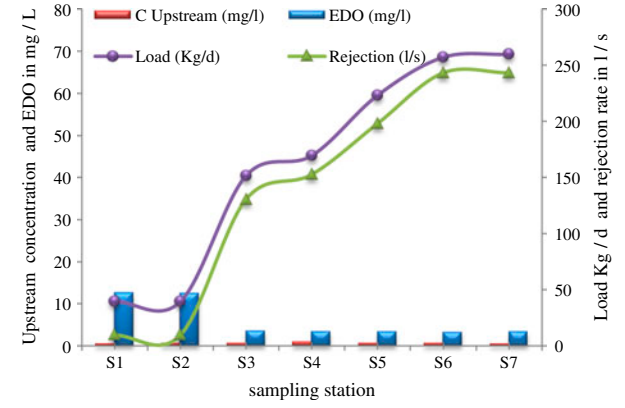

Fig. 4. EDO in concentration and charge of nitrates for the protection of aquatic life chronic effect.

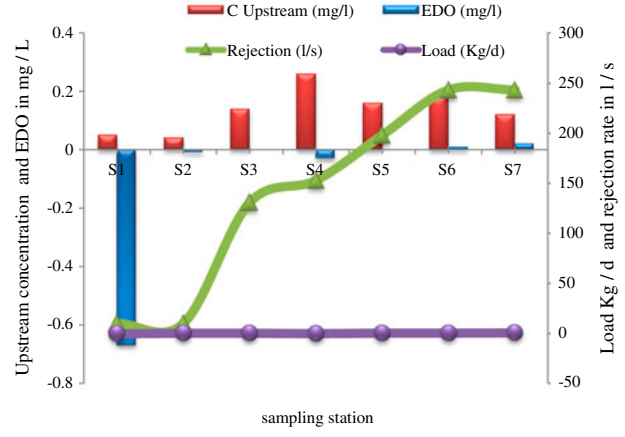

Fig. 5. EDO in concentration and Phosphates charge for the protection of aquatic life chronic effect.

The concentration of chlorides and nitrates in the effluent for the protection of aquatic life depend on the discharge rates of East Kebir Oued, and they vary from 1,033.33 to 252.64 mg/L for chlorides and 12.57 to 3.26 mg/L for nitrate. Values for chlorides and nitrates show that EDO concentrations are always higher than the quality criteria limits (230 and 2.9 mg/L).

Figs. 3 and 4 also show similar results between chlorides and nitrates, in other words, there is an increase in the upstream concentration and charge and a decrease of EDO for the two parameters simultaneously; this confirms a nitrogenous organic pollution because chloride ions and nitrate ions are present in the case of pollution from latrines (domestic discharge).

Fig. 5 shows an increase in upstream concentration of phosphates as the discharge rate increases; the EDO concentration of the contaminant ranges from negative values to zero and sometimes even to positive values, in the range of 0.02–0.05 mg/L, but still lower than the quality criterion, 0.03 mg/L. The same behavior is observed for the EDO charge, with values in the range between 0.33–0.39 kg/d.

The concentrations of the effluent for the protection of aquatic life chronic effect of phosphates have negative and zero values; this means that the Oued Kebir East has a high concentration of phosphates and hence its discharge must be banned as the EDO parameter of this contaminant is not achieved.

5. Conclusion

From the results in this work it can be concluded that in the Oued Kebir East stream the concentration of chlorides and nitrates is within the discharge limits of 250 mg/L for chlorides and 10 mg/L for nitrates, and the EDO values are reached for this criterion. Phosphates are responsible for eutrophication and dystrophization phenomena and their concentrations were greater than 0.025 and 0.1 mg/L. The EDO values were not reached, and therefore eutrophication is observed in this Oued. Occasional high values of the EDO parameters do not necessarily mean there is an immediate danger either to health or to the environment.

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