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# Physical-chemical characterisation of the urban wastewater – case study of the Boumerdes region, North – Algeria

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**Abstract:** The objective of this study is to assess the physical-chemical quality of urban wastewater from the city of Boumerdès, in northern Algeria with regard to the threshold values for irrigation or their discharge in aquatic ecosystems. Five sampling points were carried out of the study area in April 2017. The results obtained of physical-chemical parameters indicating pollution show that the water course is exposed to pollution mainly of organic origin. It's expressed by a high maximum value according to Algerian and World Health Organisation standards: chemical oxygen demand (*COD* 886 mg $O_2·dm^{-3}$), biochemical oxygen demand ($BOD_5$ 490 mg $O_2·dm^{-3}$), nitrate ($NO_3^-$ 73.09 mg·$dm^{-3}$), nitrite ($NO_2^-$ 6 mg·$dm^{-3}$), ammonium ($NH_4^+$ 23 mg·$dm^{-3}$) and phosphates ($PO_4^{3-}$ 7.3 mg·$dm^{-3}$).

The *COD* to $BOD_5$ rate of 1.8, show that the effluents must be treated before being discharged into the receiving environment. However, it is lower than 2, which makes them easily biodegradable and can be treated by a biological system such as a natural lagoon. It shows also a diversified origin of the pollution. It is predominantly domestic origin, it could have an adverse effect on public health, presenting a risk of environmental eutrophication, contamination of soil and water resources.

The physical-chemical characterisation of the urban wastewater shows that they are quite loaded and present a pollution in nitrogenous compounds, a treatment is requested before the direct discharge to the receiving environment or their reuse in the irrigation.

**Keywords:** D>Boumerdes, physical-chemical parameters, pollution, urban wastewater, water quality standards

## INTRODUCTION

Water forms the backbone of the world's economy and it is critical to the development of all spheres of human endeavour [Obi *et al.* 2006]. The scarcity of freshwater resources [Falkenmark, Wistrand 1992], due particularly to the uncontrolled increase in the population, constitutes a serious development problem in the arid regions of the world, particularly in developing countries, where water of marginal quality is gradually being used in agriculture [Belhaj *et al.* 2016]. The global trend towards urbanisation and the population growth of cities, on the one hand, require increasing volumes of water to be extracted and transported [Hunt, Watkiss 2011] for the supply of drinking water, and on the other hand, lead to a significant production of wastewater.

Urban aquatic ecosystems including streams, rivers, lakes, and estuaries have been subjected to increasing anthropogenic stress over the past decades [Adams, Greeley 2000], particularly in regions where wastewater is discharged directly into the natural environment without preliminary treatment [Emmanuel *et al.* 2009]. Indeed, surface waters often serve as a means for disposing wastes loaded with nutrients and heavy metals [Streck, Richter 1997] from residential areas, industries and manufacturing plants [Dyer *et al.* 2003].

In Algeria, the Tatarag River is the principal watercourse which pass through the city of Boumerdes and discharges into the Mediterranean Sea [Amiri *et al.* 2017]. With the exception of urban effluents collected and treated by the wastewater treatment of Boumerdes plant (ONA), a daily volume of 15,000 $m^3·d^{-1}$, all other liquid discharges of domestic origin generated by the city of Boumerdes released, without preliminary treatment, directly into this river. The continual discharge of chemical substances in aquatic ecosystems can bring about changes in the structure and functioning of the biotic community, i.e. on biotic integrity [Karr 1991]. As a function of their bioavailability, the pollutants present in effluents cause a large number of harmful effects on the biodiversity of aquatic environments [Forbes 1994]. The physical-chemical aggression sustained by surface waters due to contact with pollutants contained in liquid discharges lead to a loss of aquatic biodiversity in many cases [Emmanuel *et al.* 2009]. This study aims to assess the physicochemical quality of urban wastewater from the city of Boumerdès, in northern Algeria with regard to the threshold values for irrigation or their discharge in aquatic ecosystems.

## MATERIALS AND METHODS

### STUDY AREA

Boumerdes (36°46'00' N, 3°28'00' E) is a coastal city in the center of Algeria, located in Lower Kabylia (Fig. 1). It is located 45 km east of the capital Algiers and it extends over an area of about 2040 ha and contains a population of about 41,685 inhabitants in 2008 with a growth rate of 2.2% [City population 2008]. The wastewaters of Boumerdes city are discharged directly into the sea.

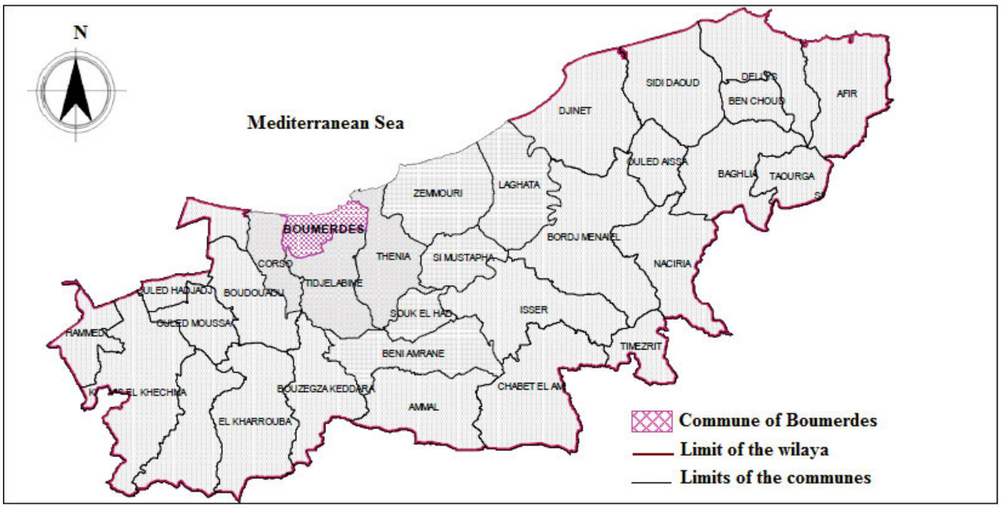


**Fig. 1.** Geographic location of the commune of Boumerdes; source: own elaboration based on ABH [2010], and Amiri [2012]

The climate in Boumerdes is Mediterranean, cold and wet in winter, hot and dry in summer. The annual rainfall varies between 500 and 1,300 mm.

### SAMPLING

To study the water quality of the study area, five sampling points were selected and noted (S1–S5) according to the light of a preliminary study of the physical-chemical parameters, the frequency of use by local residents, and according to the direction and the accessibility of the water course (Fig. 2). The sampling and collection methods were carried out according to the recommendations. In April 2017, the five samples of 1.5 $dm^3$ each in the polyethylene bottles were taken to the laboratory for physical-chemical analyses. The parameters (temperature, conductivity and pH) were measured on site using a multi-parameter (Consort 861).

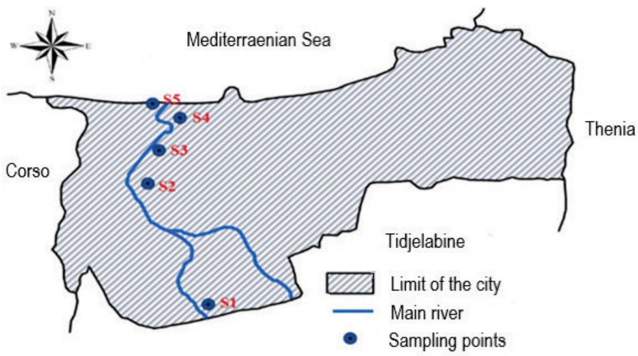


**Fig. 2.** Sampling points (S1–S5) – urban wastewater of Boumerdes city; source: own elaboration

### PHYSICAL-CHEMICAL PARAMETERS MEASURED

**The potential of hydrogen (pH)** is a parameter that measures the acidity or basicity of a solution. This parameter conditions a large number of physical-chemical balances and depends on multiple factors, including the temperature and the origin of the water. According to Blinda [2007], a pH between 5 and 9 allows a normal development of fauna and flora.

**Electrical conductivity (*EC*)** allows to appreciate the quantity of salts dissolved in water, so it reflects the degree of global mineralisation [Belghyti *et al.* 2009].

**Biochemical oxygen demand (*$BOD_5$*)** is the quantity of oxygen required by aerobic micro-organisms in the water to oxidise organic matter dissolved or suspended in the water. It is therefore a potential consumption of oxygen by biological way.

**The chemical oxygen demand (*COD*)** indicates the amount of oxygen needed to oxidise organic matters, this parameter is an indicator of the amount of chemically oxidisable organic substances present in the water [Bliefert, Perraud 2001]. The increase in its concentration could be attributed to an increase in organic and inorganic substances in the receiving environment [IGBINOSA, OKOH 2009].

**Nitrates ($NO_3^-$)** represent the most oxygenated form of nitrogen, it is a very soluble form and its presence is related to the intensive use of chemical fertilisers. In this form, nitrogen is a nutritive salt that can be used by the majority of plants [TOUATI *et al.* 2018].

**Nitrites ($NO_2^-$)** are the least stable form in the nitrogen cycle, they result from the reduction of ammonium. Their origins are related to agriculture or to urban and industrial discharges [TOUATI *et al.* 2018].

**Ammonium ($NH_4^+$):** ammonification reactions can transform organic nitrogen into ammonium, the oxygen demand by this reduced form of nitrogen is very high however this compound is odorous it is the origin of bad smells [DUSSART 1966].

**Phosphates ($PO_4^{3-}$)** can be from organic or mineral origin. Most often their presence in natural waters is the result of their use in agriculture as chemical fertilisers or pesticides [TOUATI *et al.* 2018].

The physical-chemical analysis consists in the determination of the principal parameters indicators of pollution such as *COD*, $BOD_5$, total Kjeldahl nitrogen (TKN), $NH_4^+$, $NO_3^-$, $NO_2^-$ and $PO_4^{3-}$. The threshold values recommended by national and international guidelines for the selected parameters are presented in Table 1.

**Table 1.** Threshold values recommended for the selected parameters

| Parameter | Unit | Threshold values acc. to | | |
|---|---|---|---|---|
| | | Décret exécutif n° 06-141 | OMS [1989] | Commission Directive 98/15/EEC, Arrêté du 2 février 1998 |
| Temperature | °C | 30 | 30 | – |
| pH | – | 6.5–8.5 | 6.5–8.5 | – |
| *EC* | $dS \cdot m^{-1}$ | – | <–3 | – |
| $BOD_5$ | $mg \cdot dm^{-3}$ | 35 | <30 | 25 |
| *COD* | | 120 | <40 | 125 |
| Nitrates | | – | <50 | 10 |
| Nitrites | | – | <1 | – |
| Ammonium | | – | <2 | – |
| Phosphates | | 2 | <0.94 | 1 |

Explanations: *EC* = electrical conductivity, $BOD_5$ = biochemical oxygen demand, *COD* = chemical oxygen demand.
Source: own elaboration based on literature.

These parameters were monitored in the different sampling points (five sampling points and the mixture sample). After having collected and preserved the samples according to the conditions required for wastewater, the analyses were carried out according to the recommended protocols.

## METHODS OF DETERMINATION OF THE SELECTED PHYSICAL-CHEMICAL PARAMETERS

The physical parameters measured are *T*, pH and *EC*. The chemical parameters determined are: *COD*, $BOD_5$, the content of $NO_3^-$, $NO_2^-$, $NH_4^+$ and $PO_4^{3-}$.

According to standard analysis techniques. The determination methods [RODIER *et al.* 1996] used are as follows:
- potentiometric method (Consort 861) for pH, temperature and *EC*;
- colorimetric method for the phosphate content (multi-parameter HANNA model C200);
- potentiometric method (HI 121) using a specific electrode for nitrates.

# RESULTS AND DISCUSSION

## POTENTIAL OF HYDROGEN (pH) AND TEMPERATURE (*T*)

The temperature (*T*) values in the city of Boumerdes vary between 18.0 and 21.9°C. The increase in temperature would promote the phenomenon of self-purification and increase the rate of sedimentation of suspended matter [MOUSSA MOUMOUNI DJERMAKOYE 2005]. The values pH oscillate between 7.1 and 8.3 (Fig. 3) which means that the environment is slightly basic.

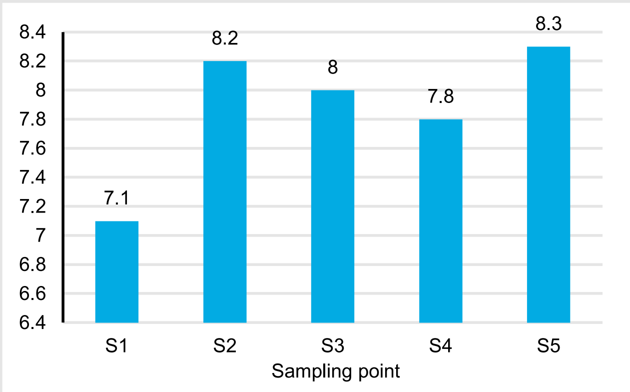


**Fig. 3.** Spatial evolution of pH; source: own study

## ELECTRICAL CONDUCTIVITY

The maximum value of *EC* is observed at point S2 with a value of 4.9 $dS \cdot m^{-1}$ (Fig. 4), the point S2 and S4 indicate a high mineralisation [RODIER *et al.* 2009] that exceeds the standard of water reused in agriculture (3.0 $dS \cdot m^{-1}$) [OMS 1989].

## BIOCHEMICAL OXYGEN DEMAND ($BOD_5$)

The maximum value of $BOD_5$ was observed at point S5 with 490 mg $O_2 \cdot dm^{-3}$ (Fig. 5), noticing that all the sampling points are higher than the Algerian standards of 35 mg $O_2 \cdot dm^{-3}$ [Décret exécutif n° 06-141] or 30 mg $O_2 \cdot dm^{-3}$ [OMS 1989] for irrigation waters or direct discharges. The increase of this parameter is related to the load of biodegradable organic matters. According to ASIA and AKPORHONOR [2007], if the values of $BOD_5$ and *COD* are

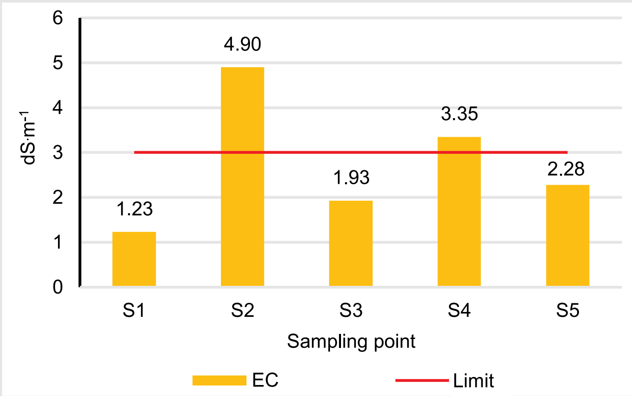


**Fig. 4.** Spatial evolution of electrical conductivity (*EC*); source: own study

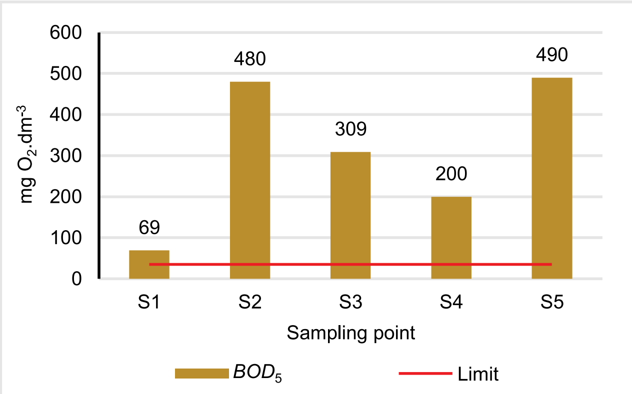


**Fig. 5.** Spatial evolution of biochemical oxygen demand ($BOD_5$); source: own study

high than threshold values, it means that the wastewater has a high pollution potential and should be treated before discharge to the environment.

## CHEMICAL OXYGEN DEMAND (*COD*)

The minimum value of *COD* is 189 mg $O_2$·dm$^{-3}$ is recorded at point S1; the maximum value of 886 mg $O_2$·dm$^{-3}$ is observed at point S5 (Fig. 6), these values are high compared to the limit values of irrigation water [OMS 1989] for discharge to a receiving environment fixed at a 120 mg $O_2$·dm$^{-3}$ [Décret exécutif n° 06-141]. These values are close to those of ONA [2010] declared by Amiri [2012].

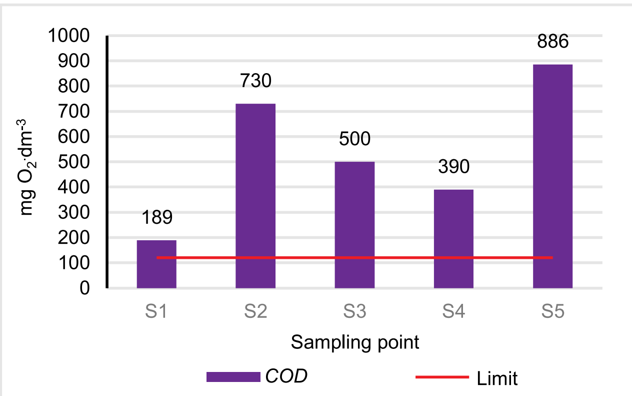


**Fig. 6.** Spatial evolution of chemical oxygen demand (*COD*); source: own study

## NITRATES

The values of $NO_3^-$ recorded oscillate between 20 and 73.09 mg·dm$^{-3}$ (Fig. 7), according to the international standard for water used for irrigation only point S1 is in conformity [OMS 1989] (<50 mg·dm$^{-3}$). These values are in concordance with those of Mouni *et al.* [2009] for the waters of the Soummam River in Algeria.

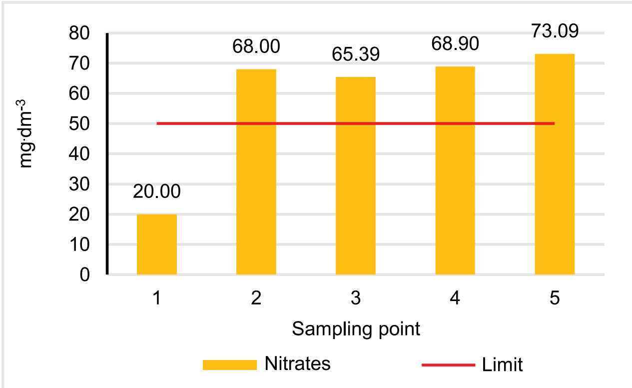


**Fig. 7.** Spatial evolution of nitrates ($NO^{3-}$); source: own study

## NITRITES

In the studied waters this element is characterised by high values with a maximum of 6 mg·dm$^{-3}$ at the location S4, probably due to domestic discharges of the municipality which are discharged into the river, as well as the phytosanitary products of fertilisers used in agriculture. The minimum value is recorded at point S1 with a value of 0.4 mg·dm$^{-3}$ (Fig. 8). According to OMS [1989; 2001], the concentrations obtained for nitrites in raw wastewater during the monitoring are higher than the international standards for water intended for irrigation (1 mg·dm$^{-3}$) or the one fixed for surface water, except for point S1. These results are in agreement with those of Derradji *et al.* [2007] for surface waters in the north-east of Algeria, Mouni *et al.* [2009] for the waters of the Soummam River in Algeria and Ahmed Baig *et al.* [2009] for the surface waters of the city of Jamshoro in Pakistan.

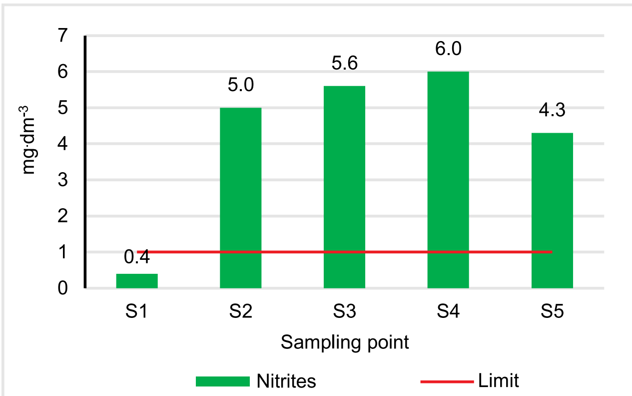


**Fig. 8.** Spatial evolution of nitrites ($NO^{2-}$); source: own study

## AMMONIUM

Theoretically, ammonia nitrogen exists in aqueous solution as either the ammonium ion or ammonia, depending on the pH of the solution, in accordance with the following equilibrium reaction acc. to Metcalf and Eddy Inc. [1991]:

$$NH_3^+ + H_2O \leftrightarrow NH_4^+ + OH^-$$

At pH levels above 7 (our case), equilibrium is displaced to the left. The spatial evolution of this parameter indicates a contamination since the values are higher than the standards of irrigation waters fixed at <–2 mg·dm$^{-3}$ [OMS 1989]. The maximum value is observed at point S5 with 23 mg·dm$^{-3}$, the minimum is observed at point S1, with a value of 11 mg·dm$^{-3}$ (Fig. 9).

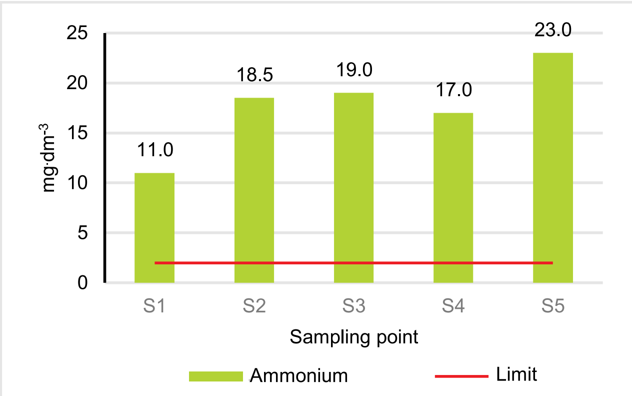


**Fig. 9.** Spatial evolution of ammonium ($NH_4^+$)); source: own study

## PHOSPHATES

The measured values of $PO_4^{3-}$ of vary between 1.35 and 7.3 mg·dm$^{-3}$ (Fig. 10), detergent discharges are probably the origin of 50–70% of the phosphorus. Detergents, and in particular laundry detergents, use polyphosphates to fight against water hardness, to help emulsify greases and to keep the dirt suspended. Polyphosphates are then released during rinsing, they have a tendency to hydrolyse into phosphates in wastewater [REJSEK 2002]. Phosphates also participates in the first line of the eutrophication process, a phenomenon with environmental consequences (algal growth) and health consequences (release of algal toxins) [FESTY *et al.* 2003], these values exceed without exception the limit of irrigation water set at (<0.94 mg·dm$^{-3}$) [OMS 1989] and the limit of discharge into a receiving environment set at 2 mg·dm$^{-3}$ [Décret exécutif n° 06-141] except for sampling point S4, according to MAAZOUZI *et al.* [2011]. It is a eutrophic environment.

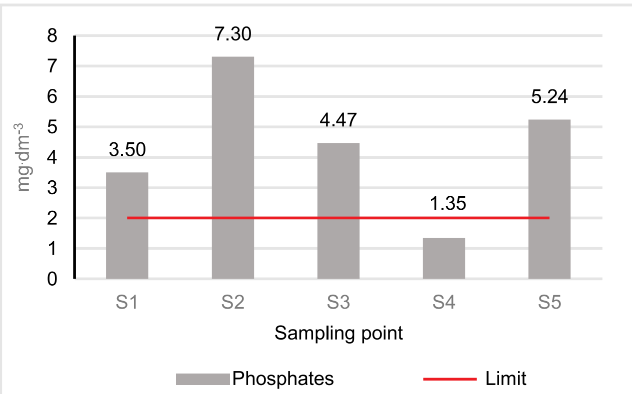


**Fig. 10.** Spatial evolution of phosphates ($PO_4^{3-}$); source: own study

## BIODEGRADABILITY

The biodegradability of organic substances occurs as a function of the speed and completeness of its biodegradability by microorganisms [SPONZA 2003]. Therefore, $BOD_5$ to $COD$ or $COD$ to $BOD_5$ and $COD$ to total organic carbon ($TOC$) ratios could be used to analyse the difficulty or ease of degradation of organic substances [EMMANUEL *et al.* 2004]. In this study, precise knowledge of the organic carbon of the wastewater samples from the city of Boumerdès, which is necessary in order to analyse biodegradability by using the ratios of global parameters, was not completed, because the *TOC* was not taken into account. However, the data obtained from the $COD$ to $BOD_5$ ratio shows a varied origin of pollution in the study area. It is predominantly domestic (ratio between 2 and 3), at the level of point S1. However, at the other locations (S2, S3, S4 and S5), it is of agri-food origin (report is between 1.5 and 2.0 which means a better biodegradability (Fig. 2). We can also conclude the absence of industrial discharge in the urban sewerage system since ($COD$: $BOD_5$ < 3) [Degremont SA 2005; RODRIGUES *et al.* 2008]. These results are in agreement with those of AMIRI *et al.* [2017].

## CLASSIFICATION OF WATER QUALITY

The organic pollution according to nitrates, nitrites at the sampling point S1 of the study area is in compliance with the standard of water reused for irrigation. Concerning the other points (S2, S3, S4, and S5), they present a pollution classified as acceptable, this pollution results from the domestic discharges of the region which are directly discharged into the river. However, all five samples show ammonia contamination (Tab. 2) due to domestic discharges from the city, runoff water and probably the leaching of plots next the watercourses witch carry nitrogen to it

**Table 2.** Surface water quality classification acc. to TOUATI *et al.* [2018]

| Chemical compound | Specification | Class | | | |
|---|---|---|---|---|---|
| | | excellent | good | acceptable | bad |
| Nitrites | value[1)] | <0.1 | 0.1–0.5 | 0.5–8 | >8 |
| | sampling point | – | S1 | S2, S3, S4, S5 | – |
| Nitrates | value | <5 | 5–50 | 50–80 | >80 |
| | sampling point | – | S1 | S2, S3, S4, S5 | – |
| Ammonium | value | <0.1 | 0.1–0.5 | 0.5–2 | 2–8 |
| | sampling point | – | – | – | S1, S2, S3, S4, S5 |

1) Values of each parameter are expressed in mg·dm$^{-3}$.
Source: own study.

[Bremond, Vuichard 1973]. These results are in line with those of Megateli [2014], on the Beni Aza waters (Blida, Algeria) and those of Touati *et al.* [2018] on Guelma groundwater.

## WATER QUALITY ACCORDING TO: $BOD_5$, *COD* AND PHOSPHATE

The waters of Tatarag River are classified as out of class for the various parameters $BOD_5$, *COD* and phosphate according to Table 3, all sampling points record a very high pollution probably caused by domestic discharges generated by the study town, random discharges and the use of fertilisers and pesticides in agriculture [Bremond, Vuichard 1973]. These results are in line with those of Megateli [2014], on the Beni Aza waters (Blida, Algeria).

**Table 3.** Water quality status for the study area acc. to ABH [2009] and Touati *et al.* [2018]

| Parameter | Specification | Class: good no pollution | quite good moderate water pollution | poor net water pollution | bad significant water pollution | out of class very high water pollution |
|---|---|---|---|---|---|---|
| $BOD_5$ | value (mg $O_2 \cdot dm^{-3}$) | <3 | 3–5 | 5–10 | 10–25 | >25 |
| | sampling point | – | – | – | – | S1, S2, S3, S4, S5 |
| *COD* | value (mg $O_2 \cdot dm^{-3}$) | <20 | 20–25 | 25–40 | 40–80 | >80 |
| | sampling point | – | – | – | – | S1, S2, S3, S4, S5 |
| Phosphate | value ($mg \cdot dm^{-3}$) | <0.1 | 0.1–0.3 | 0.3–0.5 | 0.5–3 | >3 |
| | sampling point | – | – | – | S4 | S1, S2, S3, S5 |

Source: own study.

## CONCLUSIONS

This research has approached the problem of wastewater treatment in the area of Boumerdes, whose water needs are growing, facing a degradation of this resource related to environmental pollution. The study has allowed first to characterise the polluting load of wastewater from the city of Boumerdes which is of bad quality. The waters of Tatarag River present a pollution in nitrogenous compounds classified as Acceptable and exceeding by places the tolerated standard except for ammonium all the sampling points present a bad pollution.

The *COD* to $BOD_5$ ratio, reflecting the biodegradability shows a diversified origin of the pollution in the study area. It is predominantly domestic in the majority of the analysed points, most of them present a net pollution in terms of $BOD_5$, *COD* and phosphates.

The wastewater studied according to the physical-chemical characterisation (spatial evolution) of the various parameters indicators of pollution proves to be quite charged, it can be classified as highly polluted urban wastewater, a treatment is highly requested before their direct discharge to the receiving environment or their reuse in agriculture.

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