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Annual Variation in the Performance of Settat Wastewater Stabilization Ponds Located in Settat City, Morocco

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ABSTRACT

The wastewater treatment plant of Settat city uses the natural lagooning technology, which requires low maintenance cost and little technical expertise. The purpose of this study was to evaluate the stability of plant performance during two years of operation (2019 and 2020), as well as the safety of its treated wastewater for reuse in agricultural irrigation. The results of this study show that the biochemical oxygen demand (BOD_5), chemical oxygen demand (COD) and suspended solids (SS) did not exceed the Moroccan standards for discharge. They also show a good stable pollutant load reduction with a mean of 86.44%, 86.89% and 74.61%, for BOD_5, COD and SS, respectively. On the other hand, microbiological characterization classifies the treated wastewater as "B" quality water, because the fecal coliform numbers exceed the requirement for "A" quality (1000 CFU/100 ml).

Keywords: wastewater, natural lagoon, biochemical oxygen demand, chemical oxygen demand, suspended solids, sewage treatment, wastewater reuse in agriculture.

INTRODUCTION

Water is a precious asset that suffers from various types of pollution: industrial, domestic, and agricultural. The discharge of untreated or undertreated wastewater has serious consequences, such as biological alteration and imbalance, as well as adverse effects on the environment and human health. The volume of raw wastewater is expected to increase significantly in the coming years, especially in large and rapidly growing cities.

According to Amadou [2007], the development of human activities inevitably leads to increasing water consumption, which contributes to a decrease in water quality, resulting in health and environmental damage, and hence the need to treat these waters before they are released, in order to eliminate all the polluting elements they contain, whether chemical or organic.

In Morocco, the interest toward wastewater treatment began relatively late (at the beginning of the 21st century) with the implementation of several new functional water resource recovery facilities. The Settat water stabilization ponds, also called natural lagooning facility, were commissioned in March 2006.

A study conducted by Bouzidi and Boutayeb in 2013 showed that this plant yields good performance in BOD_5, COD and SS reduction. Therefore, through this work, the authors propose carrying out a more thorough evaluation of the evolution of this plant performance 6 years after the cited work. The results from physicochemical, microbiological and parasitological parameters analyzed 20 times spanning two years will be presented, and concluded toward the suitability and safety of treated water reuse in agricultural irrigation.

MATERIALS AND METHODS

Study site

The site of the wastewater treatment plant (Fig. 1) being subject of the study, is located about 8 km from the town of Settat, which is characterized by a subhumid to semi-arid climate with temperate winters and quite hot summers; the average temperatures vary between 11 °C and 25 °C and the average annual precipitation reaches 350 mm [Bouregreg and Chaouia Hydraulic Basin Agency, 2004]

The Settat wastewater treatment plant was commissioned in April 2006, its surface area is approximately 80 hectares. It is sized to receive a nominal flow rate of 13.500 m^3/day and to treat a pollutant load of 6100 Kg BOD_5/day (175.000 population equivalent). This facility only treats the domestic wastewater of Settat City.

The facility consists of:

- Preliminary treatment: A screen which removes large waste such as bottles, plastic bags, etc., and a grit removing canal which allows sand to decant.
- 6 anaerobic ponds: These are the deepest basins; they are 3 meters deep. This depth favors the anaerobic conditions. The retention time is between 3 and 4 days.
- 3 facultative ponds: They are 1.5 meters deep and are characterized by a green color that is the result of the symbiosis between the surface algae and aerobic bacteria. The retention time is 17 days.
- 3 maturation ponds: These are the shallowest basins with a depth of 1.2 meters. This shallow depth allows the reduction of pathogenic bacteria by exposure to solar UV rays. These basins are characterized by a blue color, which is due to the prevalence of zooplankton on phytoplankton, and the retention time is 17 days. These basins can also function as facultative basins by increasing their depth to 1.5 meters.

Sampling methodology

As part of this work, sampling was carried out 20 times over two years (2019 and 2020). The samples were taken at the entrance and exit of the plant by an automatic sampler that takes a water sample every hour. At the end of the day, a composite sample was obtained by combining the 24 samples in proportion to the measured flow [Bouzidi et al., 2012]. The water samples were stored in a cooler that maintained a temperature of 4 °C in accordance with the general guide for the conservation and handling of samples (ISO 5667/3).

The analysis was carried out according to the Moroccan standards, which are similar to the AFNOR standards, supplemented by the analytical techniques recommended by Rodier and Legube [2009].

Physic-chemical parameters

The pH, temperature, electrical conductivity, redox potential, and dissolved oxygen are the

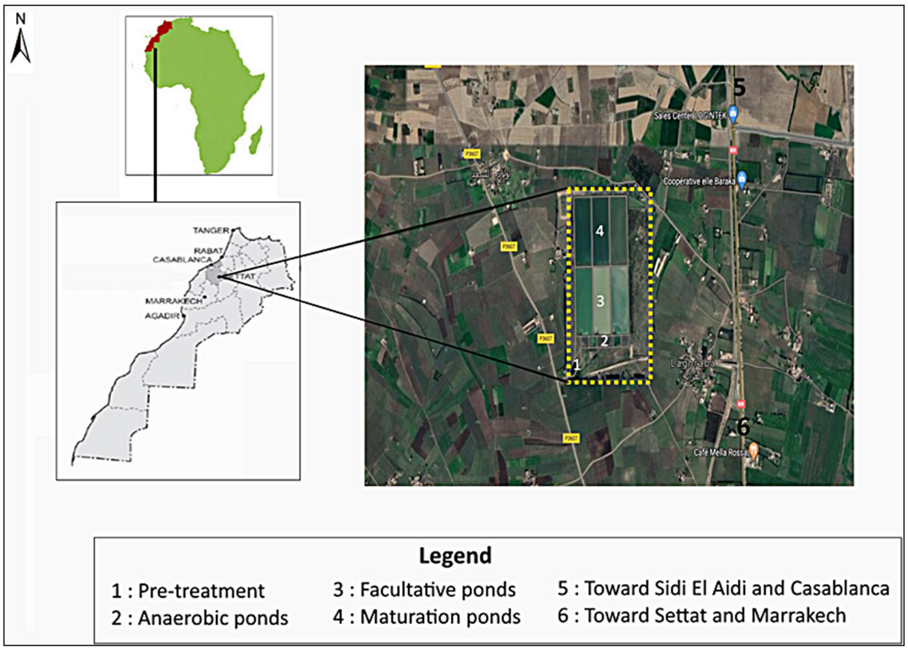

Figure 1. Location of the Settat wastewater treatment plant

parameters that were measured in situ by a multi-parameter meter, while biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), suspended matter (SS), Ammonium (NH_4), Nitrates (NO_3), Nitrites (NO_2), Total Kjeldahl Nitrogen (TKN), Total Nitrogen (TN), Orthophosphates (OP) and Total Phosphorus (TP) were measured in the laboratory within 24 hours of the sampling date.

Bacteriological and parasitological parameters

The total coliforms (TC), fecal coliforms (FC) and fecal streptococci (FS) were monitored using the membrane filtration methods. Helminth eggs were counted using the sedimentation method by Bailenger. The Table 1 shows the methods used for the analysis of physico-chemical, bacteriological and parasitological parameters.

RESULTS AND DISCUSSION

In-flow and Out-flow

The average in-flow registered during the 20 measuring campaigns over 2 years was 12,253.07 cum/d with a standard deviation of 319.71 cum (Fig. 2.A). This average has not yet reached the design flow (13.500 cum/d) which means that the facility should still be working within normal conditions regarding volume loads.

The measured average out-flow was 7,628.34 cum/d with a standard deviation of 413.54 (Fig. 2.A). It has to be pointed out that the water flow was reduced by 37.7% on average. This reduction may be due to evaporation [Hamid et al., 2014] but infiltration is also suspected as the lagoons have been made waterproof using compacted clay which could show some flaws after years of use.

pH

The average pH at the facility inlet is 7.46 with a standard deviation of 0.21 (Fig. 2.B). This average is identical to that found at the plant of Imzouren (7.46) [Diman et al., 2016] and very close to that found in the other Moroccan similar plants of Azilal (7.35) [Idrissi et al., 2015] and Dar El Gueddari (7.68) [Ayyach et al., 2016]. The value obtained at the inlet does not exceed the entry limit values (between 5.5 and 8.5) according to the sanitation specifications of the Autonomous Distribution Authority of Water and Electricity of Chaouia (RADEEC), which is to be expected in domestic wastewater.

Table 1. Methods used for the analysis of physico-chemical, bacteriological and parasitological parameters

Parameters	Method	Unit
Physic-chemical parameters		
pH (measured in situ)	NM ISO 10523 (2012)	-
Temperature (measured in situ)	NF T90-100	°C
Potential REDOX (measured in situ)	NM ISO 7888 (2001)	mV
Conductivity (measured in situ)	NM ISO 7888 (2001)	µs/cm
Dissolved oxygen (measured in situ)	NF EN 25-813	mg/l
Ammonium	NM ISO 7150-1 (1999)	mg/l
Nitrites	NM ISO 6777 (1999)	mg/l
Nitrates	NM ISO 7890-3 (2012)	mg/l
Total Kjeldahl Nitrogen	NM ISO 5663 (2001)	mg of N/l
Total Nitrogen	NF T 90-110	mg/l
Orthophosphates	COL/007-a	mg/l
Total Phosphorus	NM ISO 6878-1 (1999)	mg/l
BOD_5	NM EN 5815-1 (2012)	mg of O_2/l
COD	NM ISO 15705 (2014)	mg of O_2/l
SS	NM EN 872 (2013)	mg/l
Bacteriological and parasitological parameters		
Fecal streptococci	NM ISO 7899-2 (2007)	CFU/100 ml
Fecal coliforms	NM ISO 9308-1 (2007)	CFU/100 ml
Total coliforms	NM ISO 9308-1 (2007)	CFU/100 ml
Helminth eggs	NM ISO 7899-2 (2007)	U/l

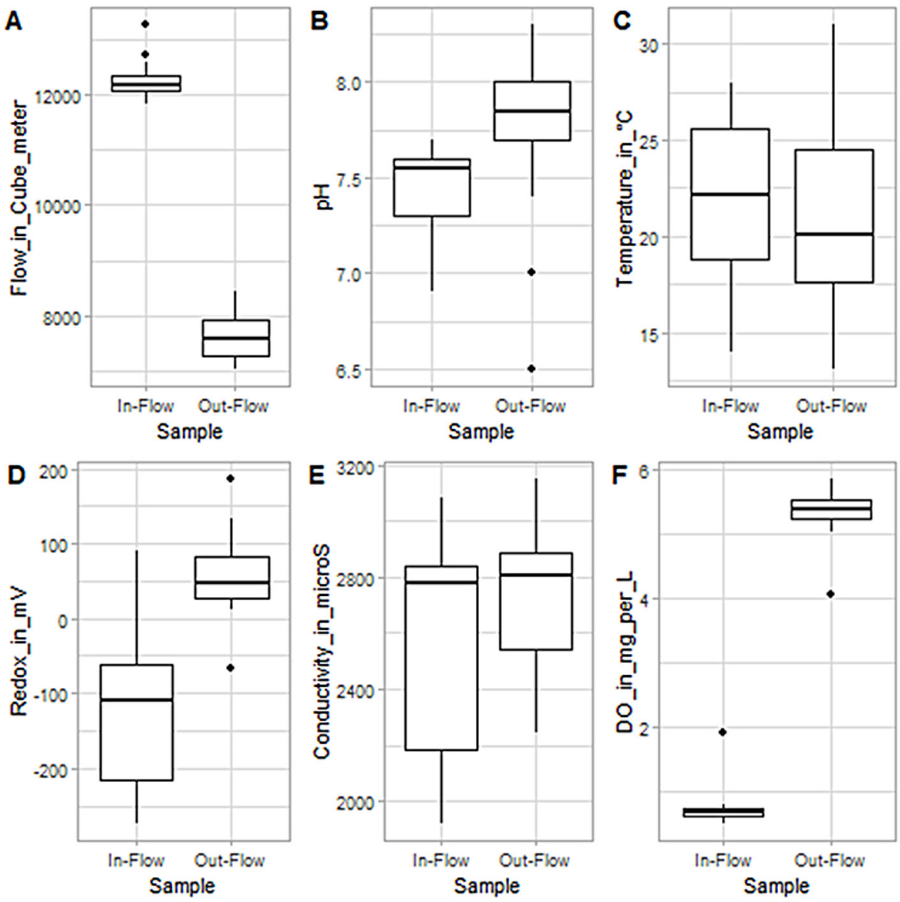

Figure 2. Variation in average values of flow (A), pH (B), temperature (C), redox potential (D), electrical conductivity (E) and dissolved oxygen (F) at the entrance and exit of the plant

The average pH at the outlet is 7.76 with a standard deviation of 0.4 (Fig. 2.B). This value is also similar to the values found in Azilal [Idrissi et al., 2015] and Dar El Gueddari [Ayyach et al., 2016], which are 7.79 and 7.74, respectively, while it is lower than that found in Imzouren (8.04) [Diman et al., 2016].

It was noted that the pH has a slight tendency towards alkalinization from inlet to outlet. It may be linked to the high photosynthetic activity due to the development of algae in facultative and maturation ponds, but all the values obtained at the outlet are within the range of direct discharge limits and within the range of the Moroccan water quality standards for irrigation [Secretariat of State to the Ministry of Energy, Mines, Water and the Environment, responsible for Water and the Environment, 2007].

Temperature

The average temperature at the entrance of the facility during the study period was 21.43 °C with a standard deviation of 4.57 (Fig. 2.C). This value does not exceed the entry limit value of 30 °C, according to the conditions set by the water distribution company (RADEEC), as is to be expected from domestic wastewater without industrial effluent that could influence the temperature of water. The average temperature at the plant entrance is close to that of Imzouren (22.4 °C) [Diman et al., 2016] and Errachidia (23.5 °C) [Hamid et al., 2014], but is lower than that recorded at Dar El Gueddari (26.4 °C) [Ayyach et al., 2016] and higher than the average temperature of the plant of Azilal (15.75 °C) [Idrissi et al., 2015].

At the exit of the plant, the average was 20.78 °C with a standard deviation of 4.97 (Fig. 2.C). This average is lower than the value found in Imzouren [Diman et al., 2016], Errachidia [Hamid et al., 2014] and Dar El Gueddari [Ayyach et al., 2016], which are 22.9 °C, 23 °C and 26.5 °C, respectively, but it remains higher than that of the plant of Azilal (17.57 °C) [Idrissi et al., 2015]. All the values obtained at the outlet are included in the range of the limit values for direct discharge to the receiving environment and in the range of the Moroccan water quality standards for irrigation

[Secretariat of State to the Ministry of Energy, Mines, Water and the Environment, responsible for Water and the Environment, 2007].

Aside, it was noted that there is no set pattern to the change in temperature between the inlet and outlet, as the outlet temperatures were recorded lower 7 times, equal 3 times and higher than the inlet 2 times. The temperature at the inlet should be directly influenced by the air temperature but at the outlet, several factors could influence it, such as sunlight exposure, wind and pond water mixing.

Redox potential

During the study, all the values of the redox potential obtained at the inlet were negative, except for those of the months of February 2019 and December 2020 which recorded a positive value that may be aberrant due to temporary oxygenation of the water due to turbulences. The average value of the redox potential obtained at the input is -118.66 mV with a standard deviation of 98.43 (Fig. 2.D). This average is much lower than that found at Azilal (-14.9 mV) [Idrissi et al., 2015]. From these results, the wastewater in the town of Settat can be characterized as reducing, according to Rodier [2005]. Unlike the values obtained at the input, all the values recorded at the output are positive with an average of 51.67 mV with a standard deviation of 59.06 (Fig. 2.D) which is very high compared to that recorded at Azilal (-19 mV) [Idrissi et al., 2015]. The Redox values are correlated with the presence of oxygen and so the higher values recorded at the outlet attest to good water purification.

Electrical conductivity

The average electrical conductivity value obtained at the entrance of the water treatment plant was 2575.3 µs/cm with a standard deviation of 384.33 (Fig. 2.E). This mean is lower than those of the plants of Imzouren [Diman et al., 2016], Errachidia [Hamid et al., 2014] and Azilal [Idrissi et al., 2015] and which are 3031 µs/cm, 2843 µs/cm and 3485.4 µs/cm, respectively.

The mean electrical conductivity of treated wastewater is 2729.25 µs/cm with a standard deviation of 263.33 (Fig. 2.E). This average is very close to that found at Imzouren (2598 µs/cm) [Diman et al., 2016], as well as lower than the averages recorded at Errachidia [Hamid et al., 2014] and Azilal [Idrissi et al., 2015], which are 2846 µs/cm and 3800 µs/cm, respectively.

During the study period, it was noticed that the electrical conductivity during some months exceeds the Moroccan standards for the quality of water intended for irrigation [Secretariat of State to the Ministry of Energy, Mines, Water and the Environment, responsible for Water and the Environment, 2007]. The high values recorded at the exit of the plant during the months mentioned above can be explained by the relatively high conductivity of domestic wastewater in the town of Settat, which reflects the conductivity of drinking water. In addition, the water undergoes a concentration effect due to the evaporation of the water in the basins, which results in higher conductivity values at the outlet compared to the values recorded at the inlet.

Dissolved oxygen

The average concentration of dissolved oxygen at the entrance of the plant is very low and remained around 1 mg/l, due to the high organic load in the raw wastewater from the town of Settat. The value of this average is 0.74 mg/l with a standard deviation of 0.28 (Fig. 2.F), and it is lower than those of Imzouren (1.14 mg/l) [Diman et al., 2016] and Azilal (1.12 mg/l) [Idrissi et al., 2015].

At the outlet, the degradation of this pollution during the wastewater treatment process led to higher concentrations of oxygen with an average of 5.33 mg/l and a standard deviation of 0.36 (Fig. 2.F). The latter is close to the average dissolved oxygen concentration of the plant of Imzouren (5.19 mg/l) [Diman et al., 2016], and higher than that of the plant of Azilal (2.15 mg/l) [Idrissi et al., 2015]. A high oxygen concentration at the outlet of the plant is an indicator of good organic degradation performance.

Biochemical oxygen demand (BOD_5)

The average biochemical oxygen demand (BOD_5) obtained at the entrance of the plant was 564.95 mg of O_2/l with a standard deviation of 42.13 (Fig. 3). The average value obtained is higher than those obtained at Azilal (433.9 mg of O_2/l) [Idrissi et al., 2015], Imzouren (484.11 mg of O_2/l) [Diman et al., 2016], Errachidia (484.23 mg of O_2/l) [Hamid et al., 2014], and Dar El Gueddari (368 mg of O_2/l) [Ayyach et al., 2016]. The organic load average recorded was 6944.62 kg BOD_5/day. This average is well above the design value (6100 kg BOD_5/day). According to the results obtained for the organic load at the input of the plant, it can be said that the capacity of the organic load is exceeded.

The BOD_5 average recorded at the outlet was 76.3 mg of O_2/l with a standard deviation of 4.96 (Fig. 3). This mean, as well as all the values obtained, are lower than the current limit values specific to domestic discharges (120 mg of O_2/l) (Order n°1607-06 of 29 joumada II 1427 (25 July 2006)). The average value obtained is much higher than the value calculated in the article by Bouzidi et al., in 2012 (30.72 mg O_2/L) which shows that the performance of the plant has declined over time. However, compared to the values obtained by 2 other natural lagooning plants in Morocco (80 mg of O_2/l and 85 mg of O_2/l, respectively, in Imzouren [Diman et al., 2016] and Errachidia [Hamid et al., 2014]) the values are close and clearly lower than those obtained at the outlet of 2 other similar plants (192.7 mg of O_2/l and 121 mg of O_2/l, respectively, at Azilal [Idrissi et al., 2015] and Dar El Gueddari [Ayyach et al., 2016]).

Chemical oxygen demand (COD)

The average of the chemical oxygen demand (COD) obtained at the inlet of the plant was 888.1 mg of O_2/l with a standard deviation of 59.48 (Fig. 3). This recorded value is almost similar to those found at the wastewater treatment plants of Imzouren (878.15 mg of O_2/l) [Diman et al., 2016], Errachidia (845.28 mg of O_2/l) [Hamid et al., 2014] and Dar El Gueddari (822.9 mg of O_2/l) [Ayyach et al., 2016], as well as lower than those found in Azilal (1120.10 mg of O_2/l) [Idrissi et al., 2015].

The average COD value at the outlet was 116.1 mg of O_2/l with a standard deviation of 11.2 (Fig. 3). This result is very close to the results noted in Imzouren (127.73 mg of O_2/l) [Diman et al., 2016], and in Errachidia (142 mg of O_2/l) [Hamid et al., 2014], while they are lower than those obtained in Dar El Gueddari (328.2 mg of O_2/l) [Ayyach et al., 2016] and in Azilal (500.16 mg of O_2/l) [Idrissi et al., 2015]. The COD values at the outlet of the plant did not exceed the limit value set by the current Moroccan limit values specific to domestic discharge (Order n°1607-06 of 29 joumada II 1427 (25 July 2006)) for any given month.

Suspended Solids (SS)

The average suspended solids (SS) value was 399.87 mg/l with a standard deviation of

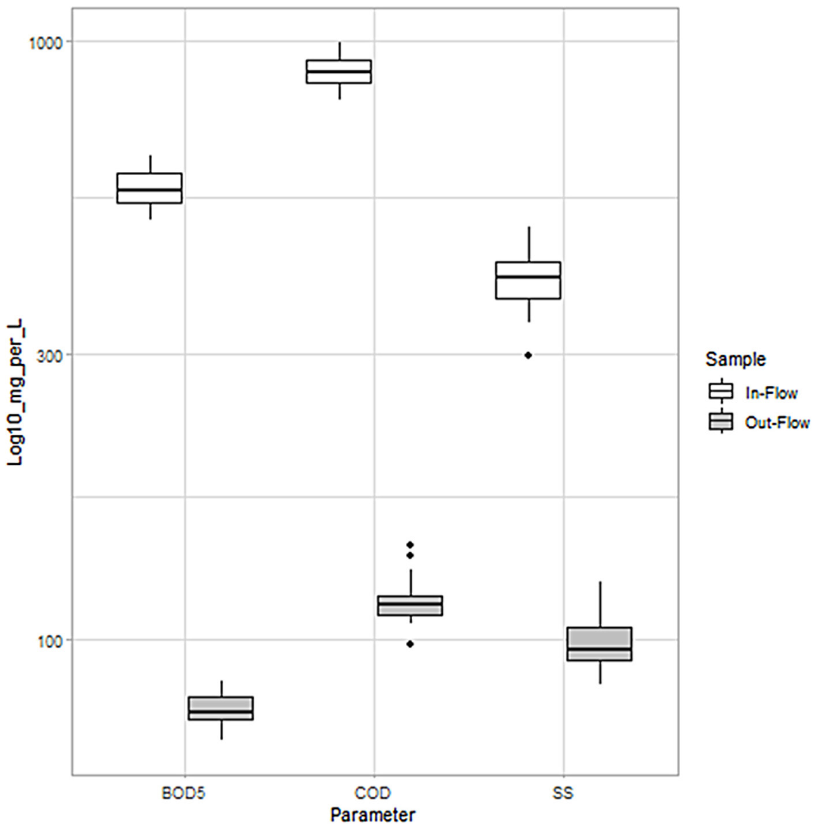

Fig. 3. Variation in average values of biochemical oxygen demand (BOD_5), chemical oxygen demand (COD) and suspended solids (SS) at the entrance and exit of the plant

48.21 (Fig. 3). The latter is almost similar to those found in the treatment plants of Azilal [Idrissi et al., 2015], Imzouren [Diman et al., 2016], Errachidia [Hamid et al., 2014] and Dar El Gueddari [Ayyach et al., 2016] and which are 559.38 mg/l, 341.3 mg/l, 499 mg/l and 325.2 mg/l, respectively.

The average SS obtained at the outlet was 99.79 mg/l with a standard deviation of 10.73 (Fig. 3). This average is clearly lower than that found at Azilal (470.61 mg/l) [Idrissi et al., 2015], while it is almost similar to the values found at Imzouren (75.7 mg/l) [Diman et al., 2016], Errachidia (54 mg/l) [Hamid et al., 2014] and Dar El Gueddari (92.2 mg/l) [Ayyach et al., 2016]. All SS values obtained at the exit of the plant throughout the study period do not exceed the current specific limit values for domestic discharge (Order n°1607-06 of 29 joumada II 1427 (25 July 2006)).

Ammonium, Nitrites, Nitrates, Total Kjeldahl Nitrogen and Total Nitrogen

Figure 4 shows that the Total Nitrogen (Inflow = 97.3, sd = 6.6, Outflow = 34.4, sd = 6.4) in the In-Flow and Out-Flow samples is mostly constituted of Kjeldahl Nitrogen (Inflow = 96.9, sd = 6.3, Outflow = 34.1, sd = 6.4). Thus, the Ammonium ion (Inflow = 75.6, sd = 6.9, Outflow = 38.6, sd = 12.3) and Organic Nitrogen are the most prevalent forms of nitrogen raw and treated wastewater in Settat. The oxidized forms are minimal even in the treated wastewater: Nitrates (Inflow = 0.4, sd = 0.2, Outflow = 0.3, sd = 0.1) and Nitrites (Inflow = 1.3, sd = 0.7, Outflow = 3.6, sd = 0.6). The minimal values of the oxidized forms of nitrogen show that the treated wastewater has not yet reached equilibrium and that there was not enough oxygen for the nitritation and nitratation phenomena. The diminution of Ammonia must be mostly due to intake by Algae, as Valero et al., [2007] showed in their study of maturation ponds that algal uptake of ammonium and subsequent sedimentation and retention in the sludge layer, after partial ammonification of the algal organic nitrogen, appears to be the dominant mechanism for permanent nitrogen removal in maturation ponds [Valero et al., 2007].

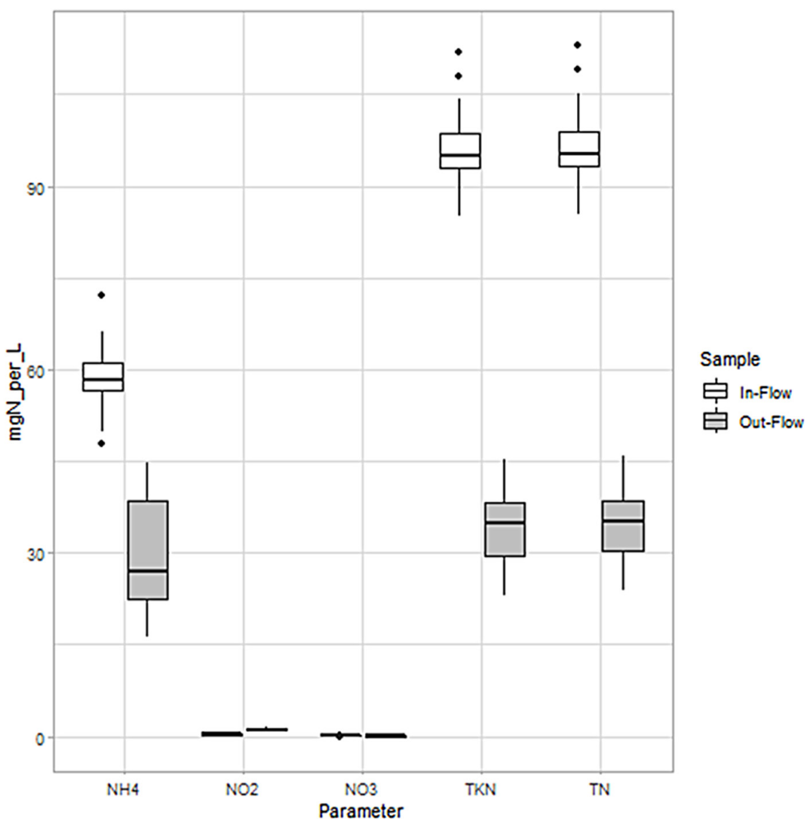

Figure 4. Variation in average values of ammonium (NH_4), nitrites (NO_2), nitrates (NO_3), total Kjeldahl nitrogen (TKN) and total nitrogen (TN) at the entrance and exit of the plant

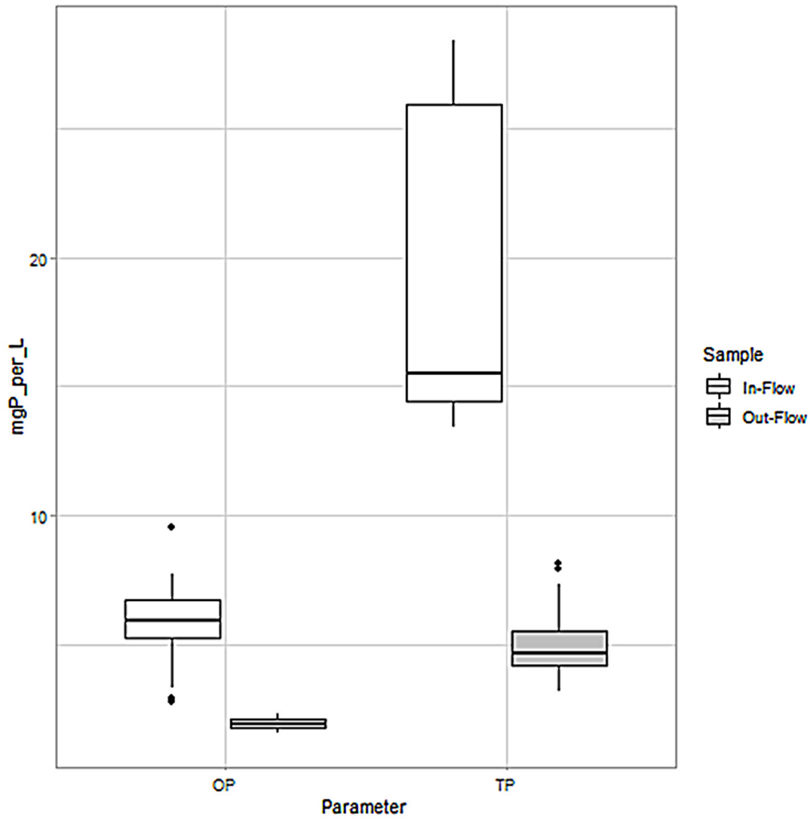

Figure 5. Variation in average values of orthophosphates (OP) and total phosphorus (TP) at the entrance and exit of the plant

Orthophosphates and Total Phosphorus

Both the Orthophosphates (Inflow = 17.8, sd = 5.2, Outflow = 5.9, sd = 0.7) and the Total Phosphorus (Inflow = 19.4, sd = 6.1, Outflow = 5.1, sd = 1.4) show a clear diminution (74% for OP and 69% for TP) in the outflow compared to the inflow (Fig. 5). This is better than generally obtained in wastewater stabilization ponds (WSP), as Phosphorus removal in WSP is generally low between 15 and 50% [Powell, 2009]. Phosphorus removal is mostly due to algal and bacterial uptake as well as sediment adsorption [Crites and Tchobanoglous, 1998], so ideal conditions for this removal could have been met in the facility (high phosphorus concentrations, high light intensity, warm temperature and shallow maturation ponds).

It was also noted that the TP inflow shows greater dispersion of the results compared to the outflow, which indicates that the phosphorus quantity in the Settat domestic wastewater varies greatly. This could influence the N/P ratio and have an effect on the algal population in the facultative and maturation ponds. In fact, eutrophication events, where the algae cover parts of the ponds, are observed several times a year.

Wastewater treatment yields

The purification yield of a facility is the ratio of the pollution eliminated over the pollution received; it defines the performance of the plant. The yield = 1 (Outlet/Inlet).

The average purification yield of the biochemical oxygen demand (BOD_5) during the study period was 86.44%. For the chemical oxygen demand (COD), the average was 86.89%. As for suspended solids (SS), the average of purification efficiency of this parameter was 74.61%.

From these results, it can be said that the wastewater treatment plant of Settat guarantees a significant reduction in the pollutant load by ensuring good purification yields for biochemical oxygen demand (BOD_5), chemical oxygen demand (COD) and suspended solids (SS). However, by comparing the obtained results with those found by Bouzidi and Boutayeb in 2013 (Table 2), an improvement in the yield of the chemical oxygen demand (COD), and deterioration in the yield of the biochemical oxygen demand (BOD_5) and suspended solids (SS) can be noticed. This deterioration of the above-mentioned parameters is explained by the fact that the facility is currently running at an organic load that exceeds

Table 2. Rate of reduction of the parameters BOD_5, COD and SS

Results	%Yield		
	Biochemical oxygen demand (BOD_5)	Chemical oxygen demand (COD)	Suspended solids (SS)
Our results	87.04	87.25	77.01
Results found by Bouzidi and Boutayeb (2013)	92	84	88

its theoretical capacity, as well as the fact that the sludge has not been removed from anaerobic ponds for more than 3 years. The deposition of sludge in the basins during years of operation results in a reduction in the residence time of the wastewater in these basins and consequently a reduction in the purification efficiency of the plant.

Coefficient of biodegradability COD/BOD_5

Wastewater can be classified into two categories: biodegradable and non-biodegradable. The biodegradability of the effluent is defined by calculating the coefficient of biodegradability of raw water effluents. This coefficient is calculated by the COD/BOD_5 ratio and depends on the origin and nature of the wastewater which can be domestic or industrial, which requires different treatments according to Bouzidi et al. [2012]. For raw wastewater, this ratio is generally between 1.25 and 2.5. If it is between 3 and 7, the wastewater can hardly be biodegradable [Bouzidi et al., 2012].

For raw wastewater, the average is 1.57. This average is lower than that calculated by Bouzidi et al., in 2012 on the same water treatment plant (2.35), which indicates an improvement in the biodegradability of Settat wastewater. It is also lower than the biodegradability coefficients found at Azilal (2.58) [Idrissi et al., 2015], Berrechid (2.35), El Gara (2.07), Ben Ahmed (2.48) and Soualem-Sahel (2.87) [Bouzidi et al., 2012]. From these results, it can be clearly observed that the raw wastewater from the city of Settat is biodegradable and the values obtained confirm the absence of industrial discharge connected to the sewerage network.

It was also noted that in contrast to the results obtained by Bouzidi et al., in 2012, the biodegradability coefficient does not rise from the inlet to the outlet. In fact, this coefficient does not change much between the inlet and outlet. This could mean that the effluent is not yet stabilized and more organic matter could be biodegraded. This claim is strengthened by the fact that BOD_5 at the outlet obtained in this study is much higher than the one calculated from the article by Bouzidi et al., in 2012 (76.33 and 30.72 mg/l, respectively).

As for the Moroccan lagooning plants cited before, it was noted that the biodegradability coefficient either stays stable or even decreases. The values in Imzouren [Diman et al., 2016], Errachidia [Hamid et al., 2014], Dar El Gueddari [Ayyach et al., 2016] and Azilal [Idrissi et al., 2015] are respectively for 1.81, 1.75, 2.24 and 2.58, respectively for the inlet and 1.60, 1.67, 2.71 and 2.60, respectively, for the outlet. It could be due to the fact that the effluent in not yet stabilized and other factors could weigh in such as the presence of algae or the elimination of non biodegradable matters by some mechanism other than bacterial degradation such as adsorption.

Correlation test with temperature and precipitations

In the Settat lagooning facility, the conceptual retention time is 40 days. Thus, in order to explore the relationship between the weather and some important parameters, the authors chose to study the correlation between the output samples of the following parameters (SS, COD, BOD_5, TN, TP and FC) and the average temperature (Tm40) as well as the total precipitations (P40) during the 40 days preceding the sampling.

The temperature and precipitation data were recorded in the Nouasser weather station (601560 (GMMN)), which is the nearest station to the Settat facility. The data was obtained through the en.tutiempo.net/climate website.

From Table 3 it can be concluded that the SS, COD, BOD_5, TN and Tm40 values are normally distributed (p value > 0.05), while the TP, FC and P40 values are not normally distributed. This will reflect on the type of correlation tests applicable. Pearson test was applied between the normally distributed parameters while the Spearman and Kendall tests were applied when the normality assumption was not verified.

Table 3. Shapiro-Wilk normality test

Parameter	SS	COD	BOD_5	TN	TP	FC	Tm40	P40
W	0.91	0.91	0.96	0.97	0.89	0.66	0.91	0.82
p value	0.07	0.06	0.51	0.71	0.02	1.36E-05	0.07	1.68E-03

The results of the correlation test (Table 4) show that, surprisingly, the variation of the temperature and precipitations do not have much of an impact on the output of the Settat lagooning facility, except for a mediocre negative correlation between the Total Nitrogen and the average temperature 40 days before sampling. It may be due to the fact that during the two years of the study, the average temperature variation was moderate (18 °C ± 4.5 with a maximum of 24.4 °C and a minimum of 11.1 °C) and the microbial community is well adjusted to this climate, so the organic and nutrient yield is stable.

As for the precipitations, despite the fact that the Settat sewage system is combined and the facility receives diluted wastewater during rain events, there was no correlation with any of the studied parameters. It may be due to the fact that 2019 and 2020 were dry years compared to the average (respectively 227 and 305 mm compared to the average 350 mm). It may also be due to the fact that the facility is equipped with a storm spillway which limits the amount of rainwater that reaches the lagoons during rain events.

Fecal streptococci, fecal coliforms and total coliforms

For bacteriological and parasitological analyses, the germs sought in the samples of the water analyzed are fecal streptococci, fecal coliforms, total coliforms and helminth eggs.

The results obtained from bacteriological analyses at the inlet reveal the presence of germs indicative of fecal contamination. The average fecal streptococci at the inlet were 5.34 E+07 germs per 100 ml with a standard deviation of 1.88 (Fig. 6). This average is less than the one found in Oujda which is 4.3 10^6 germ per 100 ml [Rassam et al., 2012]. As for the average at the exit of the plant, it is 3.22 E+03 germs per 100 ml with a standard deviation of 3.02. This average is also clearly exceeds the one found in Oujda (300 germe per 100 ml) [Rassam et al., 2012].

The average fecal coliforms at the inlet were 3.58 E+07 germs per 100 ml with a standard deviation of 2.91 (Fig. 6). This average is higher than that the one found in Azilal (4.90 E+06 germs per 100 ml) [Idrissi et al., 2015]. As for total coliforms, the average is 4.93 E+08 germs per 100 ml with a standard deviation of 2.94 (Fig. 6). This average is also higher than that found at Azilal (3.2 E+07 germs per 100 ml) [Idrissi et al., 2015].

At the outlet, the average fecal coliforms were 6.90 E+03 germs per 100 ml with a standard deviation of 7.52 (Fig. 6). This average is very high compared to those found in Errachidia [Hamid et al., 2014] and Imzouren [Diman et al., 2016] which are

Table 4. Correlation tests

Test	Value	Weather parameter	SS	COD	BOD_5	TN	TP	FC
Kendall	Correlation factor	P40	0.1	-0.06	0.2	0.22	-0.08	0
Kendall	p value	P40	0.68	0.8	0.4	0.35	0.73	1
Spearman	Correlation factor	P40	0.13	-0.05	0.23	0.3	-0.09	0.04
Spearman	p value	P40	0.59	0.83	0.33	0.2	0.7	0.86
Kendall	Correlation factor	Tm40	-0.02	-0.09	-0.26	-0.45	-0.09	0.22
Kendall	p value	Tm40	0.93	0.7	0.27	0.04	0.7	0.34
Pearson	Correlation factor	Tm40	0.19	-0.3	-0.35	-0.61	***	***
Pearson	p value	Tm40	0.42	0.21	0.13	0	***	***
Spearman	Correlation factor	Tm40	0.02	-0.13	-0.37	-0.63	-0.12	0.28
Spearman	p value	Tm40	0.93	0.58	0.11	0	0.62	0.22

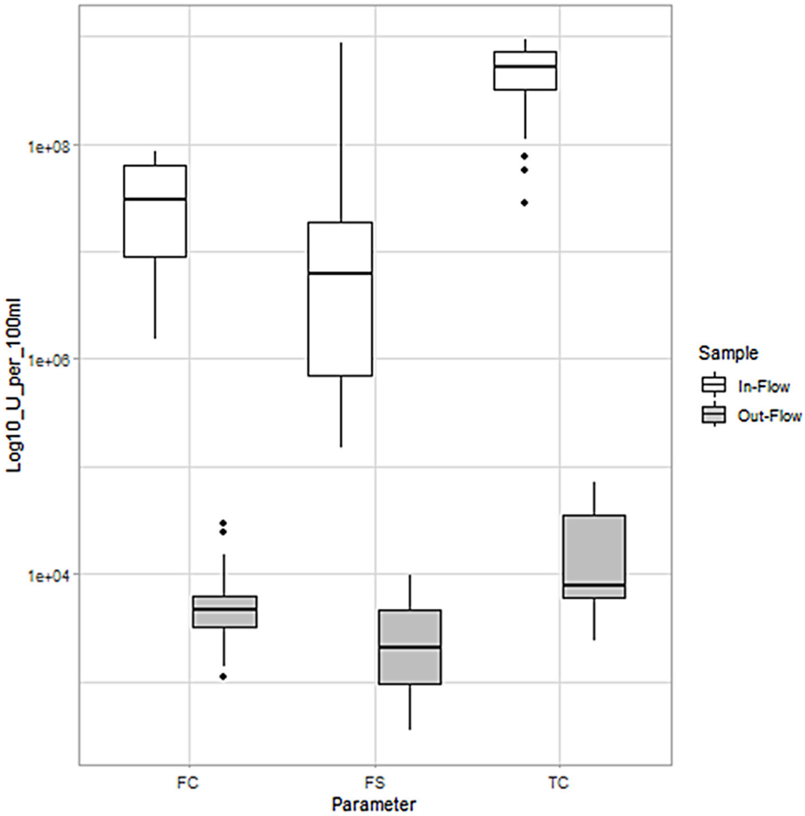

Figure 6. Variation in average values of fecal coliforms (FC), fecal streptococci (FS), and total coliforms (TC) at the entrance and exit of the plant

95 CFU/100 ml, and 157 CFU/100 ml, respectively. The average total coliforms obtained at the exit of the plant were 1.93 E+04 germs per 100 ml with a standard deviation of 2.10 (Fig. 6). This average is quite high compared to that found in Errachidia [Hamid et al., 2014] and Imzouren [Diman et al., 2016] which are 205 CFU/100 ml and 211 CFU/100 ml, respectively. The results of fecal coliforms obtained at the outlet of the plant allow deducing that the treatment adopted by the maturation ponds exceeds the values required by the A quality standards of water intended for irrigation (1000 CFU/100 ml) for all samples [Secretariat of State to the Ministry of Energy, Mines, Water and the Environment, responsible for Water and the Environment, 2007]. This results show a deterioration in microbiological purification compared to the results obtained by Bouzidi et al., in 2012 where 70% of the samples were below 1000 CFU/100 ml.

It was noted that the fecal coliform results obtained at the outlet of the Settat plant is much worse compared the similar Moroccan plants of Errachidia [Hamid et al., 2014] and Imzouren [Diman et al., 2016]. However, in contrast to the Settat plant, these two plants do not exceed their theoretical organic capacities (% working organic load / capacity is 83%, 40% and 113.84for Errachidia [Hamid et al., 2014], Imzouren [Diman et al., 2016] and Settat%, respectively). In fact, high presence of algae has been observed in the maturation ponds of the Settat plant (almost with the same concentration as in the facultative pond). The algae create turbidity and block the penetration of UV rays that are supposed to damage the bacterial DNA. As the plant is running with a BOD_5 load that surpasses its capacity, the maturation ponds play a greater role in organic matter elimination than it was designed to, and this impacts the bacteriological yields. This problem could be resolved by the expansion of the plant capacity upstream to the maturation ponds (adding new facultative ponds or switching to aerated lagooning).

It could be conclude that this lagooning plant is quite resilient concerning organic matter elimination but not bacterial pathogen elimination.

Helminth eggs

The average helminth eggs recorded at the entrance to the plant is 2.55 E+00. In the outlet, the absence of helminth eggs was noticed in the treated wastewater, which allows us to deduce that the efficacy of the lagooning treatment is largely in line with the values required by the quality standards of water intended for irrigation (absence of helminth eggs) [Secretariat of State to the Ministry of Energy, Mines, Water and the Environment, responsible for Water and the Environment, 2007].

CONCLUSIONS

The annual monitoring of the physicochemical parameters of the raw and purified wastewater from the wastewater treatment plant in the town of Settat has enabled us to deduce that this water treatment plant guarantees a significant reduction in the pollutant load. In fact, good purification yields are ensured for the biochemical oxygen demand (BOD_5), chemical oxygen demand (COD) and suspended solids (SS) which are 86.44%, 86.89% and 74.61% respectively. The effluent biodegradability coefficient shows that the wastewater from the town of Settat is biodegradable and purely domestic with the absence of industrial discharge connected to the sewerage network. As for the microbiological characterization, the treated wastewater from the city of Settat is classified in the category of quality B water because of the fecal coliforms which exceed 1000 CFU/100 ml, and can be reused in the irrigation of cereal crops, fodder, pasture and tree plantations, but not for fresh vegetables and crops that are consumed raw.

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