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ORIGINAL ARTICLE

Risk assessment for chemical pollution of dairy effluents from a milk processing plant located in Bechar (Southwest of Algeria)

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Abstract

Milk and dairy products' production lines generate pollution in the form of food waste. The management of this waste concerns professionals that fit the purpose of this study to assess the chemical risk of the raw liquid effluents that are discharged from a milk processing plant located in *Bechar* (Southwest of Algeria) by analyzing the main chemical indicator parameters of water pollution following official analytical methods. A total of ten samples were analyzed during the months of February, March and April of the year 2019. The obtained results were interpreted according to the regulatory requirements recommended by the Algerian standard related to threshold limit of physicochemical parameters' values. The obtained results showed pollution signs revealed by high levels of the organic matters, expressed by significant means related to the following parameters: chemical oxygen demand (COD: 810.33 mg/L), 5 days-biochemical oxygen demand (BOD_5: 797.91 mg/L), total suspended solids (TSS: 47.3 mg/L) and turbidity (174.014 NTU) exceeding those required by the national standard, except other physicochemical parameters, such as pH, conductivity, sulfate, nitrate and nitrite contents that did not exceed the threshold of acceptable values. Although these raw effluents present a high organic load expressed by average BOD_5/COD ratio equal to 0.985, they constitute organic matters in a dissolved form (average value of the TSS/BOD_5 ratio = 0.076). Furthermore, The COD/BOD_5 ratio that had an average value equal to 1.015 underlines the biodegradability character of discharged dairy effluents. The high pollution levels which are aggravated by the lack of wastewater treatment can hurt the environment and the biological diversity and, therefore the humans' health. This requires an immediate intervention for a solution, where it is very important that proper wastewater treatment systems should be installed for the environment protection and for the ecological balance. Otherwise, it may constitute a risk to the public health on medium- to long-term by affecting the quality of the underground reservoir known as the main source of supply for the inhabitants of arid and semi-arid areas.

Keywords Dairy effluents · Chemical risk characterization · Water and environmental pollution · Algerian standard · Bechar (Algeria)

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Introduction

Water is a natural element of paramount importance, essential for any living form; a necessary wealth for all human activities, used for drinking, cooking, agriculture, transport and recreation, among other purposes, a determining factor of production in sustainable development: it was and still is at the center of strategic interests in the world's economy (Tadesse et al. 2018). When people use water, they don't just consume it, but they also release some of it into the receiving environment as wastewater without any treatment, which contains different pollutants (Garrido et al. 2001).

Since water is not an unlimited resource, it will be imperative to strengthen other forms of unconventional use of resources, such as the use of treated wastewater, in different fields: for example using it for irrigation purposes (watering green areas), and besides, minimize pollution which can constitute frequent and complex issues ranging from the pollution of surface water, and as a result to their infiltration, they can also affect the groundwater quality that until now is considered as the main water resources particularly in arid areas (Kendouci et al. 2019) and the largest reserve of liquid freshwater in the world (Benmoussa et al. 2020).

Algeria is considered as the biggest consumer of milk and dairy products at the Maghreb level (Benyagoub and Ayat 2014). The dairy industry is experiencing an annual growth of 8% in food production. The industrial infrastructure has been designed to meet a galloping demand for milk and dairy products with the prospect to develop the production of cow milk and making it the main source of raw material supply and integrating it in the transformation process (Benyagoub et al. 2017, 2018a). Therefore, agri-food industries, in general, and dairies, in particular, are among the most demanding in terms of quality and quantity of the used water. The dairy industry produces washing water, a high strength waste, as a by-product of cleaning the facilities to maintain sanitary operations (Sukhadev Shivsharan et al. 2013). They are considered to be the most polluting for the receiving environment because they don't only reject huge volumes of wastewater with a variable pH but also reject a large part that rich in organic matter and microorganisms to the receiving environment. If the dairy industry discharges are not toxic, they are quantitatively significant, i.e., 0.3–11 L of dairy effluents per liter of processed milk (Hamy 2005).

However, treatment can be specific to the dairy or otherwise treatment plants that treat wastewater from an urban agglomeration (Daufin et al. 2000). Many others agree to purify dairy discharges by biological treatment because its nature is essentially organically biodegradable (Moletta and Torrijos 1999). The economic context makes suitable high-performance sectors such as activated sludge wastewater treatment plant (Menoret 2001).

Today, industrial companies face many challenges in the field of the environment, cost control, securing production tools and traceability of waste. By entrusting specialists, the challenges linked to the water and waste cycles can devote themselves fully to their profession and ensure the success of their commitments.

For this, the present work aimed to assess the chemical risk of dairy effluents discharged from a small milk processing plant located in *Bechar* (Algeria) by analyzing some physicochemical parameters of outgoing discharge water from this dairy industry.

Materials and methods

The physicochemical parameters analyzed in this study were as follows: temperature, hydrogen potential (pH), electrical conductivity (EC), turbidity, total suspended solids (TSS), sulfate, nitrate, and nitrite contents, chemical oxygen demand (COD) and 5 days-biochemical oxygen demand (BOD_5), which are recommended by national regulations, to identify the pollution sources with a global vision on the chemical quality of discharged wastewater.

Analysis of physicochemical parameters was performed at *Mohammed TAHRI* University of *Bechar* (Algeria).

Presentation of the studied dairy industry

It is a small milk processing plant located in Nif Errhaa-Ouakda (14 km North of *Bechar* city-Southwest of Algeria), a private investment inaugurated in November 2016. The unit produces an average of 15500 L of partially skimmed pasteurized milk/Day, and could reach up to 40000 L/Day as maximum capacity, and average production of 5000 L/week of fermented milk, depending on the availability of the powdered milk and raw cow's milk as raw material. The studied dairy industry has created a new production line in 2019 for lemonade production. This dairy unit includes an administrative block, a manufacturing workshop with two cold chambers and a steaming one, three basins for dairy effluents' collection (Fig. 1) (Benyagoub et al. 2018b; Benyagoub 2019).

The industry discharges into the environmental medium a volume of raw dairy effluents between 50 and 75 m^3/Day,

Fig. 1 Satellite view of location and structure of the studied dairy industry (Ouakda-Bechar, Southwest of Algeria) (Google maps 2020). **A** administration block; **B** manufacturing workshop; **C** basin for collection and disposal of the dairy effluents

and this depending on the cleaning and disinfection operation's frequency, which is related to the milk processing.

Sampling and physicochemical analyses

Sampling conditions

For the validity of the results, a particular attention should be given when collecting a water sample. First of all, the sample must be homogeneous, representative and obtained without modifying its physicochemical or microbiological characteristics (Rodier et al. 2009).

Water samples necessary for the physicochemical analyses were collected according to the method described by Rodier et al. (2009), in disposable sterile plastic bottles and stored at + 4 °C, and then to be analyzed within the next 24 h after collection, except for two parameters, pH and temperature, which were measured on-site.

The samples were taken by morning from basins where the sterile flask was held directly and extended to a depth of 30–50 cm from the dairy effluents' surface. When the aseptic sampling is carried out, the sample is immediately identified under a reference where for three months, a total of 10 samples of the dairy effluents were collected and analyzed (Table 1).

Physicochemical analyses

The analyzed physicochemical parameters were carried out on the basis of standard methods given by the American Public Health Association (Rice et al. 2017) as follows:

- The temperature and the hydrogen potential (pH) were measured by a thermometer and pH meter (HANNA HI2210, Italy), respectively (Rodier et al. 2009);
- The electrical conductivity was measured using a conductivity meter (HANNA HI2314, Italy) (Rodier 2005). The result was expressed in microsiemens per centimeter (µS/cm);

Table 1 Sampling frequency and dates for collection of dairy effluents

Samples	Dates of collection
S1	February 25, 2019
S2	March 4, 2019
S3	March 10, 2019
S4	March 12, 2019
S5	April 9, 2019
S6	April 15, 2019
S7	April 17, 2019
S8	April 23, 2019
S9	April 29, 2019
S10	April 30, 2019

- Turbidity was measured using a turbidimeter (HACH DR/2100N, Germany) (Marc 2013). The result was given directly in nephelometric turbidity unit (NTU);
- Total suspended solids (TSS) was determined by membrane filtration (Gravimetric method) using a filter 0.45 µm pore size and 47 mm of diameter (Kasper et al. 2018). The filter was weighed after drying at 105 °C. Before weighing the filter, it shall then be allowed to cool down to 25 °C. TSS expressed in (mg/L) was calculated using the following formula (Rodier 2005):

$$SM = \frac{(M_1 - M_0)1000}{V}$$

V: The volume of analyzed sample in mL.
M_0: The filter tare mass in mg (Before filtration).
M_1: The mass of the filter in mg (After filtration).

- The sulfate content (SO_4^{-2}) was determined by the precipitation of sulfate ions in hydrochloric acid in the form of barium sulfate. The obtained precipitate was stabilized using Tween 20 solution. The homogeneous suspension was measured using a spectrophotometer (HACH DR600, Germany) at 650 nm and refer to the sulfate calibration curve by extrapolation of the obtained optical density OD (absorbance) of the sample test. The results were expressed in (mg/L) (Rodier et al. 2009);
- In the presence of sodium salicylate, the nitrates give sodium paranitro-salicylate, colored in yellow, the colored intensity depends on the nitrate content (NO_3^-) measured by spectrophotometer (HACH DR600, Germany) at 420 nm and refer to the nitrate calibration curve by extrapolation of the obtained optical density OD (absorbance) of the sample test. The results were expressed in (mg/L) (Rodier et al. 2009);
- The nitrite reacts with sulfanilamide to form a diazo compound which after coupling with N-(1-Naphthyl) ethylenediamine dichloride results in a pink color in which the nitrite content (NO_2^-) was measured by spectrophotometer assay (HACH DR600, Germany) at 543 nm and refer to the nitrite calibration curve by extrapolation of the obtained optical density OD (absorbance) of the sample test. The results were expressed in (mg/L) (Rodier et al. 2009);
- The chemical oxygen demand 'COD' is the quantity of oxygen provided by a chemical oxidant required to oxidize the sample. This parameter was measured by the potassium dichromate method under acidic condition (sulfuric acid at ½), after boiling for 2 h of mineralization in hot acid medium (Burgaud 1969; Thomas et al. 2017); the oxidizable matters of the tested sample were oxidized by reflux heating in a strongly acid medium

with a known amount of potassium dichromate forming Cr^{3+}. The amount of Cr^{3+} was determined after an oxidation reaction being complete and was used as an indirect measure of the organic contents of the tested sample; it results in a color change where the absorbance is proportional to the quantity of reduced potassium dichromate and it was determined as oxygen equivalent. A spectrophotometer assay (UV-1700 PharmaSpec SHIMADZU, Japan) at 600 nm was made, considering the control test value and referring to the calibration curve; the results were expressed in (mg/L) (Rodier et al. 2009).

- Biochemical oxygen demand (BOD_5) is the amount of oxygen required to oxidize organic matters biologically. It assesses the biodegradable fraction of the polluting carbon load of wastewater. The incubation was carried out at 20 °C for 5 days in the dark, and the BOD was measured by a BOD meter (Velp Scientifica™F10220131, 6-position BOD analyser). The results were expressed in (mg/L) (Rodier et al. 2009).

Evaluation of organic pollution of dairy effluent

For a better organic pollution assessment of discharged effluents, the parameters relating to the biodegradability such as the coefficient $K = COD/BOD_5$, the BOD_5/COD ratio, the TSS/BOD_5 ratio and the oxidizable organic matters (OOM) have an important interest. The use of these characterization parameters constitutes a good mean to estimate the pollution level of discharged raw effluents and also to optimize the physicochemical parameters of these dairy effluents in order to propose a suitable method of wastewater treatment (Burgaud 1969; Tardat-Henry and Beaudry 1992; Messrouk et al. 2014).

Interpretation of physicochemical results

Through analysis of the physicochemical and bacteriological parameters, it is possible to determine the sources and the pollution load of wastewater. Before they are discharged into the natural environment, they must imperatively meet the established standards to protect the receiving environment against pollution. The limit thresholds are published in the Official Journal of the Algerian Republic (OJAR n.26, 2006) (Table 2).

Statistical analysis

The experiment was repeated three times where the obtained results were presented as mean ± SD, calculated using Microsoft Excel software from where graphical presentations were obtained in the form of curves.

Results

Physicochemical analyses

Temperature

Temperature is an important abiotic factor. Since its role is to solubilize of the gases in water, to separate dissolved salts and to determine the pH determination, its measurement is necessary (WHO 1987). The temperature of the

Table 2 Physicochemical parameters' limit thresholds of industrial liquid effluent discharges (OJAR n.26, 2006), and results of the analyzed samples

Parameters	Limit values (OJAR n.26, 2006)	Physicochemical analysis results		
		Minimum value	Maximum value	Mean ± SD
Temperature (°C)	30	19.67	27.66	23.38 ± 2.84
pH	6.5 à 8.5	5.09	8.27	6.96 ± 1.02
EC (µS/cm)	–	900	1200	1010 ± 110.05
Turbidity NTU	–	80.17	290.66	174.01 ± 77.37
TSS (mg/L)	35	31	71	47.3 ± 14.88
COD (mg O_2/L)	120	441.33	1231.33	810.33 ± 258.15
BOD_5 (mg O_2/L)	35	258.10	1710.20	797.91 ± 510.89
SO_4^{-2} (mg/L)	–	79.38	132	108.86 ± 15.68
NO_3^- (mg/L)	–	5.5	11.6	7.34 ± 1.77
NO_2^- (mg/L)	–	0.18	0.6	0.34 ± 0.14
COD/BOD_5	–	0.72	1.71	1.015 ± 0.37
BOD_5/COD	–	0.585	1.389	0.985 ± 0.308
TSS/BOD_5	–	0.034	0.154	0.076 ± 0.037
OOM (mg/L)	–	319.18	1550.58	802.05 ± 425.34

EC electrical conductivity, *TSS* total suspended solids, *OOM* oxidizable organic matters, *COD* chemical oxygen demand, BOD_5 5 days-biochemical oxygen demand, *SD* standard deviation

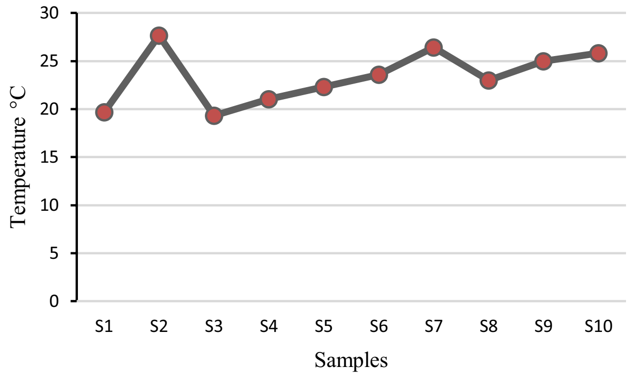

Fig. 2 Average temperature values of analyzed dairy effluents

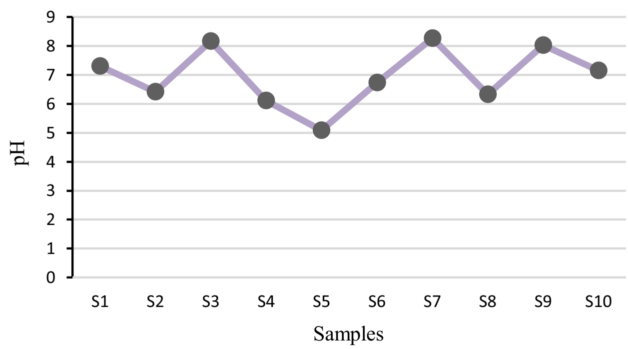

Fig. 3 Average pH values of analyzed dairy effluents

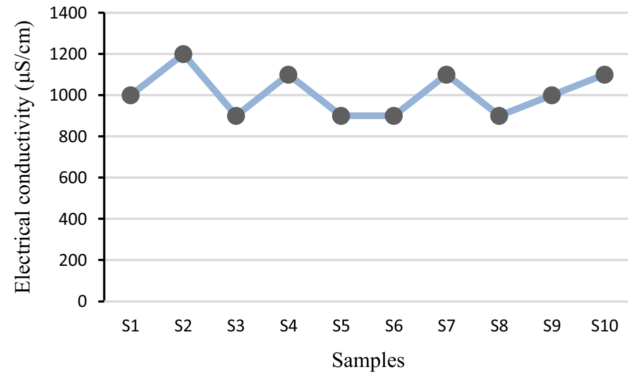

Fig. 4 Average electrical conductivity values of analyzed dairy effluents

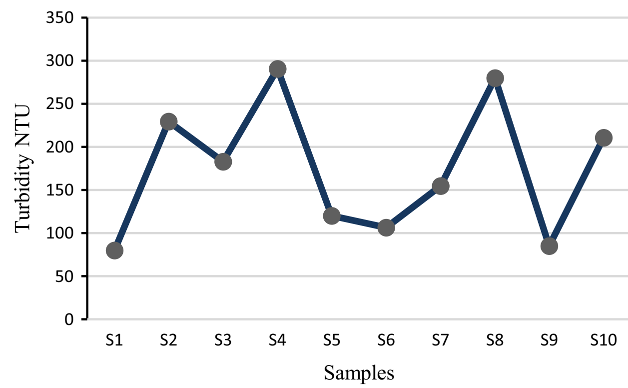

Fig. 5 Turbidity values of analyzed dairy effluents

analyzed dairy effluents shows a variation from one sample to another (Fig. 2). The highest value was recorded for sample S2 (27.67 °C) and minimum value for sample S1 (19.67 °C), with an average value for all analyzed samples equal to 23.38 °C. These values do not exceed the limits fixed by the Algerian standard (Table 2).

Hydrogen potential (pH)

The hydrogen potential of water represents its acidity or alkalinity (Rodier 1998). The pH of the studied dairy effluents reveals a high value for sample S7 (8.27); and a minimum value for sample S5 (5.09); with an average value for all analyzed samples equal to 6.96; which is within the range required by national and international regulations. However, samples S4 and S5 showed average pH values of 5.09 and 6.11, respectively (Fig. 3), which is less than 6.5 recommended by regulation.

Electrical conductivity (EC)

The electrical conductivity of water is a direct indicator of its salinity. This is a vital factor to follow when one is interested in reusing wastewater for irrigation purposes (agriculture field) (Shilton et al. 2005). A maximum value of the electrical conductivity of effluents was recorded for sample S2 (1200 µS/cm), and a minimum value of 900 µS/cm for samples S3, S5, S6 and S8 (Fig. 4), with an average value for all analyzed samples equal to 1010 µS/cm (Table 2).

Turbidity

Turbidity is related to the presence of various suspended particles in water. It can be favored by rain where the authors make a connection between turbidity or transparency and suspended solids (Bliefert and Perraud 2001). The highest turbidity value was recorded for sample S4 (290.66 NTU), while the minimum value was 80.17 NTU for sample S1 (Fig. 5), with an average value for all analyzed samples equal to 174.014 NTU.

Content of total suspended solids

The content in mineral and organic composition of the suspended solids in waters are much variable according to the rivers (sand, sludge, organic particles, plankton, etc.); they

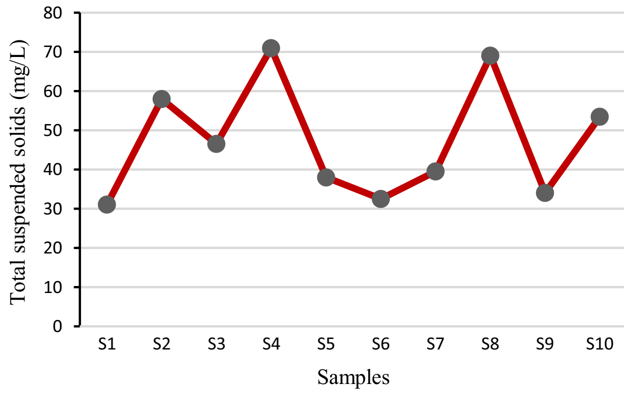

Fig. 6 Content of total suspended solids of analyzed dairy effluents

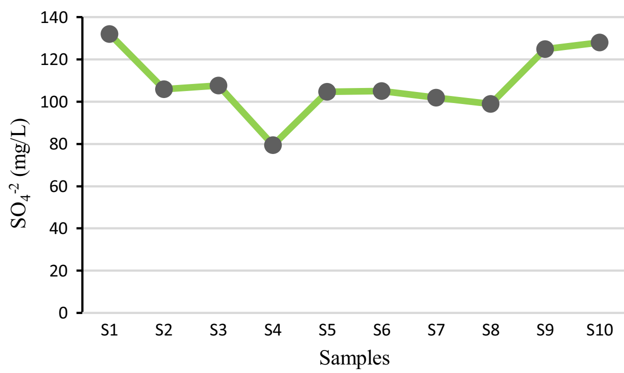

Fig. 7 Sulfate content of analyzed dairy effluents

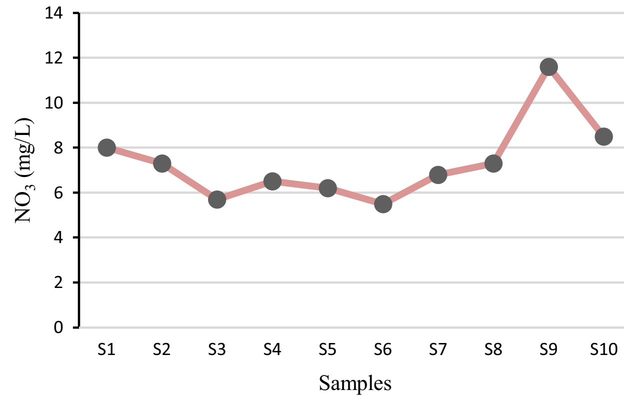

Fig. 8 Nitrate content of analyzed dairy effluents

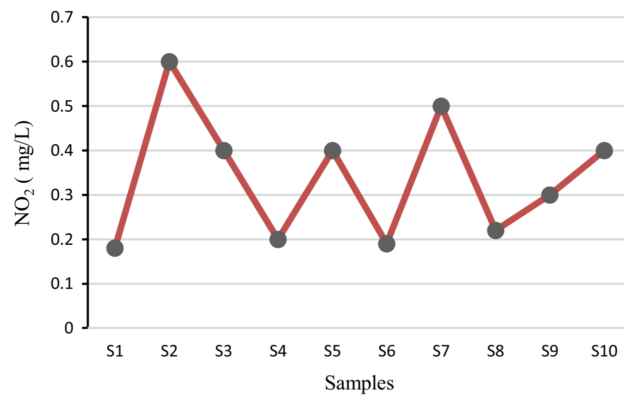

Fig. 9 Nitrite content of analyzed dairy effluents

depend on the crossed lands' nature, season, rainfall, and work, discharge waste and other factors (Rodier 2005).

TSS parameter of analyzed effluents showed a significant fluctuation from one sample to another (Fig. 6) where the highest value revealed a TSS content of 71 mg/L for sample S4, and a lowest TSS content equal to 31 mg/L for sample S1, with an average TSS value of all analyzed samples equal to 47.3 mg/L, except the following samples S1, S6, and S9, the other samples do not comply with the national regulations.

Sulfate content (SO_4^{-2})

The sulfate content of the water must be connected to the alkali and alkaline-earth elements of the mineralization. Their presence in water is usually due to bleaching workshops discharges (wool, silk, etc.), cellulose manufacturing plants (pulp paper, etc.) and dechlorination units (Rodier 2005).

The sulfate content of analyzed dairy effluents varied from one sample to another (Fig. 7). The highest content is revealed for sample S1 (132 mg/L) and a minimum value for sample S4 (79.38 mg/L), with an average value of all analyzed samples equal to 108.86 mg/L (Table 2).

Nitrate content (NO_3^-)

Nitrates such as other nitrogen forms evolve very quickly in the environment according to the nitrogen cycle (Chapman and Kimstach 1996). The nitrate content of dairy effluents varies from 5.5 to 11.6 mg/L with an average content of 7.34 mg/L (Fig. 8).

Nitrite content (NO_2^-)

Nitrite is considered to be intermediate ions between nitrate and ammoniacal nitrogen, which explains its low concentration in aquatic environments (Rodier 1984). The nitrite contents were between 0.18 and 0.6 mg/L, with an average content of 0.34 mg/L (Table 2; Fig. 9).

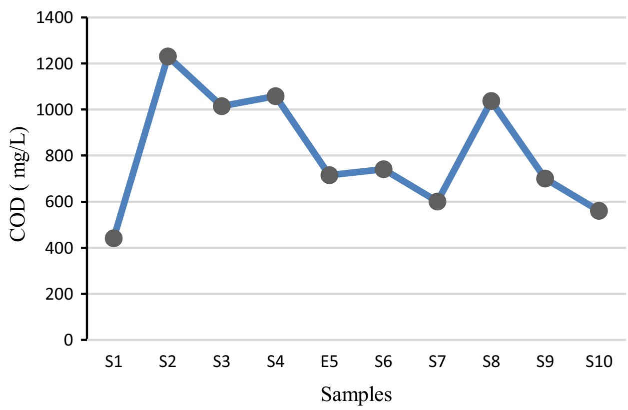

Fig. 10 The COD values of analyzed dairy effluents

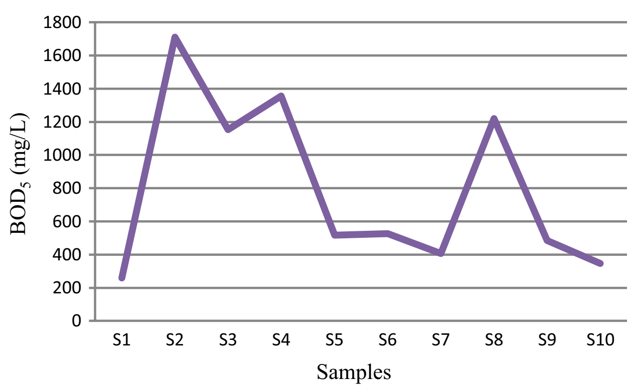

Fig. 11 The BOD_5 values of analyzed dairy effluents

Chemical oxygen demand (COD)

In the field of wastewater, to determine the water pollution, global parameters are often used, describing the amount of pollution caused by pollutants belonging to a determined group of compounds. One of these parameters is the chemical oxygen demand (COD), which is an indication of the quantities chemically oxidizable organic substances present in water (Bliefert and Perraud 2001).

The COD values of analyzed liquid effluents showed high concentrations ranging from 441.33 to 1231.33 mg/L (Fig. 10), with an average value of 810.33 mg/L. These results exceed the OJAR recommendations.

Biochemical oxygen demand (BOD_5) The significance of the water oxygenation parameter is very clear since the presence of oxygen modulates the aerobic decomposition reaction of organic matters and more generally affects the biological balance of water environments. The organic pollution values expressed in BOD_5 show significant variations from one sample to another linked to milk processing (Fig. 11). The recorded BOD_5 values vary from 258.10 mg/L (minimum value) to 1710.20 mg/L (maximum value) with an average value of 797.91 mg/L (Table 2).

Assessment of organic pollution

Biodegradability reflects the ability of an effluent to be decomposed or oxidized by microorganisms which are involved in the biological water purification process. It is expressed by the coefficient *K*.

- If ($K < 1.5$): This means that the oxidizable matters are largely made up of highly biodegradable matters.
- If ($1.5 < K < 2.5$): This means that the oxidizable matters are moderately biodegradable.
- If ($2.5 < K < 3$): This means that oxidizable matters are poorly biodegradable.
- If $K > 3$: This means that the oxidizable matters are not biodegradable. A very high coefficient *K* reflects the presence of elements in water that inhibit bacterial growth, such as metal salts, detergents, phenols, hydrocarbons, etc.

The coefficient *K* value determines the choice of the treatment method to be adopted. A biological treatment is applied when the effluents are biodegradable. Otherwise, a physicochemical treatment is applied (Tardat-Henry and Beaudry 1992; Suschka and Ferreira 1986). The studied dairy effluents have a coefficient *K* that varies from 0.72 to 1.71, which corresponds to that of domestic urban wastewater having a COD/BOD_5 ratio less than 3 (Rodier et al. 1996).

The average value of the BOD_5/COD ratio was high (0.985), it confirms that the dairy effluents are loaded with organic matters. This result is confirmed by estimating the oxidizable organic matters, which shows an average value of 802.05 mg/L.

These effluents that were characterized by a very low average value of the TSS/BOD_5 ratio (equal to 0.076) constitute mainly an organic pollution in dissolved form and easily biodegradable. Furthermore, the COD/BOD_5 ratio which corresponds to the coefficient *K* displayed an average value of 1.015 less than 1.5.

Discussion

In regions characterized by an arid climate, factors such as population growth, economic and social changes are causing ever-increasing demand for water. In recent years, Algeria has experienced a long period of drought due not only to the usual alternation between dry and wet periods but also to the global warming (Kendouci et al. 2019). All of that has pushed researchers to think again about how we can manage the resources that we have and then facing the problem of its depleting, the most important of them is the water as a source of life and the environmental pollution issues. This is part of this study which brought the idea to assess the chemical risk of dairy effluents from a milk processing plant located in Bechar (Southwest of Algeria).

In this work, the pollution assessment of dairy effluents was done by analyzing some physicochemical parameters which characterize these effluents. As a result, the analyzed dairy effluents were milky (i.e., mainly diluted milk or milk products) and characterized by a hydrogen potential (pH) ranging from 5.09 to 8.27, slightly alkaline, and located in the range recommended by the Algerian standard. These variations in pH depend on the use of chemicals such as nitric acid and NaOH (caustic soda) in the cleaning and disinfecting operation for equipment, and piping circuit of dairy industry (Hamdani et al. 2005), which can influence the pH of the receptor medium (Rodier et al. 1996).

These results are similar to those cited by Raho ghalem (2017), which studied the liquid effluents from the dairy complex of Sidi Bel Abbes (West of Algeria), where the obtained pH values were between 6.3 and 7.8 and lower than the values cited by Sekkoum (2004), who was working on the liquid effluents from *Sudlait* dairy unit of Bechar (Southwest of Algeria), the pH was 9.4 for the raw dairy effluents, and 7.5 after its biological treatment, and still lower than that cited by Mahrouche and Saaoui (2017) who were working on the liquid effluents of *Danone* dairy unit of *Djurdjura*, which was between 6.26 and 11.61. However, basic pHs have been reported by Sukhadev Shivsharan et al. (2013) for the effluents from the dairy industry of Kolhapur Maharashtra district (India) ranging from 9.8 to 10, sign of variation in the composition of the dairy effluents from one industry to another related to the milk and dairy products' processing.

In addition, the effluents' temperature was ranging from 19.33 to 27.67 °C. This parameter plays an important role in the solubility of salts and gases (in particular O_2) in water as well as the determination of pH and the chemical reactions' speed. Temperature also acts as a physiological factor on the microorganisms' growth in water (Botta and Bellon 2001). Relatively high temperatures act as additional pollution, thus influencing biological cycles (Geddah 2003) by decreasing dissolved oxygen activities which can cause serious problems in disposal of wastewater (Sukhadev Shivsharan et al. 2013). These values depend on the use of hot water where the wastewater generated by pre-rinsing operations and detergent cleaning carried out at temperatures up to 55 and 70 °C, respectively, are too hot, and the regenerative heat exchange in dairy processing (Sayad 2015). The values found are close to those cited by Raho ghalem (2017), which were between 19 and 22 °C, and similar to that cited by Sekkoum (2004), which were between 20 and 25 °C for the raw effluent and 29 °C after its biological treatment, but they are higher than those cited by Mahrouche and Saaoui (2017), which were between 11.8 and 25.1 °C, and lower than that cited by Hamdani et al. (2005), working on the dairy effluents from *Djedida* dairy unit (Morocco), which were between 23 and 43 °C with an average temperature value of 33 °C.

The electrical conductivity (EC) reflects the overall degree of mineralization and informs about the salinity. The EC of the studied dairy effluents was between 900 and 1200 µs/cm, which can be explained by the mineral composition of milk and also by the use of NaCl for the regeneration of sodium through the water softening ion-exchange resins (Raho ghalem 2017).

These values were lower than those cited by Agchariou and Moussioune (2015), for the dairy effluents from the *Danone* dairy unit of Djurdjura, with turbidity values varied from 4590 to 9590 µs/cm (an average of 7321.71 µs/cm), and those obtained by Raho ghalem (2017), that were between 1800 and 5800 µs/cm.

Water having a turbidity value of more than 50 NTU corresponds to cloudy or turbid water (Agchariou and Moussioune 2015).

The turbidity is a very important parameter to judge the quality of water treatment operations. Indeed (CREPAFC 2007):

- It indicates a higher probability of the presence of pathogen agents.
- Turbidity disrupts the disinfection process. The UV treatment is ineffective and the chlorine treatment loses its effectiveness;
- The organic matters associated with the turbidity promote the biofilms' formation in the network and, therefore, in the development of insensitive bacteria, especially to chlorine.

The studied effluents have turbidity values ranging from 80.17 to 290.66 NTU, due to the presence of colloidal matter from fat (Raho ghalem 2017), washing water loaded by particles come from soil and milk tank (Hamdani et al. 2005).

These results are close to those cited by Raho ghalem (2017), which were from 88 to 300 NTU, and higher to those cited by Kheris (2014), for *Sudlait* dairy effluents of Igli-Bechar (Southwest of Algeria) which was 107 NTU for the raw dairy effluents, and 8 NTU after biological treatment, but lower than those cited by Agchariou and Moussioune (2015), that was from 312 to 3987 NTU.

TSS content results were outside the Algerian standard, except three samples, which were from 31 to 71 mg/Land this in part at the origin of losing dairy products during manufacturing process (Raho ghalem 2017). These recorded values remain lower than those cited by

Sekkoum (2004), which was 134 mg/L for the raw effluent, and 12 mg/L after biological treatment, and those cited by Hamdani et al. (2005), which was ranged from 320 to 2353 mg/L with an average TSS value of 1019 mg/L. This is probably coming from the difference in production capacity for each dairy unit.

Regarding the sulfate content of discharged dairy effluents which was ranged from 79.38 to 132 mg/L, these values remain tolerable because the WHO suggests that the sulfate content limit should not be higher than 250 mg/L (Raho ghalem 2017). These results are lower than that given by Sekkoum (2004), which was around 340 mg/L for the raw dairy effluents, and 235 mg/L after biological treatment, and those reported by Raho ghalem (2017) that ranged from 100 to 150 mg/L, and too far from results obtained by Sukhadev Shivsharan et al. (2013) ranging from 200 to 223 mg/L.

BOD_5 values obtained by the analysis of dairy effluents have recorded an average value of 797.91 mg/L. This result is close to that found by Sukhadev Shivsharan et al. (2013) ranging from 600 to 790 mg/L, in which the high BOD_5 values could be explained by the organic matter's abundance.

Chemical oxygen demand (COD) is the amount of oxygen consumed by matters existing in water and oxidizable under defined operating conditions. In fact, the measurement corresponds to an estimation of the oxidizable matter that is present in water either its origin (organic or mineral) (Rodier 2005).

The COD values ranged from 441.33 to 1231.33 mg/L, which were too far from what is authorized for liquid effluents' discharge in Algeria. These high concentrations were due to the high pollutant loads of organic matter discharged through washing water (Kheris 2014). These results are lower than what they were reported by Mahrouche and Saaoui (2017), Sukhadev Shivsharan et al. (2013) (991–10493 mg/L; 1400–1500 mg/L, respectively), and higher than what it was found by Sekkoum (2004) 670 mg/L for the raw dairy effluents, and 91 mg/L after biological treatment. An industrial effluent with a high COD can make serious issues with the reduction of the oxygen concentration in watercourses.

TSS results in this study remain low compared to those cited by Sukhadev Shivsharan et al. (2013) (200–290 mg/L against 31–71 mg/L). Above the standard value of suspended solids, dissolved organic solids are mainly responsible for creating a nuisance (Sukhadev Shivsharan et al. 2013).

According to the study carried out by Burgaud (1969), where dairy effluents present two main categories of pollutants: The dairy products themselves, raw materials or finished products, and the reagents used for cleaning and disinfecting operation (Cleaning in place system) which are the most often acid products (nitric acid), basic products (sodium hydroxide-based solution) and disinfectant products (bleach). The process involves cleaning solutions through the plant under conditions of increased turbulence and flow velocity.

Nitrate in its natural state is soluble in soil, groundwater and waterways, also comes from the mineralization of organic nitrogen and the oxidation of ammonium (El Ouali Lalami et al. 2011). The nitrate content ranged from 5.5 to 11.6 mg/L; this is probably due to the use of nitric acid as a chemical disinfectant for closed piping circuits (Hamdani et al. 2005), by the nitrification reaction of the organic nitrogen present in the dairy effluent at the basin level. In fact, nitrification is a two-step process in which ammoniacal nitrogen is oxidized to nitrites (NO_2^-) and then to nitrates (NO_3^-) (Chachuat et al. 2001). Thus, the transfer to the sewer, a true biological reactor, which leads to the nitrates' reduction by denitrification, mainly into dinitrogen N_2 (Chachuat et al. 2001). However, significant levels of nitrate in the groundwater or waterways are an index of urban or industrial activities (discharges), they can come from water by decomposing of organic matters (Krishna et al. 2009; Benmoussa et al. 2020).

The effluents' pollutant load (suspended solids, nitrogenous matters) was mainly due to the treatment and processing of the dairy raw material. Thus, 1–8% of processed milk is lost and to be found in the effluent (Hamy 2005).

This result is lower than what was revealed by Raho ghalem (2017), from 14 to 80 mg/L, and from 20 to 30 mg/L for the study on the effluent of *Edough* dairy unit of Annaba (East of Algeria) carried out by Sayad (2015). On the other hand, the obtained values were close to those given by Sekkoum (2004) (11.14 mg/L for the raw dairy effluent, and 9.6 mg/L after biological treatment, and those cited by Kheris (2014) (11.31 and 8.2 mg/L), respectively, for dairy effluents before and after biological treatment.

Nitrite comes either from an incomplete oxidation of ammonia where nitrification was not completed or from a reduction of nitrate by the denitrifying action at high temperatures of organic nitrogen present in the effluent (Chachuat et al. 2001). The obtained values which ranged from 0.18 to 0.6 mg/L were higher than the results given by Sekkoum (2004) (0.20 mg/L) and lower than those cited by Sayad (2015) (0.6 and 1.19 mg/L).

The COD/BOD_5 ratio makes it possible to deduce whether the wastewater directly discharged into the receiving environment has domestic wastewater characteristics [the COD/BOD_5 ratio < 3] (Tardat-Henry and Beaudry 1992). The results of this ratio are an indication of the importance of pollutants to be less- or non-biodegradable (Rodier et al. 1996). These ratios clearly indicate the biodegradable nature of the studied dairy effluents.

Since the physicochemical characterization of wastewater is essential to finely define the characteristics of a treatment process (Messrouk et al. 2014), therefore, to characterize industrial pollution, we often consider the BOD_5/COD ratio, which gives very interesting indications on the pollution origin of wastewater and its treatment possibilities. In this study, this ratio has a high average value of 0.985. Even though the studied dairy effluents have high organic load, they are easily biodegradable, and therefore eliminable by biological purification process (Burgaud 1969).

This is the general case for discharges loaded with organic matters which are easily biodegradable according to Henze et al. (1997). This organic load makes this wastewater quite unstable, i.e., they quickly evolve into digested forms with olfactory nuisances.

The analyzed dairy effluents were characterized by a very low TSS/BOD_5 ratio with an average value of 0.076, constitute essentially organic pollution in a dissolved form and easily biodegradable. This is the case of a dairy industry located in *Tizi Ouzou* region (Algeria) which discharges dairy effluents at an annual flow of 1825 tons of organic matter in dissolved form and easily biodegradable that was indicated by an average value of the TSS/BOD_5 ratio equal to 0.24 (Yahi and Hami 2008).

For three months, the dairy effluents marked variations in daily and seasonal composition and flow rates which according to Sukhadev Shivsharan et al. (2013), this can complicates their treatment. However, this chemical pollution is due to the absence of a wastewater treatment plant, where there is a need to install a treatment plant based on both primary and secondary treatments (activated sludge). Noting that pretreatment operation of effluents is not always sufficient, and often leaves residual pollution that can affect the natural ecosystem's functioning of the receiving environment (Dhimni et al. 2015).

Through an innovative study conducted by ElJaafari et al. (2015), where fish scales of *Diplodus sargus cadenati* were tested as solid support for colonization of suspended biomass in the bioreactor moving bed to improve the purification performance, the obtained results on some pollution parameters (pH, COD, TSS, total nitrogen) were promising. Moreover and in this context, the dairy industry can use more economical materials known by their elimination capacities, whether, chemical and/or biological pollutants, to ensure that the sustainable development concept is at the heart of policies followed by the economic partners (Benyagoub et al. 2018b).

Conclusion

Whatever the nature of pollution, it induces a harmful effect on the environment. This is why a general awareness especially toward industrialists is more than necessary in order to preserve nature and therefore life. This awareness is followed by research to remedy the problems already caused, such as liquid effluents from agri-food industry.

This present study made it possible to appreciate and assess the chemical risk pollution by analyzing of some physicochemical parameters of dairy effluents.

From the obtained results, it seems that the analyzed dairy effluents were excessively loaded with organic matters revealed by high values of COD, BOD_5, TSS and turbidity, witnessing for considerable pollution, which exceed the requirements recommended by the national standard. They constitute one of the contamination sources of the receiving environment and can present a threat to the ecosystem and, therefore, subsequently to the public health, except for pH, temperature and other physicochemical parameters that display acceptable values.

This is at the origin of the absence of dairy effluents' treatment. However, the milk processing plant adopts a process based on biological self-purification by the elimination of their liquid effluents in aerated basins, practically three basins, each pours the overflow volume to the other basin, before being discharged into the environmental medium.

Finally, the following practices are recommended to limit the volume as well as the polluting load of liquid effluents:

- Despite the socioeconomic importance played by the studied milk processing plant in *Bechar* region, its managers are aware of the environmental responsibility of the dairy unit, where the installation of a sewer network to separate the highly charged effluents from the unpolluted ones was applied from the beginning. This can help to focus on the risk of dairy effluents which are too loaded with organic matters (Benyagoub 2019).
- Adopt practices that could minimize at the maximum of effluents discharged in a 'Cleaner production techniques' approach, based on the adoption of best practices to reduce water consumption, management of emissions and effluents (Benyagoub 2019).
- Since the results of the COD/BOD_5; BOD_5/COD and TSS/BOD_5 ratios have shown a dominant organic load that is easily decomposed by the biological way, we suggest following a biological treatment because its treatment by the physicochemical way allows only partial reduction of the pollution load (Benyagoub et al. 2018b).
- Preservation of the groundwater quality which represents the main source for drinking water and irrigation in the study area by the establishment of a well-adapted treatment unit within the dairy plant to avoid possible pollution of this non-renewable resource.
- To face the pollution issues where the investment cost is a strong driver, the industrialists should be oriented toward less expensive processes and materials that are locally available such as sands, where the study area is characterized by the great Western sand, considered as large

sands' dunes in the Algerian Sahara desert. (Benyagoub et al. 2018b) designed for the removal of organic pollutants in aqueous media. Moreover, earlier research results using these materials have been proven at the laboratory scale (Kendouci et al. 2016).

This type of treatment will allow the dairy industry, not only, to value purified water in several areas, but also, to preserve the environment and, therefore, ensure sustainable development (Benyagoub et al. 2018b).

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Compilance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval This study complies the Algerian ethical standards.

References

Agchariou W, Moussioune M (2015) Suivi et caractérisation des eaux industrielles cas de l'unité DANONE DJURDJURA. Université Abderrahman MIRA-Bejaïa (Algérie), Mémoire de Master

Benmoussa Y, Remini B, Remaoun M (2020) Quality assessment and hydrogeochemical characteristics of groundwater in Kerzaz and Beni Abbes along Saoura valley Southwest of Algeria. Appl Water Sci 10(7):170. https://doi.org/10.1007/s13201-020-01256-6

Benyagoub E (2019) Investment challenges in milk sector (Case of a dairy factory in southwest of Algeria) development prospects. Asian J Dairy Food Res 38(1):22–27. https://doi.org/10.18805/ajdfr.DR-127

Benyagoub E, Ayat M (2014) Hazard analysis and testing for implemented a HACCP system at a dairy factory in South west Algeria. Food Sci Qual Manag 32:57–66

Benyagoub E, Guessas B, Ayat M, Benyagoub R (2017) Algerian dairy industry; Can it control bacterial contaminant indicators of hygienic quality defects in the production chain of raw and pasteurized milk? Int J Adv Res 5(1):2237–2245. https://doi.org/10.21474/IJAR01/3001

Benyagoub E, Guessas B, Ayat M, Benyagoub R (2018a) Cost price/quality relationship of a strategic product and self-sufficiency challenge in the Algerian dairy sector: the case of a local dairy industry. Economia Agro-Alimentare 20(1):55–74. https://doi.org/10.3280/ECAG2018-001004

Benyagoub E, Nabbou N, Bendada F (2018b) Characterization of microbial risk level of liquid waste from a private dairy factory in Bechar (Southwest ofAlgeria). Indian J Dairy Sci 71(5):524–529

Bliefert C, Perraud R (2001) Chimie de l'environnement: Air, Eau, Sols. Déchets, Edition de Boeck

Botta A, Bellon L (2001) Pollution de l'eau et santé humaine. Université Euro-Méditerranéen TEHYS, Laboratoire de biogénotoxicologie et mutagenèse environnementale

Burgaud JL (1969) Les eaux résiduaires dans l'industrie laitière. Le Lait, INRA Editions 49(487):417–433

Chachuat E, Roche N, Latifi MA (2001) Nouvelle approche pour la gestion optimale de l'aération des petites stations d'épuration par boues activées. Revue L'Eau, l'Industrie, les Nuisances 240:53–66

Chapman D, Kimstach V, World Health Organization, Unesco & United Nations Environment Programme (1996) Selection of water quality variables. Water quality assessments: a guide to the use of biota, sediments and water in environmental monitoring, 2nd Ed, Edition Deborah Chapman: E & FN Spon, London, UK, 626 p. https://apps.who.int/iris/handle/10665/41850

CREPAFC 'Centre Régional pour l'Eau Potable et l'Assainissement à Faible Coût'(2007) Centre collaborant de l'OMS, Contrôle et suivi de la qualité des eaux usées, Protocole de détermination des paramètres physico-chimiques et bactériologiques

Daufin G, Gésan-Guiziou G, Boyaval E, Buffiere P, Lafforgue C, Fonade C (2000) Minimisation des rejets liquides de l'industrie laitière par traitements des effluents à l'aide des procédés à membrane. Tribune de l'eau 600(4):25–33

Dhimni S, Qlihaa A, Melrhaka F, Chebabe D, Dermaj A, Hajjaji N (2015) Characterization of liquid waste of packaging industry. J Mater Environ Sci 6(11):3197–320

El OualiLalami A, Merzouki M, El Hillali O, Maniar S, Ibnsouda Koraichi S (2011) Pollution des eaux de surface de la ville de FES au Maroc: typologie, origine et conséquences. J Hydraul Sci (Larhyss journal) 9(2011):55–72

ElJaafari A, Boutaleb N, Bahlaouan B, Taiek T, Ait Cheikh A, Jada A, Bennani M, Lazar S, Elantri S (2015) Ecailles de poissons: nouveau support de biomasse dans les bioréacteurs à lit mobile pour le traitement des effluents des laiteries. Déchets Sciences &

Techniques 70:29–37. https://doi.org/10.4267/dechets-sciences-techniques.3881
Garrido JM, Omil F, Arrojo B, Méndez R, Lema JM (2001) Carbon and nitrogen removal from a wastewater of an industrial dairy laboratory with a coupled anaerobic filter-sequencing batch reactor systems. Water Sci Technol 43(3):249–256
Geddah D (2003) Evaluation de la pollution industrielle et urbaine dans la région de Skikda: impact sur l'écosystème marin côtier. Université Mokhtar BADJI-Annaba (Algérie), Thèse de Magister
Google maps (2020) Site of Bechar's dairy industry (Southwest of Algeria)
Hamdani A, Moutfi A, Mountadar M, Assoubhei O (2005) Évolution de la qualité physico-chimique et bactériologique d'un effluent laitier sur un cycle annuel. Déchets. Science et Techniques-Revue Francophone d'Ecologie Industrielle 37(1):18–26. https://doi.org/10.4267/dechets-sciences-techniques.1880
Hamy L (2005) Innovation pour le traitement des effluents laitiers. Déchet-Valorisation déchet. Journal de l'environnement, section: Environnement Santé. [Internet] Consulté le 10 Janvier 2020
Henze M, Harremoes P, Jansen JLC, Avrin E (1997) Wastewater treatment, 2nd eds. Springer, Berlin
Kasper D, Amaral JHF, Forsberg BR (2018) The effect of filter type and porosity on total suspended sediment determinations. Anal Methods 10(46):5532–5539. https://doi.org/10.1039/C8AY02134A
Kendouci MA, Kharroubi B, Maazouzi A, Bendida A (2016) Variation in the quality of treated wastewater by local sand filter: the case of the Algerian Sahara sand. Hydrol Curr Res 7(3):247. https://doi.org/10.4172/2157-7587.1000247
Kendouci MA, Bendida A, Mebarki S, Kharroubi B (2019) Study of the management efficiency of the drinking water supply in arid areas: case of Bechar city (Southwest of Algeria). Appl Water Sci 9(8):192. https://doi.org/10.1007/s13201-019-1081-y
Kheris A (2014) Caractérisation de l'eau de production de la laiterie d'Igli et suivi des performances de la station d'épuration des eaux résiduaires. Université de Béchar (Algérie), Mémoire de Master
Krishna SK, Rammohan V, Dajkumar Sahayam J, Jeevanandam M (2009) Assessment of groundwater quality and hydrogeochemistry of Manimuktha River basin, Tamil Nadu, India. Environ Monit Assess 159(1–4):341–351. https://doi.org/10.1007/s10661-008-0633-7
Mahrouche A, Saaoui S (2017) Identification, caractérisation et traitement des effluents de l'unité Danone Djurdjura Algérie. Université Abderrahman MIRA-Bejaïa (Algérie), Mémoire de Master
Marc D (2013) Méthodes analytiques pour influents/effluents de bioréacteurs ou de stations d'épuration, Laboratoire de Biotechnologie environnementale, EPFL-LBE, 113/132
Menoret C (2001) Traitement d'effluents concentrés par cultures fixées sur gravier ou pouzzolane. Université des Sciences du Languedoc, Montpellier II-France, Thèse de Doctorat en sciences de l'eau et de l'environnement continental
Messrouk H, Hadj Mahammed M, Touil Y, Amrane A (2014) Physico-chemical characterization of industrial effluents from the town of Ouargla (South East Algeria). Energy Procedia 50:255–262. https://doi.org/10.1016/j.egypro.2014.06.031
Moletta R, Torrijos M (1999) Traitement des effluents de la filière laitière. Technique de l'ingénieur, Paris, France
OJAR n 26 (2006) Décret exécutif n 06–141 du 20 Rabie El Aouel 1427 correspondant au 19 avril 2006 définissant les valeurs limites des rejets d'effluents liquides industriels. Available from: https://www.ecolex.org/details/legislation/decret-executif-no-06-141-definissant-les-valeurs-limites-des-rejets-deffluentsliquides-industriels-lex-faoc064225/
Raho galem B (2017) Contribution à la caractérisation de la pollution des eaux résiduaires de la laiterie Giplait de Sidi Bel Abbes (Algérie)
Rice EW, Baird RB, Eaton AD (2017) Standard methods for the examination of water and wastewater analysis, 23rd edn. American Public Health Association American Water Works Association, Washington, USA
Rodier J (1984) L'analyse de l'eau: Eaux naturelles, eaux résiduaires, eau de mer. 6éme Ed., Edition Dunod Paris, France
Rodier J (1998) L'analyse de l'eau: Eaux naturelles, eaux résiduaires, eaux de mer, chimie, physicochimie, microbiologie, biologie, interprétation des résultats, 8thème edn. Edition Dunod, Paris, France
Rodier J (2005) L'analyse de l'eau : eaux naturelles, eaux résiduaires, eaux de mer, 8 ème edn. Edition Dunod, Paris, France
Rodier J, Bazin C, Broutin JP (1996) L'analyse de l'eau: eaux naturelles, eaux résiduaires et de mer: chimie, physico-chimie, microbiologie, biologie, interprétation des résultats. 7 ème Ed, Edition Dunod, Paris, France
Rodier J, Legube B, Merlet N, Brunet R (2009) L'analyse de l'eau: Eaux naturelles, eaux résiduaire, eaux de mer, 9 ème edn. Edition Dunod, Paris, France
Sayad L (2015) Le pouvoir auto épurateur de l'oued Seybouse sur les rejets de la laiterie de l'Edough Annaba Algérie et les objectifs environnementaux des rejets. Université Mokhtar BADJI-Annaba (Algérie), Thèse de Doctorat
Sekkoum M (2004) Contribution à l'étude de l'irrigation à la goutte à goutte par les eaux usées traitées issues d'une laiterie (Cas du Sudlait d'Igli, Béchar). Université de Béchar (Algérie), Mémoire de Magister
Shilton A, Walmsley N, Pearson H, Paterson C, Curtis T, Craggs R, Davies-Colley R, Mara D (2005) Pond treatment technology. IWA Publishing, London-UK, p 479p
Sukhadev Shivsharan V, Wani M, Khetmalas MB (2013) Characterization of dairy effluents by physicochemical parameters. Biotechnol J Int 3(4):575–580. https://doi.org/10.9734/BBJ/2013/3640
Suschka J, Ferreira E (1986) Activated sludge respirometric measurements. Water Res 20(2):137–144. https://doi.org/10.1016/0043-1354(86)90003-5
Tadesse M, Tsegaye D, Girma G (2018) Assessment of the level of some physicochemical parameters and heavy metals of Rebu river in oromia region, Ethiopia. MOJ Biol Med 3(3):99–118. https://doi.org/10.15406/mojbm.2018.03.00085
Tardat-Henry H, Beaudry J-P (1992) Chimie des eaux, 2ndème edn. Edition le griffon d'argile inc, Canada, p 537p
Thomas O, Causse J, Thomas M-F (2017) Aggregate organic constituents. In: Thomas O, Burgess C (eds) UV-Visible spectrophotometry of water and wastewater, 2nd edn. Elsevier, Amsterdam, pp 139–162
WHO (1987) Facteurs influant sur le traitement dans les étangs dans un bassin de stabilisation des eaux usées: Principales de planification et de pratique, publication technique FRMO, 10, Alexandrie
Yahi H, Hami A (2008) Caractérisation et traitement biologique par boues activées d'effluents de laiterie. Algerian J Technol 2:571–580