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Physico-chemical and bacteriological characterization of surface water in Djendjen River (North Eastern Algeria)

Krika, A.[1*] and Krika, F.[2]

1. Department of Environmental Sciences and Agronomic Sciences, Faculty of Nature Life and Sciences, University of Jijel BP 98 Ouled Aissa, Jijel 18000, Algeria
2. Department of Process Engineering, Faculty of Technology, University of Laghouat, BP 37G, Laghouat 03000, Algeria

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ABSTRACT: Djendjen River is one of the largest rivers in the region of Jijel (Algeria). Human activities such as urban discharges, industrial, agricultural, and livestock have significant effects on the quality of water. The present study attempts to evaluate the quality of water along the banks of the Djendjen River at different sampling sites, using physico-chemical and bacteriological methods. The collected samples are analyzed per standard method parameters and measured in situ. The mean values of the physico-chemical parameters of the river water samples are consistently lower than the levels, certified by the Algerian standard (exept for pH and PO_4^{3-}). The total and fecal coliform surpasses the Algerian standard limits (0 cfu/ 100 ml) at all sites, signifying that without treatment the water is unsuitable for human consumption. Results reveal that water quality of the Djendjen River is generally affected by the anthropogenic activities, taking place along its banks. The moderate organic pollution (OPI= 2-2.6) and high faecal contamination (MQI=3-3.25) of water in the study area has adverse impacts on the environment and public health, which requires a combined treatment (biological and physicochemical).

Keywords: Djendjen River, microbiological quality index, organic pollution index, water.

INTRODUCTION

Surface water pollution is one of the most widespread environmental issues of the 21st century (Perrin et al., 2014), which may negatively affect aquatic ecosystems and human health, also resulting in important constraints in the utilization of water, e.g. recreation, commercial fish farming, industrial applications, and animal or human consumption (Ferreira et al., 2010; Arsovski et al., 1991; Ranjbar Jafarabadi et al., 2016). Surface water quality is controlled by complex anthropogenic activities and natural factors (Xian et al., 2007; Bayram et al., 2013). Agriculture and urban wastewater discharges can have a significant impact on the quality of surface and ground water.

For example, continued discharge of nutrient-rich wastewater effluent into surface water resources leads to eutrophication problems (Sibanda et al., 2014). In agriculture, while the application of organic manure and/or inorganic fertilisers boosts the production of crops, making food affordable to even the low socio-economic classes,

[*] Corresponding Author Email: a.krika@hotmail.com, Tel:+213 662081901

nutrient application that exceeds plant needs is potential to pollute surface and groundwater (Sibanda et al., 2014; Bhumbla, 2011).

Water quality monitoring traditionally entails the determination of certain parameters to analyse physico-chemical (pH, BOD, DO, ammonium, nitrate, nitrite, and orthophosphate) and microbiological (total coliforms, faecal coliforms, and faecal streptococci) attributes of water. Water quality indices are tools that use an integrative methodology to convert a large set of data into a single number to express the water quality (Lumb et al., 2011); they can be calculated using physical, chemical, and microbiological data (Hurley et al., 2012).

The determination of Organic Pollution Index (OPI) and Microbiological Quality Index (MQI) with the physicochemical and microbiological parameters in the surface water can draw some conclusions as to the biodegradation of organic matter and power selfpurification of water (Djidel et al., 2008).

The Djendjen River, considered in this study, is a major riverine system in the alluvial plain of Djendjen, north east of Algeria, which continues to be affected by direct human activities (urban effluents and fertilizers); the deteriorating quality of its surface water, becoming a major concern for managers and users of this precious resource.

This study, therefore, intends to evaluate and assess water quality in Djendjen River. Its specific objectives are as the following: i) to evaluate the physico-chemical and microbiological characteristics of water; ii) to examine the effects of anthropogenic factors on water quality in Djendjen River; and iii) to determine the OPI and MQI values from measured parameters. OPI and MQI values provide a remarkable indicator of water quality for agricultural and human consumption.

MATERIALS AND METHODS

Study area

The Djendjen River basin is located in north-eastern part of Algeria (Fig. 1) between 5°30’ and 5°58’E longitude and 36°22’ and 36°48’ N latitude. It is characterized by humid Mediterranean climate. The average annual air temperature and precipitation is 18.4°C and 970.6 mm respectively, with the rainfall season between November and March. The total study area is 525 km^2.

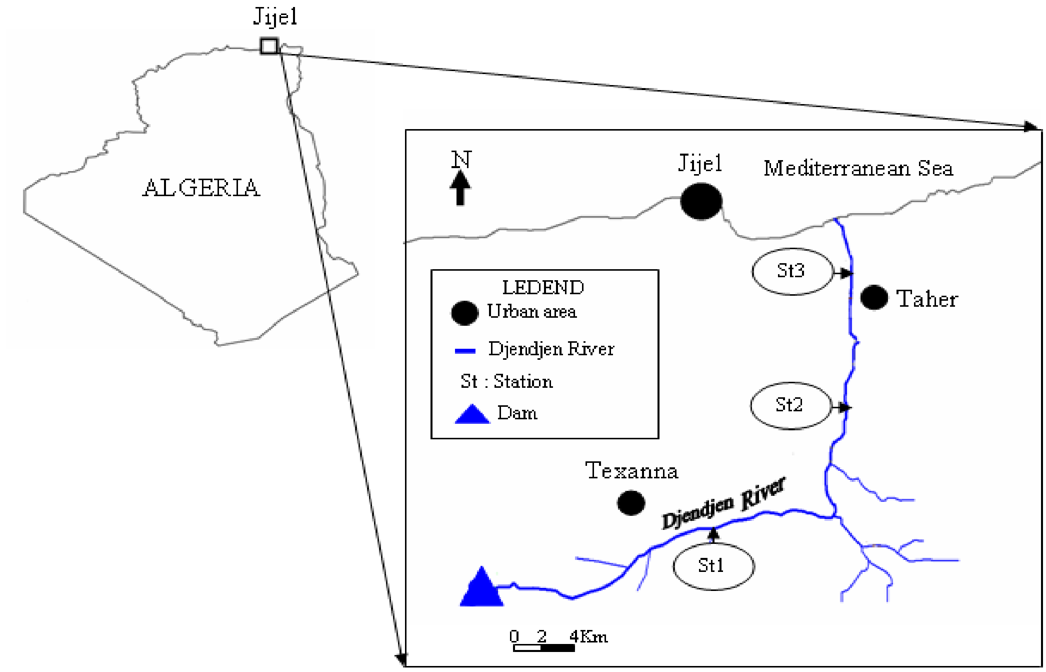

Fig. 1. Study area and sampling locations

The dominant crops in the study area are greenhouses, covering 70% of the agricultural area. Major vegetables grown are lettuce, white cabbage, tomato, and pepper.

Agricultural wastes, fertilizers and raw sewage effluents constitute the predominant anthropogenic sources in the area.

Water quality evaluation index

In order to evaluate water quality, which encompasses a number of pollutant species, an ecological approach should combine physical, chemical, and biological constituents to reflect the quality status (Chapman, 1996).

The use of Organic Pollution Index (OPI) and Microbiological Quality Index (MQI) allows us to categorize water quality by converting the diverse physico-chemical and microbiological variables into a single number in a simple, objective, and reproducible manner. Thanks to this number, we can classify and compare the water quality situations in different places or during different time lines for a specific place.

To calculate Organic Pollution Index (OPI), we have used four water quality variables including (BOD_5) [mg O_2 L^{-1}], ammonium (NH_4) [mg N-NH_4 L^{-1}], nitrite (NO_2^-) [mg N-NO_2 L^{-1}], and orthophosphate (PO_4^{3-}) [mg L^{-1}] as well as three water quality parameters, namely total coliform (TC), faecal coliform (FC), and faecal streptococci (FS) to calculate Microbiological Quality Index (MQI).

The principle of the OPI is to spread the values of polluting elements in 5 classes (Table 1), then to determine the number of corresponding class for each parameter, from its own measures, and eventuallt to obtain the average (Leclercq & Maquet, 1987). For the calculation of the Microbiological Quality Index (MQI), the limits of the classes (Table 2) have been established by Bovesse and Depelchin (1980).

Water sampling and analytical methods

Water samples were collected from 3 sampling stations namely St1 to St3, used by the local people for domestic and agricultural purposes. The characteristics of the sampling stations are as follows:

Table 1. Classes of organic pollution (Leclercq & Maquet, 1987)

Classes	BOD_5 (mg-O_2.L^{-1})	Ammonium (mg-N.L^{-1})	Nitrites (µg-N.L^{-1})	Phosphate (µg-N.L^{-1})	0PI*	Classes of organic pollution
1	<02	<0.1	<05	15	5.0-4.6	Null organic pollution
2	2.1-05	0.1-0.9	06-10	16-75	4.5-4.0	Low organic pollution
3	5.1-10	1.0-2.4	11-50	76-250	3.9-3.0	Moderate organic pollution
4	10.1-15	2.5-6.0	50-150	251-900	2.9-2.0	High organic pollution Very
5	>15	>6.0	>150	>900	1.9-1.0	high organic pollution

*OPI = average number of classes of 4 parameters

Table 2. Classes of bacteriological pollution (Bovesse & Depelchin, 1980)

Classes	TC (MPN/100ml)	FC (MPN/100ml)	FS (MPN/100ml)	MQI*	Classes of bacteriological pollution
1	<2000	<100	<05	4.3-5.0	Null Fecal contamination
2	2000-9000	100-500	05-10	3.5-4.2	Low Fecal contamination
3	9000-45000	500-2500	10-50	2.7-3.4	Moderate Fecal contamination
4	45000-36000	2500-20000	50-500	1.9-2.6	High Fecal contamination
5	>360000	>20000	>500	1.0-1.8	Very high Fecal contamination.

*The average number of MQI classes is like calculating the OPI ; TC=total coliform ; FC=faecal coliforme ; FS=faecal streptococci

St 1: Located in the upper part of the river, characterized by small rural communities and agricultural activities.

St 2: Located in the middle part of the river, characterized by human and agricultural activities.

St 3: Located in the lower part of the river with low level agricultural development.

Water samples of 1000 mL glass bottles were collected between February and June, 2015, in triplicates, with cleaned and well-dried brown with necessary precautions. They were labelled with respect to the collecting points, date, and time in order to avoid any error between collection and analysis. The water samples were collected manually from the depth of 1 m in the center of the river.

In situ, electrical conductivity (EC), dissolved oxygen (DO), and pH of water were measured directly on site. Water samples were analyzed in the laboratory for 5-day biochemical oxygen demand (BOD_5), nitrate (NO_3), nitrite (NO_2), ammonium (NH_4), orthophosphate (PO_4^{3}), fecal coliform (FC), total coliform (TC), and faecal streptococci (FS).

Analysis methods are discussed in the American Public Health Association (APHA, 1998). Otherwise, the analytical methods used for measuring the water quality parameters are presented in Table 3.

Table 3. Water quality parameters, units and analytical methods

Parameters	Unit	Analytical methods
pH	-	Digital multi-parameter system (Consort C561)
EC	$\mu S.cm^{-1}$	Digital multi-parameter system (Consort C561)
DO	$mg.L^{-1}$	Numerical oxymeter
BOD_5	$mg.L^{-1}$	BOD metre (OXITOP IS6)
NO_3^-	$mg.L^{-1}$	Spectrophotometer (JENWAY 7315)
NO_2^-	$mg.L^{-1}$	Spectrophotometer (JENWAY 7315)
NH_4^+	$mg.L^{-1}$	Spectrophotometer (JENWAY 7315)
PO_4^{3-}	$mg.L^{-1}$	Spectrophotometer (JENWAY 7315)
Total coliform	MPN/100 ml	Multiple tube technique
Faecal coliform	MPN/100 ml	Multiple tube technique
Faecal streptococci	MPN/100 ml	Multiple tube technique

The water quality parameters involved biological oxygen demand for five days (BOD_5) [mg O_3 L^{-1}], ammonium (NH_4) [mg N-NH_4 L^{-1}], nitrite (NO_2^-) [mg N-NO_2 L^{-1}], nitrate (NO_3^-) [mg N-NO_3 L^{-1}], orthophosphate (PO_4^{3-}) [mg L^{-1}], total coliform (TC), faecal coliform (FC), and faecal streptococci (FS). Table 1 and 2 present analytical methods, used to evaluate the organic and bacteriological pollution of surface water, respectively.

Statistical analysis

The obtained data was inserted into Microsoft Excel (Windows 2003) and STATISTICA (version 8.0) to compute means and standard deviation. Variance Analysis (One-way ANOVA) was used to detect significant differences between sampling sites ($P<0.05$). The Newman-Keuls multiple mean comparison test was also used to complement the ANOVA.

RESULTS AND DISCUSSION

Physico-chemical parameters

Table 4 and Figure $2_{\mathbf{a\text{-}h}}$ present a summary of results on the physico-chemical parameters of water. Results show that there are significant variations in physico-chemical parameters of water among the sampling stations (Table 5).

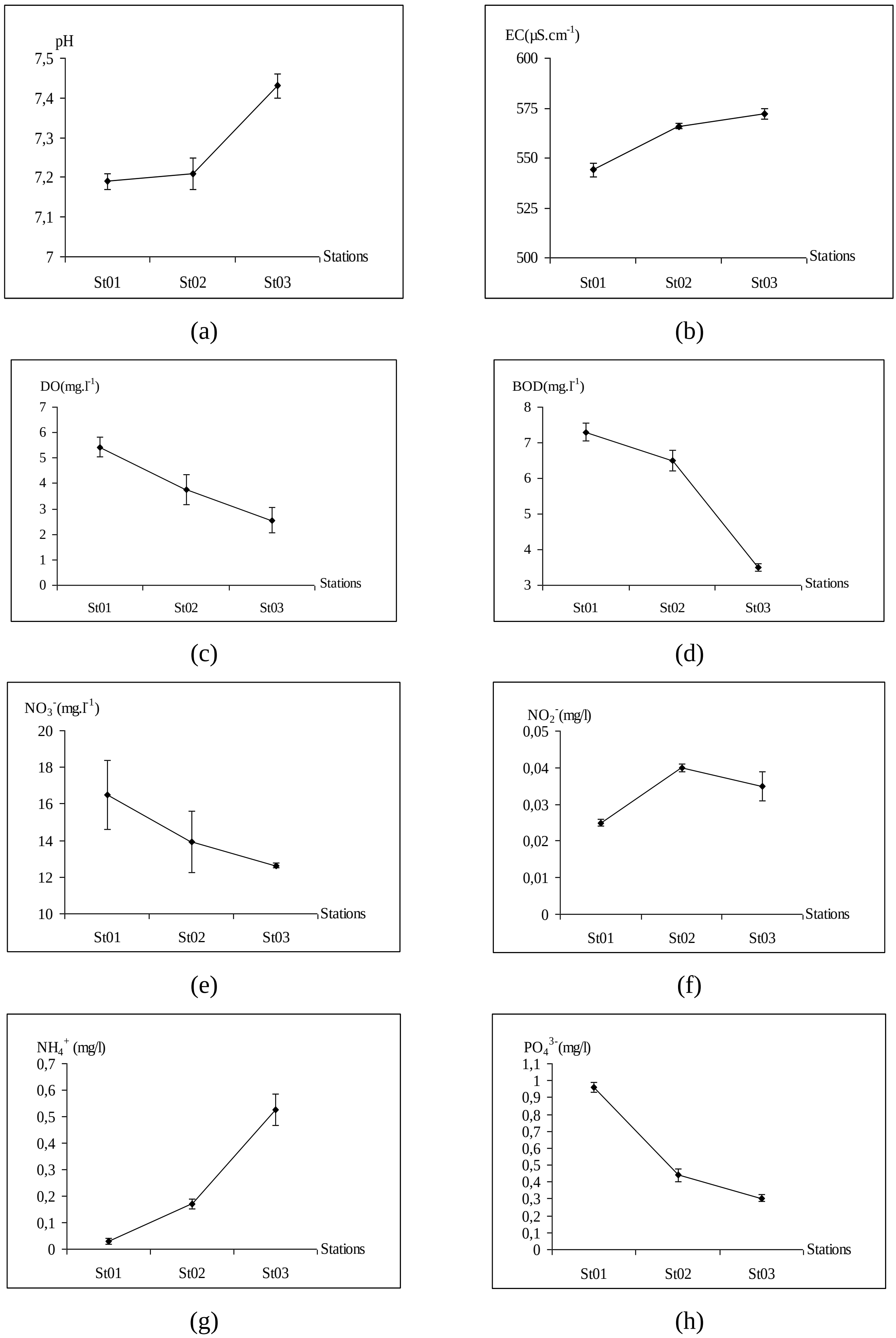

Fig. 2. Values (mean±S.E.) of physicochemical parameters and nutrient variables in different stations of the Djendjen River

Table 4. Summary of results on physico-chemical parameters of water in Djendjen River

Parameters	Mean	95% confidence limits	Minimum	Maximum	SD
pH	7.27	7.18-7.36	7.16	7.46	0.11
EC (µS.cm^{-1})	561	550.8-571.1	541	575	13.2
DO (mg.L^{-1})	3.90	2.95-4.82	2.50	5.38	1.21
BOD_5 (mg O_2.L^{-1})	5.76	4.42-7.11	3.40	7.60	1.74
NO_3^- (mg.L^{-1})	14.37	12.73-16.02	12.54	18.54	2.13
NO_2^- (mg.L^{-1})	0.033	0.028-0.039	0.025	0.042	0.006
NH_4^+ (mg.L^{-1})	0.24	0.07-0.41	0.02	0.60	0.22
PO_4^{3-} (mg.L^{-1})	0.57	0.34-0.80	0.29	0.99	0.30

Table 5. Water quality parameters (mean ± SD) at the level of the sampling stations

Parametrs	St 01	St 01	St 01
pH	7.19±0.02^{a}	7.21±0.04^{a}	7.42±0.03^{b}
EC (µS.cm^{-1})	544±3.60^{a}	566±1.41^{b}	572±2.64^{b}
DO(mg.L^{-1})	5.34±0.04^{c}	3.76±0.05^{b}	2.55±0.05^{a}
BOD_5 (mg.L^{-1})	7.31±1.77^{c}	6.50±1.50^{b}	3.51±1.17^{a}
NO_3^- (mg.L^{-1})	16.54±1.90^{b}	13.94±1.67^{ab}	12.64±0.13^{a}
NO_2^- (mg.L^{-1})	0.025±0.001^{b}	0.040±0.001^{a}	0.035±0.004^{a}
NH_4^+ (mg.L^{-1})	0.03±0.01^{a}	0.17±0.02^{b}	0.53±0.06^{b}
PO_4^{3-} (mg.L^{-1}	0.96±0.03^{c}	0.44±0.03^{b}	0.30±0.01^{a}

Table 6. Algerian standards surface water specifications (JOA, 2001)*

Parameters	Permesible limits*
pH	6.5-09
EC (µS.cm^{-1})	2800
DO (mg.L^{-1})	08
BOD_5 (mg O_2.L^{-1})	07
NO_3^- (mg.L^{-1})	50
NO_2^- (mg.L^{-1})	0.1
NH_4^+ (mg.L^{-1})	04
PO_4^{3-} (mg.L^{-1})	0.4
T. Colif (MPN/100mL)	00
F.Colif (MPN/100mL)	00
F. Strepto (MPN/100mL)	00

*JOA: Journal Officiel Algérien

- The pH of water is affected by a number of factors, among which the geology and mineral content of the catchment area, acid mine drainage, agricultural run-off, carbon dioxide concentration in the atmosphere, and accumulation and decomposition of organic detritus in the water produce weak carbonic acids that affect pH (Sibanda et al., 2014). The pH values of the Djendjen river varied between 7.16 and 7.46 (mean: 7.27). Water samples, whose pH ranges from 6.5 to 9.0, are suitable for aquatic life (WHO, 2006). The lowest pH (7.19) was found in the station 01 while the highest pH (7.42) belonged to station 03. The results show that all samples have been in accordance with the limits, decreed by Algerian standard (6.5-9) (Table 6). The basic nature of the surface water is generally due to the presence of carbonaceous rocks in the surrounding areas.
- Electrical conductivity (EC) estimates the amount of total dissolved salts, or the total amount of dissolved ions in the water, and is controlled by- among

other factors- the geology of the catchment area, determining the chemistry of the watershed soil and ultimately the water (Chang, 2008). The electrical conductivity (EC) in the surface water of Djendjen river ranged from 541 to 575 µS. cm^{-1} (mean: 561 µS cm^{-1}), which were clearly below the Algerian standard limit (2800 µS. cm^{-1}) of surface water (Table 6). Some samples, close to the Mediterranean Sea (case of station 03), generally show higher values of electrical conductivity. The high EC values, observed in station 03, can be ascribed to domestic sewage, introducing large amounts of salts into the river system. Similar findings have been observed in other works (Igbinosa & Okoh, 2009). EC increases as the concentration of dissolved salt grows and an unusual increase in the conductivity may be a testament to the pollution (Akkoyunlu & Akiner, 2012).

- DO levels are important in determining the natural self-purification capacity of a river (Mukherjee et al., 1993). The DO content in the surface water of Djendjen river varied between 2.50 to 5.38 mg $O_2.L^{-1}$ (mean: 3.90 mg $O_2.L^{-1}$). All of the water samples were below the DO limits, set by Algerian standard (8 mg $O_2.L^{-1}$) for surface water (Table 6). Most natural water systems require the DO to range within 5-6 mg.L^{-1} so that it could support a diverse aquatic population (DFID 1999). The lowest values of DO were observed in station 03 (2.55 mg $O_2.L^{-1}$) and station 02 (3.76 mg $O_2.L^{-1}$), while the highest values belonged to station 01 (05.34 mg $O_2.L^{-1}$). Decrease in DO was attributed to the degradation of organic substances, originating from domestic sewage water of suburban localities. The wastewater discharge, untreated or insufficiently treated, can reduce the dissolved oxygen content up to its total depletion (Zaharia, 1999); however, the highest value of DO (5.34 mg$O_2.L^{-1}$), found in station 01, can be attributed to photosynthetic activity of aquatic vegetation that grows in the shallow waterbodies of the river. Good levels of DO in all the sampling sites of the river may also be indicative of high re-aeration rates and rapid aerobic oxidation of biological substances (Suthar et al., 2010).
- The BOD (determined using the standard of five days and 20°C) varied between 3.4 and 7.60 mg $O_2.L^{-1}$ (mean: 5.76 mg $O_2.L^{-1}$). BOD values above the stadard limits (07 mg $O_2.L^{-1}$) were observed at station 01; however, stations 02 and 03 showed BOD values below the stadard limits (Table 6). A high value of BOD equal to 7.31 mg $O_2.L^{-1}$ was recorded at station 01, suggesting the high quantity of organic pollutants in the aquatic environments. It is generally accepted that these organic pollutants are stemmed from agricultural activities and urban sewage. Lower values of BOD were observed in the middle and lower parts of the river (i.e. station 02 and 03) equal to 2.55 and 3.76 mg $O_2.L^{-1}$, respectively.
- Nitrate, nitrite, and ammonia: Nitrogen, in the forms of nitrate, nitrite, or ammonia is a nutrient, necessary for plant and animal growth and nourishment; nonetheless, its overabundance in water can cause a number of adverse health and ecological effects (Haldar et al., 2014). Among anthropogenic sources, sewage discharge and application of nitrogen-rich fertilizers account for the general increase of nitrogen concentration in the ground and river waters (He et al., 2011). The amount of NO_3-N in the river water under study ranged from 12.54 to 18.54 mg-N. L^{-1} (mean: 14.37 mg-N.L^{-1}). All of the water samples

were below the NO_3-N limits, set by Algerian standard (50 mg-N.L^{-1}) for surface water (Table 6). The lower NO_3-N level were observed in station 03 (12.64 mg-N.L^{-1}) followed by 13.94 and 16.64 mg-N.L^{-1} at stations 02 and 01 respectively. Variation in nitrate contents of rivers may be due to the nitrate, released from fertilizers, not absorbed by the soil but washed off from the land during flows (Pradhan et al., 2009). In the study area, the presence of nitrate may be due to sewage and agriculture effluents, discharged into river.

The nitrite (NO_2-N) content varied from 0.025 to 0.042 mg-N. L^{-1} (mean: 0.033 mg-N.L^{-1}). The concentrations of nitrites presented some fluctuations among the sampling sites, owing to the location of anthropogenic activities. All of the water samples were below the NO_2-N limits, set by Algerian standard (0.1 mg-N.L^{-1}) for surface water (table 01). The highest nitrite (N-NO_2) concentrations were observed at station 02 (0.04 mg-N. L^{-1}) which seems to be greatly influenced by agricultural activities. The presence of nitrite in the environment means the presence of biological activities and even a small amount of nitrite indicates the beginning of pollution (Tunc Dede et al., 2013).

The ammonium (N-NH_4) values for the Djendjen River varied between 0.02 and 0.60 mg-N. L^{-1} (mean: 0.24 mg-N. L^{-1}). The major sources of the ammonium nitrogen pollution are fertilizer runoff and municipal wastewater (Sun et al., 2015). In the study area, ammonium was detected at all sampling stations. All of the water samples were below the N-NH_4 limits, set by Algerian standard (4 mg-N.L^{-1}) for surface water (Table 6). The highest value of ammonium was observed at station 03 (0.53 mg-N. L^{-1}), which was regarded as the main agricultural area with intensive use of fertilizers, capable of having serious effects on surface water quality. However, the lowest values of N-NH_4 0.03 and 0.17 mg-N. L^{-1} were detected in stations 01 and 02 respectively. In general, concentration of ammonium nitrogen in the surface water of the study area is worrying, especially for the lower part of the river where it is home to remarkable agricultural activitie these past years, proving that human activities such as fertilizer use contribute mainly to such severe condition of ammonium nitrogen in all Algeria (Rouabhia et al., 2010).

- Phosphate can be used as a nutrient source for the growth of plants, causing the decrease of dissolved oxygen in the water (TSE, 1990). The presence of PO_4^{3-} probably suggests that phosphate fertilizers leach from nearby farmlands (Magha et al., 2015). The orthophosphate (P-PO_4^{3-}) values in the surface water of Djendjen River varied between 0.29 and 0.99 mg P.L^{-1} (mean: 0.57 mg P.L^{-1}). Concentration of orthophosphate in the water samples exceeded the standard limit (0.4 mg P.L^{-1}) of the Algerian Standards at both stations 01 and 02 (Table 6). The highest mean value for P-PO_4^{3-} (0.96 mg P.L^{-1}) was observed at station 01 and the smallest value (0.30 mg P.L^{-1}) at station 03, which may be a consequence of drainage from urban sewage, agricultural land, and livestock production facilities. It has been documented that municipal wastewater contains substantial amount of phosphorus contributed by human urine and detergents (Ekholm & Krogenus, 1998).

Microbiological parameters

Table 7 and Figure 3 present results on microbiological tests. According to Algerian standard, surface water must have zero total coliforms, fecal coliforms, and faecal streptococci (Table 6). Coliforms indicator organisms were present in every tested water sample, their concentrations, ranging from 1400 MPN/100ml for total coliform and 502.9 to 1463.7 MPN/100ml for fecal coliform. Faecal streptococci contents of the Djendjen River were within the range of 55.7-194.9 MPN/100ml. Results show that there is no significant variation in microbiological parameters of water among the sampling stations, except for faecal streptococci (Table 8). High total coliforms, faecal coliforms, and faecal streptococci in all of the sampling sites at different stations may be due to direct interaction between the river catchment areas and human activities. The numbers of bacterial indicator organisms, detected at each sampling stations, reveal a high fecal contamination in the study area, which can be explained by the presence of several sewage outfalls from rural populations located along Djendjen River as well as agricultural practices (livestock and poultry breeding). The versatile agricultural practices are suspected to profoundly increase the load of fecal bacteria, nutrients, and other pollutants in the water (Frey et al., 2013; Walters et al., 2013). Furthermore, Lucena et al. (1988) have shown a very high level of fecal and chemical pollution, caused by untreated wastewater effluents from several suburbs of Barcelona. Effluents, discharged to rivers, contain fecal pathogens such as viruses, bacteria, and protozoa. Those microorganisms can be transported across significant distances, posing a serious threat to public health (Harnisz, 2013; Korzeniewska et al., 2013).

The surface water quality indices

Tables 9 and 10 show results of Organic Pollution Index (OPI) and Microbiological Quality Index (MQI) in sampling stations.

Table 7. Summary of results on bacteriological parameters of water in Djendjen River

	Mean	95% confidence limits	Minimum	Maximum	SD
TC (MPN/100mL)	1400	/	1400	1400	00
FC (MPN/100mL)	983.3	502.9-1463.7	150	1400	625
FS (MPN/100mL)	125.3	55.7-194.9	39	245	90.53

TC=total coliform ; FC=faecal coliform.; FS=faecal streptococci

Table 8. Distribution of the bacteriological the stations

Stations	TC (MPN /100ml)	FC (MPN /100ml)	SF (MPN /100ml)
St 01	1400±0.00[a]	1400±0.00[a]	241.70±2.88[c]
St 02	1400±0.00[a]	1400±0.00[a]	95.00±2.00[b]
St 03	1400±0.00[a]	150±0.00[a]	39.33±0.58[a]

TC=total coliform ; FC=faecal coliform.; FS=faecal streptococci

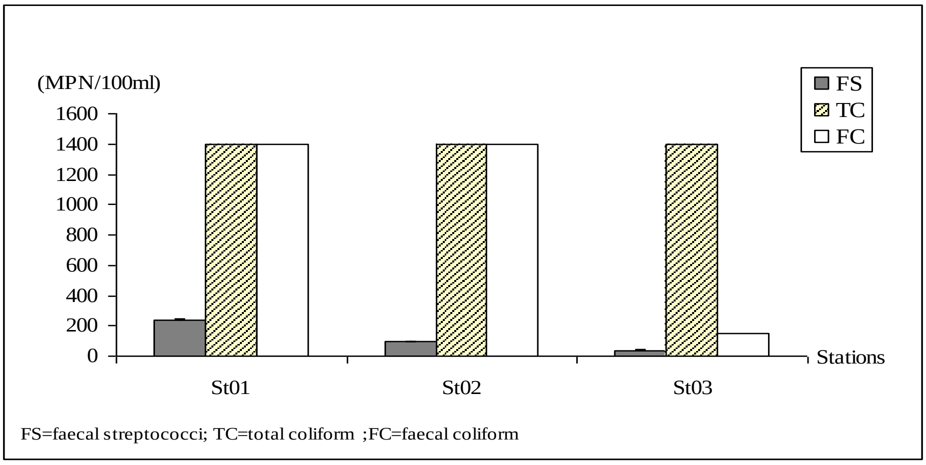

Fig. 3. Values (mean±S.E.) of microbiological parameters in different stations of the Djendjen River

Table 9. Water quality conditions based on the assessment by using Organic Pollution Index

Stations	OPI	Water Quality
St01	03	Moderate organic pollution
St02	03	Moderate organic pollution
St03	3.25	Moderate organic pollution

Table 10. Water quality conditions based on the assessment by using Microbiological Quality Index

Stations	MQI	Water Quality
St01	02.6	High faecal contamination
St02	02.6	High faecal contamination
St03	02.0	High faecal contamination

Water quality of Djendjen River had similarities in each station. The OPI of all three stations ranged between 3 and 3.2. Generally, water quality conditions along Djendjen River based on organic pollution index can be classified as moderate and human activities have negative impacts on water quality.

Values of Microbiological Quality Index (MQI) ranged between 02 and 02.6, indicating high faecal contamination at each sampling stations. Livestock and domestic waste water discharges are the significant factors to cause bacteriological pollution in the study area.

CONCLUSION

The present study has provided information on water quality status of Djendjen Rive, having assessed physical, chemical, and microbiological qualities. According to the obtained data, the water quality of the Djendjen River is influenced by human activities. Significant pollution sources have been determined that result from agricultural and domestic activities. The use of fertilizers in the cultivated land fields and discharge of municipal wastewater increase the concentration of the nutrients in the river water.

The Microbiological Quality Index (MQI), calculated for all sites, shows that Djendjen River is highly contaminated with pathogenic germs and that it may not be usable for any need without receiving a proper treatment. According to Organic Pollution Index (OPI), surface water quality of Djendjen River is moderate in all sites. From this study, the following recommendations can be made:

- There is a need for promoting awareness campaigns that aim at behavioural changes as well as integrated control of land and water resources to prevent further contamination of the river systems in the area.
- Elevated levels of several pollutants in the effluents of domestic sewage reflect the weakness and the ineffective treatment process, calling for some improvements on facilities' operations.
- Due to large amounts of bacteria in the study area, it is recommended to carry out periodical monitoring in order to assess the levels of microorganisms.

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