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The purification performances of the lagooning process, case of the Beni Chougrane region in Mascara (Algerian N.W.)

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Abstract. In order to alleviate the water shortage observed in rural areas, Algeria has resorted to the use of treated wastewater from lagooning stations. The approach to the management of domestic wastewater is all the more interesting because it is part of an environmental context for the collection, treatment and recycling of treated water for agricultural purposes. This is lagooning as a purification process. The question is whether it meets environmental and health requirements. The present work aims to monitor and analyze the purification performance of six sewage treatment plants located in the region of Mascara (West Algeria) namely: Ghriss, Bouhannifia, Hacine, Mohammadia, Tizi and Froha, to examine the reliability of this wastewater treatment system in accordance with universal standards. We notice that purification performances are low and variable and remain dependent on the season for nitrates (NO_3^-), ammonium (NH_4^+) and phosphorus.

***Keyword**:* performance, clean water, lagooning, Beni Chougrane, Algeria.

Introduction

Since the end of the 1990s, Algeria has adopted lagooning for the treatment of wastewater from rural and urban centers as the most appropriate technical solution for the economic and climatic context.

The reuse of treated wastewater is integrated into the planning and development of water resources.

To the poor distribution of rainfall, we must add the problem of pollution of water resources [CHACHOUA and SEDDINI, 2013].

The system for purifying domestic wastewater by natural lagooning remains one of the most used processes in countries with arid to semi–arid climates [BOUTAYEB and BOUZIDI, 2013], because it represents a source of water and additional renewable and reliable fertilizers [FAO, 2003]. It is a widespread practice around the world especially in developing countries.

Faced with the challenge of ensuring the coverage of water needs for agriculture in Algeria, an active policy of mobilization of water resources has been implemented, as well as new management instruments. It is the reuse of wastewater in agriculture [HANNACHI *et al.*, 2014]. Particular attention is paid to the health aspect in this field [ALOUINM, 1993].

The lack of wastewater management affects both the health of residents and those responsible for their evacuation [GAYE and NIANG, 2002].

In the field of water purification in Algeria, the capacity varies from 1000 to 750 000 equivalent–inhabitants for a total capacity of nearly 3.5 million equivalent–inhabitants.

The situation of sewage treatment is dramatic given that the total volume of wastewater discharged annually is estimated at nearly 600 million m^3, including 550 lagoons for the only northern agglomerations. It appears that this figure will rise to almost 1150 million m^3 by 2020 [CHERRARED *et al.*, 2007].

The main factors that can affect the environment are chemical, physical, biological and climatic [DAHMANI, 2002, VARDANIAN *et al.*, 2018; STOLERU *et al.*, 2018].

The use of treated wastewater for agricultural purposes has until now been based on water and environmental

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legislation. The recent regulations specific to the use of wastewater taken in application of the provisions of the Water Act require a regulatory framework in this area. The quality standard in force sets the specifications for treated wastewater used for irrigation, and in particular for the physic–chemical standard indicated in Table 1, which sets an arithmetical average number of the maximum permissible concentration of treated wastewater.

Table 1.
Algerian standards for wastewater reuse in irrigation: physicochemical parameters

Parameters [Unit]			Maximum allowable concentration			
Physical	pH		6.5<pH<8.5			
	Total Suspended Solid	ml/L	30			
	Electrical Conductivity	ds/m	3			
Chemical	BOD_5	mg/L	30			
	COD	mg/L	90			
	Nitrogen (NO_3^-–N)	mg/L	30			
Parameters [Unit]		**Maximum allowable concentration**		**Parameters [Unit]**	**Maximum allowable concentration**	
Toxic elements for type of fine–textured soils, neutral or alkaline	Aluminum	mg/L	20	Iron	mg/L	20
	Arsenic	mg/L	2.0	Phenols	mg/L	0.002
	Beryllium	mg/L	0.5	Lead	mg/L	10.0
	Boron	mg/L	2.0	Lithium	mg/L	2.5
	Cadmium	mg/L	0.05	Manganese	mg/L	10.0
	Chrome	mg/L	1.0	Mercury	mg/L	0.01
	Cobalt	mg/L	5.0	Molybdenum	mg/L	0.05
	Copper	mg/L	5.0	Nickel	mg/L	2.0
	Cyanides	mg/L	0.5	Selenium	mg/L	0.02
	Fluorine	mg/L	15	Vanadium	mg/L	1.0
				Zinc	mg/L	10.0

Note: Source: Official Journal of the Algerian Republic (JORA) No. 41 of July 15, 2012

The objective of this work is a three–year follow–up approach (2015, 2016, 2017), a comparative analysis of the purification performance of six lagoon treatment plants treat domestic wastewater, located in the Mascara region (West Algeria) namely: Ghriss, Bouhannifia, Hacine, Mohammadia, Tizi and Froha, in order to examine the reliability and performance of this purification system with Algerian standards.

Material and methods

Presentation of the study area. The six wastewater treatment plants, which are the subject of this study, are located in the Mascara region of northern Algeria (Figure 1).

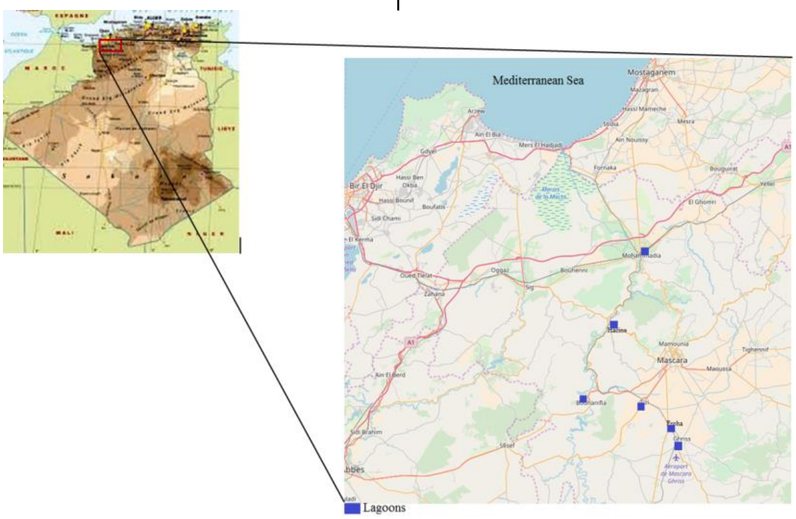

Figure 1. Geographical situation and location of studied lagoons

It includes 47 municipalities and covers an area of approximately 600,000 ha, of which 53 % is agricultural [BOUCHETATA, 2006].

The six (6) lagooning stations (Ghriss, Bouhannifia, Hacine, Mohammadia, Tizi, Froha) are operational on all seventeen (17) lagoons. The sites are influenced by the same climatic conditions; the characteristics of the lagoons are presented in Table 2.

Table 2.

Characteristics of studied lagoonages

Lagoon	**Hacine**	**Bouhanifia**	**Froha**	**Ghriss**	**Tizi**	**Mohammadia**
Level of treatment	Tertiary 2BA+2BF	Tertiary 2BA+2BF	Tertiary 2BN+2BF+2M	Tertiary 3 BA+3BF	Secondary 2BF+BM	Tertiary 2BN+2BF+BM

BA: Aerobic Basin, BF: Basin Optional, BM: Basin Maturation

The study area is subject to Mediterranean and Saharan climatic influences at the same time. It suffers from a serious water deficit, marked by very clear irregularities of the precipitations. Rainfall recorded varies between 350 and 550 mm per year, depending on the exposure of the region.

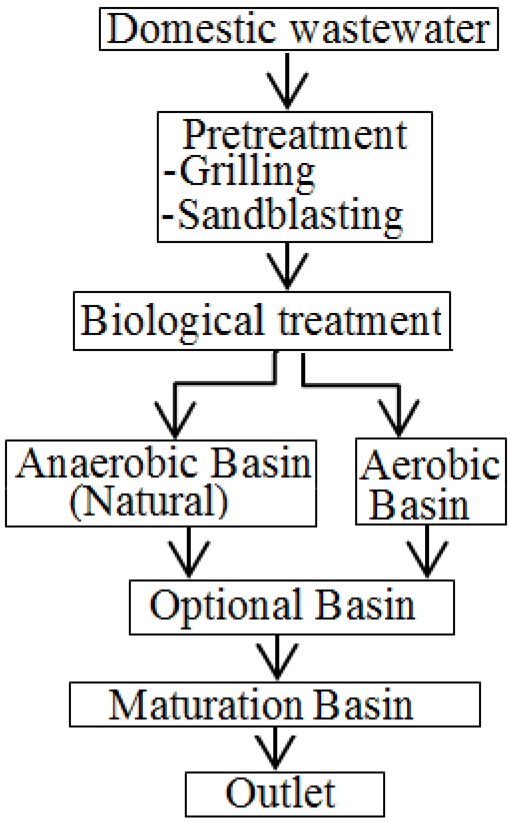

Figure 2. Diagram of the operation of a lagoon station

The most rainy month remains the month of February (42.57 mm) against the month that records the smallest amount of rain is the month of July (2.93 mm). The temperatures highlight the existence of two distinct seasons: a cold season that spans six months from November to April. This has led to the use of treated wastewater to meet part of the agricultural water needs. Currently, the average daily flow of treated water from the seventeen stations across the region reaches 19147.4 m^3 / d.

Treatment method. Domestic water treatment lagooning consists of pre–treatment (screening and grit removal), and biological treatment either anaerobic (natural) or aerobic (equipped with aerators) Figure 2.

Sampling and sampling method. A follow–up of the physic–chemical parameters of the wastewater was carried out, where we proceeded to the realization of the samples during the continuous periods monthly during three years (2015, 2016 and 2017).

Table 3.

Methodology of physic–chemical parameters

Settings	**Measurement methods**
pH	pH meter
DBO5	DBO meter (Oxi Top WTW)
MES	Centrifugation method (HettickZentrifugen)
DCO NO_3^-, NH_4^+, TP	Colorimetric determination by spectrophotometer (HACH DR/2000)

The storage of wastewater samples was carried out in accordance with the general guide for the conservation and handling of ISO 5667/3 samples.

Samples were taken at the main raw water collector at the entrance of each wastewater lagoon on the basis of a composite sample proportional to the flow measured over a 24–hour period input (raw and before treatment), and output (after treatment). Physic–chemical sampling required the collection of one (1) liter per month. The analyzed parameters are: the hydraulic potential (pH) is measured in situ, the parameters such as the suspended matter (MES), the biological oxygen demand (BOD_5), nitrates (NO_3^-), ammonium (NH_4^+), total phosphate (TP) and the chemical oxygen demand (COD) are analyzed in the laboratory. The protocol for analyzing physic–chemical parameters is carried out according to the methods mentioned by Rodier and collab. [RODIER *et al.*, 1996] (Table 3).

Results and discussion

The following tables 4, 5 and 6 present the maximum and minimum values of the analysis for each station at entry and exit in comparison with the standards, and the average treatment efficiencies observed for the different treatment plants in the study area.

Table 5.

Comparative results obtained with respect to the Standards of the Official Journal of the Algerian Republic (JORA) N° 41 of July 15, 2012

Samples \ Parameter per year			2015				2016				2017			
			pH	MES (mg/L)	DCO (mg/L)	DBO_5 (mg/L)	pH	MES (mg/L)	DCO (mg/Ll)	DBO_5 (mg/L)	pH	MES (mg/L)	DCO (mg/L)	DBO_5 (mg/L)
Ghriss Lagoon	Input	Max	8	395	1488	593	8.1	741	4360	1998	7.9	528	1637	1400
		Min	7.7	82.5	712	370	7.4	102	815	266	7.3	190	1199	423
	Output	Max	8.6	57. 5	211	111.5	8.9	21	198	454	8.6	55	214	157
		Min	8	16	105	34	8.2	82	146	10	7.6	24	50	20
Bouhanifia Lagoon	Input	Max	8.2	292	1260	720	8.7	420	1005	470	8.4	123	1356	1085
		Min	6.8	51.5	319.5	84	7.6	52	154	65	6.9	23	233	103
	Output	Max	8.7	101	344	164	9.2	42	655	380	9.5	81	208	190
		Min	8.1	4	77	1	7.7	4	78	10	6.9	15	72	20
Hacine Lagoon	Input	Max	8	570	2270	963	8.6	1317	3610	1003	8.8	1158	6746	1650
		Min	7.6	66.5	681	16	7	228	472	164	7.2	82	480	150
	Output	Max	8.8	65	264	117	9.4	132	324	280	9.7	185	352	553
		Min	7.7	12	133.5	4	8.4	13	166	13	8.1	30	58	28
Tizi Lagoon	Input	Max	8	1472.5	3067	950	7.9	1756	3940	1098	8.1	785	1465	1250
		Min	7.2	78	308	148	6.8	72	645	319	7.1	56	1465	254
	Output	Max	8.5	160	230	201	9	100	2410	724	8.5	59	307	200
		Min	7.6	4	41	34	8.1	15	192	53	7.2	30	158	84
Mohamadia Lagoon	Input	Max	8.2	570	760	241	8.4	220	576	263	8.2	56	388	591
		Min	7.5	24	104	64	7.3	16	124	37	7.3	8	78	51
	Output	Max	8.8	45	238	106	8.9	73	422	209	8.3	69	236	127
		Min	7.3	3	13	12	7.3	4	73	21	7.7	21	48	33
Froha Lagoon	Input	Max	8.1	290	2389	767	8.4	1900	4020	724	8	517	6461	2500
		Min	8.3	152	740	302	7.3	40	666	335	7.4	173	662	302
	Output	Max	9.1	350	226	137	9	583	510	596	8.9	280	521	205
		Min	7.9	15	117	60	7.9	13	164	60	7.3	42	150	85
Norme			6.5–8.5	30	90	30	6.5–8.5	30	90	30	6.5–8.5	30	90	30

The figures below show the critical values at the entrance and exit of each lagoon. The values of lagoon water temperature vary according to seasonal rhythm, with a maximum value of 25.4 °C in August and a minimum value of 17.5 °C in April and an average of 21.45 °C.

Table 5.

Critical values for nitrates, ammonium and phosphate

Parameter / Samples	Lagune de Ghriss				Lagune de Bouhanifia				Lagune de Hacine			
	Input		Output		Input		Output		Input		Output	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
NO_3^-(mg/l)	2.098	1.003	0.98	0.0451	3	1.003	0.897	0.465	3.42	1.008	0.989	0.435
NH_4^+ (mg/l)	140	45	77	24	151	42	84	20	155	45	86	25
TP (mg/l)	11.2	1.1	9.1	3.2	6.4	4.1	5.2	2.7	18.5	8.1	9.1	4.1
Parameter / Samples	Lagune de Tizi				Lagune de Mohammadia				Lagune de Froha			
	Input		Output		Input		Output		Input		Output	
	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
NO_3^-(mg/l)	3.07	1.24	1.352	0.657	2.26	1.007	0.985	0.578	3.02	0.98	1.078	0.687
NH_4^+ (mg/l)	172	56	80	26	78	39	35	17	187	67	76	45
TP (mg/l)	9.8	6.8	7.8	4.2	5.6	4.1	4.1	2.8	10.2	8.1	7.4	4.9

Table 6.

Purification performance of organic materials and pollution indicators

Parameter	Purification yield (%)						Average yield of the area (%)
	Ghriss	Bouhanifia	Hacine	Tizi	Mohammadia	Froha	
MES	87	70	84	86	54	53	72
DBO5	87	67	82	67	49	73	71
DCO	88	69	89	53	44	83	71
NO_3^-	56	54	55	54	40	47	51
NH_4^+	46	50	44	54	55	57	51
TP	40	31	40	35	25	35	34

According to Potelon and Zysman, the temperature of the surface waters (rivers, lakes and reservoirs) is very variable according to the seasons and can go from 2 °C in winter to 30 °C in summer [POTELON and ZYSMAN 1998]. The increase in temperature in the months of July and August, according to Moumouni Djermakoye, favors the phenomenon of self–purification and increases the rate of sedimentation of suspended matter [MOUMOUNI DJERMAKOYE, 2005].

The hydrometric potential (pH). For the six lagoons, the pH is between the values limited by the standards at the entrance of the lagoons (slightly alkaline). As can be seen in Figure 3, there is a slight increase in the pH of the water at the outlet of the lagoons especially for the three lagoons of Bouhanifia, Froha and Hacine compared to the water inlet (Figure 4), which confers non–compliance with the standards.

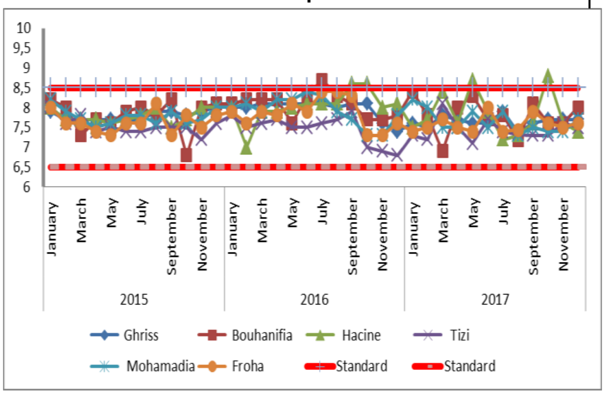

Figure 3. Variation of the pH at the entrance of the lagoons

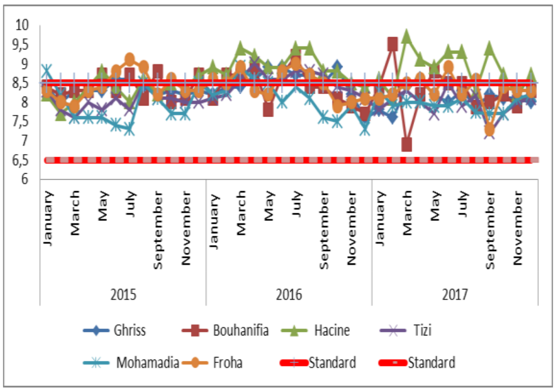

Figure 4. Variation of the pH at the exit of the lagoons

We can justify this increase in pH by the H ions generated during the nitrification operation. PHs between 5 and 9 allow normal development of fauna and flora.

Suspended Matters (SM). The presence of suspended matters at the entrance is very noticeable in the six lagoons, especially at the Froha, Tizi and Hacine stations. Average treatment yields in terms of SM vary between 53 and 87 %. The SM are reduced by sedimentation in the lagoon system mainly in the anaerobic basin. The highest average yield is observed for the Ghriss station with an 87 % reduction.

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The concentration of SM fluctuates in the waters is decreased at the inlet by contribution to the output Figure 5 and 6. So there is an average degradation of organic matter in all lagoons, except that of Ghriss where the degradation is significant compared to the others.

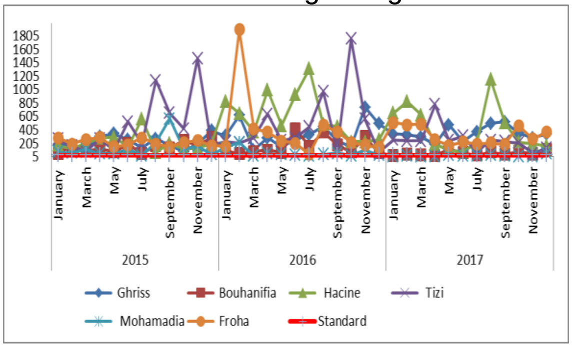

Figure 5. Variation of SM at the entrance of the lagoons

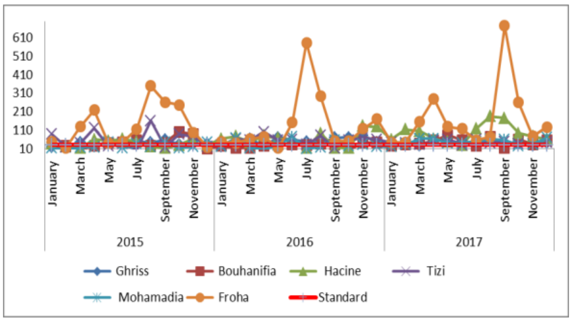

Figure 6. Variation of SM at the exit of the lagoons

The average concentrations in the treated water are greater than the limited value according to the standards. It is also noted that degradation yields and concentrations of purified water are close to each other, except those of Froha which have a low yield and the highest outflow concentration. This can be explained by the increase in the level of the suspended matter otherwise known as the number of days of degradation is insufficient compared to the rate of the concentration of organic matter in the lagoon Froha. The lagoons studied are not sufficient for the removal of suspended solids.

Biochemical oxygen demand (BOD_5). The observed purification yields reached 71 % in terms of BOD_5 for all treatment plants. The highest average yield is at the Ghriss Station with 87 % having three aerobic basins and three optional basins that push further processing. The lowest value is that noted for the station of Mohammadia with 49 %. The average abatement rate in the study area remains satisfactory. The treatment efficiency in terms of BOD_5 is more important for tertiary level treatment plants. These results are comparable with the yields observed by Mara and Pearson, who observed a reduction of BOD_5 varying between 73 and 85 % in the Mediterranean countries [MARA and PEARSON 1998], like Maiga and collab. observed yields reaching 85 % under Sahelian climate [MAIGA *et al.*, 2007]. The same observation was observed by Papadopoulos and collab. in Greece where yields exceeded 90 % [PAPADOPOULOS *et al.*, 2001].

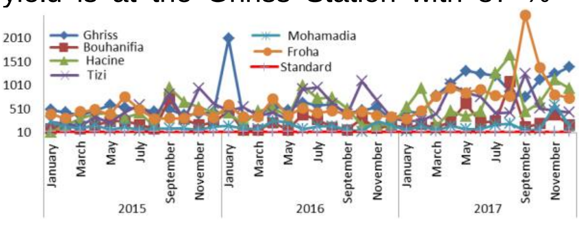

Figure 7. Variation of BOD5 at the lagoons entrance

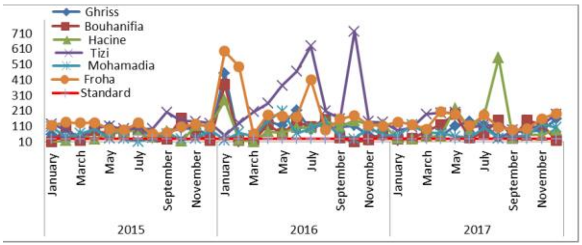

Figure 8. Variation of the BOD5 at the exit of the lagoons

BOD_5 values at inlet to outlet (Figure 7–8) are above standards, meaning that treated wastewater has a high pollution potential, ie, biochemical oxygen demand is very high especially in the lagoons of Froha, Tizi and Hacine. This is because the high values of this parameter are a good indicator of the biodegradable organic matter content. So, we should be careful before releasing it into the environment.

Chemical oxygen demand (COD). The average treatment efficiency in terms of COD varies between 44 and 89 %. The highest average yield is observed for the station of Hacine with an abatement of 89 %. The concentration of the chemical oxygen demand (COD) decreased in the six lagoons by comparing the values at the inlet with that of the outlet (Figures 9 and 10). The COD values of the lagoons of Hacine, Tizi and Froha are very high compared to the others, but all the values of the lagoons are higher than the norms.

According to Igbinosa and Okoh, the increase in COD concentrations during the summer season could be attributed to an increase in organic and inorganic substances in the receiving environment [IGBINOSA and OKOH 2009. BONEA *et al.*, 2017, PENTEA et al., 2016, STOLERU *et al.*, 2012]. This means that the treated wastewater from the six lagoons has a high pollution potential and we should therefore be careful before discharging it into the environment.

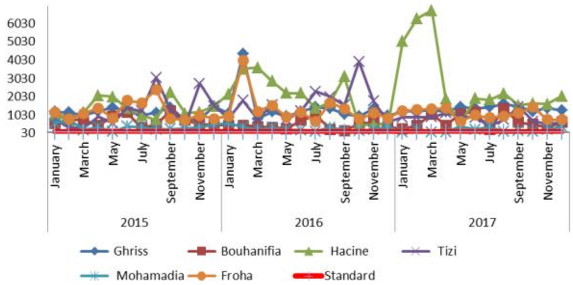

Figure 9. Variation of COD at the entrance of the lagoons

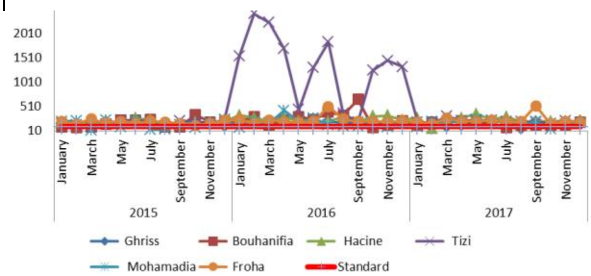

Figure 10. Variation of COD at the outlet of the lagoons

Ammonia pollution abatement (NH_4^+), nitrates (NO_3^-), phosphate. For nitrogen, purification performance is very unstable and depends on the season. The recorded values of ammonium (NH_4^+) in the samples are between 17 mg / L and 86 mg / L at the output of the lagoons.

The average NH_4^+ allowances observed vary between 44 and 57 %, the highest average yield is observed for the lagoon of Froha with 57 % abatement and the average yield of the study area is 51 %. Indeed, at the final stage of treatment, particularly in maturation ponds, it is the nitrate form that is predominant and the nitrogen content changes slightly.

Similarly, for phosphorus, the level of elimination is low and unstable. The recorded TP values in the samples ranged from 2.7 mg / L to 9.1 mg / L at the output of the lagoons, the average removal efficiency varying between 25 % and 40 % with an average yield of the study area of 34 %. The recorded values of nitrates (NO_3^-) in the samples are between 0.045 mg / L and 1.35 mg / L at the output of the lagoons with an average reduction observed vary between 40 and 56 %, the highest average yield observed is that of lagoon of Ghriss with a reduction of 56 % and the average yield of the study area is 51 %. Slim and collab. found that an infinite amount of nitrate in surface water is related either to the increased algal growth in these sites [SLIM *et al.*, 2005. BONCIU *et al.*, 2018; BONEA *et al.*, 2018; GROZEA et al., 2017, STOLERU *et al.*, 2016], or to the joint "denitrification" phenomenon that converts NO_3^- nitrate to N_2 through the presence of nitrate organic material. Indeed, the dissolved phosphorus is not absorbed by living microorganisms and its content remains more or less unchanged in low oxygen environments. However, at the final stage of treatment, an additional production of phosphorus can be observed following the transformation of the organic matter and the release of the micro–organisms. Phosphates come from leaching. They are at the forefront of the eutrophication process, a phenomenon with environmental (algal development) and sanitary (algal toxin release) consequences.

Conclusions

The results obtained indicate that the physic–chemical quality of the treated wastewater does not always comply with the official criteria. With regard to pH, SM, BOD_5, COD, NH_4^+, NO_3^-, TP lagoon basin treatment performance has a very strong relationship with the influx of wastewater and the concentrations in wastewater treated by the lagoons studied.

The purification yields observed for all the lagoons vary from 49 to 87 % as abatement for the BOD_5. This average yield varies between 44 and 89 % for COD and between 53 and 87 % for suspended solid Matters (SM). For ammonium (NH_4^+) parameters (51 % abatement on average), nitrates (NO_3^-) (51 % abatement on average) and phosphorus (34 % abatement on average), where levels abatement remain low. The residual concentrations of these effluents in terms of ammonium, nitrates and phosphorus, remain interesting for reuse in agriculture. The classification of these six lagoons according to the system of evaluation of the quality of the purified water, made it possible to conclude that the wastewater treated by these lagoons stations does not meet the Algerian norms of the discharges of effluents.

So, it is clear that the lagoons studied are not sufficient to have purified water of the quality required for release into a natural environment. In perspective, it is planned to carry out microbiological analyzes, which are necessary to evaluate the conformity of purified water with the reuse standards (official journal of the Algerian Republic n ° 41 of July 15, 2012).

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