Quality control of water through statistical study of the performance of the treatment plant upstream of the Koudiat Medouar dam

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Abstract

In the face of water scarcity, due mainly to the steady decline in rainfall over the last few decades, and with a view to preserving still healthy water resources and protecting the environment and public health, Algeria then adopted a rich wastewater treatment program through the commissioning of several wastewater treatment plants. These stations have the role of concentrating the pollution contained in the wastewater in the form of residues called sludge, which can be recovered in agriculture, and to reject purified water meeting specific standards, which in turn can be reused in irrigation, industry and municipal uses.
The main objectives of this work are to:
• Research the trend of raw and treated water quality by smoothing the data using the arithmetic moving average technique
• Identify cases of malfunction, overtaking, and inadmissible water quality
• Evaluate the performance of the station by a probabilistic analysis

Key words: *performance, pollution, sewage treatment station, moving average, probabilistic analysis*

1. Introduction

Treatment of polluted wastewaters is an essential requirement to make a reduction of the pollutant load so that they will be directed to wastewater treatment plants to concentrate the pollution in the form of small volumes of residues (sludge), and to reject purified water meeting specific standards by physicochemical and biological processes. The present study considered the activated sludge wastewater treatment plant in the town of Timgad (Wilaya of Batna With as a model system, focusing on its effectiveness in reducing the pollutant loading and on its proper operation.

2. Characteristics of study area

The Timgad wastewater treatment plant is located north of the town, southwest of the Koudiat Medouar dam, and is located on the right bank of Wadi Soultz upstream of the dam. The station is an activated sludge type and operates at medium load for the purification of the wastewaters of the city of Timgad, in order to protect the receiving environment [1].

Figure 1. Aerial photo of the town of Timgad and KOUDIAT MEDOUAR dam

3. Results and discussion

Table1 summarizes the main descriptive characteristics of the water quality upstream and downstream of the station for the period 2011-2015 i.e. five years.

Table 1. Descriptive analysis of pollution parameters [2]

Paramètre	Inlet				
	X	Ecart type	CV	max	min
TSS (mg/l)	265,41	137,04	0,52	970,00	65,00
BOD5(mg/)	229,55	88,59	0,39	502,00	48,00
COD(mg/l)	436,87	141,87	0,32	932,00	143,00
pH	7,37	0,26	0,04	7,99	6,02
NO3 (mg/l)	0,37	0,47	1,29	2,60	0,01
PO4(mg/l)	2,77	1,54	0,56	6,84	0,19
NH4(mg/l)	21,85	7,73	0,35	44,00	5,83
NO2(mg/l)	0,12	0,15	1,17	0,66	0,01
paramètre	**Oulet**				
	X	Ecart type	CV	max	min
TSS (mg/l)	3,05	3,45	1,13	25,00	0,001
BOD5(mg/)	3,19	5,84	1,83	34,00	0,30
COD(mg/l)	36,34	29,67	0,82	149,00	5,00
pH	7,19	0,72	0,10	7,98	0,00
NO3 (mg/l)	2,05	2,53	1,23	10,52	0,01
PO4(mg/l)	1,27	1,51	1,18	5,30	0,01
NH4(mg/l)	3,63	3,58	0,99	22,50	0,01
NO2(mg/l)	0,54	1,10	2,06	4,50	0,00

At the inlet to the plant, the mean values of TSS (TSS=265.41 mg/l), and COD (COD=436.87 mgO2/l), BOD_5 (BOD5=229.55 mgO2/l) and the values of NO3 (NO3=0.37 mg/l), PO4 (PO4=2.77mg/l) indicated that the quality of the raw water was poor.

At the outlet to the plant, the mean values of the pollution parameters are in conformity with the standards of rejection. Standard deviation, the coefficient of variation and the corresponding ranges showed greater dispersion of the parameters NO_3, BOD5, COD, TSS, NH_4, and NO_2 at the inlet to the plant, compared to the outlet. This was mainly due to the large heterogeneity in the quality of wastewater at the entrance to the plant.

3.1 Determining wastewater capacity of the plant

The calculation of the processing capacity of the station for five years is given as follows:

Table 2. The wastewater capacity of the Timgad wastewater treatment plant

P*	Nv**	Treatment capacity %					
		2011	2012	2013	2014	2015	5 years
Débit (m3/j)	5832.	/	/	/	33.29	28.38	26.81
BOD5 (mg/l)	425.	31.06	34.62	52.82	59.34	54.90	46.55
COD (mg/l)	849.	58.01	48.05	51.26	53.38	55.92	53.32
TSS (g/l)	549.	38.01	32.67	46.70	58.26	53.66	45.86

* Parameter; ** Nominal value

The results presented in Table 2 show that Timgad plant operates at approximately 50% regarding of the BOD5, the COD, TSS and around 30% of its nominal capacity in terms of treated flow. These low circulating flows led to high residence times in the various wastewater treatment plant (desander, the decanter, the thickener, etc.) and this was the main causes of plant bad operation cases (fermentation, unpleasant odors and sludge proliferation).

3.2 Determination of total exceeding cases and ineligibly exceeding of the water quality limit

The maximum number of samples for which exceeding of the limit value are allowed shall be fixed according to the number of samples [3].

Figures 1 and 2 give a global picture of total exceeding cases and ineligibly exceeding of the raw and purified water quality limits during the study period (2011, 2012, 2013 and 2014).

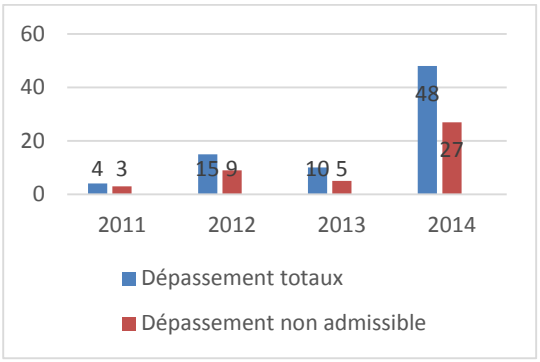

Figure1. Total exceeding and ineligibly exceeding of the Quality of urban wastewater (raw water).

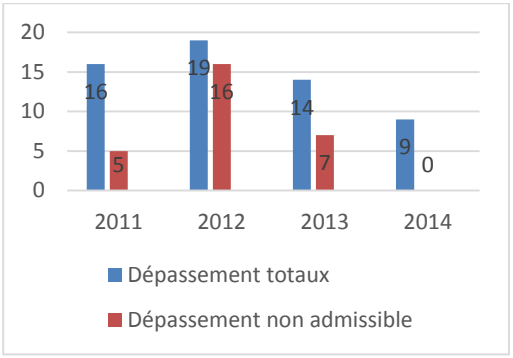

Figure2. Total exceeding cases and ineligibly exceeding of rejection standards OMS (purified water)

Figure 1 shows the deterioration of the quality of raw wastewater at the entrance to the plant; it appears that the number of total exceeding cases as well as the number of ineligibly exceeding cases increased from year to year. In the case of purified water, Figure 2 shows a decrease in the number of total exceeding and ineligibly exceeding cases.

3.3 Research on the trend of raw water quality

The estimate of the water quality trend is determined by smoothing by the arithmetic moving average as follows [4]:

Trend TSS

Figure 3 shows the evolution of TSS as a function of time, ranging from 50 to 450 mg / l, with an average of 265 mg / L. The use of smoothing by the moving average eliminates a large part of the oscillations and shows a tendency to increase the TSS.

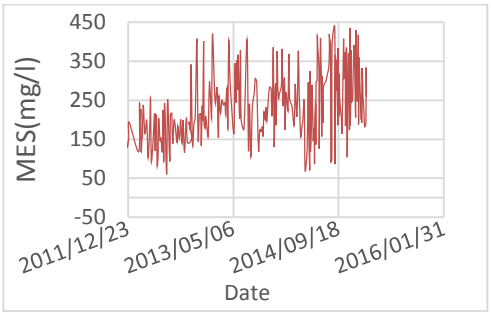

Figure3. Evolution of the input MES

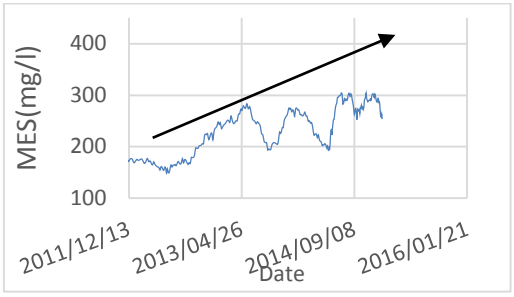

Figure4. The moving average of 16 days of TSS

Trend BOD_5

The BOD5 variation presented in Figure 4 shows that the BOD5 values were low (less than 450 mg/l) but did not allow an easy visualization of the BOD5 trend because the oscillations were numerous. The implementation of the moving average eliminated the oscillations and showed the trend of the evolution of the BOD5. An increase trend of the BOD5 appeared at the entrance of the plant.

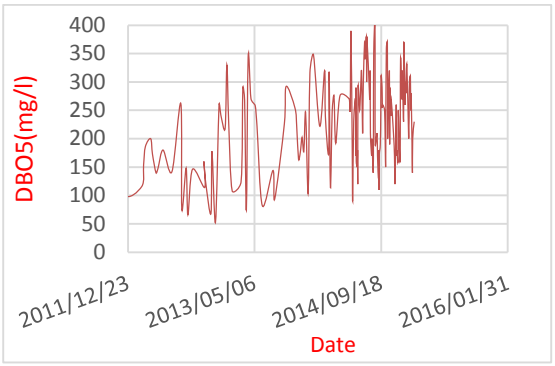

Figure5. .Evolution of the input BOD5

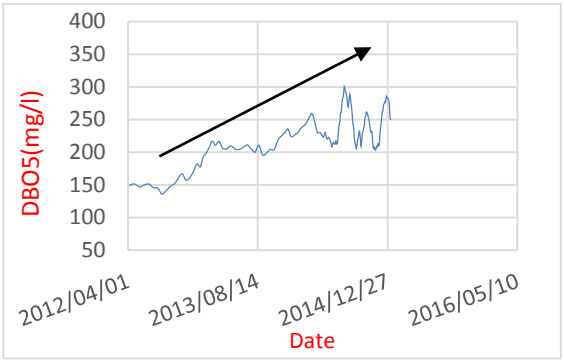

Figure 6. The moving average of 16 days of BOD5

Trend COD

COD variability was low throughout the study period with values not exceeding the urban wastewater quality standard (700 mg/l). The oscillations of the COD as shown in Figure 5 were important, which made it impossible to assess the trend of COD. The application of the moving average made it possible to observe more clearly the stability of the COD

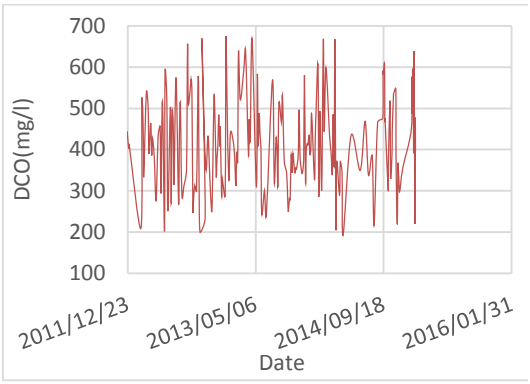

Figure 7. Evolution of the input COD

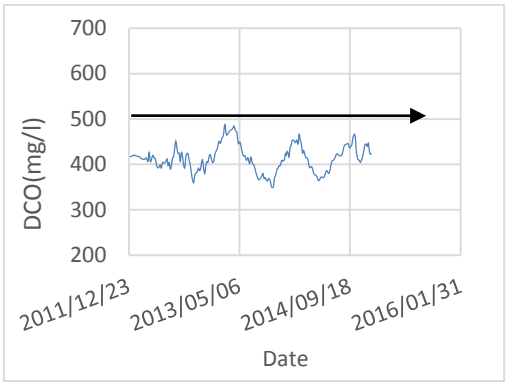

Figure8. The moving average of 16 days of COD

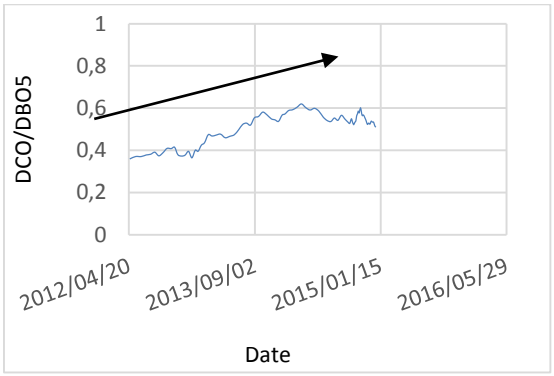

Figure10. The moving average of 16 days of COD/BOD5

Trend of report COD/BOD5

The presentation of the ratio of biodegradability COD / BOD5 (see Figure. 6) as a function of time

Parameter	TSS	COD	BOD_5
Average value of the confidence interval 95%	20.18	52.93	4.15
Standard	35	125	25

shows that its value was between 0.1 and 0.9, indicating that the raw sewage was biodegradable. This raw presentation did not allow any conclusions to be drawn as to the trend of this report. The application of the moving average technique shows (see Figure 6) a rising curve, thus revealing that the quality of the wastewater at the inlet of the Timgad purification plant tends to be increasingly poor.

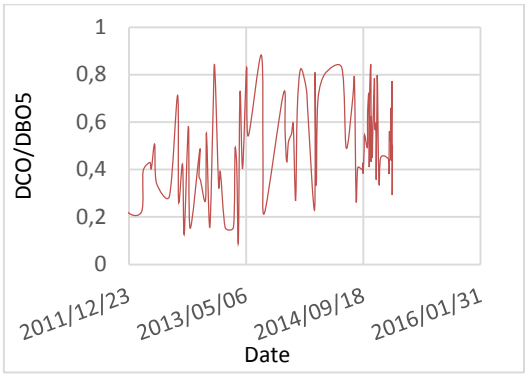

Figure9. Evolution of the input COD/BOD5

3.4 Estimation of the performance of the station by a probabilistic analysis

- **By calculation of reliability coefficient**

The estimation of the performance of the station consisted of checking that the standards had not been exceeded, not with respect to the values of normal discharge standards, but with respect to the values mx (values of rejection standards at a given probability). Is done by calculating the reliability coefficient and the value mx as follows:

Table 3. Reliability coefficient

From the following equation:

$$m_X = (CF) * C_{NR} \quad (1)$$

with: m_x: Average concentration of the parameter considered; *CF*: reliability coefficient; C_{NR}: rejection standard of the parameter considered.

$$m_X = (Cv^2 + 1)^{1/2} * Exp\left\{ - \mathbf{Z_{1-\alpha}} \mathbf{*[\ ln(Cv^2 + 1)]^{1/2}} \right\} * (X_S) \quad (2)$$

With [5, 6]:

$$CF = (Cv^2 + 1)^{1/2} * Exp\left\{ - Z_{1-\alpha} * [\ \ln(Cv^2 + 1)]^{1/2} \right\} \quad (3)$$

The results of the calculation are shown as follows:

Tabe 4. Reliability coefficient calculation of the parameter treating process at the TIMGAD plant

Paramètre	Average	Standard	Reliability coeff	m_x
TSS	3.05 mg/l	35	0.328	11.48
BOD_5	3.19 mg/l	25	0.410	10.25
COD	36.34 mg/l	125	0.486	60.75

As shown in the table above and for a risk of 5%, the mean values of TSS, BOD5 and COD were respectively lower than the values corresponding to mx. Then the plant was 95% efficient.

- **By calculation of the maximum of the confidence interval of the mean of parameter values** [7]

The estimation of the performance of the plant was made by comparing the maximum values of the confidence intervals of the means of the BOD5, COD and TSS parameters with the rejection standards. This consisted of adjusting the data to the probability laws, Confidence intervals of the parameter averages. The results of the following table show that the maximum values of the 95% confidence intervals were lower than the rejection standard values. Then the station was 95% efficient.

- **By calculation of the maximum value of the confidence interval of the max parameters values**

The evaluation of the performance of the station was made by comparing the maximum values of the confidence intervals of the maximum values of the BOD5, COD and TSS parameters with the rejection standards. The calculation results indicated that, apart from the COD, the maximum values were lower than the discharge standards.

Table 5. The maximum value of the 95% confidence interval, of the parameter treating method at the TIMGAD plant.

Parameter	TSS	COD	BOD_5
Max value of the confidence interval 95%	34,35	142,18	18,31
Standard	35	125	25

4. CONCLUSION

The Timgad wastewater treatment plant aimed to reduce the pollutant loads of the town of Timgad by the activated sludge process. The statistical analysis of the pollution parameters showed their great variability at the input with respect to the output.

Analysis of total number of cases of overruns and cases of ineligibly exceeding quality raw water showed the degradation of water quality upstream of the plant. The application of smoothing by the moving average technique confirmed this result and indicated the rising curves of BOD5, TSS and the biodegradability ratio COD / BOD5, thus revealing that the quality of the waste water at the inlet of Timgad sewage treatment plant tended to be increasingly less than average. On the other hand, the calculation of the number of exceeding cases of the norms at the exit of the station during the study years (2011-2014) regressed, and the evaluation of probabilistic analysis of the plant performance shows that the plant of the town of Timgad was 95% efficient.

List of symbols

BOD5: Biochemical oxygen demand

COD: chemical oxygen demand

TSS: Total suspended solids

COD/BOD5:helps to qualify the biodegradability of effluent

NO3:quantity of Nitrate

NO2: quantity of Nitrite

NH4:quantity of ammonium

PO4: quantity of orthophosphate

pH: pH value

mx: Average concentration of the parameter considered

CF: reliability coefficient

CNR: Rejection standard of the parameter considered

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