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Original Research Article

Assessment of spatial and seasonal water quality variation of Oum Er Rbia River (Morocco) using multivariate statistical techniques☆

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ABSTRACT

The aim of this study is to assess the spatial and temporal water quality variation and to determine the main contamination sources in the Oum Er Rbia River and its main tributary, El Abid River. The water quality data were collected during 2000–2012 from fourteen sampling stations distributed along the river. The water quality indicators used were TEMP, pH, EC, turbidity, TSS, DO, NH_4^+, NH_3^-, TP, BOD_5, COD and F. *coli*. The water quality data was analyzed using multivariate statistical methods including Pearson's correlation, PCA, and CA. The results showed that in some stations the water quality parameters were over Moroccan water standards. PCA applied to compare the compositional patterns among the analyzed water samples, identified and four factors accounting for almost 63% of the total variation in the data. This suggests that the variations in water compounds' concentration are mainly related to point source contamination (domestic and industrial wastewater), non-point source contamination (agriculture activities), as well as natural processes (weathering of soil and rock). CA showed relatively spatial and seasonal changes in surface water quality, which are usually indicators of contamination with rainfalls or other sources. Overall, this study showed that the water was potentially hazardous to health of the consumers and highlighted the need to treat industrial and municipal wastewater and to encourage sustainable agricultural practices to prevent adverse health effects. We therefore suggest wise management of anthropogenic activities in the catchment of Oum Er Bia River and their tributaries.

1. Introduction

The rivers represent the major source of water used for human consumption, culture irrigation, and industrial purposes. Efficient management of these water resources requires information about the river water quality and its variability. This need is quite marked in semi-arid countries such as Morocco whose water resources are becoming increasingly difficult to renew, due to their over exploitation by rapidly growing population. The deterioration of river water quality water can result from natural processes and more recently due to anthropogenic activities through the discharge of industrial and domestic wastewater as well as agricultural drainage to the rivers. However, the big bulk of rivers' pollution comes from industrial and domestic wastewater and agricultural drainage (Carpenter et al., 1998; Jarvie et al., 1998). Seasonal variations in both of these anthropogenic and natural processes such as temperature and precipitations, affect the quality of river water and lead to different attributes between seasons (Vega et al., 1998). Therefore, regularly monitoring and evaluating the quality of river water are required for integrated management of these water resources (Singh et al., 2005). For monitoring the quality of river water, sampling networks seem to be an excellent source of information for local and temporal vision of the state of the water of the river. These networks provide an overview of the temporal condition as well as seasonal and geographical evolution of the ecosystem (Berzas et al., 2000; Simeonov et al., 2003). To assist in the processing and analyzing these data that have been increasing over time, the more appropriate and most used methods are the multivariate statistics (i.e. López-López et al., 2014; ; Wang et al., 2014; Osman et al., 2012; Garafa et al., 2011; Bouza-Deano et al., 2008; Idris, 2008; Mendiguchía et al., 2004).

Recently, the multivariate statistical approach becomes popular for a better understanding of water quality and ecological status, due to their ability to treat large volume of spatial and temporal data from a variety of monitoring sites. In the scientific literature, different statistical techniques, including a cluster analysis (CA), principal component analysis (PCA), factor analysis (FA) and discriminate

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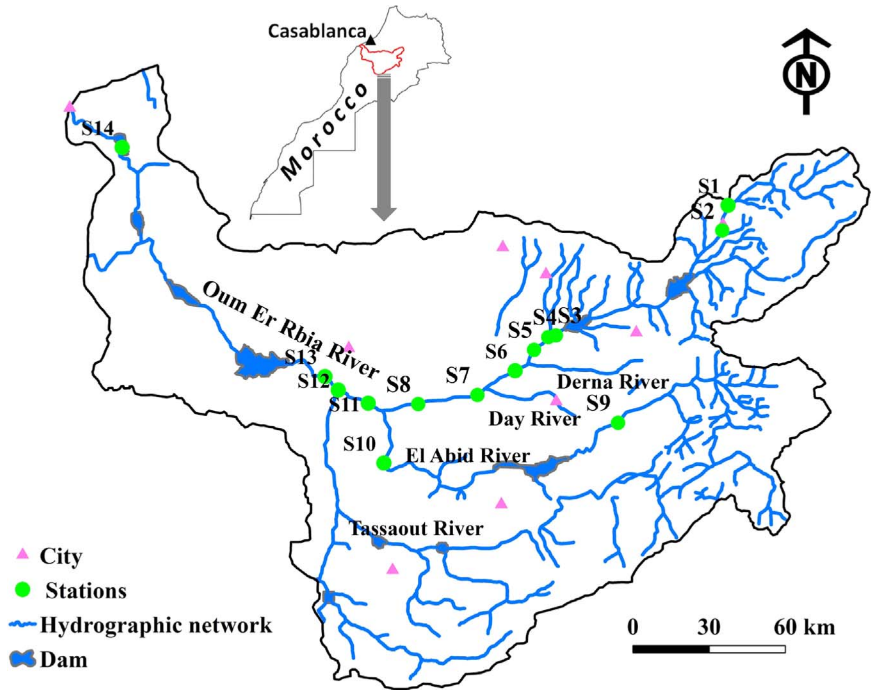

Fig. 1. Oum Er Rbia river basin and water quality stations.

analysis (DA), were used for this kind of studies because they are capable to assess temporal and spatial variations in river water quality and to identify potential sources of water contamination (i.e. Phung et al., 2015; Khan et al., 2016; Sharma et al., 2015; Varekar et al., 2015; Kumarasamy et al., 2014; Thuong et al., 2013; Razmkhah et al., 2010b; Kazi et al., 2009; Kumar & Dua, 2009; Varol & Sen, 2009; Zhang et al., 2009). For instance, Phung et al. (2015) used CA, PCA, FA and DA to evaluate temporal/spatial variations of surface water quality in Can Tho City, a Mekong Delta area of Vietnam. Kumarasamy et al. (2014) used CA and PCA/FA to investigate the hydrochemistry of a Tamiraparani river basin, Southern India. Khan et al. (2016) applied CA to hydrochemical data to assess spatial variability in the water quality of Ramganga River and its tributaries (Ganga Basin, India). Correlation analysis and PCA and CA components were used by Sharma et al. (2015) to study the seasonal variation, identify potential sources of pollution, and clustering of monitoring stations of Ganga and Yamuna Rivers in Uttarakhand State (India). Other works were conducted using PCA and CA (Simeonov et al., 2003, Bouza-Deano et al., 2008, Kazi et al., 2009, Hai et al., 2009, Razmkhah et al., 2010b). Furthermore, other studies (Boyacioglu & Boyacioglu, 2007; Zhang et al., 2009; Zhou, Liu, & Guo, 2007) applied the PCA and CA methods to classify the sampling sites and to identify the latent pollution source.. All above studies showed that the PCA and CA statistical methods are important tools to determine underlying relationships between the water quality parameters, identify sources of pollution, and group similar monitoring stations into clusters with similar characteristics. For these reasons, we opted for the use of these two of these statistical methods, PCA and CA, to study the water quality in Oum Er Rbia River.

In Morocco, several studies on identifying the sources of contamination in many rivers have been conducted over the last decade, showing that their water quality has been deteriorating with various anthropic activities (i.e. Bader et al., 2015; El Baghdadi et al., 2015; Hayzoun et al., 2015; Nadem et al., 2015; Mourhir et al., 2014; Barakat et al., 2013; El Morhit et al., 2013; Barakat et al., 2012; Iavazzo et al., 2012; Oufline et al., 2012; Derwich et al., 2011; Naoura & Benaabidate, 2011; Alla et al., 2006; Taoufik & Dafir, 2005; Koukal et al., 2004). In Oum Er Bia basin, the vulnerability of water resources pollution is due to strong agricultural and industrial activity including oil mills, phosphate extraction, livestock farming, and sugar beet processing. Because of the deteriorating water quality at the Oum Er Rbia basin, the Hydraulic Basin Agency of Oum Er Rbia (Ministry of Energy, Mines, Water and Environment of Morocco), started an environmental monitoring program for surface water and groundwater in the basin since over two decades. From this long-term monitoring of the water physico-chemical and bacteriological parameters, huge and complex amounts of data were generated whose treatment is difficult, and requires methods of reduction in dimensionality of the data, namely statistical methods.

The objective of the present study is to analyze and interpret a large data set obtained during a 12-year (2001–2012) monitoring program in Oum Er Rbia River and its tributary Oued El Abid. To achieve this objective, matrix correlation, PCA and CA multivariate techniques were applied to (1) determine the similarities and differences between the sampling stations, (2) evaluate the contribution of water quality parameters to temporal variations in surface water quality, and 3) identify the contamination affecting water quality and their potential sources. The results are expected to help evaluate the spatial–temporal evolution of Oum Er Rbia water quality and consequently enable managers to understand the main sources of pollution at the different locations along the river basin.

2. Material and methods

2.1. Study area

Oum Er Rbia River basin is located in the Center-Western of Morocco (Fig. 1), at 31°19.33′–33°22.21″N lat. and 5°8.55′–8°22.53′W Long., and covering an area of 48.070 km^2. Annual rainfall in the Oum Er Rbia basin varies between 1100 mm on the Middle-Atlas and 300 mm in the downstream area of the river, with a mean of 550 mm (fUSAID, 2010). It is concentrated from October to April with maximum between December and February (Lionello et al., 2006). It snows on average 20 days/year over 800 m. Temperature varies between 5 and 50 °C with mean minimum and maximum values of 3.5 °C (January) and 38 °C (August) (USAID, 2010). Evaporation can reach 2500 mm/year with a monthly maximum of 300 mm in July and August. Water supplies of the Oum Er

Rbia basin are valued at 3360 million m^3/year, ranging from a high of 8300 Mm^3 and a minimum of 1 300 Mm^3. Contributions from many sources associated with those of snowmelt guarantee sustained low flows for the Oum-Er-Rbia making it the most consistent of the Moroccan rivers.

The investigated Oum Er Rbia River covers a length of 550 km from the Middle Atlas at 1800 m, through the Tadla plain and the coastal plateau, and flows into the Atlantic Ocean at Azemmour city. The main tributaries of the river are those of the left bank namely Oude Derna, El Handek, Tessaout, Lakhdar and El Abid Rivers (Fig. 1). Many dams and reservoirs have been built on the Oum Er Rbia River to generate hydroelectric power, to provide water for irrigation, and to supply domestic and industrial water. The Oum Er Rbia River and their tributaries crosses some regions characterized by strong agricultural (large irrigated areas and livestock), industrial (oil mills, phosphate extraction, and sugar beet processing). In addition, untreated municipal sewage ends up in the Oum Er Rbia River and its tributaries. The industrial effluents connected to the wastewater system are negligible. The daily sewage effluents are estimated to be 44.000 m^3. The total daily pollution produced by urban population and transported by sewage is approximately 50 t of oxidizable matter, 8.4 t of crude protein and 1.25 t of phosphorus material.

2.2. Sampling and monitored pollutants

As an effort to monitor changes in the Our ErRbia water quality, the Hydraulic Basin Agency of Oum Er Rbia, Ministry of Energy, Mines, Water and Environment of Morocco, has installed a program of measurement of multiple parameters at periodic times in different monitoring stations along the Oum Er Rbia River and its tributary Oued El Abid. The present study was conducted to analyze and interpret data obtained from this monitoring program in order to assess the evolution of water quality of Oum Er Rbia River and its tributaries. Water samples were collected from 14 sampling stations distributed alongside the Oum Er Rbia and El Abid Rivers (Fig. 1, Table 1), during different periods over 12 years (2000–2012). The sampling was done on seasonal basis viz., during winter (December to April) and low-water (April to November) seasons. The sampling stations were selected on the basis of their contamination vulnerability, i.e., the stations near to the river source were supposed to be less impaired by urban contamination and the stations downstream to the city were supposed to be more impaired by this contamination type. The stations located just upstream and downstream from the urban and rural zones are S2, S3, S4, S8 and S10, and just after the confluence of the Oum Er Rbia River with its tributaries are S6, S7, S11 and S12. The rest of the monitoring stations are located on areas vulnerable to the nonpoint source pollution along the river (S13 and S14). S1 and S9 stations are near the source of Oum Er Rbia and El Abid Rivers, respectively. These both sites are considerate relatively non-affected area by domestic pollution. The monitored water quality parameters, their units and the methods of analysis are summarized in Table 2. The temperature (TEMP), pH, electrical conductivity (EC), turbidity and dissolved oxygen (DO) of each water sample were measured in situ. The other parameters, namely total suspended solids (TSS), ammonia (NH_4^+), nitrate (NO_3^-), total phosphorus (TP), biological oxygen demand (BOD_5), chemical oxygen demand (COD), and fecal coliforms (F. *coli*), were analyzed in laboratory using the same analytical techniques following the standard methods (Rodier et al., 2009). The obtained data are compared to the Moroccan quality standards (Table 3) adopted by the Ministry of Energy, Mines, Water and Environment of Morocco (2002).

Table 1
Water quality monitoring stations of the Oum Er Rbia River and its tributaries.

Stations		Rivers
S1	Taghat	Oum er Rbia
S2	Downstream of Khénifra discharge	Oum er Rbia
S3	Tadla dam	Oum er Rbia
S4	Downstream of Tadla discharge	Oum er Rbia
S5	Kasba Zidania	Oum er Rbia
S6	Mechraa Ed Dahk confluence	Oum er Rbia
S7	Oued Day confluence	Oum er Rbia
S8	Downstream of Ould Zidouh discharge	Oum er Rbia
S9	Ait Ouchen	El Abid
S10	Ouaouirinth	El Abid
S11	Ouled Sidi Driss	Oum er Rbia
S12	Bssi Bissa	Tassaout
S13	Tassaout confluence	Oum er Rbia
S14	Upstream of Sidi Said Mâachou dam	Oum er Rbia

Table 2
The water quality parameters and their analytical method in this study.

Parameters	Analytical method	Unit
Temperature	Temperature probe	°C
pH	Potentiometry/pH probe	
Turbidity	Turbidimetry	NTU
Total suspended solids	Gravimetric	mg/l
Electrical conductivity	Conductometry	µs/cm
Ammonia	Spectrophotometry	mg/L
Nitrate	Spectrophotometry	mg/L
Dissolved oxygen	Oximeter	Mg/l
Total phosphorus	Spectrophotometry	mg/L
Biological oxygen demand	BOD meter	mg/l
Chemical oxygen demand	COD meter	mg/l
Fecal coliforms	Spread plate methods	UFC/100 ml

In order to facilitate consistent evaluation of the dataset of these multiple variables monitored during various periods at different sampling stations, multivariate analyses of the water quality dataset were performed through Pearson's correlation, PCA and CA. All statistical computations in this study were made using Microsoft Excel 2007 and IBM SPSS 20.

Dataset analysis was performed using the Pearson correlation analysis in order to evaluate the relationship between water quality variables. This minimizes the effect of between-stations correlations and between-sampling campaigns relationships. To interpret the coefficients' correlation, a common source, uniform distribution and similar behaviors must be assigned to the correlated variables (Azaza et al., 2011; Parizi & Samani, 2013). A correlation coefficient near −1 or 1 means a strongest or negative or positive relationship between two variables and its value closet to 0 means no linear relationship between them at a significant level of $p < 0.05$ (Kumar et al., 2006). However, it should be noted that with larger samples, a low strength of correlation, for example $r < 0.50$, can be highly statistically significant at $p < 0.01$.

The data were further checked for normality by conducting Kaisere Meyere Olkin (KMO) and Bartlett's Sphericity tests in order to check if our measured variables can be factorized efficiently. The KMO index compares the values of correlations between variables and those of the partial correlations. When KMO index is close to 1, the PCA of the variables is suitable; but when it is close to 0, the PCA is not relevant. Generally, this index should be greater than 0.5 for satisfactory factor analysis. In our analysis, the KMO had a value of 0.551. Bartlett's Sphericity test was used to check the null hypothesis that the inter-correlation matrix comes from a population in which the variables are uncorrelated (Shrestha & Kazama, 2007). The null hypothesis was rejected at the significance level of 0.05, but in our study, the level value is 0 which is small enough to reject the null hypothesis. In fact, the PCA was applied efficiently on our data to identify underlying interrelationship amongst the parameters.

PCA was applied on reduced standardized data sets to extract information about correlation among variables analyzed in the water samples (Mahlknecht et al., 2004; Srivastava and Ramanathan, 2008). Z-scale standardization with mean and variance of zero and one, was

Table 3
Moroccan surface water guidelines (2002).

Quality classification	TEMP °C	pH	EC (µS/cm)	Turbidity (NTU)	TSS	DO	BOD_5	COD (mg/l)	NH_4^+	NO_3^-	TP	F. coli (UFC/100 ml)
Excellent	< 20	6.5–8.5	100–750	< 15	< 50	> 7	< 3	< 20	< 0.1	< 10	< 0.1	< 20
Good	20–25	6.5–8.5	750–1300	35–70	50–200	7–5	3–5	20–25	0.1–0.5	10–25	0.1–0.3	20–2000
Moderate polluted	25–30	6.5–9.2	1300–2700	35–70	200–1000	5–3	5–10	25–40	0.5–2	25–50	0.3–0.5	2000–20000
Polluted	30–35	< 6.5 or > 9.2	2700–3000	70–100	1000–2000	3–1	10–25	40–80	2–8	> 50	00.5–3	> 20000
Highly polluted	> 35		> 3000	> 100	> 2000	< 1	> 25	> 80	> 8		> 3	

used in order to minimize the influence of difference on variance of variables and to adjust for the disparity in the variable sizes and in the measurements units (Simeonov et al., 2003; Liun et al., 2003). Calculation was achieved based on the correlation matrix of measured parameters, and the PCA scores were obtained from the standardized variables data. The varimax rotation is used to maximize the variance of the squared loadings. The Kaiser's criterion (Kaiser, 1960) was used to determine the number of factors to retain.

To investigate similarity and dissimilarity in composition between sampling stations (temporal and spatial variability), CA analysis was employed on the normalized data by means of the Ward's method, using squared Euclidean distances as a measure of similarity (Massart & Kaufman, 1983; Singh et al., 2005; Zhao et al., 2011). The Ward's method says that the proximity between two clusters is the increase in the squared error. This is the most common method to categorize more accurately groups (Willet, 1987). For all parameters tested, distributions were centered and reduced prior to clustering. The result is illustrated by a dendogram presenting the clusters and their proximity (Forina et al., 2002) with a reduction in dimensionality of the original data.

3. Results and discussion

3.1. Water quality evaluation

The summary of the range, mean value, standard deviation of measured variables in the river water samples at 14 stations for the summer and winter seasons, and the Moroccan quality standards (2002) are provided in Tables 3, 4, respectively. Pearson's correlation coefficient (r) gives an idea about the possible relationships between biophysical variables. Table 5 presents the values of Pearson's correlation coefficient ($p < 0.01$) for pairs of variables at all sampling stations and campaigns.

A high standard deviation indicates that the data is widely spread, due to the presence of temporal variations caused likely by natural and/or anthropogenic polluting sources.

The water TEMP causes significant environmental impacts (Leynaudn, 1968) by influencing the physical, chemical and biochemical (WHO, 1987). In the present study, the TEMP values recorded ranged between 9.5 and 39.2 °C. The recorded TEMP showed higher level in summer, and substantial increase towards downstream. The measured pH values varied between 6.91 and 9.25, and they are generally within the recommended range 6.5–8.5 of Moroccan standards, except for few levels significantly higher recorded at stations S6, S10, S11 and S12. It was higher in summer compared to winter season. The lower pH values are recorded at stations close to wastewater discharge points (S3, S4). It was negatively correlated with TSS (r=0.14) and turbidity(r=0.20).

The turbidity concentration shows a wide ranging between 0 and 61107 NTU, indicating that the river water had moderately to highly polluted quality according to Moroccan standards (over 60% the samples). There was a positive correlation between turbidity and water TSS (r=0.77), TP (r=0.16) and NH_4^+ (r=0.15), but no apparent correlation between turbidity and F. *coli*. The highest values were recorded during the winter season in upstream stations, and during summer in stations close to the confluence of Oum Er Rbia River with their tributaries which are characterized by a summer floods and high flow regime. This could be explained by the presence in water, besides microorganisms, of colloidal materials such as silt, clay, organic and inorganic material into fine particles (WHO, 2008). The TSS concentrations, ranging between 1.4 and 37043 mg/l in summer season, peaked in confluence areas of tributaries and recipient river (Oum Er Rbia), and decreased when moving away from these areas. This could be particularly attributable to runoff waters after storm events (Kistemann et al., 2002). Since the TSS was low in stations located far from confluence areas especially in winter, there were probably other factors that contributed to the water turbidity. At winter season, the significantly higher mean TSS values recorded at S2, S3, S4 and S5 stations compared to downstream stations could be attributed to *urban wastewater discharges*.

EC high level is observed in all stations of Oum Er Rbia River, and ranged between 314 and 3500 µS/cm. It's due to significant amount of dissolved salt in the major springs supplying Oum Er Rbia River. Water EC shows a slight decrease moving downstream, despite increasing or decreasing discharge. The mean EC values were 1990 µS/cm at S3 and 1295 µS cm^{-1} at station S14. At El Abid River, the EC the level is low and ranges between 521 µS cm^{-1} at S9 and 714 µS cm^{-1} at S10. The net increase in conductivity level at station S10 which lies downstream of El Abid River, especially near the Ouaouirint village, would be linked to both agricultural and domestic human activity. According the Moroccan guidelines (2002), these measurements also indicated that the major water samples ranked as moderate to highly polluted class in terms of water quality. EC showed significant positively correlated with COD but negatively correlated with TSS, NO_3^- and TP.

$NH_4^+$is a water-soluble gas that exists at low levels (0.1 mg/l) in natural waters. NH_4^+comes from the nitrogen-containing organic material and gas exchange between the water and the atmosphere (Chapman & Kimstach, 1996). It also comes from the biodegradation of waste and inputs from domestic, agricultural and industrial, and that is why it is a good indicator of contamination of water ways. The measured NH_4^+values vary between 0 and 3.59 mg/l in winter and between 0 and 2.40 mg/l in summer, and showed a significant positive correlation ($p < 0.01$) with F. *coli* (r=0.26), turbidity (r=0,147), TSS (r=0,103) and BOD_5 (r=0,144), and a significant negative correlation with DO (r=−0,124). NH_4^+ values remain below the normal rate set by the Moroccan standards in several stations showed normal values, except in S2, S4 and S8 stations that are located downstream of wastewater discharges of Khenifra, Kasba Tadla and Dar Ould Zaidouh cities, respectively. In these stations higher values (> 50% of the samples) were recorded, indicating moderate to highly polluted river water. This showed the negative impact of discharges from cities on the water quality of the studied rivers.

NO_3^- concentrations in natural waters are in the order of 1–10 mg/l. At excessive concentrations, NO_3^- impacts negatively fauna and flora. The average concentrations of NO_3^- in this study ranged from 0 to 24.2 mg/l with around 80% of analysis are lower than 10 mg/l in summer and around 75% higher than 15 mg/l in winter. The measured NO_3^- concentrations showed significant negative correlation with TEMP (r=−0.50) and EC (r=−0.20), and positive correlation with COD (r=0.73). This indicates that the NO_3^-concentrations are likely

Table 4
Statistical descriptive for the parameters analyzed at all stations.

		TEMP °C	pH	EC (µS/cm)	Turbidity (NTU)	TSS	DO	BOD_5	COD (mg/l)	NH_4^+	NO_3^-	TP	F. coli (UFC/100 ml)
S1	MeanSD	16.53 3.33	8.22 0.26	2276.03 470.41	105.18 165.76	207.84 643.23	9.21 0.88	1.59 2.3	17.63 10.86	0.05 0.05	8.45 5.81	0.31 1	643.5 1267.84
S2	MeanSD	18.01 3.6	8.1 0.42	1690 392.47	711.17 1750.21	42.44 43.88	8.37 1	1.98 1.08	19.98 7.89	0.74 0.34	6.17 6.76	0.28 0.23	16284.62 32819.25
S3	MeanSD	19.74 4.21	8.09 0.39	1692.71 406.71	556.43 1050.12	40.35 54.25	8.39 0.68	1.46 2.17	22.89 15.62	0.14 0.1	7.92 6.96	0.21 0.3	1006.92 1591.84
S4	MeanSD	19.91 5.06	8.03 0.4	1673.46 414.63	1213.55 1771.7	36.66 56.79	6.71 2.06	3.85 4.45	20.6 11.72	0.91 1.03	6.29 7.04	0.54 0.58	20863.64 38090.79
S5	MeanSD	20.95 4.16	8.04 0.41	1590.58 403.48	837.61 1746.09	58.5 77.7	8.21 0.93	0.84 1.02	18.44 14.85	0.11 0.08	7.51 7.51	0.24 0.38	926.92 1934.37
S6	MeanSD	20.67 4.98	8.26 0.3	1646.74 578.86	546.15 1917.67	498.46 1605.94	8.99 1.36	2.05 1.82	29.8 73.08	0.09 0.12	9.11 6.94	0.21 0.22	890.13 3382.46
S7	MeanSD	21.49 4.5	8.14 0.21	1569.38 390.93	250.1 616.03	63.44 55.35	8.29 1.03	1.66 1.12	20.95 11.56	0.17 0.14	5.61 7.13	0.26 0.37	413.08 357.76
S8	MeanSD	22.26 4.07	8.11 0.23	548.62 64.12	345.35 758.56	86.48 54.95	7.4 1.22	1.26 0.69	25.97 13.56	0.4 0.96	9.49 8.37	0.19 0.15	1122.31 2003.97
S9	MeanSD	19.46 5.98	8.01 0.24	2155.17 310.46	417.11 808.47	901.7 2528.75	8.54 0.95	1.88 2.22	17.61 14.47	0.09 0.08	5.67 5.54	0.5 1.31	151.15 135.68
S10	MeanSD	21.15 4.9	8.18 0.22	1079.62 322.31	280.25 445.17	457.74 2087.47	8.37 1.29	1.18 0.9	17.9 13.61	0.08 0.09	11.28 6.14	0.22 0.28	1372.66 6495.6
S11	MeanSD	21.87 4.63	8.18 0.26	1543.64 451.09	548.78 1672.39	373.23 1071.65	8.75 2.05	2.08 2.01	23.79 18.74	0.09 0.09	10.36 7.25	0.5 1.26	4046.61 13722.15
S12	MeanSD	22.12 4.23	8.03 0.21	1413.37 389.27	1001.76 4331.88	950.65 3637.3	8.76 2.09	1.56 1.99	19.9 21.58	0.08 0.1	12.62 6.77	0.21 0.46	1081.6 3801.12
S13	MeanSD	21.8 4.56	8.22 0.25	1530.45 488.47	573.07 1982.24	805.91 2424.85	8.43 1.48	2.23 1.71	21.71 14.34	0.11 0.14	10.68 7.1	0.44 0.71	1414.58 4775.79
S14	MeanSD	21.98 4.07	8.2 0.22	1646.06 271.36	156.75 541.86	63.95 284.06	8.64 1.05	2.04 2.12	21.57 15.15	0.09 0.08	8.91 8.11	0.11 0.11	331.19 881.83

due to the leaching from agricultural land. All of the NO_3^- samples were well below the level of 25 mg/l, qualifying the water quality as excellent to good quality class.

DO content is an essential parameter that maintains the equilibrium of aquatic ecosystems. It is commonly used to assess the water resource quality (Qadir et al., 2002; Sanchez et al., 2006). The river running water contains about 10 mg/l. Mean concentrations of DO in study are generally level of below 7 mg/l, but they remain significant with values of 2.80–21.80 mg/l in summer season and 5.92–14.02 mg/l in winter season, qualifying the water quality as quality good to excellent. Spatially, lower values were observed at stations downstream of wastewater discharges from cities (S4 and S8), due to local domestic wastewater. In correlation matrix, it was found that DO was negatively correlated to TEMP. As documented by Kumari et al. (2013), , this was explained by the fact that increasing temperature reduces the dissolution of ambient DO in river water. Also, Yang et al. (2007) hypothesized that the low DO values in summer were linked to the high activities of microorganisms requiring large amounts of oxygen for metabolizing activities and for organic matters degradation. DO in our study present also negative correlation with NH_4^+, indicating that low DO concentration decreases nitrification rate (ammonia oxidation) (Ruiz et al., 2006). Consequently, this explained the positive correlation between DO and NO_3^-.

TP includes organic and inorganic phosphorus. In surface water, it content is less than 0.1 mg/l. The discharge of domestic and industrial water and the drainage of agricultural land fertilized contribute to increase the concentration. TP shows concentrations of from 0.01 to 8.85 mg/l, with more than 50% of the samples show values above the level of the good quality (0.3 mg/l) in winter season, and less than 14% of samples monitored in summer season have values above said level. The highest values were recorded in upstream stations (close to discharge points) in winter and in downstream stations in summer period, indicating a mixed origin due to a likely effect of leaching and runoff from fertilized farmland (Groupement ADI/CACG, 2010) and effluent from certain industries (e.g. food processing) and domestic waste. TP correlated reasonably well with turbidity, TSS, BOD_5 and F. *coli* suggesting that TP originated from natural and anthropogenic sources.

BOD_5 and COD are two parameters used to quantify the organic contamination load (Galal-Gorchev et al., 1993). BOD_5 in the various stations shows values between 0.10 and 15 mg/l with nonsignificant variation between seasons. These values indicated that the water samples ranked as excellent to polluted quality with respect to Moroccan standards (2002). BOD_5showed positive correlation with TP and F. *coli* indicating that the wastewater effluent input contribute to BOD_5 in studied river basin. COD is widely used for determining waste concentration (Kazi et al., 2009). COD shows contents between 0.02 and 149 mg/l, with some variations between seasons, especially for stations situated downstream the confluence of El Abid River. Also, higher values are monitored at stations (S2, S3, S6, S8, S9) located downstream of wastewater effluents. The high COD values compared to BOD_5 values and the non-correlation between them, indicate that the major part of organic material is not biodegradable. All of the above indicate that the COD could be related to the leaching and transport of natural, domestic sewage, agricultural and industrial pollutant. Compared to Moroccan standards, different stations with more than 50% of samples show a moderately to highly polluted quality, especially in summer.

The main sources of F. *coli* are untreated wastewater, animal husbandry, grazing areas, and the application of manure. The presence of F. *coli* is an indicator of the bacteriological quality of water. The monitored concentrations of F. *coli* ranged between 0 and 120,000 CFU/100 ml, and do not satisfy the Moroccan standards of the surface water quality in many stations, especially in winter. These stations are located downstream urban liquid discharge points. As also shown in Table 5, there was a significant positive correlation between F. *coli* and

Table 5
Correlation matrix of water quality parameters (Pearson correlation coefficients (r)).

	TEMP	pH	EC	Turbidity	TSS	DO	BOD_5	COD	NH_4^+	NO_3^-	TP	F. *coli*
T°	1											
pH	0.02	1										
EC	−0.08	−0.06	1									
Turb	0.08	**−0.20****	−0.08	1								
TSS	0.01	**−0.14****	**−0.13****	**0.77****	1							
DO	**−0.33****	0.00	0.02	−0.03	−0.07	1						
BOD_5	0.04	0.02	0.04	0.03	0.05	0.02	1					
COD	**−0.67****	0.03	**0.27****	−0.03	−0.03	**0.23****	0.00	1				
NH_4^+	−0.02	−0.05	−0.08	**0.15****	**0.10****	**−0.12****	**0.14****	−0.02	1			
NO_3^-	**−0.50****	−0.01	**−0.20****	−0.01	0.02	**0.17****	−0.01	**0.73****	0.02	1		
TP	−0.08	−0.06	**−0.21****	**0.16****	**0.26****	0.04	**0.31****	0.03	0.06	**0.16****	1	
F Col	0.05	−0.04	−0.07	0.09	0.06	−0.08	**0.38****	−0.10	**0.30****	0.02	**0.26****	1

** Correlation is significant at $p < 0.01$ level (2-tailed)

BOD_5 (r=0.38), NH4+(r=0.30) and TP (r=0.26), confirming that they have an origin, nevertheless, in common part.

3.2. Source identification of monitored variables

The PCA based on the correlation matrix was performed to understand the underlying relationships between the water quality variables of all monitoring stations, and to identify their characteristics. The Kaiser's criterion (Kaiser, 1960) was used to determine the number of PCs to retain. The PC loadings were classified as 'strong', 'moderate', and 'weak' corresponding to absolute loading values of > 0.75, 0.75–0.50 and 0.50–0.30, respectively (Liu et al., 2003). The scree plot graphs are used widely to identify the number of PCs of the basic data structure (Liu et al., 2003). The scree plot (Fig. 2) showed the sorted eigenvalues from large to small as a function of the PC number. This figure shows a pronounced change of slope after the 4th eigenvalue; four components were retained. Loadings of four retained PCs are expressed in Table 6.

In this study, eigenvalues greater than 1 were extracted from the PCs having. Four principal components were obtained with eigenvalues > 1 (Kaiser Normalization) that explained almost 63% of the total variance in the water dataset (Table6). The variables with eigenvalues lower than 1, were removed due to their low significance (Kim and Mueller 1978).

The first factor (PC_1), accounting 21.76% of the total variance, showed high positive loadings of COD, NO_3^-, weak positive loading of DO, and high negative loading of TEMP. This factor can be attributed to biogenic and anthropogenic (urban wastewater) pollution sources. NO_3^- may additionally derive from agricultural areas in the region where inorganic nitrogen fertilizers are in common use. The second factor (PC_2) explained 17.80% of the total variance. It had negative weak loading on pH, and strong positive loading on TSS and turbidity, and could be attributable to the physical and chemical properties of the water, and to natural weathering of the basin. These three variables originated primarily from run-off with high load of solids and wastes from point sources of pollution like agricultural fields, and domestic areas (Gazzaz et al., 2012). The studied rivers receive large amount of debris due to continuous erosion of soil from the river watersheds and of the Atlas Mountain. The third factor (PC_3), explaining 15.43% of the total variance, contains a large positive loading on F. *coli*, TP and BOD_5, and weak positive loading on NH_4^+. This factor including organic and nutrient variables may be associated to influences from municipal and industrial point-source discharges, agricultural non-point sources, livestock operations, and/or domestic sources (Simeonov et al., 2003). Hence, it can be regarded as the contamination index of river water. The fourth factor (PC_4) accounting for the lowest total variance (10.31%), has a strong positive loading on EC, weak loading on BOD_5, and weak negative loading on NO_3^-, which is indicative of mixed source of contamination comprising of natural processes as well as anthropogenic inputs.

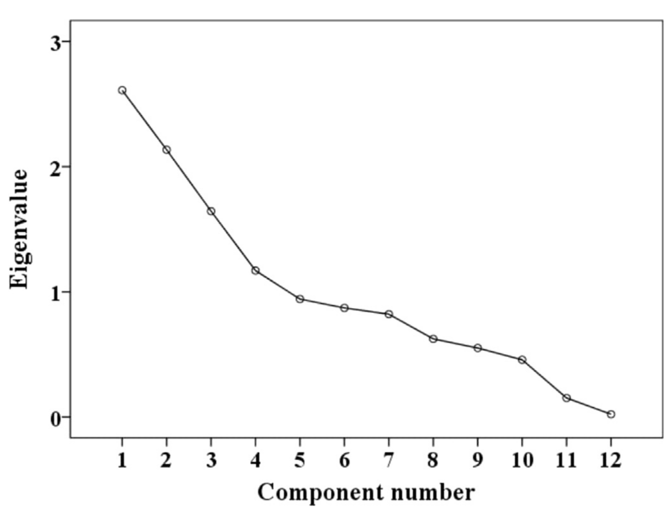

Fig. 2. Scree plot of the eigenvalues.

These PCA analyses identified the potential contamination sources of Oum Er Rbia river water. This contamination is due to a mixed source including natural processes and anthropogenic activities. The discharging untreated urban wastewater into surface water system constitutes the major point anthropogenic contamination source. The non-point source which also contributes immensely in Oum Er Rbia water contamination is from agricultural activities; especially the river runs through agricultural areas known by intensive culture and livestock farming.

3.3. Spatial and temporal variation in river water quality

CA was applied to categorize spatial and temporal similarity group of all monitoring stations according to their water quality similarities. The dendrograms of stations obtained by Ward's method in the summer and winter seasons are shown in Fig. 3.

Spatial CA result showed that all 14 monitoring stations were classified according to three clusters in summer (Fig. 3) and winter (Fig. 4) seasons. The stations in each group have similar water contamination types and greatness.

In summer season, the cluster 1 included the stations S1, S3, S5, S6 and S7 that are located upstream part of the Oum Er Rbia River. The stations S10 and S14 located at the downstream of El Abid and Oum Er Rbia Rivers, respectively, showed the similar quality characteristics with the previous stations. The cluster 2 is composed by the stations S8, S9, S11, S12, and S13. These two clusters 1 and 2 correspond to moderate contaminations. The cluster 3 included stations S2 and S4 that are located just downstream of the urban wastewater discharge

Table 6
Loadings of experimental variables (12) on principal components for the whole datasets.

PCs	COD	NO_3^-	TEMP	DO	TSS	Turbidity	pH	F. *coli*	TP	BOD_5	NH_4^+	EC	eigenvalues	% of variance
PC_1	**0.90**	**0.82**	**−0.81**	**0.43**	−0.06	−0.06	0.00	−0.09	0.08	−0.14	0.08	0.19	2.42	20.13
PC_2	0.01	−0.04	0.08	−0.01	**0.95**	**0.95**	**−0.45**	−0.04	0.06	−0.02	0.21	0.03	2.05	17.12
PC_3	−0.02	0.03	0.02	−0.06	0.15	0.10	0.08	**0.76**	**0.72**	**0.71**	**0.46**	−0.05	1.85	15.43
PC_4	0.15	**−0.30**	−0.06	0.22	−0.14	−0.10	−0.18	0.03	−0.29	**0.34**	−0.26	**0.87**	1.24	10.31

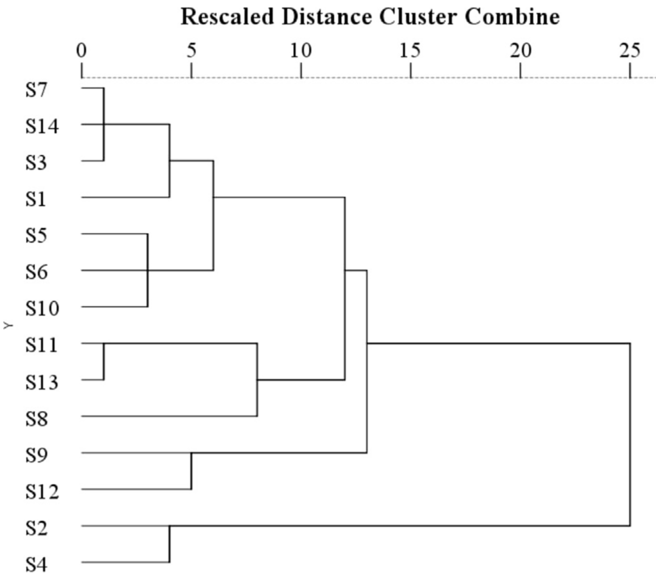

Fig. 3. Dendogram based on hierarchical clustering (wards method) for complete stations in summer season and winter season.

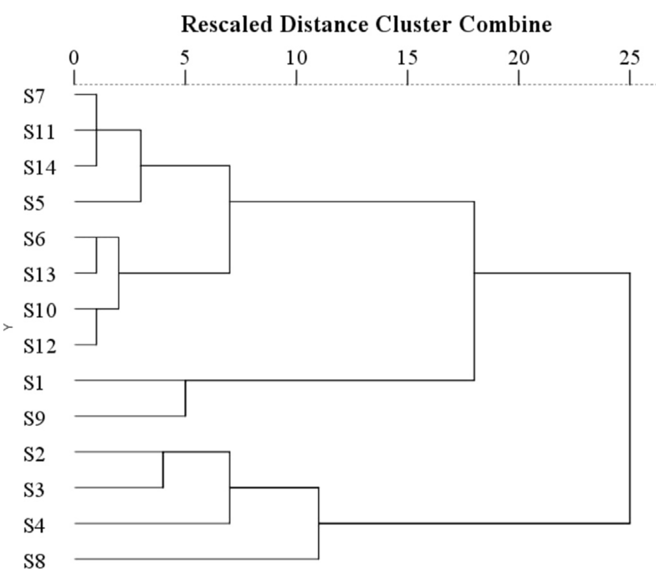

Fig. 4. Dendogram based on hierarchical clustering (wards method) for complete stations in winter season.

points of Kasba Tadla and Khenifra Cities, respectively. This cluster corresponds to highly pollution, compared to the other clusters (1–2), due to the urban wastewater discharge. During the summer, due to the lack of precipitation, tributaries become dry and therefore urban wastewater discharges do not reach the Oum Er Rbia River. Another effect of lack of precipitation is the decrease of the diffuse input of contaminants through leaching of watershed soils. This explains why the contamination during the summer is mostly located in the stations located immediately downstream of the great cities, especially Kasba Tadla and Khenifra.

In winter season, the dendrogram shows that all monitoring locations cluster into three clusters. The cluster 1 corresponding to relatively high levels of water contamination compared to the others clusters. This cluster is formed by the uppermost monitoring stations S2, S3, S4, S5, S7 and S8, located at the Oum Er Rbia river upstream section. Important anthropogenic sources can be detected in this river section. This upstream section received urban and rural wastewater effluents discharged directly into Oum Er Bia River (S2, S3, S4, S8) and via their tributaries. Also, at this zone, pollutants from leaching of soil by intensive agricultural and livestock activities constitute the common non-point contamination sources. The cluster 2 is formed by the stations S1 and S9 that is situated upstream of Oum Er Rbia and El Abid River, which consisted to less contaminated areas. Rock and soil alteration represent the only source of potential contamination. The cluster 3 composed by the rest stations mainly located downstream of the Oum Er Rbia river basin, it corresponded to relatively moderate levels of river contamination. Stations of cluster 3 received pollutants from domestic wastewater and mostly from non-point sources, such as animal waste and manure and soil leaching and runoff.

4. Conclusion

This study was conducted to identify the sources of contamination on the water quality in the Oum Er Bia River and its tributary Oued El Abid. Multivariate statistics including Pearson's correlation, PCA and CA were employed to evaluate spatial and seasonal variations of surface river water quality data. According to obtained physicochemical an biological results, some variables at most stations showed average concentration exceed those recommended by the guide levels allowed by the Moroccan Directive concerning the quality of river water. This indicated that the river water is affected from the pollutants in the river catchment area. The PCA techniques helped in identifying the factors or sources causing the degradation of water quality. The cause of water quality variations is mainly related to contamination load from diffuse (non-point) sources due to weathering of mineral and soil (PC_1, PC_2 and PC_4 factors), and from urban wastewater discharge (PC_3). CA applied to categorize spatial and temporal similarity group of all monitoring stations according to their water quality similarities was performed, and revealed the presence of nonpoint and point sources of contamination and the temporal variations that are controlled by the precipitation and water runoffs. In summer season, the contamination is linked to the stations (S2 and S4) located downstream of the urban wastewater discharge points. These stations were identified as affected by organic contamination, and corresponded to relatively high levels of river contamination. In the stations situated at the mid and downstream of Oum Er Rbia River, the water contamination it remains moderate due to lack of leaching and runoff. The water quality in winter is controlled by mixed origin of natural, wastewater discharges and surface runoff.

We conclude that the management of domestic and industrial wastes is required to lower the accumulation of pollutants in water and soil, and to minimize environmental degradation. This should be achieved by installing municipal solid waste landfills, and proper treatment of municipal and industrial wastewater before being released to the environment, and also the improvements in agricultural practices. The results showed also the importance of multivariate statistical assessment of large datasets to get better information about the quality of surface water which can help the environmental managers to make better decisions regarding action plans.

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