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Hydrolink

IMPACT OF ANTHROPOGENIC ACTIVITIES ON PHYSIOCHEMICAL PROPERTIES OF WADI EL BEY (NORTHEAST OF TUNISIA)

BY NAHED BEN-SALEM, MAKRAM ANANE, SEIFEDDINE JOMAA & SALAH JELLALI

Wadi El Bey and its two tributaries Wadi El Maleh and Wadi Tahouna, is one of the main Wadis flowing into the Gulf of Tunis. The main pollution sources in the region of Grombalia-Soliman were investigated through intensive sampling campaigns, allowing detailed mapping of the spatial distribution of pollution in the Wadis. Industrial wastewater discharges in the region seem to be mostly responsible for water quality degradation in Wadi El Bey, and therefore represent a severe threat of groundwater pollution in the region.

Population growth and the relative improvement of the standard of living in the Mediterranean (MED) coastal cities led to the expansion of agricultural and industrial activities, resulting in large water consumption[1]. This growing anthropogenic pressure resulted in significant increase in pollutant loads discharged into the hydrographic network, which in turn impacts significantly the aquatic ecosystem. To address this problem, different national, regional and international environmental protection initiatives have been established. Among these, the Marine Strategy Framework Directive (MSFD) that was developed to achieve a good environmental status in the MED Sea by reducing the causes of eutrophication and its consequences[2]. Also, a partnership on groundwater issues was developed between EU and non-EU countries of the MED region, where actions to reduce the marine pollution in the MED Sea and solutions on surface water resources management were suggested (e.g., ENI SEIS II SOUTH Project[1]). At the national level, two big initiatives are undertaken currently in Tunisia named the Water Code and Water 2050[3],[4] which concern the establishment of mid- and long-term national strategies regarding water resources management and environmental preservation by the horizon 2050. Special attention is paid to coastal water resources management and wastewaters valorisation and reuse. Despite these numerous initiatives, some water systems are experiencing challenging conditions due to multiple interacting anthropogenic pressures. Among them are the Wadis feeding the Gulf of Tunis, which constitute the natural outlet for surface runoff, but also domestic and industrial effluents, as well as discharges from agricultural drainage. For instance, Wadi El Bey is the stream most polluted by industrial wastewaters (Figure 1). The primary sources of pollution in Wadi El Bey are tanneries, paper mills,

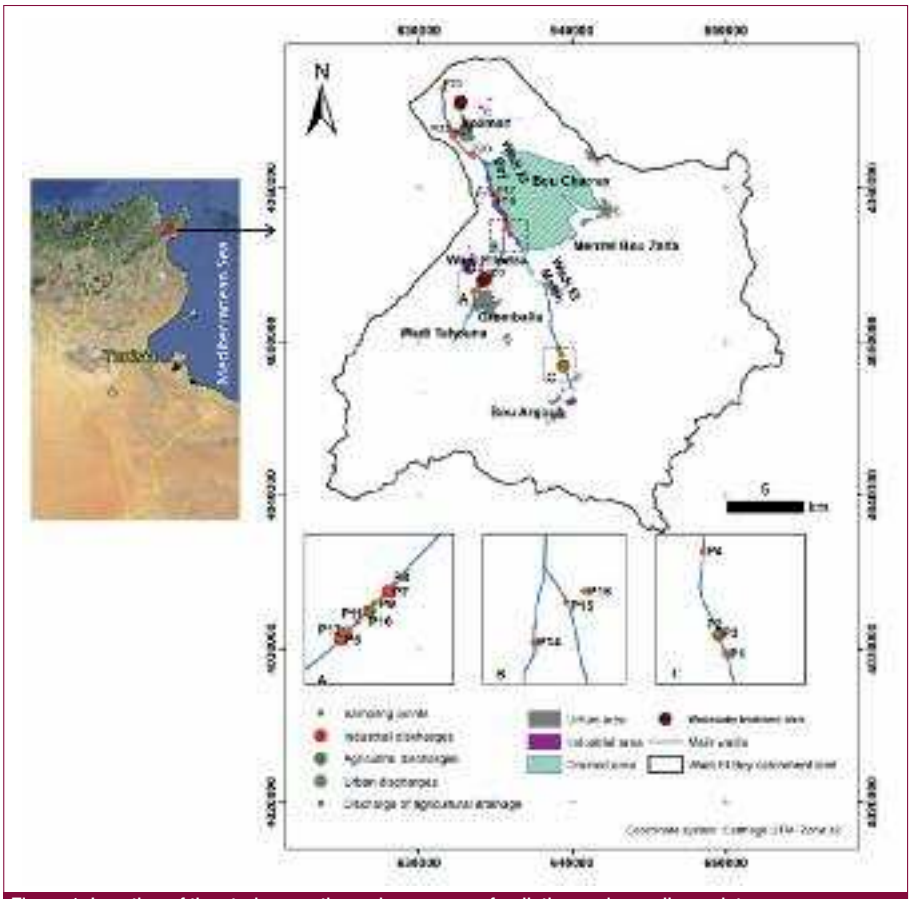

Figure 1. Location of the study area, the major sources of pollution and sampling points

breweries, tomato processing and slaughter products. Faced with this precarious situation and for better preservation of the receiving environment, the Tunisian government decided to support the implementation of a study for the decontamination of the Gulf of Tunis[3]. The main objectives of this study are to: (i) perform an inventory of the main pollution sources of Wadi El Bey from industrial and urban pollution activities, (ii) evaluate the degree of its pollution based on extensive physicochemical analyses of its waters at different locations from the watershed upstream until the Soliman's wetland (close to the MED sea), and (iii) to map the spatial distribution of each pollution parameter using Geographical Information Systems.

Study area description

The Wadi El Bey watershed is located in the northeastern of Tunisia. It covers a total area of about 513 km^2 and includes several urban agglomerations including Soliman, Bou Argoub, Grombalia and Menzel Bouzelfa with several industrial areas (Figure 1). Rainfall in this area is

characterized by temporal irregularity with a rainy season spread over a period from September to May and a dry season in summer. The lowest temperatures are observed in January with an average of 12.3 °C. The geological layers present a stratigraphic succession from the lower Eocene to the Quaternary. The study area consists of a vast plain with gentle slopes (0-3%), directed towards the MED Sea. The hydrographic network extends downstream to the wetland of Soliman and is subject to many sources of pollution mainly the Grombalia, Bou Argoub and Soliman Waste Water Treatment Plants (WWTPs), the Grombalia and Soliman industrial areas and the Bou Charray agricultural drainage network (Figure 1). This lagoon covers approximately 2.25 km^2 and has a depth of less than 5 m. It communicates with the sea through a small canal. The study area is mainly agricultural with the presence of some agri-food and textile industries.

A total of 17 surface water sampling points (Figure 1) distributed along the hydrographic network have been used, located upstream and downstream of the point sources of pollution from industrial, domestic and agricultural discharges. Six additional samples were taken from the sources themselves; three from urban WWTPs output, two from industrial WWTPs and one from the agricultural drainage main stream. The main physicochemical parameters (pH, Electrical Conductivity (EC), Dissolved Oxygen (DO), Turbidity, the Suspended Matter (SM), the Total Dissolved Salts (TDS), Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD5)) were analyzed in the laboratory, according to AFNOR (French Association of NORmalization) standards[4], along with the main major elements (chlorides, sulphate, orthophosphate, nitrate, ammonium and sodium)obtained by ion chromatography. For each analyzed parameter, the descriptive statistics were performed and compared to the Tunisian standards of surface water discharge in order to assess the contamination level of Wadi El Bey surface water. Then the analyzed physic-ochemical parameters were interpolated from the sampled points to the entire hydrographic network using the diffusion kernel, a method of interpolation with barriers. The obtained maps depict the spatial distribution of each analyzed parameter over the entire hydrographic network from the first sampling point to the outlet in Soliman lagoon.

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Makram Anane received his PhD from Lérida University, Spain, in 2004, on remote sensing applications for agriculture. His current research interest includes assessment and mapping of the impact of irrigation on soil and groundwater, conception and building geodatabases on water and wastewater, application of GIS, multi-criteria decision analysis and remote sensing for agriculture and water management.

Salah Jellali served as a full professor in sciences and engineering for water at the Wastewaters and Environment Laboratory of the Water Research and Technologies Centre (CERTE), Tunisia. He is actually a member of the Chair for the development of industrial estates and free zones at the Centre for Environmental Studies & Research, Sultan Qaboos University, Oman. He obtained a dual Engineering diploma from the high school of rural equipment of Medjez El Bab (Tunisia) and from the National School for Water and Environmental Engineering, Strasbourg, France and MSc (1996) and PhD (2000) degrees in Water and Engineering for water from the University of Strasbourg, followed by a postdoctoral position and a brief experience in BURGEAP, Strasbourg. His research interests include wastewaters treatment by low cost materials, nutrients recovery from wastewaters and reuse in agriculture, local water management, and groundwater flow and pollutants transport modeling for a sustainable management.

Results and discussion

Physicochemical elements

The mean pH was about 7.4, varying between 6.86 and 7.86. With the exception of the discharge of the industrial area of Grombalia, all measured pH values fall within the range of values allowed by discharge standard NT-106.02 (i.e., between 6.5 and 8.5). The mean EC and salinity are relatively high (3.23 mS/cm and 4 g/L), indicating that the discharges operated in Wadi El Bey are highly mineralized. The highest values were measured at the discharge of the tannery. This can be explained by the use of several types of salts in their industrial processes such as chromium salts.
The concentration of DO in the samples ranges from 0.43 to 3.96 mg/L with an average value of 2.53 mg/L and a Coefficient of Variation (CV) of 0.49.These low values reflect a fairly steady state of microbiological activity. All measured values of DO are below the threshold acceptable for proper development of aquatic life (4 mg/L). The minimum DO contents were recorded at the sampling points downstream of the Grombalia industrial area and after the tannery discharge. At these two locations, the DO contents were less than 1 mg/L indicating a very critical state in this portion of the river. This oxygen deficiency is mainly caused by high organic matter concentrations in the discharge sources and also by low water-flow velocities. The spatial distribution of DO illustrates a striking heterogeneity between the different sections of the Wadi. At the confluence of Wadi El Maleh with Wadi Ellouza, the quality of the water, in terms of DO, improves slightly (Figure 2).

Almost all sampling points in Wadi El Bey water have turbidity values that exceed the tolerable threshold. Except for waters at some locations like Wadi El Maleh and before the outlet of lagoon El Maleh, these values do not exceed the acceptable limit specified in the Tunisian standards.

The average value of SM was 121.86 mg/L, which exceeds the Tunisian standards (i.e., 50 mg/L) and highlights the high pollutant load discharged into this river and also the fairly slow flow rate. The SM represents all the mineral and organic particles contained in the water in a

suspension state. The levels of SM in Wadi El Bey waters vary from 9 to 463 mg/L, which can be rather harmful to the biological diversity of this watercourse, since these levels can cause the decrease of DO and light penetration, thus affecting the photosynthesis process. TDS values vary between 1558 and 5538 mg/L, with an average value of 2934 mg/L. This can be explained by the use of mineral salts in industrial processes, and by the contribution of drainage water, which is quite rich in salts. The surface waters of Wadi El Bey have high concentrations of TDS.

Various measured COD values were much higher than the Tunisian standards (i.e., 125 mg/L) and are indicative of very high pollutant loads discharged in Wadi El Bey. The maximum concentration of COD was measured at the disposal level of the Grombalia industrial area, which is about 16 times higher than the standard. Apart from the samples collected in Wadi El Maleh and downstream of the discharge of agricultural drainage, all other points are characterized by COD values that exceed the acceptable threshold. Similarly, the highest BOD5 values were measured at the Grombalia industrial area. This shows that the pollution contained therein is not subject to biological degradation. The measured values of BOD5 vary between 15 and 400 mg/L. The waters of Wadi El Maleh are the least loaded in terms of BOD5. Concerning Wadi El Bey, its waters are less loaded with BOD5 compared to the other streams, which is attributed to the effect of dilution.

Major elements

Wastewater discharges have high levels of chlorides ranging from 624 to 4005 mg/L. This latter value exceeds eight times the Tunisian standards and corresponds to the discharged wastewater by the Grombalia tannery. These high levels are mainly due to the use of NaCl in the tanning process. The industrial zone of Grombalia also discharges water with chloride content about three times higher than the corresponding standard. Wadi El Bey is characterized by an average sulphate concentration of 518.9 mg/L. The surface water of the Wadi El Bey watershed shows, also, chlorides contents that vary from 622.6 mg/L at Wadi El Maleh to 2038.6 mg/L at the discharged wastewaters from the tannery.

Orthophosphate concentrations, however, were negligible in all sampling points. Except at the outlet of Wedi El Bey Watershed, this value, even if it is relatively low in absolute, exceeds by sixteen times the Tunisian standard (i.e., 2 mg/L). With the exception of sites substantially rich in phosphates, the rest of the water samples have low or negligible concentrations. Similarly, when approaching the lagoon of Soliman, phosphate concentrations continue to increase to reach relatively high values. This could lead to eutrophication and the intense proliferation of algae in this lagoon. The high phosphate concentrations are attributed to the presence of agricultural activity on both sides of this river, where the use of nitrogen fertilizers is predominant [5].

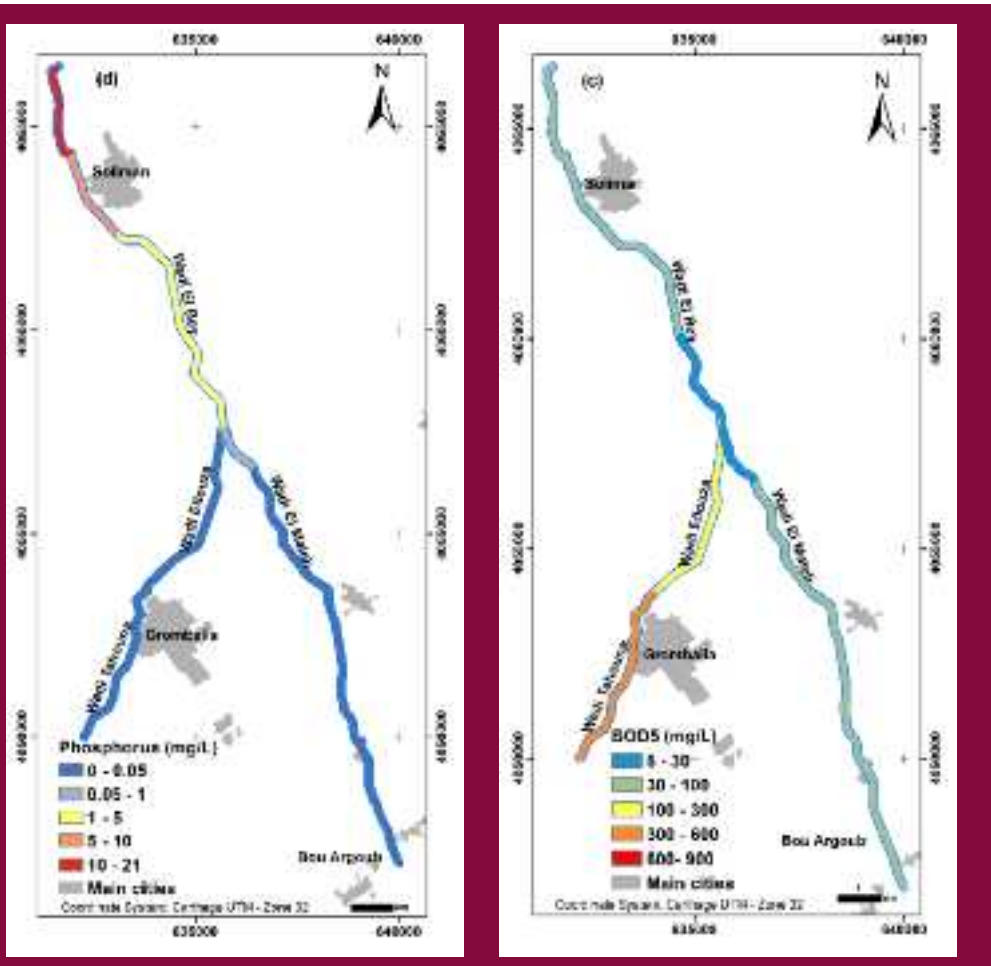
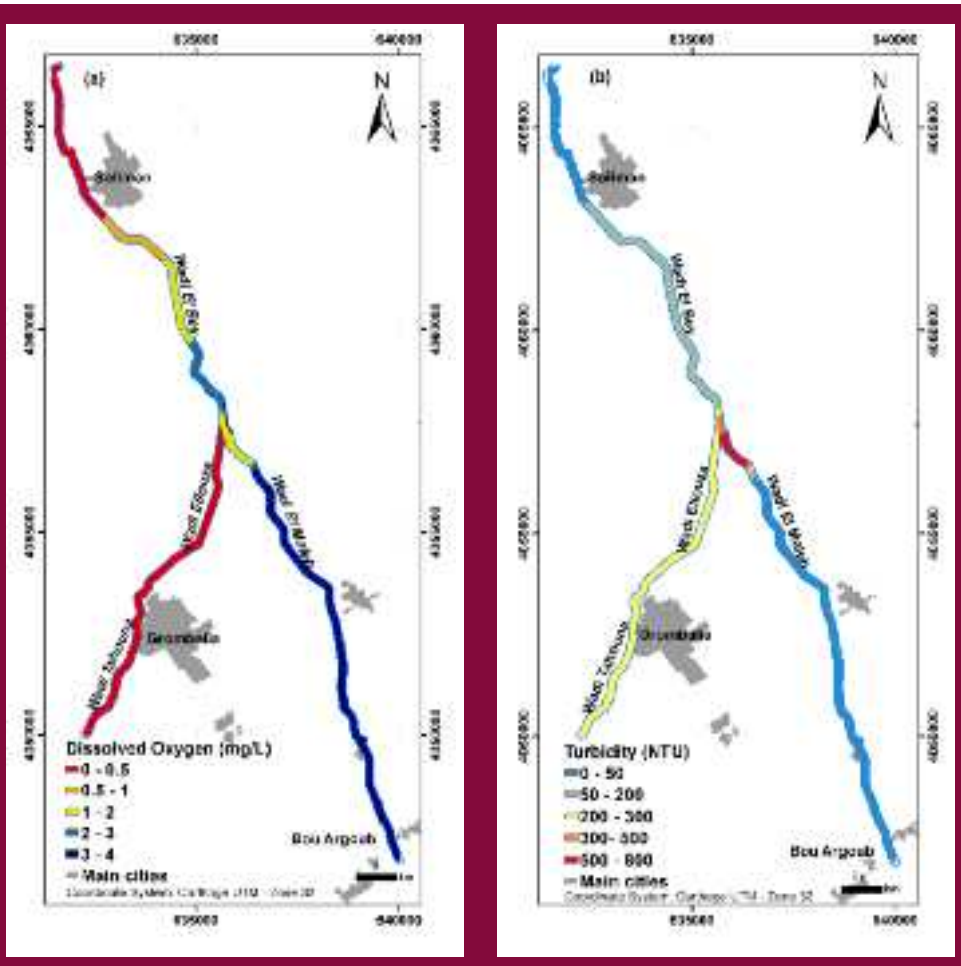


Figure 2. Spatial distribution of a) Dissolved oxygen, b) Turbidity.

The concentrations of nitrate ions are relatively low, varying between 1.16 mg/L and 49.74 mg/L, with an average value of 8.10 mg/L, complying with the Tunisian standard (i.e. 90 mg/L). The corresponding CV exceeds 1.0, indicating that there is a disparity in concentrations between sampled points. This disparity is reflected in the sensitivity of nitrates to the physical and chemical conditions of the environment. Virtually, all discharge waters have low nitrate concentrations. With the exception of agricultural tile drain, the measured nitrate content is about 179 mg/L. It can be explained by the agricultural activities based on the excessive use of nitrogen fertilizers in the Bou Charray agriculture area. The spatial distribution of nitrate levels shows characteristic surface water values but is also low compared to levels found in other studies [6]. The spatial distribution of nitrates along Wadi El Bey and its tributaries shows that the water sampled in the various streams has acceptable levels of nitrates.

Conversely, the ammonium ion contents are relatively high compared to the corresponding discharge standard. Several sampling points do not comply with the Tunisian Norm (i.e. 10 mg/L). All water discharged in Wadi El Bey has magnesium levels that exceed the discharge standard. As for nitrates, the highest magnesium values are recorded in the drainage network of the agricultural area of Bou Charray. Sodium levels in Wadi El Bey waters vary in a heterogeneous way, from a minimum of 300.79 mg/L at Wadi El Bey downstream to a



c) BOD5 and d) phosphorus levels in sampled waters

maximum of 913.5 mg/L at the sampling point after discharging of the tannery. This last maximum value is three times higher than the Tunisian standard.

Relationship between pollutants transport and groundwater processes

It is essential to underline that the attenuation of the pollution in Wadi El Bey downstream of the Grombalia watershed could be directly linked to the infiltration of pollutants through the vadose zone to the shallow groundwater[7]. This pollution transport/transfer is mainly due to the physicochemical characteristics of both the pollutants and the porous media. For instance, pollutants with small molecular size such as nitrates are generally very mobile and are not retained significantly even by soil layers rich in an organic matter[8]. However, heavy metals discharged by industrial effluents (including tanneries) could be easily and significantly adsorbed by soil layers which reduce the groundwater pollution risk[9]. On the other hand, the soil layers properties, mainly hydraulic conductivity, porosity and organic matter content, as well as oxides, could considerably influence the degree of pollutant transport to the groundwater [10]. Indeed, homogeneous soils with high hydraulic conductivity and porosity facilitate the transport of pollutants from the wadis to the shallow groundwater due to the low contact time between pollutants molecules and soil particles [11]. On the other hand, the industrial pollution discharging at specific locations could enhance the formation of a biofilm that could significantly reduce the organic pollutants transport to the groundwater [12].

Conclusions

This work demonstrates that the wastewaters discharged by the industrial zone of Grombalia and specifically the tannery induce a serious pollution of various Wadis of Grombalia region. The main affected parameters concerned the COD, the BOD5 and the TDS contents. Moreover, the tile drain network in the agricultural area of Bou Charray has significantly increased nitrates and phosphorus content due to the use of synthetic fertilizers. Water samples analyses have shown that natural attenuation of the Wadi El Bey pollution occurs while moving downstream. This finding might be mainly the result of a dilution process and especially infiltration into the underground environment, which represents, a real danger to the shallow groundwater. The preservation of the water quality of Wadi El Bey and its tributaries depends on the improvement of the water quality discharged by the industrial zone of Grombalia and also the tannery operating in this city. Setting up WWTPs specific to the nature of the generated pollution inside these two industrial sites would be the best solution to tackle this pollution problem. Continuous monitoring of the pollution using specific sensors (i.e., [13]) by adopting the high frequency monitoring approach at these identified different pollution hotspots but also along the longitudinal direction of the Wadi flow will make it possible to better assess the spatial and temporal variation of the physicochemical quality of the Wadi and its impact on the Gulf of Tunis and groundwater system.

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