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Impact of organic and microbiological pollution on the quality of water in Boussellam Valley and its environment, Setif City, Northeast Algeria

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Abstract. *Boulgueraguer Z, Chaffai H, Gasmi L, Djabri L, Hani A. 2022. Impact of organic and microbiological pollution on the quality of water in Boussellam Valley and its environment, Setif City, Northeast Algeria. Biodiversitas 23: 2621-2629.* Water pollution is a major threat and a global challenge that endangers life on earth at risk because water plays a major role in daily life. Several sources of water pollutants, i.e., organic, industrial, domestic and microbial pollution, may trigger an outbreak of water-borne diseases. Boussellam Valley crosses the Quaternary formations, which dominate the extent of the plain surrounding the region of Sétif in the North-East of Algeria. It is one of the main water resources, mainly for drinking water supply and irrigation. The shallow water table composed of the geological formations containing this aquifer is very heterogeneous in texture and varies considerably from upstream to downstream of the sub-watershed. Thus, the North and East zones are marked by chloride-calcium facies, the central part by a Bicarbonate-calcium facies. At the same time, sulfate-magnesium facies characterize the West zone. This study aimed to evaluate the pollution by organic elements: nitrites, nitrates, and microbiological elements: total and fecal coliforms and streptococci and their impact on the water quality. Samples were collected during May and June 2021 from 5 stations along the valley, and 18 wells were spread out on the plain. The analysis of nitrites and nitrates was carried out by liquid chromatography. In addition, the colony counting of coliforms and streptococci was carried out according to the recommendations of the Algerian water company. The results show an increase in the concentration of nitrites, nitrates, total and fecal coliforms, and the streptococci, particularly in valley waters with very high levels that exceed the normal threshold of drinking water. This increase may be due to wastewater discharges and the intensive use of fertilizers, septic tanks, leaching of animal manure, runoff water, and rearing of domestic or wild animals. The increased levels of nitrites, nitrates, total and fecal coliforms, and the streptococci increase the risk of the vulnerability of the waters of the plain to pollution and degradation of surface waters and the environment in general.

Keywords: Boussellam Valley, organic and microbiological pollution, Sétif, water

INTRODUCTION

Nowadays, water pollution is considered one of the most important universal challenges facing developed and developing countries. Water pollution greatly affects the environmental health of people all over the world (Bassem 2020). Water pollution is the substances mixed with water that could change its physical, chemical, and biological water properties, destroying the natural structure of water and causing changes that harm the health of humans and living things (Kılıç 2021). Some chemicals affecting human health are heavy metals such as chlorides, ammonium, sulfates, nitrates, nitrites, and phosphates (Sintondji et al. 2017). Based on the origin of pollutants, it can be distinguished as their fundamental occurrence on earth, the development of natural products through transformation and synthesis (Singh et al. 2020). There is a great relationship between water pollution and health problems (Halder and Islam 2015). According to the World Health Organization (WHO) report, there are about 600 million cases of diarrhea and dysentery and 46000 infant deaths per year due to polluted water and insufficient sanitation (Some et al. 2021).

One of the major problems that threaten the Boussellam plain is the risk of water pollution caused by the various organic substances, chemical materials, and microbiological elements discharged into the valley's waters. Therefore, the objective of this study is to determine the various sources of pollution in the Boussellam plain, their evolution, and the procedures that must be undertaken to preserve the quality of water in this region, which occupies very fertile land with a vast agricultural activity, especially cereals.

Water pollution caused by microbiological and organic elements in arid and semi-arid areas has been the subject of several scientific studies (Boudeffa et al. 2020; Lambert et al. 2020; Rita et al. 2020; El-Kalliny et al. 2021; Haied et al. 2021; Krumova-valcheva et al. 2021; Prabhavati et al. 2021). These previous scientific research studied water pollution in basins with the same socio-economic and environmental characteristics as the Boussellam region. More than a million inhabitants live on the territory of Boussellam plain and carry out various agricultural and industrial work that threaten waters and the environment.

MATERIALS AND METHODS

Presentation of the study area

The Boussellam Valley is one of the permanent watercourses in Algeria and is one of the waterways most affected by all types of pollution. It is the main hydrographic tributary of the Sétif region and the main source of the 65 km dam of Ain Zada. This latter is considered the main source that supplies drinking water to the towns of Sétif, El Eulma, Bordj-Bou-Arreridj, and Bougaâ.

The Boessellam plain, crossed by this valley, represents one of the richest plains in Algeria due to its important agricultural activity, especially cereals, which make a considerable contribution to the national economy. Currently, the Boussellam plain is vulnerable to water pollution, which can endanger its productivity and the loss of soil, hydrological and hydrogeological characteristics (quality of surface and underground water). For this reason, the data collection during May and June 2021 may inform the evolution of certain chemical, physicochemical and microbiological parameters of the waters in the Boussellam plain and their impact on the environment.

The study area represents the heart of the upstream Boussellam plain. It covers the municipalities of Sétif and Mezloug with a total area of 262.85 km2 with nearly 600,000 inhabitants, of which the upstream Boussellam sub-basin contains 35% of the surface of the great Boussellam of code 1506 according to the Algerian Agency for Hydrographic Basins. It is located between the great Constantine basin to the East, that of Hodna to the South, and the sub-basin of Middle Boussellam to the West; the upstream Boussellam sub-basin extends over the high Sétif plains with an area of 1785 km2, and is part of the territory of the wilaya of Sétif located in the North-east of Algeria (Figure 1).

Sampling

The water samples from 18 wells across the plain of Boussellam and 5 stations installed along the talweg of Boussellam upstream were analyzed for the physicochemical and microbiological properties. The monitoring took place over two periods (Figure 2, Tables 1, 2, 3).

The physicochemical parameters, including pH, temperature, conductivity, salinity, TDS, and DO, were measured on-site. The analysis of Nitrites and Nitrates was carried out in the laboratory of the water treatment station of the Beni Zid Dam, Wilaya of Skikda. The analysis of the microbial parameters, i.e., Total and fecal coliforms and Streptococci, is carried out at the municipality of El Eulma Wilaya de Sétif during May and June 2021.

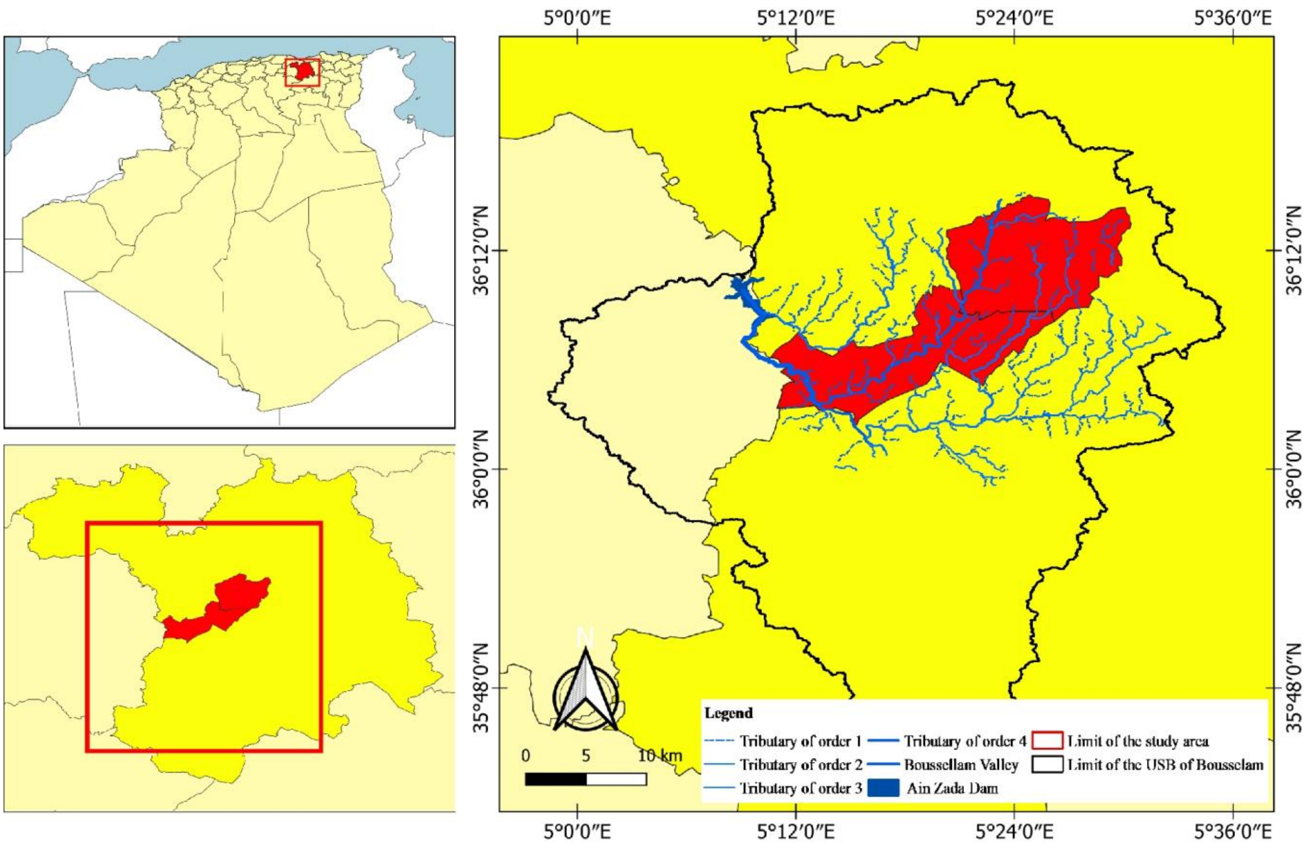

Figure 1. The geographical situation of the study area in Boussellam Valley, Setif City, Algeria. Note: ArcGIS 10.7, Geographic coordinate systems: WGS 1984. Projected coordinate systems: WGS 1984_UTM_Zone_31N_Unit meter

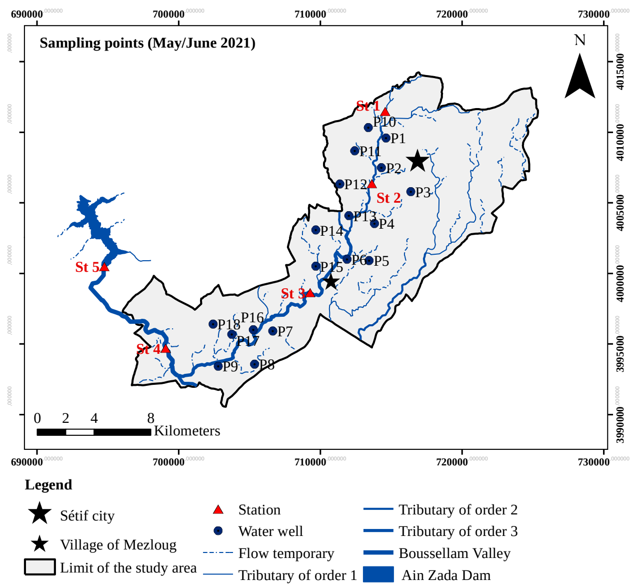

Figure 2. Sampling points in the upstream Boussellam sub-basin, Setif City, Algeria (May/June 2021). Note: ArcGIS 10.7, Geographic coordinate systems: WGS 1984. Projected coordinate systems: WGS 1984_UTM_Zone_31N_Unit meter

Table 1. Sampling stations in the Boussellam Valley, Setif City, Algeria (May/June 2021)

Sampling station	X (m)	Y (m)	Z (m)
St 1	714571.1	4011487.3	1026
St 2	713627.1	4006371.3	920
St 3	709273.9	3998647.4	883
St 4	699074.7	3994714.6	855
St 5	694757.7	4000499.1	874

Note: ArcGIS 10.7, Geographic coordinate systems: WGS 1984. Projected coordinate systems: WGS 1984_UTM_Zone_31N_Unit meter

Table 2. Sampling areas in the Boussellam Valley, Setif City, Algeria (May/June 2021)

Sampling station	Sampling area
St 1	Upstream of the Boussellam Valley upstream
St 2	After the City of Sétif
St 3	After the City of Mezloug
St 4	The confluence of the Boussellam Valley and its main tributary Guellal Valley
St 5	Downstream of the Boussellam Valley upstream (Ain Zada dam)

Note: ArcGIS 10.7, Geographic coordinate systems: WGS 1984. Projected coordinate systems: WGS 1984_UTM_Zone_31N_Unit meter

Table 3. Sampling points in the Boussellam Plain, Setif City, Algeria (May/June 2021)

Water point	X (m)	Y (m)	Z (m)
P1	714630.4	4009599.6	1038
P2	714308.9	4007487.3	991
P3	716375.4	4005788.3	1038
P4	713803.9	4003538.3	991
P5	713436.5	4000920.9	996
P6	711875.2	4001012.7	941
P7	706640.5	3995915.7	915
P8	705354.7	3993573.8	895
P9	702783.2	3993436.1	890
P10	713384.8	4010334.3	1069
P11	712426.3	4008681.1	1037
P12	711370.1	4006339.3	1023
P13	712013.1	4004089.3	956
P14	709671.1	4003079.1	951
P15	709671.6	4000507.9	926
P16	705262.9	3996007.5	907
P17	703747.5	3995686.1	912
P18	702415.9	3996420.8	917

Note: ArcGIS 10.7, Geographic coordinate systems: WGS 1984. Projected coordinate systems: WGS 1984_UTM_Zone_31N_Unit meter

RESULTS AND DISCUSSION

Physico-chemical characteristics

The physicochemical characteristics of water are greatly affected by organic and microbiological pollution (Arman et al. 2021). Therefore, this study evaluated the principal parameters causing water pollution in the Boussellam Valley.

pH and temperature

The pH values varied from 7 to 9 for all the water points collected from the valley or the plain and for all the periods. The lowest pH value was obtained from the P12 well (7, 09) in May 2021, and the highest value was from station St2 (8, 89) in June 2021, with a slight variation.

The water temperature ranges from 9.3°C to 22.6°C for the valley waters and varies from 17.5°C to 18.3°C for the waters of the plain (wells) in May. The temperature was varied from 20.1°C to 26.5°C for the valley waters and varied from 17.9°C to 19.7°C for the waters of the plain in June 2021. The results showed that the temperature of surface water (the valley) is slightly high compared to groundwater (the plain), in which the measurements were taken at different times of the day at the end of spring and early summer (Tables 4 and 5).

Table 4. Physico-chemical parameters (May 2021)

Point	X (m)	Y (m)	Z (m)	H(m)	pH	C (µs/cm)	Salinity (g/L)	TDS (ppm)	DO (%)	DO (ppm)	Water T (°C)
St 1	714610.9	4011575.7	1026	1026	7.36	508	0.246	279	42.96	3.9	22.6
St 2	708763.6	3997751.7	920	920	8.74	1780	0.9	979	30.96	2.8	19.3
St 3	699605.8	3993024.9	883	883	8.88	2700	1.395	1485	27.72	2.5	19.8
St 4	696890.2	3996572.1	855	855	8.26	1463	0.733	804	25.41	2.3	20.1
St 5	694825.2	4000560.7	874	874	8.01	985	0.486	541	46.33	4.2	19.3
P1	714630.4	4009599.6	1038	1028	7.32	601	0.292	330	25.34	2.3	17.9
P2	714308.9	4007487.3	991	988	7.65	704	0.343	387	26.45	2.4	18
P3	716375.4	4005788.3	1038	1026	7.88	725	0.354	398	19.84	1.8	18
P4	713803.9	4003538.3	991	989	7.96	884	0.434	486	19.85	1.8	18.2
P5	713436.5	4000920.9	996	991	8.42	965	0.475	530	19.75	1.8	17.8
P6	711875.2	4001012.7	941	937	8.36	1624	0.818	893	28.73	2.6	18.2
P7	706640.5	3995915.7	915	910	8.33	1554	0.781	854	23.2	2.1	18
P8	705354.7	3993573.8	895	890	8.21	1238	0.616	680	19.87	1.8	18.1
P9	702783.2	3993436.1	890	885	8.35	2399	1.231	1319	33.24	3	17.9
P10	713384.8	4010334.3	1069	1055	7.49	623	0.303	342	28.65	2.6	18.3
P11	712426.3	4008681.1	1037	1028	7.28	776	0.379	426	25.35	2.3	18.2
P12	711370.1	4006339.3	1023	1012	7.09	736	0.359	404	25.29	2.3	17.8
P13	712013.1	4004089.3	956	950	8.14	1547	0.777	850	28.73	2.6	18.1
P14	709671.1	4003079.1	951	945	8.06	1145	0.568	629	19.86	1.8	18
P15	709671.6	4000507.9	926	918	8.22	1469	0.736	807	25.41	2.3	18.1
P16	705262.9	3996007.5	907	899	8.75	2345	1.202	1289	31.02	2.8	17.5
P17	703747.5	3995686.1	912	905	8.32	1865	0.945	1025	16.59	1.5	17.6
P18	702415.9	3996420.8	917	910	8.04	1724	0.87	948	23.22	2.1	17.6

Note: ArcGIS 10.7, Geographic coordinate systems: WGS 1984. Projected coordinate systems: WGS 1984_UTM_Zone_31N_Unit meter

Table 5. Physico-chemical parameters (June 2021)

Point	X (m)	Y (m)	Z (m)	H (m)	pH	C (µs/cm)	Salinity (g/L)	TDS (ppm)	DO (%)	DO (ppm)	Water T (°C)
St 1	714610.9	4011575.7	1026	1026	7.51	616	0.299	338	40.25	3.6	26.5
St 2	708763.6	3997751.7	920	920	8.89	1984	1.984	1091	26.32	2.3	20.1
St 3	699605.8	3993024.9	883	883	8.82	2765	2.765	1520	25.41	2.7	21
St 4	696890.2	3996572.1	855	855	8.35	1247	1.247	685	23.87	2.1	23.8
St 5	694825.2	4000560.7	874	874	8.24	1023	1.023	562	45.28	4.1	28.5
P1	714630.4	4009599.6	1038	1026	7.16	748	0.748	411	23.85	2.2	18.2
P2	714308.9	4007487.3	991	987	7.32	759	0.759	417	24.65	2.2	18.3
P3	716375.4	4005788.3	1038	1029	7.79	847	0.847	465	19.02	1.8	19.4
P4	713803.9	4003538.3	991	986	7.85	885	0.885	486	18.24	1.7	18.5
P5	713436.5	4000920.9	996	987	8.32	901	0.901	495	18.65	1.7	18.4
P6	711875.2	4001012.7	941	933	8.42	1798	1.798	988	27.95	2.5	19.4
P7	706640.5	3995915.7	915	908	8.41	1598	1.598	878	21.74	2	18.3
P8	705354.7	3993573.8	895	885	8.33	1345	1.345	739	17.48	1.6	18.1
P9	702783.2	3993436.1	890	881	8.48	2630	2.63	1446	31.54	2.8	18.3
P10	713384.8	4010334.3	1069	1050	7.5	780	0.78	429	27.95	2.5	19.6
P11	712426.3	4008681.1	1037	1027	7.3	748	0.748	411	25.36	2.3	19.7
P12	711370.1	4006339.3	1023	1010	7.25	864	0.864	475	24.95	2.3	19.4
P13	712013.1	4004089.3	956	946	8.32	1825	1.825	1003	28.44	2.6	18.3
P14	709671.1	4003079.1	951	942	8.1	1265	1.265	695	18.64	1.7	17.9
P15	709671.6	4000507.9	926	915	8.36	1399	1.399	769	24.86	2.3	18.5
P16	705262.9	3996007.5	907	894	8.86	2549	2.549	1401	30.48	2.8	18.5
P17	703747.5	3995686.1	912	903	8.38	2046	2.046	1125	15.24	1.4	18
P18	702415.9	3996420.8	917	907	8.16	1894	1.894	1041	22.45	2	18.1

Note: ArcGIS 10.7, Geographic coordinate systems: WGS 1984. Projected coordinate systems: WGS 1984_UTM_Zone_31N_Unit meter

Salinity, conductivity, and TDS

The salinity of valley waters varied from 246 mg/L to 1395 mg/L, and the salinity of groundwater varied from 292 mg/L to 1231 mg/L in May. The salinity of valley water varied from 299 mg/L to 2765 mg/L, while the salinity of groundwater varied from 748 mg/L to 2630 mg/L in June. The increase in salinity shows the strong mineralization of the water in the area. However, it is still within drinking water standards (< 3000 mg/L). A previous study conducted by Boulgueraguer et al. (2018) in the same region showed that hardness reached from 35 F° in October 2014 for the P1 well to 73 F° in April 2016 for the P8 well which gives the appearance of hard water (from 30 to 40 mg/L) to very hard water (+ 40 mg/L). The conductivity was between 500µs/cm and 2600 µs/cm. Therefore, according to the Wilcox classification, it is necessary to reclassify water from bad to good class for irrigation. The total dissolved solids TDS ranged from 279 ppm to 1446 ppm for all points and stations over the two months.

Dissolved oxygen (DO)

The rate of Dissolved Oxygen (DO) in the Boussellam Valley water ranged from 2.3 mg/L (25.4%) to 4.2 mg/L (46.3%) in May and ranged from 2.1 mg/L (23%) to 4.1 mg/L (45%) in June. However, the rate of DO in the plain was slightly lower rate from 1.4 mg/L to 3 mg/L (33%). It might be due to the direct contact of free surface waters, which results in a greater quantity of Oxygen. However, these concentrations are not sufficient for aquatic life, especially fish with a minimum requirement of 5,5 mg/L in hot water and 6,5 mg/L in cold water to sustain life (concentrations will increase for species in the first stages of life, i.e., 6 mg/L in hot water and 9,5 in cold water) according to Canadian Water Quality Guidelines (1991).

Chemical facies

The composition of major ions and their distributions in the Piper diagram is evaluated in a previous study conducted by Boulgueraguer et al. (2018). The result indicated three main chemical facies, i.e., chloride bicarbonate-calcium and sulfated-magnesian, except the point P9, which is sulfated-calcium. The chloride-calcium facies is found in wells P2, P3, P4, P5, P11, and P12. These wells are located in the northern and eastern parts of the study area. The mineralization could be indicated by the Mio-plio-quaternary saline alluvial formations, the gypsum marls, the Triassic dolomites, and the Cenomanian and higher chloride contents. The bicarbonate-calcium facies are located in the center of the plain and consist of wells P1, P6, P7, and P8. Their mineralization is due to the carbonate formations bordering the chalk slick and the Cretaceous limestones. The third facies is the sulfated-magnesian facies covering the western part of the plain and consist of wells P10, P13, P14, and P15. The high sulfate and magnesium contents can be explained by the cation exchange between the gypsum and dolomite formations and by the dissolution of fertilizers containing these two elements, such as Epsom salt which constitutes a source of Mg^{+2} and $SO4^{-2}$. Only one well (P9) is included in the Sulphated-calcium facies, probably due to the dissolution of gypsum present locally in the region.

Nitrites (NO_2^-)

The concentration of nitrites in the waters of the plain is closely related to the pollution of the waters of the Boussellam Valley and other factors affecting the groundwater. This result is in line with the study by Cheng et al. (2016). Nitrites concentrations were rapidly changed in the waters of the Boussellam Valley downstream of Ain Zada Dam, with a concentration of 0.01 mg/L. This concentration was similar to Station 1 (St 1) before the towns of Sétif and Mezloug. On the other hand, station 2 (St 2), which was installed after the city of Sétif, showed a large increase in the concentration of Nitrites (1.11 mg/L in May) and (1.14 mg/L) in June. Nitrite concentration continued to increase along the valley mainly due to wastewater discharged into the valley mainly from the towns of Sétif and Mezloug and other agglomerations in the area until reaching the downstream (Ain Zada dam). High values of nitrites were recorded at Station 5 (St5 (1.52 mg/L in May and 1.67 mg/L in June, but these values are low compared to Station 4 due mainly to the dilution of waters of the valley by the waters of the dam. High values are recorded just after the confluence zone of Boussellam Valley with its largest tributary Guellal Valley with the values of station 4 (St4 (1.46 mg/L in May and 1.85 mg/L in June). The concentrations of Nitrites are higher in June than in May due mainly to the depletion of the valley's waters in the summer period (Figure 3).

The iso-value map of Nitrite (Figure 4) shows a heterogeneous distribution. It differs from one area to another depending on several factors. The low concentrations were found upstream of the study area and in more distant areas of the talweg. High concentrations in the plain were obtained downstream and approached the Boussellam Valley. The concentrations ranged from 0.11 mg/L (P1) to 0.77 mg/L (P9) in May and from 0.1 mg/L (P10) 1 mg/L (P16)) in June. Table 6 shows the increase in Nitrites concentrations due to the distance to the valley.

Table 6. Nitrite concentration in the plain relates to the distance to the Boussellam valley, Setif City, Algeria

Boussellam valley		Boussellam Plain		Distance from the well water to the valley (km)
Station	**Nitrites concentration mg/L (May 2021)**	**Well water**	**Nitrites concentration (May 2021)**	
St2	1.11	P13	0.65	08
	1.11	P4	0.53	102
	1.11	P14	0.52	834
St3	1.32	P16	0.71	10
	1.32	P17	0.63	115
	1.32	P18	0.62	784

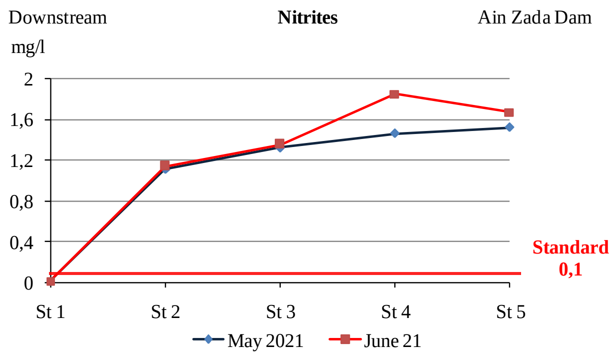

Figure 3. The concentration of nitrites in the waters of Boussellam Valley, Setif City, Algeria

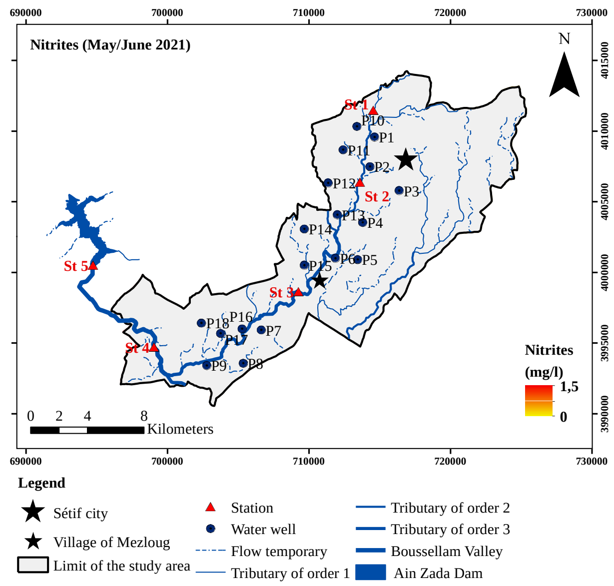

Figure 4. The distribution of Nitrite in the waters of the Boussellam plain, Setif City, Algeria. Note: ArcGIS 10.7, Geographic coordinate systems: WGS 1984. Projected coordinate systems: WGS 1984_UTM_Zone_31N_Unit meter

The change in nitrite concentration is a significant impact of valley water pollution on those of the plain; however, there are other sources of pollution because many wells located further from the valley are subject to Nitrites pollution. It is probably due to fertilizers and animal husbandry livestock as the area is known for its extensive agricultural activities. On the other hand, there were different nitrite contents compared to previous works by Boulgueraguer et al. (2018), particularly in 2014 and 2016.

Nitrates (NO_3^-)

The impact of water pollution in the Boussellam Valley on the water quality of the surrounding plain cannot be ignored. It indicated the continuous changes in nitrate concentrations in the waters of the valley. Nitrate concentration increases upstream of the sub-basin to downstream (Ain Zada dam). However, these concentrations remain within the standards (< 50 mg/L) even though they evolve gradually compared to the station control (St1), i.e., 19.55 mg/L in May and 20.25 mg/L in June.

The contractions increased at stations 2 and 3, which were installed after the towns of Sétif and Mezloug, respectively. Nitrate concentration at St2 was 32.46 mg/L in May and 35.36 mg/L in June, while at St3 was 35.72 mg/L in May and 37.12 mg/L in June. High nitrate concentrations were recorded at station 4 (St 4), which is installed in the confluence zone of the Boussellam Valley and the tributary valley Guellal, i.e., 38.65 mg/L in May and 39.98 mg/L in June. The nitrate concentration at Ain Zada Dam was slightly low in station 5 (St5), i.e., 34.45 mg/L in May and 37.25 mg/L in June. It is probably due to the dilution of the valley's waters by the dam's waters. Although the concentration is increasing, it is still in the standard range. However, these waters remain at risk of contamination (Figure 5).

The iso-value map of nitrates (Figure 6) shows a heterogeneous distribution. It differs from one area to another depending on several factors. The low concentrations were found upstream of the study area and in the more distant areas. of the talweg. On the contrary, the high concentrations in the plain were found downstream and approached the Boussellam Valley. The nitrate contents ranged from 14.61 mg/L (P14 (14.61 mg/L) to 32.15 mg/L (P16)) in May and ranged from 17.31 mg/L (P4) and 34.85 mg/L (P16) in June. According to Thorbum et al. (2003), agricultural activity generates nitrate pollution. Table 7 shows the increase in Nitrates concentrations due to the distance to the valley

The variation of nitrate concentrations indicated the effect of water pollution of the Oued on those of the plain. Nitrate pollution also originated from the intensive use of fertilizers and livestock due to the extensive agricultural activity, particularly cereals. As for nitrites, this study showed that nitrate concentrations also have an annual variation that is similar to the results from previous works of Boulgueraguer et al. (2018).

Total coliforms and fecal coliforms

Harmful bacteria in the water is an important index of microbial pollution (Ahmed et al. 2003; Nexhdet et al. 2018). Coliforms are a group of bacteria commonly found in the environment, such as soil or vegetation and the intestines of mammals, including humans (Pal 2014). This type of pollution in this study was evaluated through the dosage of total and fecal coliforms.

Table 7. Nitrates concentrations in the plain relate to the distance to the Boussellam valley, Setif City, Algeria

Boussellam Valley		Boussellam Plain		Distance from the well water to the valley (km)
Station	**Nitrates concentration mg/L (May 2021)**	**Well water**	**Nitrates concentration (May 2021)**	
St2	32.46	P13	29.46	08
	32.46	P4	23.78	102
	32.46	P14	14.61	834
St3	35.72	P16	32.15	10
	35.72	P17	26.95	115
	35.72	P18	26.36	784

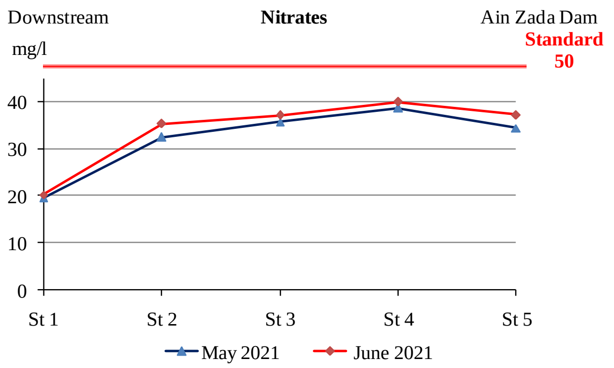

Figure 5. The concentrations of nitrates in the waters of Boussellam Valley, Setif City, Algeria

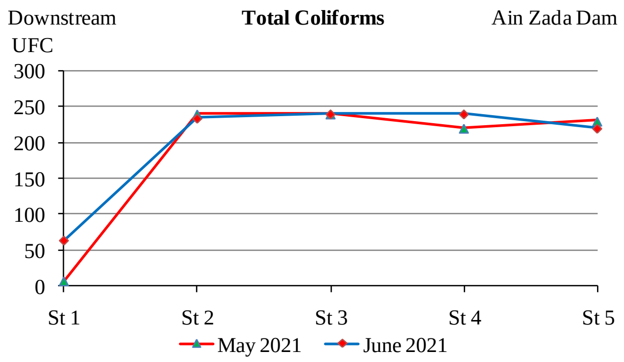

Figure 7. The concentration of total coliform in the waters of the Boussellam Valley, Setif City, Algeria

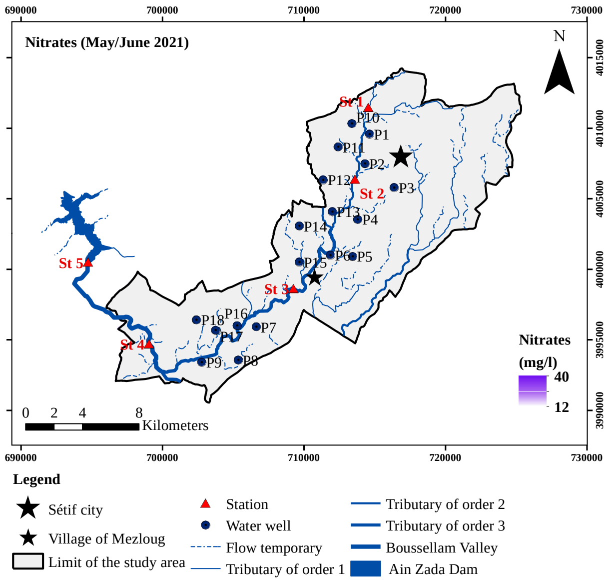

Figure 6. The distribution of nitrates in the waters of the Boussellam plain, Setif City, Algeria. Note: ArcGIS 10.7, Geographic coordinate systems: WGS 1984. Projected coordinate systems: WGS 1984_UTM_Zone_31N_Unit meter

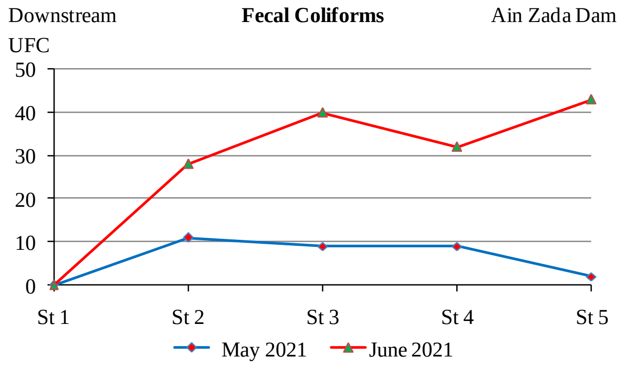

Figure 8. The concentration of fecal coliform in the waters of the Boussellam Valley, Setif City, Algeria

Total coliforms in the waters of Boussellam Valley from upstream to downstream were varied. A low quantity of Total coliforms was obtained in station 1 (St1= 6 UFC/100 mL in May and 64 UFC/100 mL in June). The level of total coliforms increases in station 2 (St2= 240 UFC/100 mL in May and 234 UFC/100 mL in June) until the Ain Zada Dam, with the total coliforms of 230 UFC/100 mL in May and 220 UFC/100 mL in June in station 5 (St5) (Figures 7 and 8). The increase in total coliforms indicated severe pollution, mainly from untreated domestic wastewater discharged from the cities of Sétif and Mezloug and other agglomerations in the valley. The levels found greatly exceed WHO standards (10 UFC/100 mL).

The concentration of fecal coliforms in Boussellam Valley was low, ranging from 2 to 11 UFC/100 mL in May and 28 and 43 UFC/100 mL in June (Figure 8).

The low concentration of fecal coliforms may be due to the drying of the valley's waters during this period. There was no trace of fecal coliforms in station 1 (control); therefore, it indicated that the wastewater discharged from the cities and neighboring agglomerations is the main cause of this contamination. World Health Organisation (WHO/OMS) (2000) stated that water must not contain any trace of fecal coliforms.

Heterogeneous distribution was observed in the total coliforms and fecal coliforms in the groundwater of the Boussellam plain. The concentration of total coliforms and fecal coliforms differs from one area to another depending on the sources of pollution, which generally originate from septic tanks, improperly treated wastewater disposal, leaching of animal manure, runoff water, and captive breeding of domestic animals or wild animals which varied from 2 UFC/100 mL in May and 2 UFC/100 mL in June in well P2 and 22 UFC/100 mL in May and 30 UFC/100 mL in June in well P9. There was no trace of total coliforms in wells P1, P10, P11, P14, and P18 (Figure 9). The concentration of fecal coliforms varied from 1 UFC/100 mL in May and June in well P5 and 9 UFC/100 mL in May and June in well P13. However, no trace of fecal coliforms in wells P1, P2, P3, P4, P10, P11, P12, P14, P18 (Figures 9 and 10).

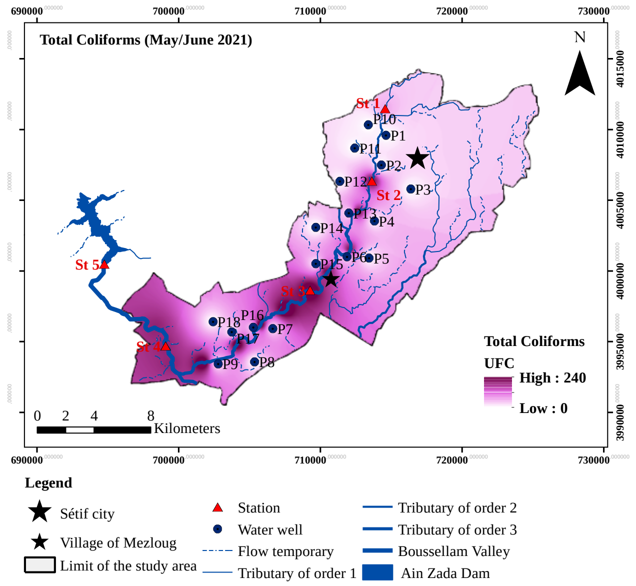

Figure 9. The distribution of total coliform content in the waters of the Boussellam plain. Note: ArcGIS 10.7, Geographic coordinate systems: WGS 1984. Projected coordinate systems: WGS 1984_UTM_Zone_31N_Unit meter

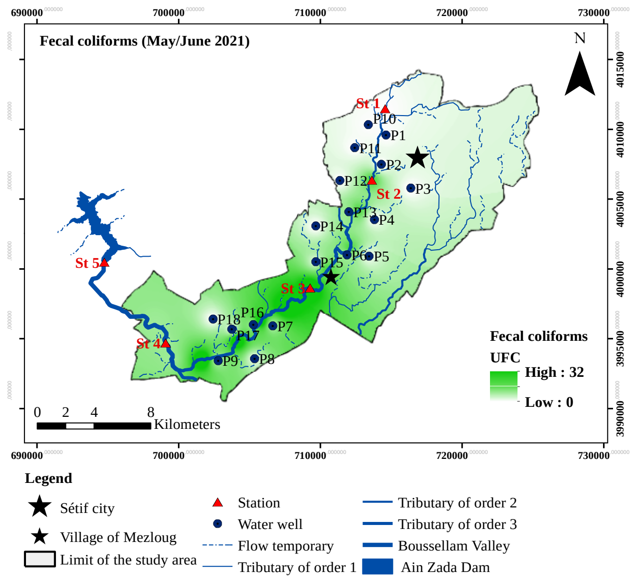

Figure 10. The distribution of fecal coliform content in the waters of the Boussellam plain. Note: ArcGIS 10.7, Geographic coordinate systems: WGS 1984. Projected coordinate systems: WGS 1984_UTM_Zone_31N_Unit meter

Streptococci

Streptococci levels in the waters of Boussellam Valley in stations 2 and 3 were 2 UFC/100 mL in May and 3 UFC/100 mL and 4 UFC/100 mL for the stations 2 and 3 in June 2021, respectively, so there is a risk of contamination of Streptococci in the valley waters. The WHO guidelines stated that the water must not contain any trace of Streptococci. The isovalue map does not show any trace of Streptococci in the waters of the plain. It confirms that the plains are not subject to any pollution from the valley (Figures 11 and 12).

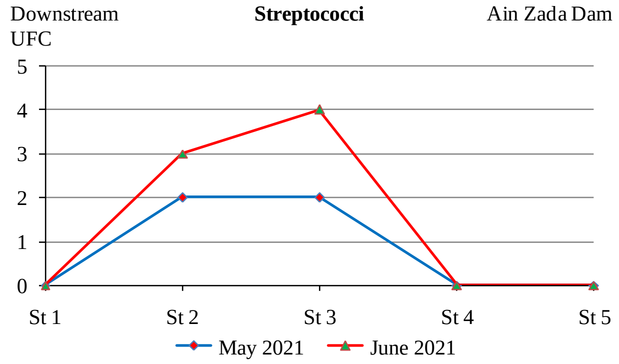

Figure 11. Total Streptococci in the waters of Boussellam Valley, Setif City, Algeria

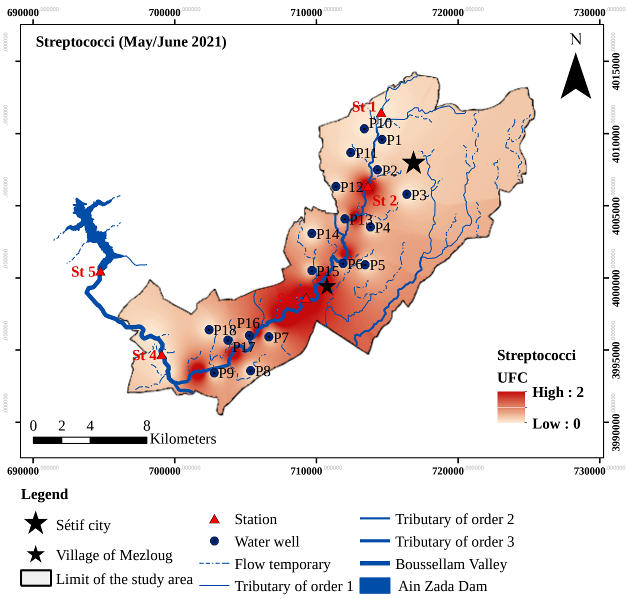

Figure 12. The distribution of Streptococci levels in the waters of Boussellam plain, Setif City, Algeria. Note: ArcGIS 10.7, Geographic coordinate systems: WGS 1984. Projected coordinate systems: WGS 1984_UTM_Zone_31N_Unit meter

In conclusion, the following facies chemically characterizes Boussellam Valley's waters sub-watershed, i.e., chloride-calcium, sulfate-magnesium, and bicarbonate-calcium with slight variations in Ca^{+2}, Mg^{+2}, (Na^{+}+ K^{+}), Cl^{-}, SO_4^{-2}, and HCO^{3-}. This variation is due to various factors such as the dilution of well water by rain, the dissolution of quaternary formations containing chlorinated evaporites and gypsum, and the relationships between the water table and the valley depending on the period considered. Nevertheless, the salinity is still in the acceptable range at all water points so that the waters can be used for irrigation.

The contamination of the waters of Boussellam valley by nitrite is continuously increasing (≥ 0.1 mg/L), which suggests a risk of water pollution in the plain of Boussellam valley, including the well closest to the valley is the most threatened and contaminated. On the other hand, the concentration of nitrates remains within the standards (< 50 mg/L). Still, the plain is at risk of nitrate contamination following its continuous increase, mainly due to domestic wastewater and the intensive use of fertilizers. In addition, the plain is also at risk of contamination by microbial pollution, particularly by fecal and total coliforms (≥ 10 UFC/100 mL) and streptococci. However, water should be free from total coliforms, fecal coliforms, and Streptococci contamination. The main causes of this contamination are wastewater discharges, intensive use of fertilizers, septic tanks, leaching of animal waste, runoff, and livestock.

REFERENCES

Ahmed H. 2003. Faecal coliforms in pond water, sediments and hybrid tilapia *Oreochromis niloticus* and *Oreochromis aureus* in Saudi Arabia. Aquaculture Research 34: 517-524. DOI: 10.1046/j.1365-2109.2003.00832.x.

Arman NZ, Salmiati S, Aris A, Salim MR, Nazifa TH, Muhamad MS, Marpongahtun M. 2021. A review on emerging pollutants in the water environment: existences, health effects and treatment processes. Water 13: 3258. DOI: 10.3390/w13223258.

Bassem SM. 2020. Water pollution and aquatic biodiversity. Biodiversity Intl J 4 (1): 10-16. DOI: 10.15406/bij.2020.04.00159.

Boudeffa K, Fekrache F, Bouchareb N. 2020. Physicochemical and biological water quality assessment of the Guebli river, northeastern Algeria. Rasayan J Chem 13 (1): 168-176. DOI: 10.31788/RJC.2020.1315255.

Boulgueraguer Z, Chaffai H, Toumi N, Saidi S, Djorfi S, Djabri L. 2018. Origin of mineralization and impact of anthropogenic pollution on water quality in Boussellam wadi and its environment, Wilaya of Sétif (North-East Algeria). J Biol Environ Sci 12 (6): 176-185.

Cheng C, Huijun X, En Y, Xuanxu S, Peng D, Jian Z. 2016. Nutrient removal and microbial mechanisms in constructed wetland microcosms treating high Nitrates/nitrite polluted river water. RSC Adv 6 (70848): 70848-70854. DOI: 10.1039/C6R A13929A.

El-Kalliny AS, Abd-Elmaksoud S, El-Liethy MA, Abu Hashish HM, Abdel-Wahed MS, Hefny MM, Hamza IA. 2021. Efficacy of cold atmospheric plasma treatment on chemical and microbial pollutants in water. Chem Select 6 (14): 3409-3416. DOI: 10.1002/slct.202004716.

Haied N, Khadri S, Foufou A, Azlaoui M, Chaab S, Bougherira N. 2021. Assessment of groundwater pollution vulnerability, hazard and risk in a semi-arid region. J Ecol Eng 22 (10): 1-13. DOI: 10.12911/22998993/142234.

Halder JN, Islam MN. 2015. Water pollution and its impact on the human health. J Environ Human 2: 36-46. DOI: 10.15764/EH.2015.01005.

Kılıç Z. 2021. Water pollution: causes, negative effects and prevention methods. ZU J Inst Sci Technol 3 (2): 129-132. DOI: 10.47769/izufbed.862679.

Krumova-Valcheva G, Gyurova E, Mateva G, Milanov M. 2021. Microbiological effect of complete replacement of Nitrites/Nitrates with starter cultures in traditional raw-dried fermented sausage "Lukanka Panagyurska,". Bulg J Vet Med. DOI: 10.15547/bjvm.2021-0043.

Lambert N, Anirudha G, Marc N. 2020. Assessment of coliforms Bacteria contamination in Lake Tanganyika as bioindicators of recreational and drinking water quality. South Asian J Res Microbiol 6 (3): 9-16. DOI: 10.9734/SAJRM/2020/v6i330150.

Nexhdet S, Ibrahim H, Gafur QX, Bajram A. 2018. The microbiological quality of water, pathogenic microorganisms in food products and fecal contamination in the rivers of the Republic of Kosovo. Rasayan J Chem 11 (4): 1399-1404. DOI: 10.31788/RJC.2018.1144065.

OMS. 2000. Directives de qualité pour l'eau de boisson; volume 2 – critères d'hygiène et documentation à l'appui. Organisation mondiale de la Santé, 2e édition, 1050.

Pal P. 2014. Detection of coliforms in drinking water and its effect on human health - A Review. Intl Lett Nat Sci 17: 122-131. DOI: 10.18052/www.scipress.com/ILNS.17.122.

Prabhavati, Somanathreddy CP, Shivakumar K. 2021. Assessment of physicochemical parameters and water quality (Rotifera diversity) of Bhima river at Katti Sanghavi Bridge (Karnataka, India). UPJOZ 42 (23): 20-28.

Rita A, Karoli N. 2020. Factors affecting distribution of coliforms bacteria in semi-arid groundwater sources- Tanzania. Intl J Biosci (IJB) 16 (4): 487-499. DOI: 10.12692/ijb/16.4.487-499.

Singh J, Yadav P, Pal A K, Mishra V. 2020. Water Pollutants: Origin and Status. In Sensors in water pollutants monitoring: Role of material. Springer, Singapore. DOI: 10.1007/978-981-15-0671-0_2.

Sintondji LO, Vodounnon JA, Akognongbe AJS. 2017. Quality of water and sources of pollution of chenal cotonou. IJAEMR 2 (6).

Some S, Mondal R, Mitra D, Jain D, Verma D, Das S. 2021. Microbial pollution of water with special reference to coliform bacteria and their nexus with environment. Energy Nexus 1: 100008. DOI: 10.1016/j.nexus.2021.100008.

Thorbum PJ, Biggs JS, Weier KL, Keating BA. 2003. Nitrates in groundwaters of intensive agricultural areas in coastal Northeastern Australia. Agric Ecosyst Environ 94 (1): 49-58. DOI: 10.1016/S0167-8809(02)00018-X.