Following the development and growth of urban, agricultural and industrial activities in Morocco, the production of wastewater has become very important. This causes a great health and environmental risk. Therefore, the treatment of wastewater becomes a necessity for environment protection (Hachemi et al., 2012). The purpose of wastewater treatment is either to discharge into the natural environment or to reuse the water that must meet standards set by the authorities responsible for water resources management. According to Hâité (2010), the volume of wastewater in Morocco is estimated at 900 million m$^3$ / year in 2020. The pollutant load of wastewater is estimated at around 131715 tons of organic load, 42131 tons of nitrogen and 6230 tons of phosphorus (Mandi et al., 2013). Morocco, like most of the southern Mediterranean countries, suffers from the scarcity of conventional water resources, which constitutes a social, agricultural, and economic problem. The water problem in these countries is the result of a combination of arid climatic
conditions as well as an increase in water needs due to population growth and the development of tourism. It is, therefore, necessary to provide alternative water sources for agriculture to replace the high quality water required for consumption (Angelakis et al., 1999). In this context, the reuse of treated wastewater seems to be a good alternative especially in irrigation. This resource is abundantly and permanently available. It has many advantages, notably reasonable cost compared to desalinating seawater or digging wells. It ensures the balance of the natural water cycle and protection of the environment, as has been proven in many countries of the Mediterranean region, such as Israel, Cyprus, Jordan and Tunisia (Angelakis et al., 1999). Despite the benefits of wastewater reuse, it could present significant risks for users and the environment (Habbari et al., 2000; Cha et al., 2004; Qadir et al., 2010; Fatta-Kassinos et al., 2011). Multiple studies have proven that microbial contamination represents a real risk. A large variety of pathogenic microorganisms has been isolated from wastewater (Vaz-Moreira et al., 2014). Chemical contaminants pose serious risks to health and the environment; wastewater can contain pesticides, pharmaceuticals and heavy metals (Tarchouna et al., 2010; Köck-Schulmeyer et al., 2013). Currently, Morocco has more than 100 wastewater treatment plants which are part of pollution control strategy, reuse of treated wastewater, and contribution to sustainable development (Tahri et al., 2015). In this context, The Anza-Taghazout sector in the Agadir region (southwestern of Morocco) is among the sectors benefiting from the new treatment plants: lamellar settling in Anza and activated sludge in Aourir. The setting up of wastewater treatment plants in this sector is a major step towards modifying the sanitary quality of the marine ecosystem in this area. The new station of Aourir using activated sludge technology is the first in its kind in the Agadir region, characterized by its semi-arid climate. This very low charge station located between Tamraght and Aourir will serve more than 61,000 citizens. The purpose of this study was to evaluate the possibility of reusing the treated wastewater from the Aourir treatment plant in the irrigation of green spaces. It mainly consists in estimating the overall organic pollution and the sanitary quality of the effluents. In order to ensure the proper adaptation of this treatment system with the semi-arid climate of the region, it is necessary, first of all, to identify the sources of pollution at the entrance of this station, and then to evaluate its purification performance. The results will be confronted with the Moroccan and European standards.

Figure 1. Geographical location of Aourir wastewater treatment plant
MATERIAL AND METHODS

Geographical location of the study site

The Aourir treatment plant (30°32'44.189"N, 9°42'29.297"W) is located near the ocean, northwest of Aourir and about 700 m south of the Taghazout bay tourist resort located 12 km from the Agadir city and 8 km from Taghazout. The Aourir treatment plant covers an area of 2.5 hectares (200 × 125 m). Figure 1 shows the location of this treatment plant.

Description of Aourir treatment plant

The effluent treatment channels includes a water treatment system with pretreatments, biological treatment and tertiary treatment, as well as a sludge treatment and a stale air treatment (deodorization) line (Figure 2). Conventional pretreatment consists in a succession of screening, grit removal and de-oiling, followed by a combined treatment between the biological system (Table 1), which consists in passing the treated wastewater into two aeration tanks for biological degradation of the organic matter by biomass, followed by a mechanical system which consists in decanting all the sludge in the clarification tanks. The biological treatment is the activated sludge type with a very low load. Tertiary finalization treatment consists in series of mechanical filtration operations (10-μm microfiltration) and UV disinfection (Table 1). The total flow of treated wastewater would be around 7600 m³/d for 60 833 population equivalent at the project saturation horizon (2030), which corresponds to

| Treatment Stages | Characteristics |
|------------------|-----------------|
| **Biological Basin** | |
| Number of basins | 2 |
| Maximum flow rate per basin | 840 m³/h |
| Unit volume of the contact area | 145 m³ |
| Length of stay | 10 min |
| **Air Zone** | |
| Number of basins | 2 |
| Unit volume of basins | 5 974 m³ |
| Global sludge age | 21 j |
| Length of stay | 38.5 h |
| **Clarification Basin** | |
| Number of basins | 2 |
| Maximum flow rate | 840 m³/h |
| Maximum flow rate per basin | 462.5 m³/h |
| Total diameter of the basin | 32.4 m |
| Height in water of the cylindrical part | 3.5 m |
| **Tertiary Filtration** | |
| Type | Mechanical filtration on canvas |
| Cut-off threshold | 10 μm |
| Number of filters | 2 |
| Maximum flow rate | 840 m³/h |
| Maximum flow rate per filter | 420 m³/h |
| Unit filtering surface | 45 m² |
| Filtration speed | 9.3 m/h |
| **UV Disinfection** | |
| Type | lampes UV-C basse pression |
| Number of reactors | 3 |
| Maximum flow rate | 840 m³/h |
| Maximum flow rate per reactor | 280 m³/h |
| UV transmittance | 65% |
| Wavelength | 254 nm |
| Exposure dose | 65.2 mJ/cm² |
| Power per reactor | 12 kW |
a peak hour flow of 840 m$^3$/h. The current flow rate that the subjected to treatment in the plant is approximately 1600 m$^3$/d.

**Samples collection**

A total of 63 samples were collected over 21 months; from April 2017 to December 2018. Monthly, three samples were collected (Figure 1). It included: raw water (RW) at entrance to the plant, biological treated water (BTW), and finally, treated water disinfected with ultraviolet radiation (UV-TW) at the exit of the UV reactors.

**Studied parameters**

The overall physicochemical parameters (T $^\circ$, pH, dissolved O$_2$ and conductivity) were measured in situ using a “Conductivity Meter” and “pH-meter” by the THERMO Scientific electrode, and the BANTE electrode instrument for the measurement of dissolved oxygen. BOD$_5$, COD, SS were measured on monthly composite samples (RW, BTW, UV-TW). For suspended solids (SS), the measurement method adopted was differential weighing by filtration on GFC filter and drying at 105$^\circ$C (AFNOR, T90–105). The five-day biological oxygen demand (BOD$_5$) was determined by using the manometric method with a respirometer (types WTW), according to the AFNOR standard (AFNOR, T90–103). The chemical oxygen demand (COD) was determined with the oxidizability with potassium dichromate (AFNOR, T90–101). The determination of nitrates (NO$_3^-$) was performed with the method based on sodium salicylate (AFNOR T90–013). Orthophosphates (PO$_4^{3-}$) were determined by colorimetric measurement of the phosphomolybdic complex formed (AFNOR T90–023). The bacteriological analyses of the wastewater samples consisted in enumerating the germs indicative of fecal contamination, i.e. total coliforms (TC), fecal coliforms (FC), Escherichia coli (E. coli) and fecal streptococci (FS). The enumeration methods depend on the origin, nature and quality of the sample. In the conducted study, the bacterial enumeration was performed by the technique of dilution and spreading of 0.1 mL of the diluted sample on the agar specific to the microorganisms sought on the raw wastewater. The treated water was analyzed with the membrane filtration technique (100 mL on 0.45 μm membrane). Incubation on TTC-Tergitol-Agar for 24 h at 44$^\circ$C for fecal coliforms (ISO 9308–1, 2000), and 24 to 37$^\circ$C for total coliforms. Bile tryptone agar with X-glucuronide (TBX agar) for 24 h at 44$^\circ$C for E.coli (ISO 9308–1, 2000). Slanetz-Bartley agar at 37$^\circ$C for 48 h for fecal streptococci (ISO 7899–2, 2004).

**Statistical analysis**

The relationship between the microbiological and physicochemical parameters was analyzed using the Pearson Correlation Test. The analysis of variance (ANOVA) was performed in order to compare the changes in the water quality at the inlet and outlet of the treatment plant, caused by the treatment system. The ANOVA test was used to compare the concentrations of each parameter between seasons, years and between treatment steps using SPSS statistics24 with a significance level of 0.05 and 0.01.
RESULTS

Physicochemical parameters

The monthly wastewater temperature is shown in Figure 3a. The RW temperature ranges from 20.3±1.55°C to 27.75±0.21°C, with an average of 23.20±0.27°C. For BTW, it varies between 16±0.33°C and 27±0.20°C with an average of 21.17±0.33°C. The temperature of UV-TW, it is between 15.6±0.84°C and 26.9±0.84°C with an average of 20.9±0.42°C. During the sampling period, the pH values ranged from 7.40±0.04 to 8.53±0.08 and 7.02±0.02 to 8.33±0.23 for RW and UV-TW, respectively (Figure 3b). The average pH value of RW is about 8.14±0.06 indicating low alkalinity of wastewater, 7.76±0.08 of BTW; however, the annual average of UV-TW remains close to neutral 7.67±0.09. The average values of Electrical Conductivity in RW, BTW and UV-TW are 1712.76±5.11, 1287±5.44 and 1291.97±8.38 (μS/cm), respectively; it varies between 1374±3.53 and 2188±2.82 in RW; 1110±2.10 and 1644±1.22 in BTW; 1111.5±12.0 and 1643±1.41(μS/cm) in UV-TW (Figure 3c).

The concentration of dissolved oxygen in RW varies between 0.22±0.02 mgO₂/L and 3.48±0.09 mgO₂/L with an average value of 1.46±0.08 mgO₂/L. The average concentration of dissolved oxygen in BTW is 8.91±0.04 mgO₂/L, the minimum value is 5.82±0.04 mgO₂/L and the maximum is 10.44±0.12 mgO₂/L. For UV-TW, the dissolved oxygen content varies between 6.01±0.06 mgO₂/L and 10.85±1.41 mgO₂/L, with an average value of 9.09±0.04 mgO₂/L (Figure 3d). The lowest concentration of dissolved oxygen in RW was recorded in the summer of 2018 (0.61±0.36 mgO₂/L), while the highest concentration in UV-TW was found in the summer of 2017 (10.02±0.34 mgO₂/L).

Table 2 shows the evolution of COD in RW and UV-TW. It varies between 722.56±11.43 mgO₂/L (autumn of 2017) and 1344.90±18.38 mgO₂/L (summer of 2018) with an average value of 1059±19.2 mgO₂/L for RW. For UV-TW, the highest concentration was recorded in the summer of 2017 (117.35±3.48 mgO₂/L) and the lowest in the autumn of 2018 (39.44±2.28 mgO₂/L). The average concentration of BOD₅ in RW is around 469.73±15.7 mgO₂/L, the
The analysis of the NO₃⁻ and PO₄³⁻ nutrient contents in the RW and UV-TW of the Aourir wastewater treatment plant (Table 3) shows that the average values are much lower than those usually found in domestic wastewater. The average concentration of NO₃⁻ in RW is around 2.03±0.45 mg/L, while the lowest seasonal concentration was recorded in the autumn of 2018 (0.9±0.14 mg/L), whereas the minimum was recorded in the autumn of 2017 (0.35±0.14 mg/L).

The mean values for PO₄³⁻ in RW and UV-TW are 10.54 mg/L±0.18 and 7.22±0.18, respectively. For RW, the highest seasonal concentration was recorded in the summer of 2017 (13.55±2.26 mg/L), and the lowest recorded in the summer of 2018 (11.55±2.08 mg/L) (table 2).
UV-TW, 8.45±0.06 mg/L is the highest seasonal concentration of PO$_4^{3-}$ recorded in the summer of 2017 and 1.77±0.06 mg/L is the lowest seasonal concentration recorded in the autumn of 2018 (Table 3).

The measured data of physicochemical parameters were statistically analyzed using ANOVA. The statistical analysis indicates high significant difference between seasons of all measured parameters $p<0.001$, in all types of water. In addition, a high significant difference is observed between steps of treatment $p<0.001$.

### Typology of Aourir waters

Table 4 shows that the values recorded for the COD/BOD$_5$ ratio is 2.25±0.22. The BOD$_5$/COD values recorded during the study period range from 0.37 to 0.58. The SS / BOD$_5$ ratio is in order of 1.3±0.18 in 2017 and 2018. The obtained results indicate that the OM concentrations are significant; the highest concentration is recorded in summer 2018 (819.78 mg/L) (Table 4); the mean value was 660.48 ± 77.01 mg/L. This result, as well as the other ratios, reflect the relatively high loads of organic matter transported by the Aourir effluent.

### The bacteriological characteristics of the wastewater and the purified water of the Aourir station

The bacteriological analysis focused on monitoring fecal contamination germs, total coliforms, fecal coliforms, *E. coli* and fecal streptococci (Enterococci). The results presented in this section corresponds to the sampling period of 2017 and 2018 in RW, BTW and UV-TW for a

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**Table 3.** Seasonal variation of nitrates and orthophosphates pollution in the Aourir wastewater treatment plant over the years 2017–2018

| Season | Parameters | NO$_3^-$ (mg/L) | NO$_2^-$ (mg/L) | Limit of direct discharge NO$_2^-$ (mg/L) | Removal percentage | PO$_4^{3-}$ (mg/L) | PO$_4^{3-}$ (mg/L) | Limit of direct discharge PO$_4^{3-}$ (mg/L) | Removal percentage |
|--------|-----------|----------------|----------------|----------------------------------------|-------------------|----------------|----------------|----------------------------------------|-------------------|
| RW     | UV-TW     | RW            | UV-TW         |                                        |                   | RW            | UV-TW         |                                        |                   |
| Spring 2017 | Min 1.52 | 0.94 | Max 1.28 | 0.78 | Average 1.37 | 0.84 | SD 0.08 | 0.13 | 39% | 10.56 | 7.24 | 13.09 | 8.26 | 11.59 | 7.62 | 0.08 | 0.07 | 34% |
| Summer 2017 | Min 2.12 | 0.3 | Max 2.33 | 1.14 | Average 2.2 | 0.76 | SD 0.04 | 0.06 | 65% | 11.7 | 8.26 | 13.7 | 9.19 | 12.79 | 8.45 | 0.07 | 0.06 | 34% |
| Autumn 2017 | Min 1.13 | 0.31 | Max 1.45 | 0.42 | Average 1.3 | 0.35 | SD 0.11 | 0.14 | 73% | 8.53 | 7.24 | 11.2 | 8.99 | 9.9 | 8.19 | 0.18 | 0.04 | 17% |
| Winter 2018 | Min 1.38 | 0.65 | Max 1.84 | 0.8 | Average 1.66 | 0.71 | SD 0.16 | 0.16 | 57% | 10.83 | 7.52 | 12.96 | 8.34 | 11.57 | 7.9 | 0.07 | 0.15 | 32% |
| Spring 2018 | Min 1.1 | 0.47 | Max 1.77 | 0.87 | Average 1.51 | 0.69 | SD 0.15 | 0.13 | 54% | 10.43 | 7.38 | 11.55 | 8.24 | 11.13 | 7.7 | 0.25 | 0.08 | 31% |
| Summer 2018 | Min 2.08 | 0.43 | Max 2.5 | 0.69 | Average 2.36 | 0.54 | SD 0.14 | 0.14 | 77% | 8.4 | 1.38 | 10.14 | 7.2 | 10.02 | 5.01 | 0.1 | 0.52 | 50% |
| Autumn 2018 | Min 2.06 | 0.77 | Max 3.15 | 1.01 | Average 2.6 | 0.9 | SD 0.15 | 0.14 | 65% | 8.51 | 1.56 | 10.4 | 1.96 | 9.42 | 1.77 | 0.09 | 0.06 | 81% |
possible evaluation of their abatement. The bacterial load in RW and UV-TW shows a strong fluctuation during the different seasons of the two sampling years for all bacterial parameters $p<0.001$. The highest concentration of total coliforms in RW was recorded in the summer of 2018 by $7.75 \log_{10} \text{CFU/100 ml}$, and the lowest was recorded in the winter of 2017 by $6.36 \log_{10} \text{CFU/100 ml}$ (Figure 4 a). The annual average of total coliforms in RW is approximately $7.05 \log_{10} \text{CFU/100 ml}$. This number decreases considerably in BTW with a value of $3.35 \log_{10} \text{CFU/100 ml}$ and in UV-TW with a value of $2.13 \log_{10} \text{CFU/100 ml}$. The highest concentration of total coliforms in UV-TW was recorded in the spring of 2018 with a value of $2.30 \log_{10} \text{CFU/100 ml}$, and the lowest was recorded in the summer of 2017 with a value of $1.92 \log_{10} \text{CFU/100 ml}$.

The average fecal coliform load in RW is about $6.47 \log_{10} \text{CFU/100 ml}$ and $1.67 \log_{10} \text{CFU/100 ml}$ in UV-TW (Figure 4 b). The highest concentration of fecal coliforms in RW was recorded in the summer of 2018 ($7.27 \log_{10} \text{CFU/100 ml}$), while the lowest was marked in the autumn of 2017 ($5.88 \log_{10} \text{CFU/100 ml}$). The fecal coliform concentrations in UV-TW reached the maximum in the summer of 2018 ($1.96 \log_{10} \text{CFU/100 ml}$) and the lowest abundance was recorded in the autumn of 2018 ($1.51 \log_{10} \text{CFU/100 ml}$).

For *E. coli*, a one-year sampling was performed from January 2018 to December 2018 (Figure 4 c). In RW, it shows an annual average concentration of $6.9 \log_{10} \text{CFU/100 ml}$, the

![Figure 4. Monthly variation of bacteriological parameters during the sampling period](image)

a) Total Coliforms (TC), b) Fecal Coliforms (FC), c) *Escherichia coli* (*E. coli*), d) Fecal Streptococci (FS)
highest concentration was marked in the summer season of 2018 (7.28 log$_{10}$ CFU/100 ml), while the lowest concentration was recorded in the winter of 2018 (6.08 log$_{10}$ CFU/100 ml). UV-TW does not exceed 1.77 log$_{10}$ CFU/100 ml as an annual average value, the highest load is recorded in the summer of 2018 (2.03 log$_{10}$ CFU/100 ml), and the lowest was recorded in the winter of 2018 (1.58 log$_{10}$ CFU/100 ml).

The average number of fecal streptococci in RW is 6.02 log$_{10}$ CFU/100 ml, while UV-TW contain an average value of less than 2 log$_{10}$ CFU/100 ml (Figure 4 d). The highest concentration of fecal streptococci in RW was recorded in the summer of 2018 (6.65 log$_{10}$ CFU/100 ml) while the lowest concentration was recorded in the autumn of 2017 (5.38 log$_{10}$ CFU/100 ml). UV-TW recorded the highest abundance in the autumn of 2017 with a value of 1.76 log$_{10}$ CFU/100 ml, and the lowest in the summer of 2017 with a value of 1.15 log$_{10}$ CFU/100 ml (Figure 4 d). According to the statistical study, a significant difference p<0.001 between RW and UV-TW was found for the four indicators of fecal contamination.

**DISCUSSION**

**Physicochemical parameters**

Agadir is among the regions of the Moroccan kingdom most affected by the scarcity of conventional water resources. The reuse of treated wastewater seems a necessity to reduce the pressure on the groundwater. Currently, UV-TW from the Aourir wastewater treatment plant is reused to irrigate a golf course in Taghazout bay tourist resort. This study gives the bacteriological and the physicochemical quality of UV-TW, to evaluate the effectiveness of UV disinfection and to prevent their health and environmental risks.

Throughout the study period, the temperature of all types of water was below 30°C, which are favorable values for the operation of bioreactors (Adouani et al., 2015). The high fluctuation observed is due to climate change, the treatment stages, and the chemical and biological reactions. These recorded temperatures do not exceed the limit values for direct discharges to the receiving environment (Official Bulletin, 2002). Water temperature is an ecological factor with significant ecological impacts (Makhoukh et al., 2011). It is important in the aquatic environment and has an influence on physicochemical and biological reactions (Chapman, 1996). Bourouache et al., (2019), who monitored the performance of a percolation infiltration system in the same region, found that temperature is always below 35°C in different types of water, and concluded that this temperature is adequate for the proper functioning of anaerobic sludge digestion. The pH values in the different types of water are close to neutral. In general, despite the observed fluctuations, the pH evolution (UV-TW) is always between 6.5 and 8.4, which are considered limit values for direct discharges into the natural environment and a normal pH zone according to the quality standard for water intended for irrigation (Official Bulletin, 2002). In Algeria, a comparison study of two free biomass treatment plants (aerated lagoon and activated sludge) concluded that there is an asymmetric distribution of the pH values in both treatment plants. The aerated lagoon reflects an asymmetric distribution towards low pH concentrations, whereas the activated sludge reflects an asymmetric distribution towards high pH concentration values (Bachi et al., 2020). However, it should be noted that the pH values that are too acidic or too basic could affect the biological treatment processes. In this regard, Deronzier et al., (2002) reported that a drop in pH below 7 significantly slows nitrification. In addition, the pH values ranging from 5.6 to 8.6 promote the bacterial growth necessary for the biological degradation of organic pollutants (Maiga et al., 2006). The pH between 6.5 and 7.5 is generally recommended for wastewater treatment plants, as low pH promotes the growth of filamentous fungi and other organisms responsible for sludge flotation (Arcand et al., 2005).

The strong fluctuation of the electrical conductivity recorded in the RW and UV-TW can be explained by the removal of a high concentration of ions throughout the activated sludge treatment process. Contrary to the M’zar plant in the same region equipped with a percolation infiltration system, several authors – Bourouache et al., (2019); Et-Taleb et al., (2014); El Haouti et al., (2015) – have recorded an increase in the concentration of electrical conductivity in the treated water at the outlet of the WWTP. They have enhanced this growth by the mineralization of organic matter by bacteria during the treatment process and by the chemical and geometrical properties of the use of sand in the percolation infiltration basins. The results obtained in this study are consistent with the
work carried out on the Yemen activated sludge plant in an arid climate; this study concluded that
electrical conductivity is slightly reduced by the
treatment system, and that physical and biological
treatments have a reduced effect on electrical
conductivity (Merghem et al., 2016). The quality
standards for irrigation water allows deducing
that treated wastewater is acceptable for crop irri-

gation. Similarly, these average values are below
2700 $\mu$S/cm, which is considered the limit value
for direct discharge into the receiving environ-
ment (Official Bulletin, 2002).

A strong increase in the concentration of dis-
solved oxygen in UV-TW is due to a good aera-
tion of water, necessary for the development of aerobic microorganisms ensuring the oxidation of organic matter (Deronzier et al., 2002). However,
in an activated sludge wastewater treatment, the
dissolved oxygen (DO) contained in the treated
water must be higher than 2 mg/l (Merghem et al.,
2016). The respect of these thresholds ($O_2>2$
mg/l) creates favorable conditions for both to-
total aerobic biodegradation and the establishment
of the nitrification phenomena. It is important to
note that dissolved oxygen is a good indicator of
the degree of water pollution and the presence
of aerobic bacteria capable of developing in the
environment.

The suspended solids (SS) concentrations
continue to change especially in spring and sum-
mer. In addition, the effluents from the Aourir
plant reflect remarkable particulate pollution,
especially in summer, which is explained by a ma-

or hydraulic spill due to significant domestic and
tourist activity in the region. The recorded val-
ues remain below the direct discharge limit value
(50 mg / L) throughout the monitoring period (Of-

icial Bulletin, 2002). It should be noted that sus-

pended solids represent all mineral and organic

carried in the water. It depends on the

nature of the land crossed, the season, the precipi-
tation, the nature of the discharges, etc. (Rodier
et al., 1959). It causes the water turbidity and a
reduction in light penetration. Turbidity also
indicates the presence of suspended solids, but high
turbidity allows microorganisms to attach to sus-
pended particles, which protects them from treat-
ment (Mouhanni et al., 2013). The removal of
suspended solids was able to reach a maximum
of 98% total removal in the UV-TW that under-
went final filtration. This result is even higher
than that of Hamoda et al., (2004) which man-
aged to reach 70% removal of suspended solids
after secondary water filtration. The same is true
for Petala et al., (2006), who managed to achieve
a turbidity removal percentage of about 45% after
sand filtration, while the activated carbon process
increased turbidity removal to more than 60%.
The study conducted by Bach et al., (2020) on
the performance comparison of two free biomass
treatment systems (aerated lagoon, activated
sludge), showed that the SS removal rates were
highest in the case of the activated sludge system
(96.6%–93.4%) and the lowest in the case of aera-
ted lagoon system (39.2%–67%) with an aver-
age difference of more than 43%. These results
allow concluding that the combination of the
investigated treatment system was successful in
removing particulate pollution.

The importance of monitoring organic pol-
lution parameters is summarized by the fact that BOD$_5$ (Biochemical Oxygen Demand) allows
the evaluation of biodegradable organic matter
present in water (Hassoune et al., 2006). COD
(Chemical Oxygen Demand) is used to assess the
concentration of organic or mineral matter dis-
solved or suspended in water, through the amount
of oxygen necessary for their total chemical oxida-
tion (Rodier et al., 1959). The results of biolog-
ical oxygen demand (BOD$_5$) and chemical oxy-
gen demand (COD) are related empirically to the
oxidizable matter (Bali et al., 2010). An increase
in the organic load was noticed during the second
year of sampling and significant difference was
recorded between the two sampling years $p<0.001$
(2017–2018). The concentrations of BOD$_5$ and
COD in UV-TW are less than 100 mg O$_2$/L and
500 mg O$_2$/L, respectively, considered as a limit
values for direct discharges into the natural envi-
ronment. The treatment efficiency of the Aourir
activated sludge can be summed up by the 95.5%
and 91.8% abatement recorded for BOD$_5$ and
COD, respectively. A great concordance between
the obtained results and those of Abdulla et al.,
(2020), who worked on activated sludge system
in Jordan, were noticed. They found that BOD$_5$
comes out with average values of 25 mg O$_2$/L, and
COD reaches an average value of 120 mg O$_2$/L;
these results were taken in 2017/2018 in the same
period of our study.

The Agadir region has several treatment
plants that treat most of the region’s effluents.
In order to have a general view on the treatment
efficiency of the Aourir plant, it is interesting to
compare the activated sludge system with other
treatment systems in the region. Mimouni et al.,
(2011) followed the efficiency of percolation infiltration in the Bensergao plant. The organic pollution abatement was very interesting; BOD$_5$ reaches a rate of 99.9% and 92.8% for COD. Mouhanni et al., (2013) followed the M’zar plant also equipped with a percolation infiltration system and showed an important treatment efficiency with a BOD$_5$ reduction rate of 98% and 98% for COD, Bourouache et al., (2019) continued the follow-up and confirmed the efficiency of the fixed biomass treatment (Table 8). The COD/BOD$_5$ ratio is a very important factor in assessing the biodegradability of the wastewater. The ratio is below 3 which designates a domestic effluent indicating a good biodegradability of the oxidizable material (Boutayeb et al., 2012). The BOD$_5$/COD ratio, gives more indication of the origin of wastewater pollution and its treatment possibilities (Benyakhlef et al., 2007). The values recorded show a high organic load and confirm the possibility of an easy biological treatment, being higher than 0.3. The BOD$_5$/COD ratio indicates a dominance of organic matter (Bouknana et al., 2014). The SS/BOD$_5$ ratio remains within the normal range between one and three. The ratio confirmed the organicity of the effluent and provided the information on sludge production (Quevedo et al., 2012). The term “oxidizable matter” (OM) corresponds to a weighted average of two global parameters the COD and the BOD$_5$, by assigning a double coefficient to BOD$_5$ (Rodier et al., 1959). The OM is a very useful parameter for assessing the pollutant load and possibility of connection of industrial plant to the municipal sewerage network. In reality, most organic materials become polluting only when they are found in excess in the environment (Bouknana et al., 2014).

Nitrate is the final product of aerobic stabilization of nitrogen compounds. It is considered the most stable oxygen compound present in water. In natural resources, the nitrate levels are often low (< 20 mg/l) (Baharvand & Daneshvar, 2019). The discharge of large amounts of wastewater is the most important source of nitrate to surface water more than to groundwater. The results of the nitrate content measurement of RW and UV-TW in the Aourir plant showed that the amount of nitrate in the treatment process is reduced. Moreover, they have indicated an acceptable result according to environmental standard threshold (< 30 mg/l). Consequently, the NO$_3$ removal efficiency is estimated at 63% during the water treatment process in the Aourir treatment plant. The concentrations of orthophosphates have significantly decreased in UV-TW; these values remain below the direct discharge limit value (10 mg/L) which demonstrates the purifying power of the activated sludge technique. However, this decrease is insufficient because it would be necessary to reach the values in the range of 0.6 to 1 mg/L to have a water with the same phosphate content as that existing in Moroccan rivers (Mimouni et al., 2011). The PO$_4^{3-}$ removal efficiency is estimated at 39% at the exit of the Aourir plant.

### Bacteriological parameters

Water disinfection is a treatment that aims to reduce the presence of pathogenic microorganisms in water. In order to comply with Moroccan standards, the Aourir plant uses UV radiation to disinfect BTW. Several criteria affect the effectiveness of UV treatment, with the insufficient energy dose damaging the genetic material of the organism rather than destroying it (Collivignarelli et al., 2018). High SS can significantly reduce the effectiveness of UV disinfection (Sharrer et al., 2005). In this sense, previous studies have shown that certain types of bacteria can easily pass through the treatment process while remaining viable (Fonteneau et al., 2017). TC, FC, E. coli and FS enumeration results at the RW levels of the Aourir plant represent a maximum bacterial load of 7.75 log$_{10}$ CFU/100 ml, 7.27 log$_{10}$ CFU/100 ml, 7.28 log$_{10}$ CFU/100 ml, 6.65 log$_{10}$ CFU/100 ml, respectively. This load is of the same order of magnitude as that generally found in urban effluent (Shahalam, 1989; Mezrioui & Baleux, 1994). In UV-TW, the bacterial load is lower than in RW, the average concentration of TC, FC, E. coli, and FS is 2.13 log$_{10}$ CFU/100 ml, 1.67 log$_{10}$ CFU/100 ml, 1.77 log$_{10}$ CFU/100 ml, 2 log$_{10}$ CFU/100 ml. This research showed that the UV disinfection of the Aourir plant was sufficient to provide the water that meets the Moroccan standards. The combination of UV disinfection and microfiltration gave interesting results. After treatment, wastewater poses a potential risk to human health and the environment, so constant monitoring is necessary. The obtained results were compared with those of Petala et al., (2006), who worked with a conventional activated sludge process followed by a system composed of a moving bed sand filter, a granular activated carbon adsorption bed and ozonation system as tertiary treatment. They indicated that an ozone
concentration of 7.1 mg/L in secondary effluents provoked a reduction of total coliforms to about 2.6 \log_{10}; fecal coliforms to about 3.3 \log_{10}; and to 0.7 \log_{10} of fecal streptococci. These results indicate that the disinfection applied in our case (UV) also has an effect close to that of ozonation. In turn, Lazarova et al., (1998), who studied disinfection technologies, indicated that 3-log removal of total coliforms, fecal coliforms and fecal streptococci were obtained by peracetic acid at 10 mg/L for a contact time of 10 min, by UV radiation at 35 mW.s/cm². Despite these results, ozonation has the advantage of having a significant effect on all types of bacteriophages and protozoan cysts, even when low treatment doses and short contact times are applied. Climatic conditions play an important role in the treatment process (Joel et al., 2018), which is most evident in monthly temperature fluctuations. Indeed, during the summer seasons of the study, significant loads were recorded. In the Aourir plant, it appears that the initial bacterial loads and climate change were the main factors influencing the bacteriological quality of the treated effluent. In Morocco, there is no standard for fecal streptococci. Although these organisms are very useful in providing more information on fecal contamination of the water (Boehm et al., 2014). It is therefore necessary to ensure continuous monitoring to assess the effect of seasonal variations on the different bacterial loads. The FC/FS ratio is a more valuable information tool for assessing sources of pollution than using the FC densities alone (Raji et al., 2015). Geldreich (1966) indicated that this ratio (FC/FS) could be used to differentiate between the contaminations from human sources, (FC/FS > 4), domestic animals (FC/FS between 0.1 and 0.6), and wildlife (FC/FS < 0.1). In the performed study, the ratio of FC/FS is around 3.39, which allows deducing that most of the pollution is of human origin. The abatement rates for fecal contamination indicators, recorded in the Aourir plant, are in agreement with the values found in the literature, which show that biological processes can reduce coliform abundance from 3 to 4 logarithmic units. It is in the order of 90% for activated sludge (Omura et al., 1989), 99% for extended activated sludge and for fixed culture reactors, and 99% for lagooning (Finch et al., 1986). These abatement rates are related to the settling rate, the hydraulic residence time, and the quality of the raw wastewater. In the case of this study, the rate of reduction of fecal contamination indicators seems very important for the different parameters. The efficiency of the treatment of Total Coliforms, Fecal Coliforms, *Escherichia coli*, Fecal Streptococci is in the order of 4.92; 4.8; 5.13 and 4.57 \log_{10}, respectively, which equals an efficiency of 99.99% for all parameters. Therefore, it can be deduced that the adopted treatment represents a high efficiency and performance.

**Correlation between physicochemical and microbiological parameters of raw and treated wastewater**

The correlations between physicochemical and bacteriological parameters for both types of water (RW, UV-TW) are detailed in Table 6 and 7. For RW, the physicochemical parameters were not significantly correlated with the concentrations of TC, FC, FS and *E. coli* except for conductivity which is significantly correlated with the TC concentrations (r=0.612, p=0.034). For UV-TW, FC and *E. coli* concentrations have significant positive correlation with electrical conductivity and dissolved oxygen. For FC, a correlation of (r=0.659, p=0.020) with electrical conductivity, and (r=0.712, p=0.009) with dissolved oxygen. *E. coli* has a correlation of (r=0.695, p=0.012) with electrical conductivity and (r=0.602, p=0.038) with dissolved oxygen. SF also represents a significant positive correlation with dissolved oxygen of (r=0.797, p=0.002). The correlation between the physicochemical and microbiological parameters did not show a high correlation except for the dissolved oxygen and the electric conductivity. Contrary to Pearson et al., (1987)

| Table 5. Abatement of Bacteriological parameters |
|-----------------------------------------------|
| Type of water | RW | BTW | UV-TW | Abatement U-log | Abatement % |
|----------------|------------------|---------------|-----------------|-----------------|-------------|
| TC \log_{10} CFU/100 ml | 7.05±0.18 | 3.35±0.04 | 2.13±0.05 | 4.92 | 99.99 |
| FC \log_{10} CFU/100 ml | 6.47±0.04 | 2.83±0.09 | 1.67±0.06 | 4.8 | 99.99 |
| *E. coli* \log_{10} CFU/100 ml | 6.9±0.05 | 3.68±0.06 | 1.77±0.08 | 5.13 | 99.99 |
| FS \log_{10} CFU/100 ml | 6.02±0.05 | 2.74±0.06 | 1.45±0.06 | 4.57 | 99.99 |
who showed a correlation between the FC and the Temperature and the pH, it explains that the temperature and the high pH favor the mortality of coliforms in the waters. Other studies of seasonal variation in bacterial flora of the wastewater and soil in the vicinity of industrial area by Malik et al. (2002), recorded the effect of physicochemical parameters on the fecal coliform variability. The observed relationship between dissolved oxygen and fecal contamination indicator bacteria is directly related to the essential factors of aeration treatment where oxygen is an essential factor for treatment. The effect of physicochemical parameters on bacteria was also summarized in the study by Rosenfeld et al. (2006). He found that the load of fecal indicator bacteria is not only related to seasonal, spatial or source variability. It is also related to the fact that each type of bacteria dies at a different rate depending on environmental factors (temperature, salinity, nutrient concentration, predation, the presence or absence of bacteria, absence of bacterial toxins, solar radiation, coagulation, flocculation, and particle adsorption), all of which have an impact on the ultimate death of bacteria.

**CONCLUSIONS**

In Agadir, many studies have been conducted on the process of sand percolation infiltration on different aspects: physicochemical, microbiology and parasitology (Table 8). This research presents the specification to study a new system implemented in the region (activated sludge), and investigate its operation in a semi-arid climate. Monitoring of the microbiological and physicochemical parameters in all types of waters from Aourir treatment plant made it possible to assess their quality. The quality and quantity of wastewater that the Aourir plant receives depend essentially on the quantity of water consumed by the population. They also depend on the intensity of tourist activities according to the seasons. This causes fluctuations in the level of physicochemical and microbiological pollution of effluents.
during the year. The following conclusions were drawn from this study: All parameters were in accordance with the Moroccan standards. UV-TWs distinguished for the watering of green spaces meet the criteria set by the Moroccan and WHO reuse standards. However, UV control is necessary in order to take appropriate preventive measures to reduce the health risk and prevent further pollution of green spaces and groundwater. As a perspective, the authors are planning to study the effect of reuse of treated wastewater on irrigated green spaces.

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Table 8. Purifying performance of wastewater treatment plants in the Agadir region.

| Studies          | Location            | Treatment process | Treatment system | Performance |
|------------------|---------------------|-------------------|------------------|-------------|
| Mimouni et al., (2011) | Bensrgao (Agadir, Morocco) | Infiltration-percolation | Primary decanting | SS | BOD5 | COD | FC* | FS* |
|                  |                     |                   | Sand filtration | - | 75% | 99.9% | 92.8% | 5.38 | 4.4 |
| Eddabra, (2011)  | Drarga (Agadir, Morocco) | Infiltration-percolation | Primary decanting | Secondary treatment | - | - | - | - | 4.51 | 3.93 |
| El Heloui et al., (2016) | Tiznit (Morocco) | Natural lagoon | Anaerobic basin | Facultative Basin | Maturity Basin | 71% | 88.75% | 91.39% | 4.37 | - |
| Mouhanni et al., (2013) | M’zar (Agadir, Morocco) | Infiltration-percolation | Primary decanting | Secondary treatment | UV | 99.08% | 99.55% | 97.41% | 3.73 | 3.49 |
| Our studies      | Aourir (Agadir, Morocco) | Activated sludge | - | Aeration basin, clarification | Microfiltration, UV | 98% | 96% | 91.80% | 4.9 | 4.5 |

FC*, FS* abatement in U-log
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