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Performance of two free biomass biological wastewater treatment processes (Aerated Lagoon and Activated Sludge) in Ouargla area, Algeria with referring to re-use the treated water in aquaculture

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ABSTRACT

The present study was done to compare between two free biomass biological wastewater treatment processes (WWTP): (i) aerated lagoon AL which is an extensive process and (ii) activated sludge AS which is an intensive process. For the removal rates and exit concentrations of physical pollution (Total Suspended Solids TSS), biological pollution (Biochemical Oxygen Demand after 5 days BOD_5 and Chemical Oxygen Demand COD), nitrogen pollution (Nitrite and Nitrate) and phosphorus pollution (Orthophosphates) of both processes were collected and analyzed. The results showed that there is satisfactory removal rate of TSS, BOD_5 and COD in accordance with Algerian and world health organization (WHO) effluent discharge standards for the case of AS process. While for AL process, removal rates of the three cited parameters were low and concentrations were higher than that of WHO discharge standards. In accordance to the nutriments (nitrogen and phosphorus), the removal rates are very low in the AL WWTP and very high in the AS WWTP. Generally, the residual concentrations remain very high in the treated effluent of both plants and could constitute a great risk of eutrophication and cause the formation of algal blooms in AL WWTP. According to these results, the AS is the most efficient process in Ouargla region.

INTRODUCTION

Water is an important vital natural resource used for drinking and other developmental purposes in our lives **(Trivedi, 1992; Bibi et *al*, 2016).** Water pollution is any chemical, physical or biological change in the quality of the water that has a harmful to environment and human health **(Briggs, 2003; Alrumman, 2016)**. Being a universal solvent, water is a major source of infection. According to United Nations Educational, Scientific and Cultural Organization UNESCO **(UNESCO, 2003)**, one liter of waste water pollutes eight liters of fresh water. Water pollution can have various sources including industrial (degassing at sea, discharge from paper mills, oil discharges, etc.), agricultural (use of fertilizers, pesticides, etc.), and from automobiles (unburnt fuels, oil, etc.) **(Baig, 2009; Wang, 2010; Mian, 2010).** According to world health organization (WHO), 80% diseases are water borne where drinking water in various countries does not meet WHO standards **(Khan, 2013).** Up to 3.1% deaths occur due to the unhygienic and poor quality of water **(Pawari and Gawande, 2015**). WHO and UNICEF **(2000)** reported that water pollution causes 2.2 million deaths per year, mostly of children under five years old.

In Algeria, water pollution caused water-borne diseases and contributes, unfortunately, to the reduction of the quantities of fresh water which are already rare and consequently to the braking of national development **(Sutton and Zaimeche, 1992; Ali Rahmani and Brahim, 2017; Kherifi and Bekiri, 2017).** This situation leads to the construction of several water treatment and wastewater treatment plants in Algeria in order to minimize the negative effects on people and environment. For the importance of this issue, several researches were focus on the water pollution in different sectors in Algeria **(Benderradji and Krika, 2011; Bettiche *et al*, 2017; Touati, 2018).**

In this paper, we will focus on the biological wastewater treatment by studying the performance of two biological treatments with free biomass processes: aerated lagoon (AL) as an extensive process and activated sludge (AS) as an intensive process under an arid climate in the northern Sahara, Ouargla region, south-east of Algeria. Also, the study will refer to the availability of re-use the treated water in aquaculture as a food source in this arid area.

MATERIALS AND METHODS

Study area

The area concerned by this study is Ouargla region, located in the South-East of Algeria (Figs. 1 a&b) (31° 57′ N, 5° 19′ E). This region is a phoenicultural area with 2,363,700 palm trees and an economic pole of Algeria thanks to the petrol from Hassi Messaoud basin. For water resources in Ouargla, groundwater, of Terminal complex and continental Interlayer fossil reservoirs, is the own source **(Moulla and Guendouz, 2003; Tabouche and Achour, 2004; Idder, 2007).** The two wastewater plants of our study located in two towns; Aerated Lagoon plant in Ouargla town (c) and Activated Sludge plant in Touggourt town (d).

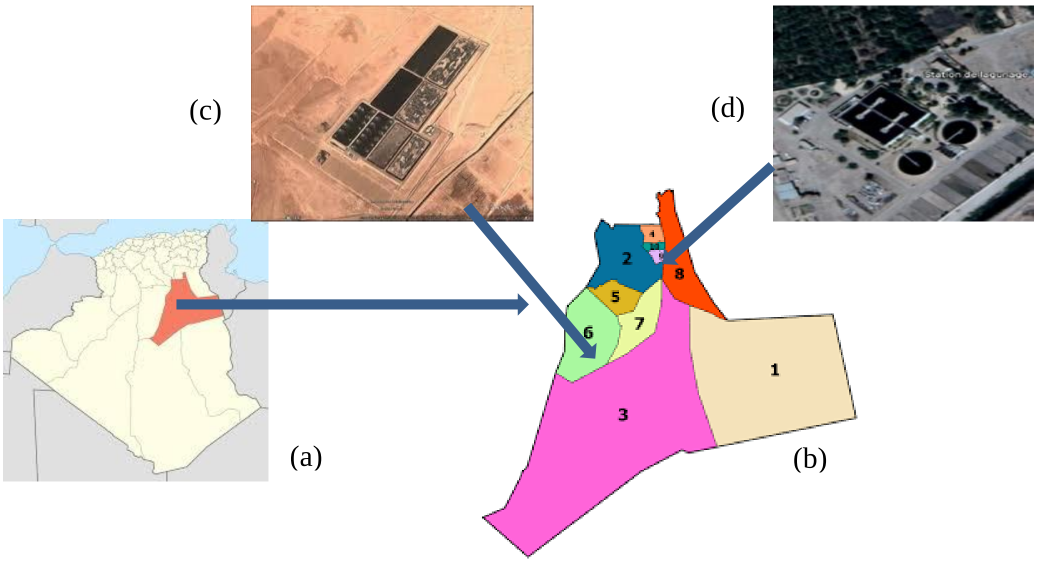


Figure (1). Ouargla region (a and b) with the two wastewater plants of the present study: Aerated Lagoon plant in Ouargla town (c) and Activated Sludge plant in Touggourt town (d)

Sampling

Water sampling is made once a week at the entrance and the exit of the two wastewater plants during the period from 2011 to 2018.

Methods

Analyses of physical parameters (water temperature and hydrogen ion concentration) and of different parameters of pollution: (i) physical pollution (Total Suspended Solids TSS); (ii) biological pollution (Biological Oxygen Demand BOD and Chemical Oxygen Demand COD); (iii) nitrogen pollution (Nitrate and Nitrite); and phosphorus pollution (Orthophosphate), are made according to standard methods as shown in Table 1.

Table 1. Parameters and analysis methods

Pollution parameters	Test methods
TSS (mg/l)	By centrifugation (NFT 90-105-2)
BOD_5 (mg/l)	By the dilution and seeding method with addition of allyl thiourea (ATU) (NF EN 1899-2)
COD (mg/l)	By NF T 90-101 (NF T 90-101)
Nitrogen (Nitrite) (mg/l)	Spectrophotometer type DR/2000
Nitrogen (Nitrate) (mg/l)	Spectrophotometer type DR/2000
Phosphorus (Orthophosphate) (mg/l)	Spectrophotometer type DR/2000

This study is undertaken to verify the purifying performance of the two given processes over time and to compare the performance of the two processes. To do this, pollution parameters data were collected and analyzed during eight years from 2011 to 2018. This purifying performance of a given parameter is determined by the following formula:

$$\mathbf{X}\,(\%) = \frac{Xe - Xs}{Xe} * \mathbf{100}$$

RESULTS

Wastewater treatment in Algeria

Wastewater treatment is a strategic axis for water and ecological balance. As a result, major programs for the construction of treatment plants have been designed and launched to protect human and environment.

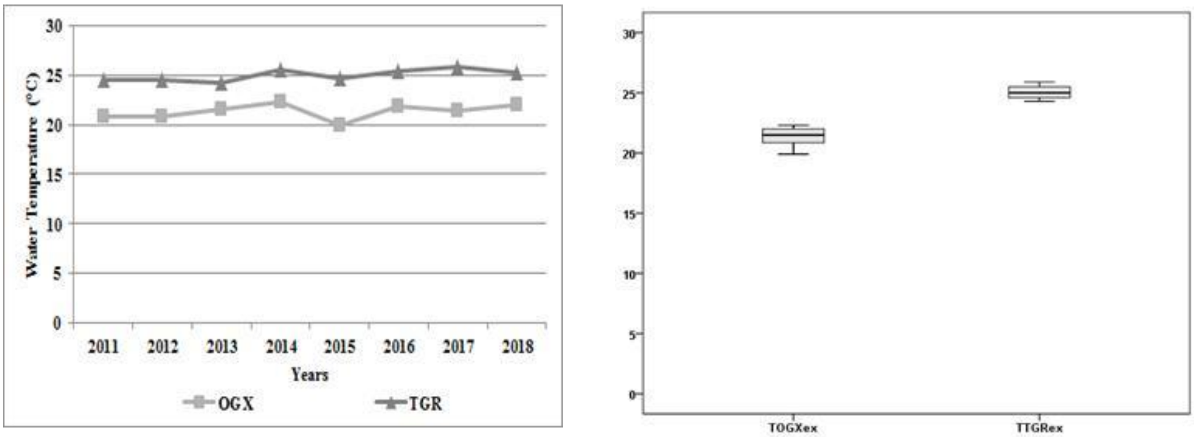
According to the Ministry of Water Resources **(MWR) (2020)**, Algeria has 177 wastewater treatment plants that treat around 805 million m^3 per year. The National Sanitation Office (NSO) operates 154 of these stations (75 lagoon plants, 76 activated sludge-type plants and three planted filters plants) distributed throughout the national territory **(NSO, 2020)**. The resource factor was predominant for the majority of stations. However, since 2006 the wastewater recovery factor has been gradually integrated into the operation for some treatment plants **(NSO, 2020)**. Among the 154 WWTPs, there are only 17 that are concerned with the reuse of treated wastewater in agriculture and the volume reused at the end of August 2016 is estimated at 14.6 million m^3 **(NSO, 2019).**

In Ouargla region (south-east of Algeria), there are five WWTPs (two of aerated lagoon, two of planted filters and one of activated sludge). Only the treated wastewater of aerated lagoon plant of Said Otba is reused by the farmers but without control of local authorities.

Water Temperature

Temperature is considered to be the most complicated parameter in sewage treatment methods, especially biological treatment of wastewater **(Obaid *et al*., 2015).** However, the temperature of wastewater is considered to be a fairly important parameter which influences biological treatment, aquatic life and the suitability of the water for other useful uses **(Metcalf and Eddy, 2004)**. Figure (2) presents the variation (a) and Boxplots (b) of water temperature in the two WWTPs during eight years from 2011 to 2018. According to figure (2), the water temperatures in the WWTP by activated sludge were higher than those of WWTP by aerated lagoon during the eight years of study and the difference was about 3.7°C. Also, the water temperatures in the two WWTPs do not have a fixed trend and do not vary in the same way (Fig. 2a).

For the Boxplots, Figure (2b) shows that in the case of both processes, the median is centered, which implies a symmetrical distribution of water temperature values. For the length of the box, it is very small in both cases which mean a low variability in the water temperature values. The values of water temperature are between 24.3°C and 25.9°C in activated sludge process, and between 19.9°C and 22.3°C in the aerated lagoon process.



(a) (b)

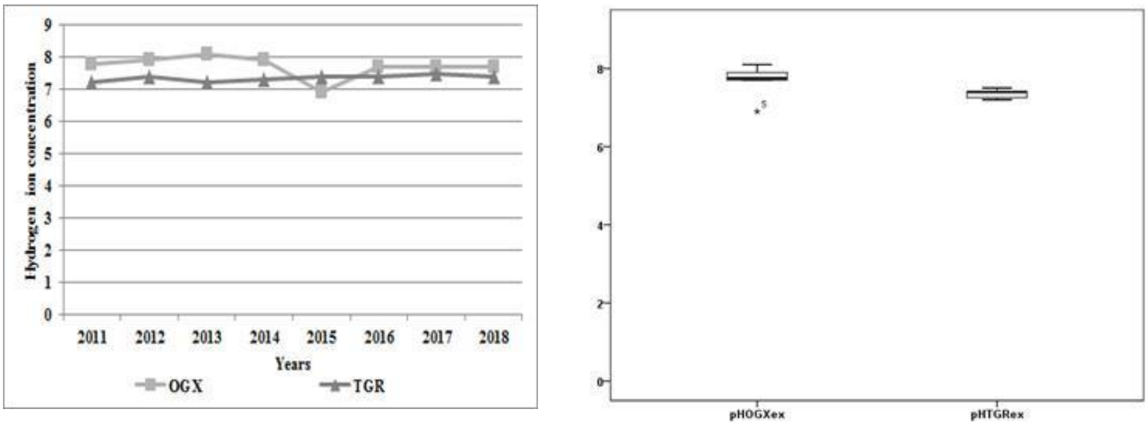
Figure (2). Variation (a) and Boxplots (b) of water temperature in the two WWTPs

Hydrogen ion concentration (pH)

pH is an important limiting chemical factor for aquatic life. Wastewater pH has been identified as one of the parameters which influence effective wastewater treatment **(Aboulhassan *et al*., 2000; Juttner *et al*., 2006)**. The annual variation in pH and its Boxplots are shown in Figs. 3 (a & b), which show that the pH in WWTP from AL is higher than that in WWTP from AS with an average difference of 0.4.

For the annual variation, the values oscillate between 6.9 and 8.1 in the case of the AL process and between 7.2 and 7.5 for the AS process (Fig. 3a). Therefore, the treated wastewater from the two WWTPs was alkaline.

From the boxplots, it noticed that the length of the two boxes is very small and that there is an asymmetric distribution of the pH values in the two WWTPs (Fig. 3b). In the case of AL WWTP, the median is at the bottom of the box which means an asymmetric distribution towards the low concentration values of pH. For AS WWTP, the median is in the top of box which means an asymmetric distribution towards the high concentration values of pH.



(a) (b)

Figure (3). Variation (a) and Boxplots (b) of pH in the two WWTPs

Total Suspended Solids (TSS)

Total suspended solids is a water quality measurement usually abbreviated TSS **(Moran *et al*., 1980).** This parameter was at one time called non-filterable residue (NFR), a term that refers to the identical measurement: the dry-weight of particles trapped by a filter, typically of a specified pore size **(Subclass, 2014).** Figs. 4a&b show the variation of removal rates and the exit concentrations of TSS during the eight years of study.

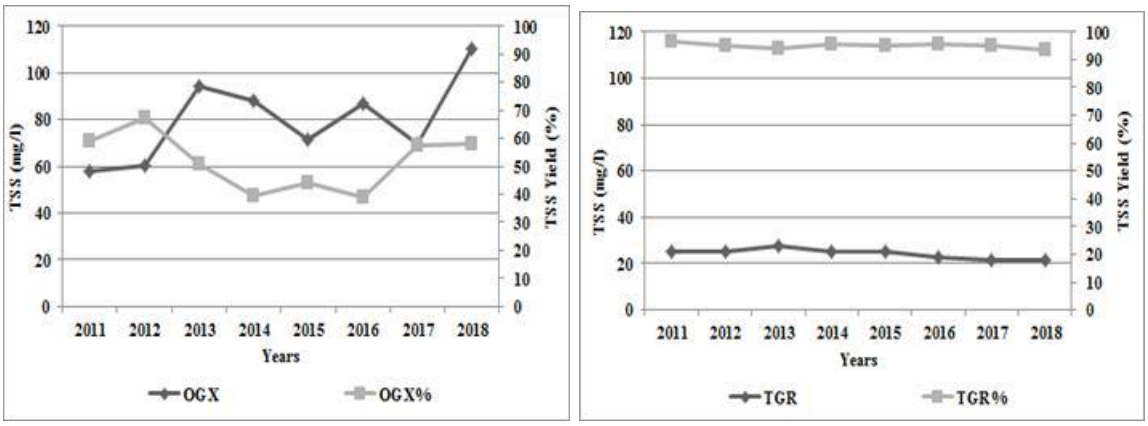
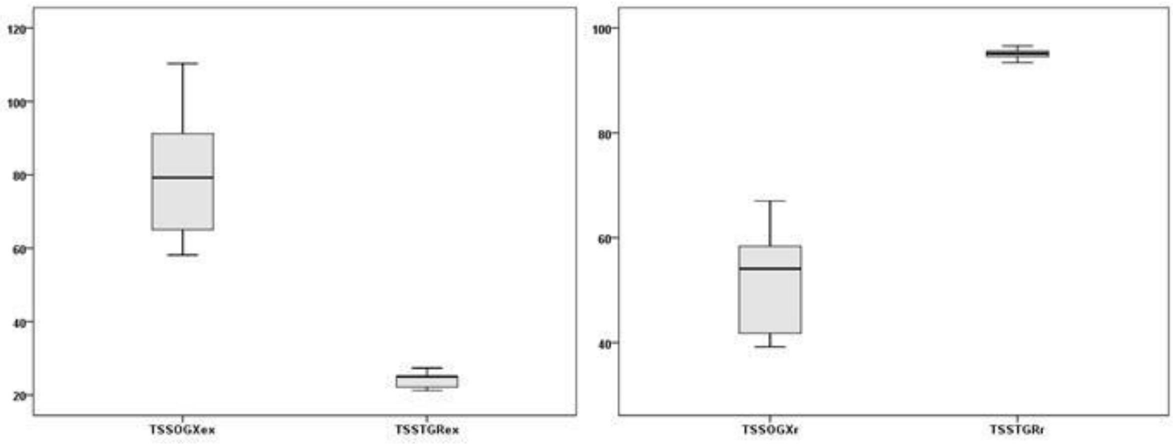


Figure (4). Variation of TSS removal rates and TSS exit concentrations in the two WWTPs

Removal rates of TSS were the highest in the case of AS (TGR) system (96.6%-93.4%) (Fig. 4) and it was the lowest in the case of AL (OGX) system (39.2%-67%) with an average difference exceeding 43%. It is noticed that, removal rates of AL show that the performance of this process has gone down until 2016 when the removal rate curve rises again. In the case of AS, performance tends to decrease but with low rates.

For the TSS exit concentrations (Fig. 4), the results show that there is also a big average difference (>55mg/l) between TSS exit concentrations of the two WWTPs. Concentrations were unstable during the eight years of study in AL system and tends to decrease in the AS system. They varied between 60.5 and 110.3 mg/l in WWTP of AL and between 21.26 and 27.36 mg/l in WWTP of AS.

To better analyze the variability of the values and the way in which they are distributed, we used boxplots (Figs. 5a&b).



(a) (b)

Figure (5). Boxplot of TSS exit (a) and removal rates (b) concentrations in the two WWTPs

The first observation to be made by looking at the boxplots of TSS exit concentrations (Fig. 5a) and TSS removal rates (Fig. 5b) is that there is an inversely proportional relationship between removal rates and concentration at the exit of WWTPs. It is also remarked that the boxes in the case of AL (OGX) are longer than those of the case of AS (TGR) which means that there is a great variability in the AL system compared to the AS system where there is no great variability. According to median position, figure 5a shows that there is a symmetric distribution of TSS exit concentration values in the case of AL WWTP and an asymmetric distribution towards the high concentration values of TSS in the case of AS WWTP. Regarding to figure 5b and for the case of AL process, the median of the TSS removal rates is at the top of the box which means an asymmetric distribution towards the high removal rate values of TSS. For the case of AS, there is a symmetric distribution of TSS removal rate values (Fig. 5b).

Biochemical Oxygen Demand (BOD_5)

Biochemical oxygen demand, also sometimes referred to as Biological oxygen demand, is the amount of dissolved oxygen needed by aerobic biological organisms to break down organic material present in a given water sample at certain temperature over a specific time period. The BOD value is most commonly expressed in milligrams of oxygen consumed per liter of sample during 5 days of incubation at 20 °C and is often used as a surrogate of the degree of organic pollution of water **(Nagel *et al.*, 1992; Sawyer *et al.*, 2003)**.

Figure (6) presents the variation of BOD_5 removal rates and BOD_5 exit concentrations of the two systems, AL (OGX) and AS (TGR) during the period from 2011 to 2018.

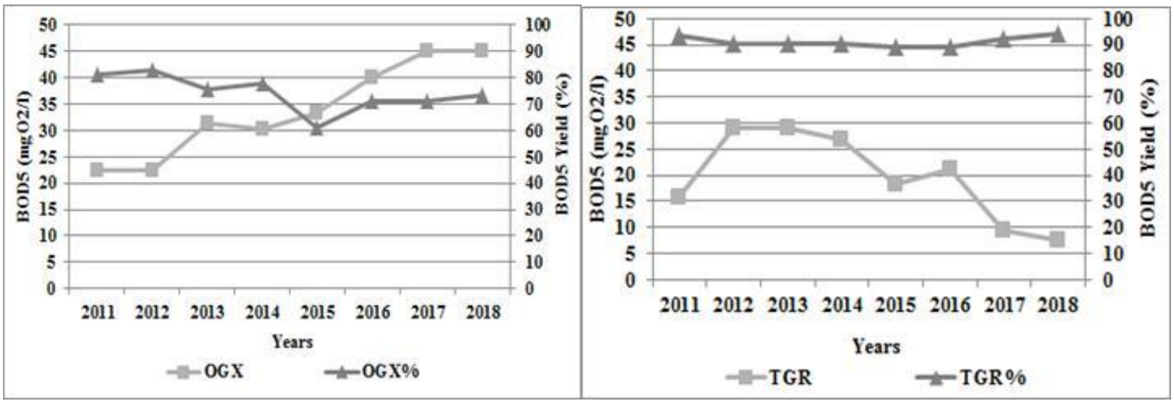
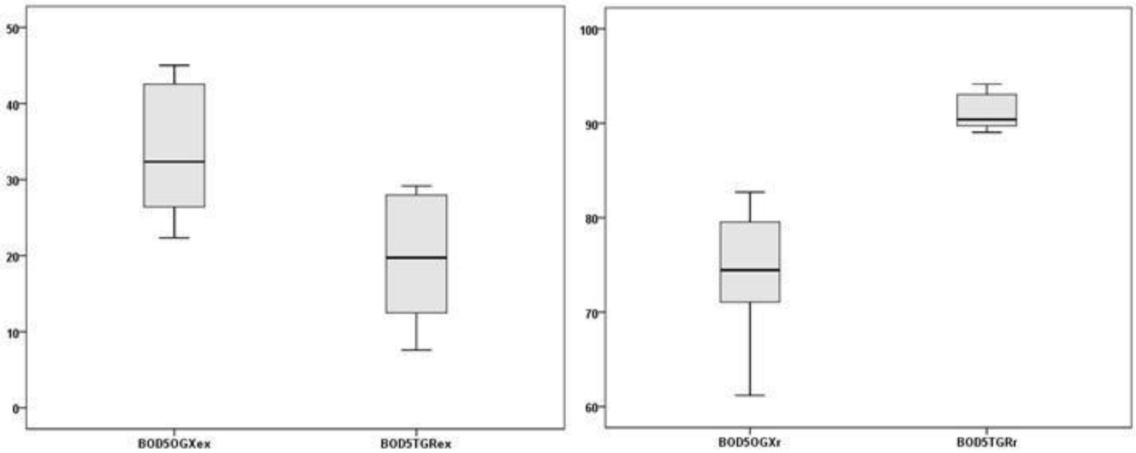


Figure (6). Variation of BOD_5 removal rates and BOD_5 exit concentrations in the two WWTPs

The results show that the lowest values of BOD_5 removal rates are registered in AL process. The BOD_5 removal rates have tendency to decrease going from 2011 to 2018 in the case of AL and to remain unchanged (very low variability) for the case of the AS process. For the concentrations of BOD_5 at the exit of the two WWTPs, the values increase from one year to another in the treatment with LA (22.3 mg/l - 45 mg/l) and they decrease from one year to another in the treatment with AS from 2012 (7.6 mg/l – 29 mg/l).

As in the case of TSS, it is noted that there is an inversely proportional relationship between the removal rate values of BOD_5 and those of the concentration of BOD_5 (Figs. 7a&b).



(a) (b)

Figure (7). Boxplot of BOD_5 removal rates and BOD_5 exit concentrations in the two WWTPs

The lengths of the boxplots show that there is a remarkable variability of values of removal rate and exit concentration recorded during the eight years of the study. For AL WWTP, medians of BOD_5 removal rate and BOD_5 exit concentration are at the bottom of the box which involves an asymmetric distribution towards the low removal rate and concentration values of BOD_5. Concerning AS WWTP, median of BOD_5 exit concentration values is in the center of box which means a symmetrical distribution but that of removal rate values is in the bottom of box which means an asymmetric distribution towards the low removal rate values of BOD_5.

Chemical Oxygen Demand (COD)

COD is defined as the amount of oxygen equivalents consumed in oxidizing the organic compounds of samples by strong oxidizing agents such as dichromate or permanganate. It is expressed in milligrams per liter (mg/L) that indicates the mass of oxygen consumed per liter of solution (**Kumar, 2010**).The following figure 8 shows the variation of COD removal rates and COD exit concentrations of the two systems (AL and AS) between 2011 and 2018.

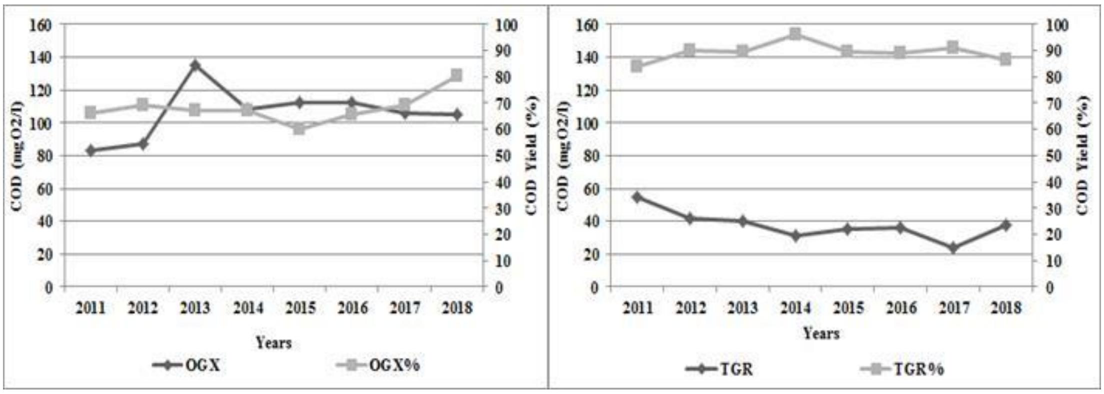


Figure (8). Variation of COD removal rates and COD exit concentrations in the two WWTPs

It is clear that COD removal rates of AL system are less than of the AS systems. Going from a year to another (Fig. 8), we remark that there is no clear difference between values of removal rates in the case of AS (84% -95.9%). This difference is very remarkable in the case of AL (59.8% - 80.3%). Figure 8 indicates also that there is a difference of exit concentration values and this average difference is more than 68 mg/l. which is stable in the case of AS and WWG processes and there is an increase removal rate values.

For the annual variations of the concentrations at the exit of the WWTPs, figure (8) shows that there is a tendency of increase in the case of AL and another of decrease in the case of AS going from 2011 to 2018.

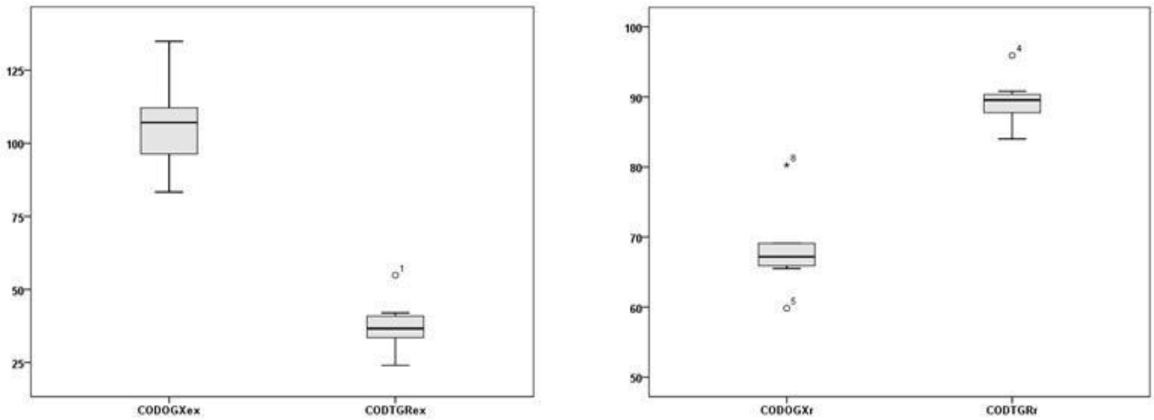


Figure (9). Boxplot of COD removal rates and COD exit concentrations in the two WWTPs

Except of that of the concentration values at the exit of the AL (OGX) plants, the lengths of the boxplots in figure 9 show that there is little variability in the removal rate and exit concentration. In the case of AS (TGR) WWTP, the median is in the center of exit concentration box which means a symmetrical distribution of COD exit concentration values; for removal rate box the median is in the top which means an asymmetric distribution towards the high removal rate values of COD. For AL WWTP case, the medians are not in the center. For exit concentration values the distribution is towards the high values of COD and for removal rate values the distribution is towards the low values of COD. It should also be noted that there is an inversely proportional relationship between the COD exit concentration and the COD removal rate.

Nitrogen Nitrite (NO_2^-)

Nitrites are an important step in the metabolism of nitrogen compounds. They are part of the nitrogen cycle between ammonia and nitrates and represent only an intermediate stage, their presence in water is therefore rare and in small quantities **(Rejsek, 2002).** Nitrites can be dangerous, both short term and long term and can produce carcinogenic nitrosamines in the human body through its reaction with amines or amides **(Ensafi *et al.*, 2004).**

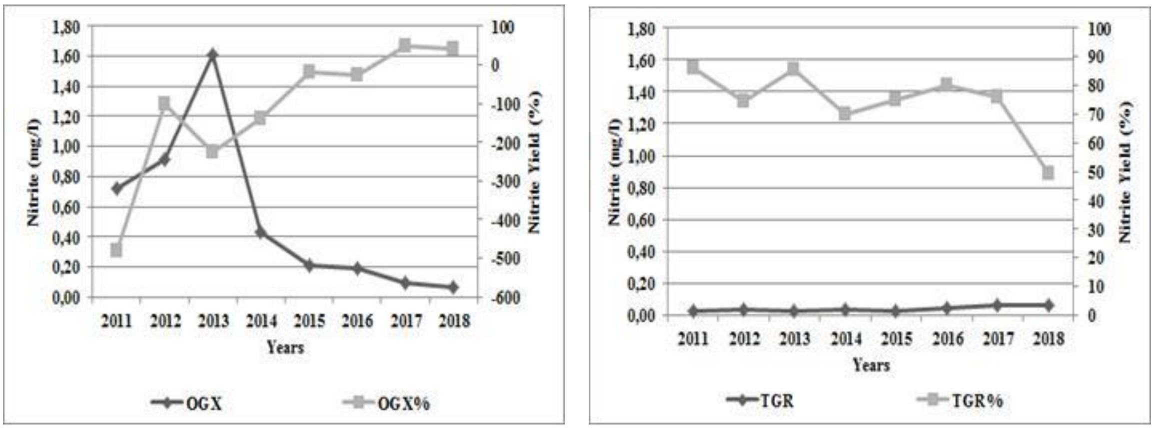


Figure (10). Variation of Nitrite elimination rates and exit concentrations in the two WWTPs

The important point to be made in figure 10 is that the nitrite concentrations at the exit of AL plant are strangely high compared to those of AS plant. It is only after 2015 that the values fell below 0.2 mg / l. For AS WWTP, all values are below 0.1 mg/l.

For elimination rates, Figure (10) shows that elimination rates tend to increase over time and were negative during the first six years in the AL plant. For the AS system, the elimination rates were unstable and tend to decline over time.

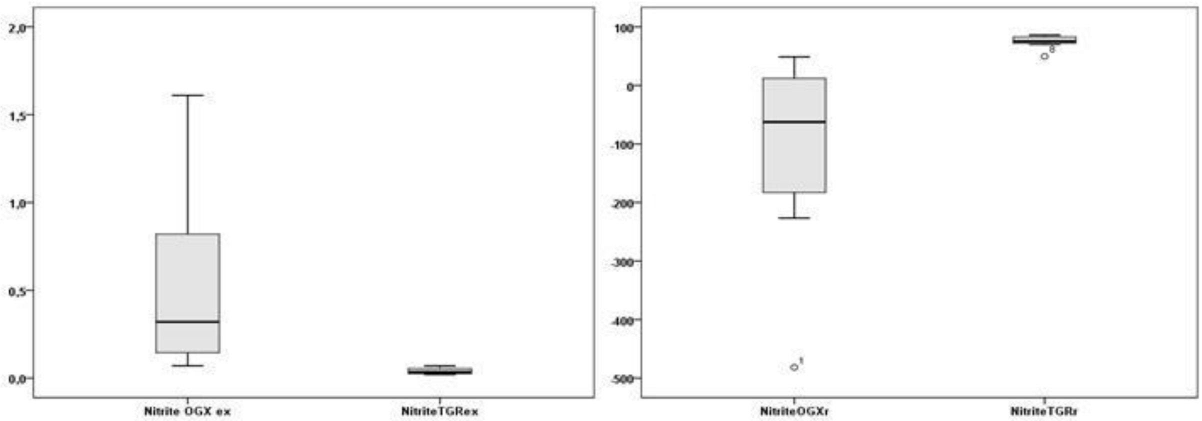


Figure (11). Boxplot of Nitrite elimination rates and exit concentrations in the two WWTPs

Figure (11) presents boxplots of nitrite elimination rate and nitrite exit concentration values. It is well seen that lengths of boxes of elimination rate and exit concentration in the case of AL WWTP are large (-481%- 48% and 0.07 mg/l – 1.61 mg/l) and compared to those of AS WWTP (49% - 86% and 0.02 mg/l – 0.07 mg/l). Median of nitrate exit concentration in AL WWTP shows an asymmetric distribution towards the low exit concentration values. That of elimination rate for the same plant indicates an asymmetric distribution towards the High elimination rate values. For the AS WWTP, the two medians are centered which implies a symmetrical distribution of nitrite elimination rate values and nitrite exit concentration values.

As for the other parameters analyzed previously, it is well noted that there is an inversely proportional relationship between the elimination rate of nitrite and its concentration at the exit of the plants.

Nitrogen Nitrate (NO_3^-)

Nitrates are the final stage in the oxidation of nitrogen. They are found naturally in water largely come from the action of the flow of water on the ground constituting the watershed **(Rejsek, 2002).** The main effect of nitrate on the environment is devastating to aquatic ecosystems by growing of undesirable plant on the water area or called also eutrophication phenomena, which correspond the toxicity of aquatic organisms by depletion of oxygen dissolved in the medium **(Du *et al.*, 2003; Shao *et al.*, 2010).**

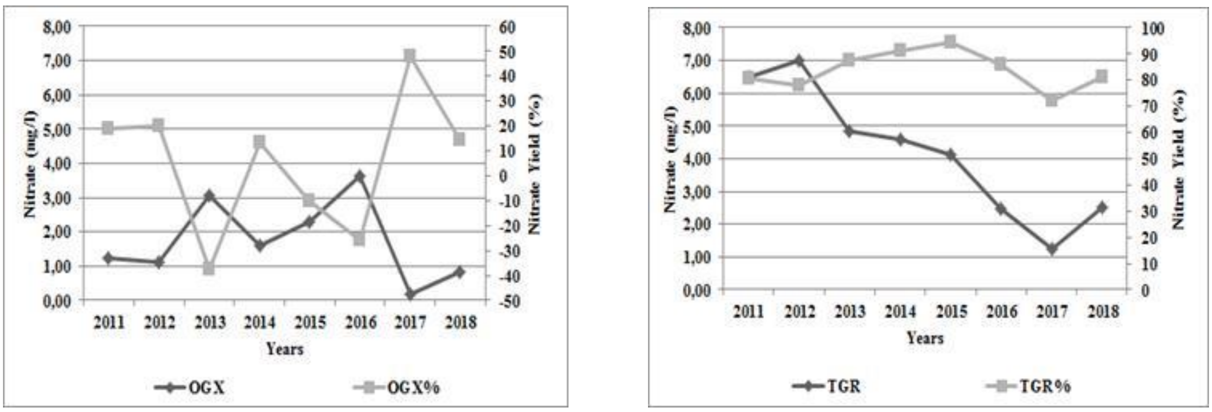


Figure (12). Variation of Nitrate elimination rates and exit concentrations in the two WWTPs

According to Figure 12, the elimination rate and the nitrate concentration at the exit of the AL WWTP vary in a random way (no clear trend). Maximum elimination rates and minimum exit concentrations are recorded during the last two years (2017 and 2018).

Concerning the AS WWTP, it is well observed that the concentration at the exit of the plant decreases rapidly from one year to another to reach the minimum in 2017 and then increases slightly in 2018. For the elimination rates of this process, they increase between 2011 and 2015 then decrease to reach the minimum in 2017.

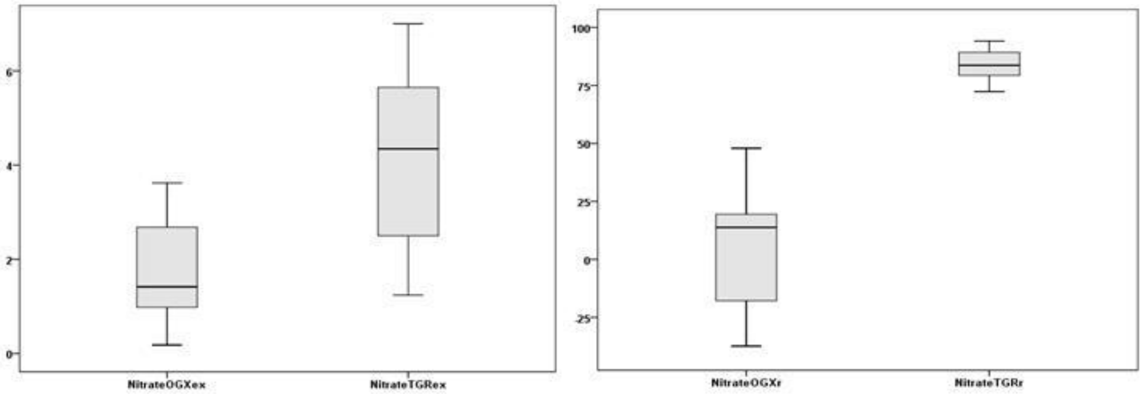


Figure (13). Boxplot of Nitrate elimination rates and exit concentrations in the two WWTPs

The boxplots (Fig. 13) show that with the exception of the elimination rate of AS WWTP where there is a low variability (72% - 94%), there is a great variability in the nitrate elimination rate (-37% - 48%) and nitrate exit concentration (0.18 mg/l – 3.62 mg/l for AL and 1.24 mg/l - 7 mg/l for AS) values. It is also clear that there is: (i) an asymmetric distribution towards the low values of the nitrate exit concentration in AL WWTP, (ii) an asymmetric distribution towards the high values of the nitrate exit concentration in AS WWTP, (iii) an asymmetric distribution towards the low values of the nitrate elimination rate in AL WWTP and (iv) a symmetric distribution of values of the nitrate elimination rate in AS WWTP.

Orthophosphate (PO_4^{-3})

The most common forms of phosphorus present in wastewaters are organic compounds, orthophosphates and polyphosphates. 70 to 90% of phosphorus in drain liquids is either orthophosphate or polyphosphate, which can get hydrolyzed up to orthophosphate **(Ruzhitskaya and Gogina, 2017)**. Phosphorus, as soluble orthophosphate, is a critical nutrient in all biological processes. It is utilized by bacteria in making energy (ATP molecules) and in creating phospholipid bilayers.

From Figure 14, it is obvious that there is an increase and then a decrease in the concentration of orthophosphate at the exit of the AL WWTP but within a small interval (1.7 mg/l - 3.5 mg/l). For AS WWTP, there is a trend of decrease in the exit concentration of orthophosphate going from 2011 to 2018 and in a rapid way (1.57 mg/l- 17.8 mg/l) particularly between 2012(17.8 mg/l) and 2013 (4.88 mg/l).

Concerning elimination rate, Figure 14 indicates that there is a random variation in performance of AL WWTP. At first, the elimination rate drops from 55% to 13% between 2011 and 2014 then gradually increases until 2017 to reach 37% then falls back to 2018 (16%). For AS WWTP, the curve shows a rapid and continuous increase in elimination rate (from 37% in 2011 to 89.5% in 2015) followed by a slow decrease to reach 82% in 2018.

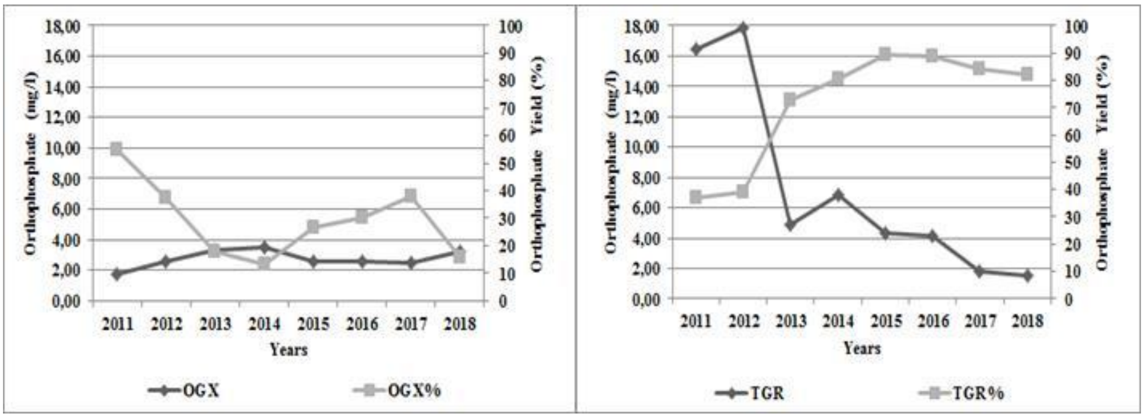


Figure (14). Variation of Orthophosphate elimination rate and exit concentrations in the two WWTPs

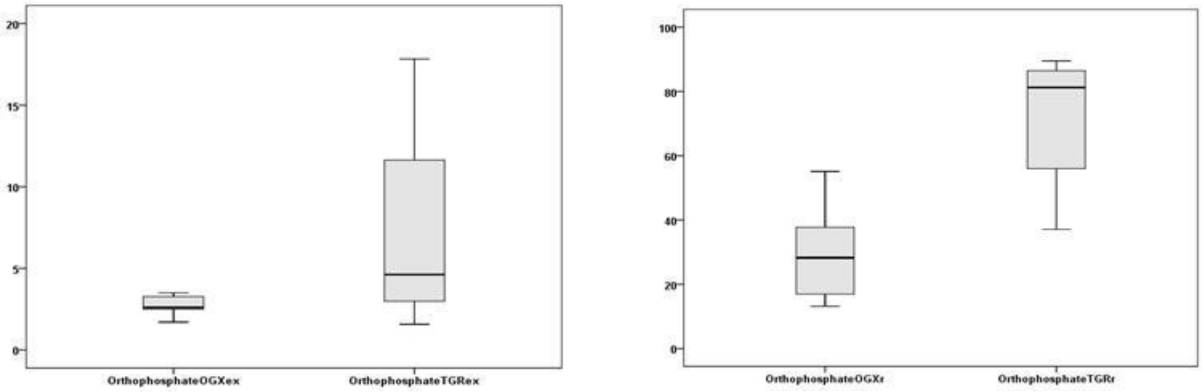


Figure (15). Boxplot of Orthophosphate elimination rates and exit concentrations in the two WWTPs

Figure 15 indicates that exit concentration values are very variable in the case of AS WWTP and are not in the case of AL WWTP. The distribution of orthophosphate values in both WWTPs is asymmetric towards the low values of orthophosphate exit concentration.

For elimination rate values, the variability is great in the two WWTPs with an advantage for AS WWTP. For the position of the median, figure 15 shows that it is slightly in the top for the case of AL WWTP and visibly in the top for the case of AS WWTP. These positions indicate an asymmetric distribution towards the high values of orthophosphate elimination rate.

DISCUSSION

Organic load removal

Results relating to the physical and biological pollution parameters show that average removal rates during the study period are 52% for TSS, 74% for filtered BOD_5 and 68% for DOC in the case of AL process and 95% for TSS, 91% for filtered BOD_5 and 89% for COD in the case of AS process. For AL system, removal rates were low and relatively too variable over time (very high standard deviation values: 10.1% for TSS, 6.8% for BOD_5 and 5.7% for COD) compared to those recorded in the case of AS system (low standard deviation values: 0.9% for TSS, 1.9% for BOD_5 and 3.4% for COD). These values in terms efficiency show that AS process is more efficient than that of AL process. Compared to other studies, the aerated lagoon process performance is lower than that found by **Rassam *et al.* (2012)** who found rates of 88% (TSS), 89% (COD) and 90% (BOD5); by **Hamid *et al.* (2014)** who recorded removal rates of TSS, BOD5 and COD with values of 88%, 82% and 83% respectively. Removal rate values of Ouargla AL WWTP are as low as that recorded in WWTPs of natural lagoon of Sidi Senoussi and Emir Abdel Kader located in western of Algeria **(Chachoua and Seddini, 2013).**

These average removal rates show the malfunction of AL WWTP and this may be due to several problems encountered in the station such as the continued breakdowns of aerators, hence the low concentrations of dissolved oxygen, the large volume wastewater to be treated, the quality and quantity of pollutant loads and climatic conditions in particular air temperature and low wind velocity.

For AS process and by comparing with other studies, the average removal rates are mostly greater than 90% and this is the same observation made by **Oliveira et al. (2017).** Compared to studies made by **Nikmanesh *et al.* (2018), Shahot *et al.* (2015)** and **Shahmoradi *et al.* (2014)**, our AS WWTP is more efficient. On the other hand, it is less efficient with respect to the average removal rates recorded in the WWTP studied by **Zazouli *et al.* (2010)** and **Mohammadi *et al.* (2016).**

Regarding the exit concentrations, the values recorded in AL system are 33.74 ± 9.00 mg/l for BOD_5, 106.16 ± 15.92 mg/l for COD and 79.93 ± 18.02 mg/l for TSS. These values exceed by 2 to 3 times those recorded at the exit of the AS system which were 19.64 ± 8.48 mg/l for BOD_5, 37.63 mg/l for COD and 24.15 ± 2.11 mg/l. Therefore, in addition to the large difference between the values for a given parameter, the standard deviations show a remarkable variability of the concentrations over time for both WWTPs.

Compared to the Algerian and WHO discharge standards, the concentrations of BOD_5, COD and TSS are below the values of the Algerian standards of discharged treated wastewater (35 mg/l, 120 mg/l and 35 mg/l) **(JORA, 1993)** and Those of the WHO standard (30 mg / l, 90 mg / l and 30 mg / l) **(WHO, 1989)** in the case of AS process. For the AL process, concentrations of BOD_5 and COD are lower than those of Algerian standard but higher than those of WHO standard. For TSS, the concentration at the exit of the AL is higher than those of the Algerian and WHO standards.

According to our results and those of previous studies on the two processes, the average removal rates and concentrations of physical and biological parameters at the exit of WWTPs depend on the pollutant load, the size of the treatment plant, the number and surface of the basins, basin type (aerobic, anaerobic, facultative) and climatic conditions **(Rassam *et al.*, 2012; Shahot *et al.*, 2015)**.

Nutrient removal

Nitrogen removal was analyzed in only one form, which is nitrogen nitric (nitrite and nitrate). For phosphorus, it is the orthophosphates that were analyzed. According to **Prigent (2012)**, orthophosphate is the most abundant form in domestic wastewater. It represents 60–85% of total phosphorus due to the hydrolysis of polyphosphates and organic phosphates.

The capability of the AL system for orthophosphates removal was weak, with average removals around 29 %. For AS system, orthophosphates removal rate was so high and around 71%. The average residual contents of orthophosphates of the effluent at the exit of the two plants were 2.74mg/l for AL and 7.23 mg/l for AS. These values are very high compared to the tolerable limit of 0.94 mg/l in orthophosphates for a discharge of effluents into a medium susceptible to eutrophication **(WHO, 1989; Abou Nahra, 2006; Prigent, 2012)**.

Results of nitrogen nutrient average removal show that high rates of nitrite and nitrate are registered in AS WWTP and are respectively 74% and 83%. In the case of AL system, the average removal rate is negative (-112%) for nitrite and very weak (5%) for nitrate. These results indicate that nitrite concentrations at the exit of AL WWTP increase and exceed those recorded at the entrance. Results show also that concentrations of nitrate and nitrite at the exit of both WWTPs are under WHO standards **(WHO,1989)**. According to **Kälin and Siegrist (2009)**, increased nitrite concentrations are usually an indication of a disturbance of microbiological processes, of an overloaded plant or insufficient aeration capacity. Microbiological inhibition can be caused by toxic substances, seasonal variations in temperature or generally unfavorable conditions for Nitrite Oxidizing Bacteria **(Kälin and Siegrist, 2009)**. It is important to mention here that high nutrient concentrations, such as nitrogen and phosphorus, stimulate algal blooms, degrading the water quality in these aquatic ecosystems **(Ritter and Shirmohammadi, 2001)**. This explains the formation of algal blooms in the finishing basin of AL WWTP and the high concentration of TSS at the exit of this plant.

Treated wastewater reuse for aquaculture

One of the common worldwide scenarios for water reuse includes beneficial use of treated municipal wastewater and its associated nutrients for aquaculture **(Alderson *et al.*, 2015; Kumar and Asolekar, 2016)**. Such considerations are important because in 2014 more fish for human consumptions came from aquaculture than global fisheries **(FAO, 2016)**, and this trend must continue to meet future global food production demands. According to our results, the recorded values of water temperature and pH are within the tolerance interval for the case of some types of fish such as *Oreochromis niloticus* **(Sarig,1969; Mires, 1995; Ross, 2000).** But microbiologically, there is evidence that fish and plants obtained from aquaculture fed through aqueous discharges may be contaminated with human pathogens related excreta, on the surface or, for fish only, in the intestines **(WHO, 2012).** In the two WWTPs of our study, there is no total elimination of germs, but the removal rates are very high in the case of AL system and exceed 97%. This is explained by the presence of solar ultraviolet radiation which destroys numerous pathogenic germs and which ensures a certain decontamination of the effluent **(El Haité, 2010).** This solar radiation and in the presence of a large amount of nutrients (especially phosphorus) are the source of algae growth and aquatic plants in particular in AL WWTP. So, with further microbiological examination, the treated water can solve the problem of water scarcity for aquaculture and other purposes in this arid area.

CONCLUSION

In many countries, the municipal wastewater is treated biologically before being discharged into the nearby watercourses **(Chen *et al.*, 2002)**. Our study assessed the treatment performance of two free biomass biological wastewater treatment processes.

The results show satisfactory removal rate of total suspended solids in accordance with Algerian and WHO effluent discharge standards for the case of AS process. For AL process, removal rate of TSS is low and its concentration is higher than that of Algerian and WHO discharge standards. The elimination of BOD_5 and COD remains partial with high rates in the case of AS process and the residual values of the filtered BOD_5 and COD are: (i) for AS process under the levels recommended by Algerian authorities and WHO, and (ii) for AL process under the levels recommended by Algerian authorities and above WHO standards.

The removal rates of nutrients (nitrogen and phosphorus) are very low in the AL WWTP and very high in the AS WWTP. The residual concentrations remain very high in the treated effluent and could constitute a great risk of eutrophication. They are at the origin of the formation of algal blooms in the case of AL process.

According to these conclusions, the AS is the most efficient process under our climatic conditions. For the LA process, it is recommended to remedy the problems of breakdown of aerators which are the cause of the drop in the dissolved oxygen concentration which is the engine of the various actions carried out by the aerobic bacteria.

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