Wastewater Reuse for Irrigation Purposes: The Case of Aïn Témouchent Region

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Contents

Abstract The objective of this work concerns the characterization of wastewater and purified water of Aïn Témouchent wastewater treatment plant (WWTP) which uses an activated sludge treatment process. A quality parameter monitoring of the collected domestic effluents made it possible to characterize these waters. The analyses included temperature, pH, suspended matter (SM), dissolved oxygen (DO), chemical (COD) and biochemical (BOD_5) oxygen demands, turbidity, total

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nitrogen (TN), total nitrogen Kjeldahl (TNK), nitrites (NO_2^-), nitrates (NO_3^-), ammonium (NH_4^+), total phosphorus (TP), and orthophosphates (PO_4^{3-}).

Although heavily loaded with organic matter, wastewaters drained to the WWTP have COD/BOD_5 ratios indicating satisfactory biodegradability of the organic pollutants.

Comparison of the analyzed parameters with the standards of the Official Journal of the Algerian Republic (JORA) shows that cleaned water can be safely discharged into the natural environment. These parameters are also consistent with the JORA and WHO wastewater reuse standards for irrigation purposes.

Keywords Activated sludge, Clean water, Irrigation, Quality, Reuse, Wastewater, WWTP

1 Introduction

Surface water, groundwater, and soil qualities are one of the most severe matters of concern, and the most exposed water bodies to pollution are rivers because they are the discharge medium of industrial and municipal wastewater. The release of such unregulated wastewater has severely deteriorated such aquatic environment and has caused immense environmental problems not only to the environment but also to human beings [1].

Anthropogenic effects like municipal waste discharge and agricultural and industrial activities play a major role in determining the surface water quality in a given region [2, 3], and the application of regulations or standards becomes indispensable if not mandatory to reduce and prevent pollution [4]. Nowadays existing treatments can reduce the pollutant concentrations to nonhazardous levels and make it possible to obtain water of better quality from wastewater, thanks to the existing treatment processes. The treatment and disposal of wastewater do not only minimize environmental impacts but also can be used for irrigation purposes and in uses that do not require drinking water (e.g., recreational activities, industrial uses, aquifer recharge, firefighting, aquaculture, domestic uses, etc.) [5–14]. For example, water with a high BOD_5 and COD when released into the natural water bodies destroys the water quality that may support aquatic life [1] and then DO decreases.

The reuse of treated wastewater in agricultural irrigation has become a constraint especially in semiarid and arid regions in terms of quantity and from the contained nutrient benefits [15]. It allows the conservation of nutrients reducing the need for artificial fertilizers [16].

To face the water scarcity and the environmental deterioration, Algeria has become aware of the urgent need for the construction of sewage treatment infrastructures. Among the treatment plants operated by ONA (National Sanitation Office) through Algeria, some are concerned with the reuse of treated wastewater in agriculture. This chapter aims to monitor the quality of raw and purified wastewater of Aïn Témouchent WWTP and to compare them with the Official Journal of the Republic of Algeria (JORA) [17] standards for effluent discharges and that of the WHO [18] for wastewater reuse for irrigation purposes.

2 Material and Methods

To characterize wastewater (at the entrance) and cleaned water (at the exit) of the WWTP of Aïn Témouchent, physical and chemical analyses were carried out at the WWTP laboratory. These analyses allowed us the knowledge of the nature of the existing polluting loads in water and its variations. The samplings were done weekly and fortnightly during July 2016–March 2017 period. The physicochemical parameters, to be checked, are for weekly analyses the temperature, the dissolved oxygen, the electrical conductivity, pH, suspended matter (SM), and turbidity.

The parameters monitored bimonthly were chemical oxygen demand (COD), biochemical oxygen demand (BOD_5), nitrogen forms (total nitrogen, nitrate, nitrite and ammonium), total Kjeldahl nitrogen (TKN), and phosphorus (total phosphorus "PT" and phosphates "PO_4^{3-}").

The sampling was done by an automatic sampler RPS20 with multi-fixed flasks (24) allowing the realization of an automated sampling as a function of the flow during the considered period (24 h). The samples are therefore mixed and homogenized to form the average sample before being transferred to the vials for analysis.

Measurements of temperature (T), pH, and electrical conductivity (EC) were made using an MM41 multimeter and dissolved oxygen (DO) by an O_2 meter which probe is introduced into a 600 ml beaker containing the water sample. The result to be marked is the value recorded on the display of the device after stabilization.

Determination of suspended matter was performed by the filtration method, and turbidity which is an indication of the presence of suspended particles in the water was determined using a turbidimeter.

BOD_5 was determined using an OxiTop measurement system. This system is more practical, is fast, and gives representative results. The determination of the COD was carried out by colorimetric determination with the potassium dichromate. Total phosphorus analysis was carried out by the LANGE LCK (348/350) vial test and total nitrogen by the LATON LCK (138/338) vial test.

The WWTP with a capacity which is expected to treat the pollution of more than 82,000 equivalent inhabitants and an inflow of 10,920 $m^3\ d^{-1}$ is intended to intercept and to purify domestic wastewater of 72,800 inhabitants. It is based on a low-load activated sludge biological process, i.e., process used for the treatment of domestic effluents that dominates small and medium communities. It has been selected to treat the carbon, nitrogen, and phosphorus feedstock, and the sludge is thickened and dewatered on a belt filter and drying bed.

3 Results and Discussions

In order to characterize the treated water and to control its quality with regard to its use for irrigation purposes, monitoring of physical and chemical parameters was carried out at the entrance and the exit of the studied WWTP during the years 2016 and 2017. All the results of the analysis presented here have dealt with the temperature, the pH, the conductivity (EC), the dissolved oxygen (DO), suspended matter (SM), biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total Kjeldahl nitrogen (TKN), ammonium (NH_4^+), nitrates (NO_3^-), nitrites (NO_2^-), total phosphorus (TP), and phosphates (PO_4^{3-}).

The maximum, minimum, average standard deviation values of the analyzed parameters for raw and purified wastewater are summarized in Table 1.

3.1 Water and Air Temperatures

At the entrance of the WWTP, the water temperature values of wastewater are between 6 and 19°C (average, 12.4°C; SD, 4°C) (Table 1), and at the outlet, they vary slightly from that of wastewater between 6 and 21°C (average, 12.7°C; SD, 4°C) (Table 1). The lowest temperature value was recorded during January and the highest one in August (Fig. 1). The highest values were observed during the warm season and the lowest one during the wet season.

Water temperature is an important factor in the aquatic environment that governs almost physical, chemical, and biological reactions. The values taken by the temperature are in a range favorable to the microbial activity (<30°C). This promotes biological purification and self-purification of wastewater.

Also, the air temperature average at the WWTP was 19.8°C (SD, 6°C). Its values oscillate between 8°C (January) and 28.5°C (August) (Fig. 2) during the study period.

Figure 2, representing water and air temperature variations, shows that these two parameters are intimately linked. This dependence is well evidenced by a correlation coefficient of 0.78.

The recorded wastewater temperature values are all below 30°C considered as the limit value for direct discharge into the receiving medium according to JORA.

3.2 pH

The role of pH is crucial for the growth of microorganisms and is an important parameter for the interpretation of corrosion in the pipelines of WWTPs. On the other hand, a temperature increase, decreasing the pH, participates in the acidification of the medium or conversely.

Table 1 Physical and chemical parameters of raw and treated wastewater

	Raw wastewater				Treated wastewater				JORA 2006	WHO 2012
Parameters	Min	Max	Average	SD	Min	Max	Average	SD		
T air (°C)	8	28.5	19.8	6	–	–	–	–	–	–
T water (°C)	6	19	12.4	4	6	21	12.7	4	30	–
pH	6.17	10.6	7.9	1	6.27	10.8	7.9	1	6.5–8.5	6.5–8.5
EC (μS cm^{-1})	1,240	2,730	1,870	295	1,460	2,550	1,755	239	–	<3,000
SM (mg L^{-1})	84	464	177	69	2	17	8.5	4	35	100–350
Turbidity (NTU)	80	395	166	65.4	3.11	19	8	4.1	–	–
DO (mg O_2 L^{-1})	0.46	4.46	1.84	1	6.49	9.63	8.43	0.6	–	–
BOD_5 (mg O_2 L^{-1})	130	480	226.4	74	2	8	4.9	1	30	110–400
COD (mg O_2 L^{-1})	243	628	409	98.8	18.7	43	26.5	7	120	–
TKN (mg L^{-1})	31.81	79.42	50.5	12.3	3.01	11.6	7.7	2.4	30	20–85
PT (mg L^{-1})	3.96	9.3	5.4	1.4	1.09	4.86	3	1.1	10	6–20
NO_3^- (mg L^{-1})	0.57	1.07	0.7	0.12	5.43	10.7	8.1	1.5	–	–
NO_2^- (mg L^{-1})	0.073	0.7	0.2	0.2	0.011	0.16	0.1	0.6	–	–
NH_4^+ (mg L^{-1})	19.35	64.37	39	10	2.21	2.9	1.1	0.6	–	–
PO_4^{3-} (mg L^{-1})	2.79	6.4	4.1	1.3	2.97	6.4	2.8	1.2	–	–

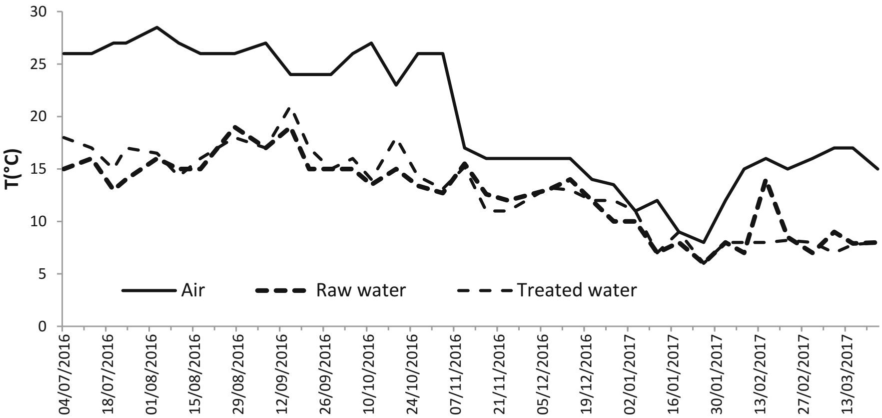

Fig. 1 Temporal variations of air and raw and treated wastewater temperatures

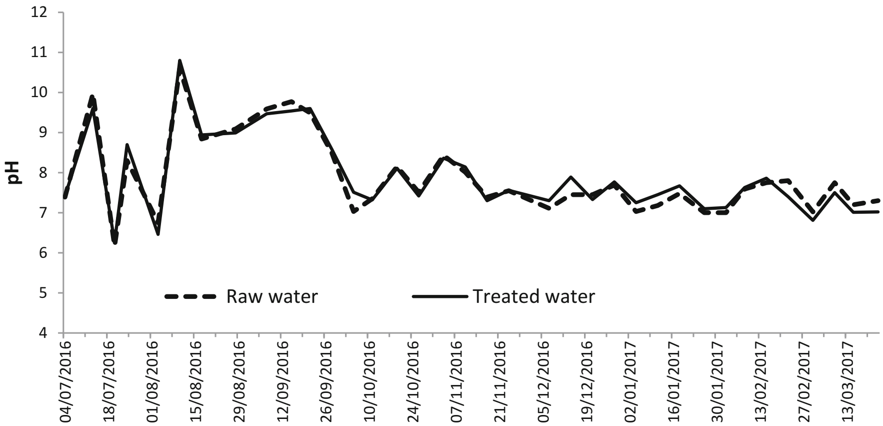

Fig. 2 Temporal pH variations of raw and treated wastewater

Figure 2 shows the pH variations of the wastewater at the inlet and outlet of the WWTP. The recorded pH values range from 6.17 to 10.6 (Table 1) for raw water and from 6.27 to 10.8 for treated water (Table 1) with an average of 7.9 and a standard deviation of 1. The pH values of treated water are, in general, within the range (6.5 and 8.4) of the JORA direct release limits. These values are also in line with the irrigation water standards advocated by the WHO for the reuse of wastewater.

3.3 Electrical Conductivity (EC)

The purpose of the EC measures is to control the quality of the wastewater; it reflects the degree of overall mineralization and tells us about the water salinity [19]. Its measurements can be used to monitor the processes in wastewater treatment that causes changes in conductivity such as biological phosphorus and nitrogen removal [20].

The EC results (Table 1 and Fig. 3) show that wastewater in the study WWTP is strongly mineralized with values varying between 1,240 and 2,730 μS cm^{-1} (average, 1,870 μS cm^{-1}; SD, 295 μS cm^{-1}) at the WWTP entrance. Treated water also shows higher values ranging from 1,460 to 2,550 μS cm^{-1} (average, 1,755 μS cm^{-1}; SD, 239 μS cm^{-1}). The lowest EC values were observed in February and coincide with periods of rainfall. This decrease is therefore most likely due to the dilution effect.

The comparison of the analyzed water conductivity values with the WHO water quality standards for irrigation is used to infer that this wastewater is acceptable for crop irrigation (low to moderate restriction).

3.4 Suspended Matter (SM)

The suspended matter is involved in the composition of water through its effects of ion exchange or absorption of trace elements as well as on microorganisms [21]. When water is treated, various viruses and bacteria can be attached to and migrate along with the solid particles; the elimination of suspended solids is related to the elimination of germs [22].

SM concentrations of the raw water recorded during the study period range from 84 to 464 mg L^{-1} with an average of 177 mg L^{-1} and a standard deviation of 69 mg L^{-1}.The maximum SM values were recorded in November for raw water, i.e., during the wet season (Fig. 4).

At the entrance of the WWTP, the levels in SM are very important. After purification, they decrease (Fig. 4) to reach concentrations between 2 and

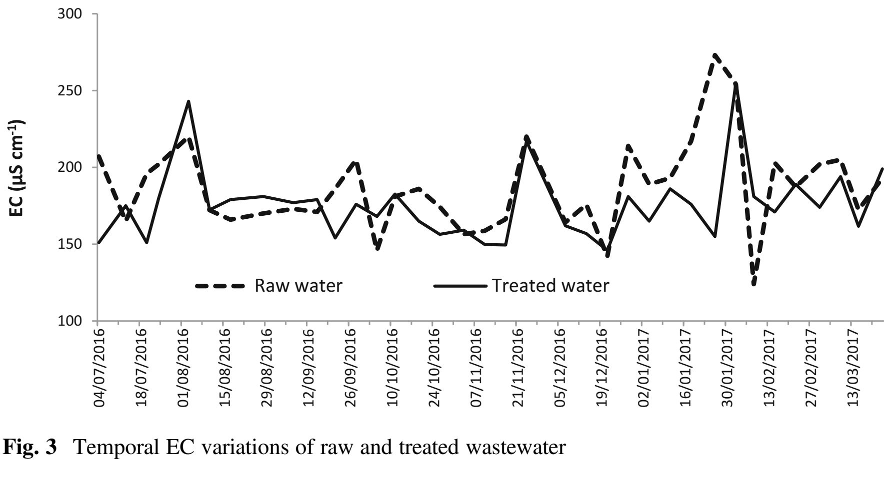

Fig. 3 Temporal EC variations of raw and treated wastewater

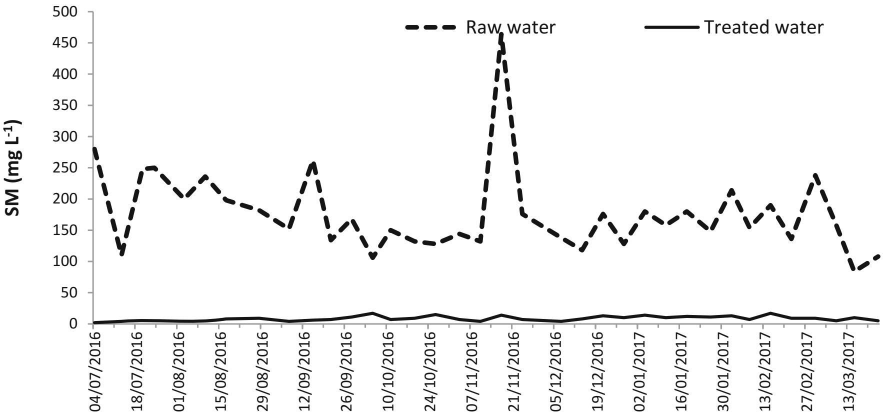

Fig. 4 Temporal SM variations of wastewater and treated water

17 mg L^{-1} with an average of 8.5 mg L^{-1} and a standard deviation of 4 mg L^{-1} (Table 1).

Being less than 35 mg L^{-1}, treated water is considered to be within the standard limit for the receiving environment according to JORA. Similarly, these values are below the lower limit of the standard (100–350 mg L^{-1}) recommended by the WHO for the reuse of wastewater in crop irrigation.

3.5 Turbidity

A high level of turbidity can lower the soil permeability and in turn pollute the soil surface through surface flow [23, 24] and can affect the performance of the irrigation facilities. In raw and cleaned water, turbidity values vary from 80 to 395 NTU (average, 166 NTU; SD, 65.4 NTU) and from 3.11 to 19 NTU (average, 8 NTU; SD, 4.1 NTU), respectively (Fig. 5).

3.6 Dissolved Oxygen (DO)

The dissolved oxygen levels in WWTP raw wastewater (Table 1) range from 0.46 mg O_2 L^{-1} (August) to 4.46 mg O_2 L^{-1} (January) with an average of 1.48 mg O_2 $L^{-1}$and a standard deviation of 1 mg O_2 L^{-1} (Fig. 6). For treated wastewater, DO content increases compared to that of wastewater. Its values are between 6.49 and 9.63 mg O_2 L^{-1}, with an average of 8.43 mg O_2 L^{-1} and a standard deviation of 0.6 mg O_2 L^{-1} (Table 1 and Fig. 6). This increase in DO concentration in waters is explained by the wastewater oxygenation in the aeration basins.

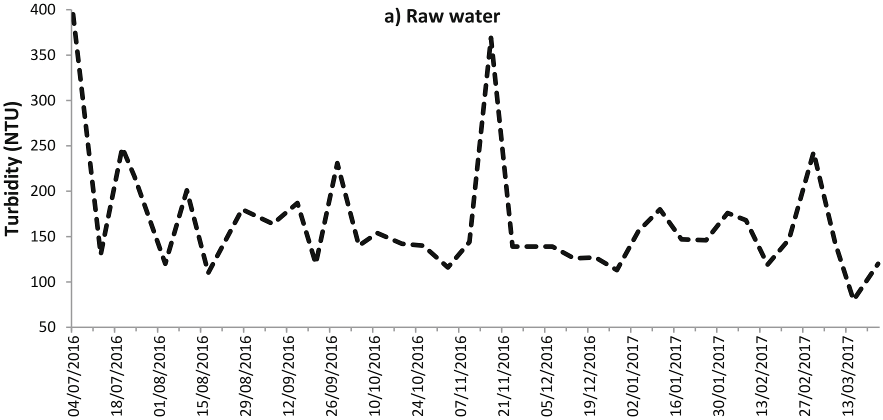

Fig. 5 Temporal turbidity variations of (**a**) raw and (**b**) treated wastewater

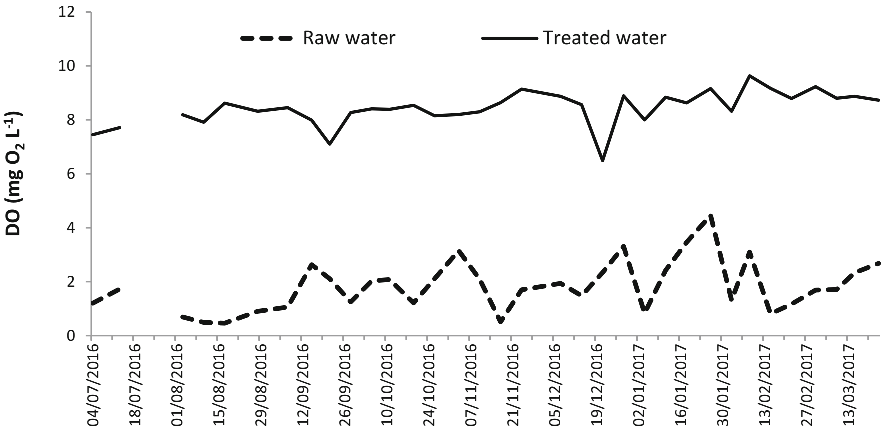

Fig. 6 Temporal DO variations of (**a**) raw and (**b**) treated wastewater

3.7 Biochemical Oxygen Demand for 5 Days (BOD_5) and Chemical Oxygen Demand (COD)

Biological oxygen demand (BOD_5) and/or chemical oxygen demand (COD) analyses are widely used as water quality parameters to assess organic pollutants in water bodies as well as the efficiency of wastewater treatment plants [25, 26].

BOD_5 refers to the amount of oxygen required for the destruction of decomposable organic matter by biochemical processes. It is directly correlated with organic matter in raw sewage [27]. In wastewater, BOD_5values are high. They range from 130 to 480 mg O_2 L^{-1} (average, 226.4 mg O_2 L^{-1}; SD, 74 mg O_2 L^{-1}) (Table 1 and Fig. 7).

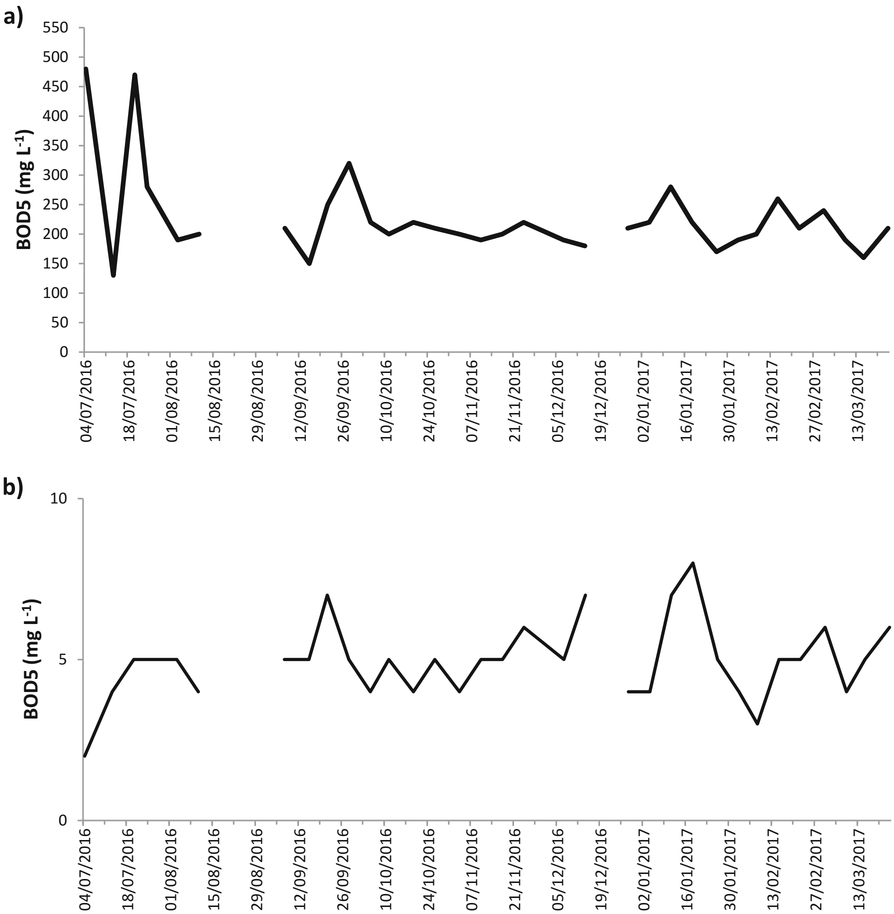

Fig. 7 Temporal BOD_5 variations of (**a**) raw and (**b**) treated wastewater

These results show that water of Aïn Témouchent city is heavily loaded by organic matter and exceed the allowed BOD_5 discharge level (JORA standards) in rivers (35 mg O_2 L^{-1}). This situation could, in general, have adverse effects on water quality if these waters are discharged into watercourses or used for irrigation purposes without prior purification. After purification, the BOD_5 values decrease and range between 2 and 8 mg O_2 L^{-1} (average of 4.9 mg O_2 L^{-1}; SD, 1 mg O_2 L^{-1}) (Table 1 and Fig. 7). They become consistent with the JORA wastewater discharge standard (35 mg O_2 L^{-1}) and are below the WHO lower limit (110–400 mg O_2 L^{-1}) for irrigation wastewater reuse.

COD is used to assess the concentration of organic or inorganic matter, dissolved or suspended in water, through the amount of oxygen required for their total chemical oxidation [28].

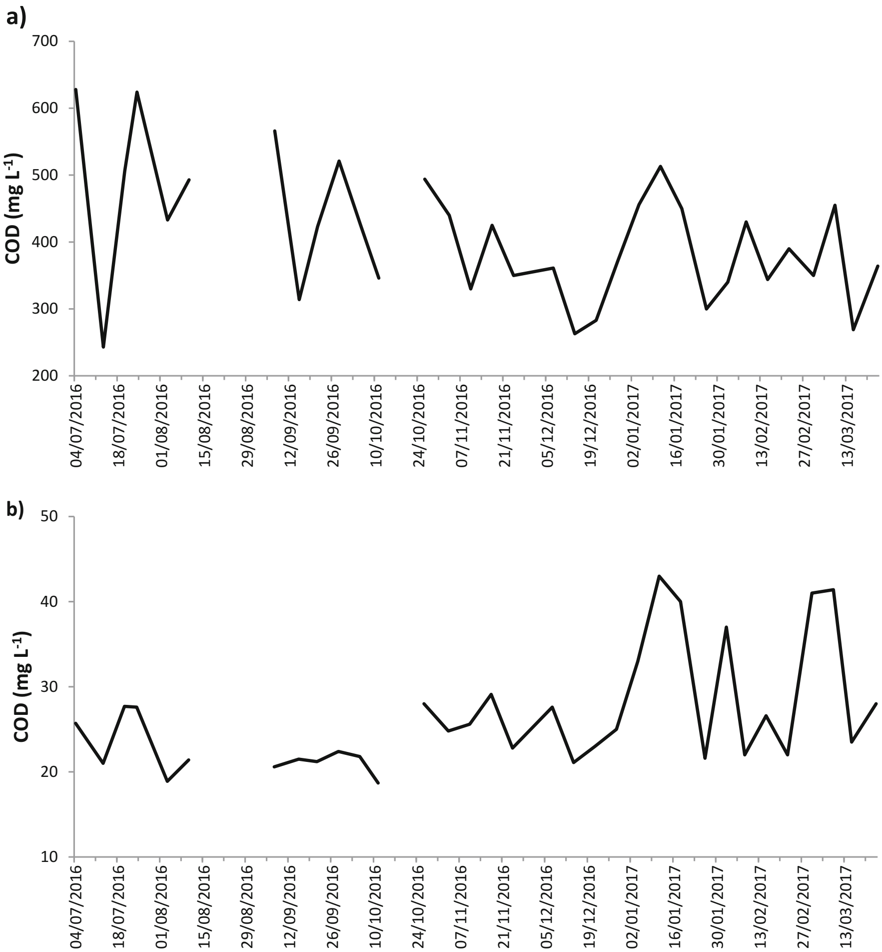

Fig. 8 Temporal COD variations of (**a**) raw and (**b**) treated wastewater

The obtained results show that the COD in water entering the WWTP vary between 243 and 628 mg O_2 L^{-1} in November and July, respectively (Fig. 8) (average, 409 mg O_2 L^{-1}; SD, 98.8 mg O_2 L^{-1}) (Table 1), indicating that Aïn Témouchent city wastewaters are heavily loaded with biodegradable and nonbiodegradable organic matter exceeding the average allowable value of 120 mg O_2 L^{-1} (JORA) authorized in watercourse discharges. This situation could, in general, have adverse effects on water quality due to the drop in oxygen content.

After treatment COD water content decreases sharply (Fig. 8), reaching values between 18.7 and 43 mg O_2 L^{-1} (average, 26.5 mg O_2 L^{-1}; SD, 7 mg O_2 L^{-1}).

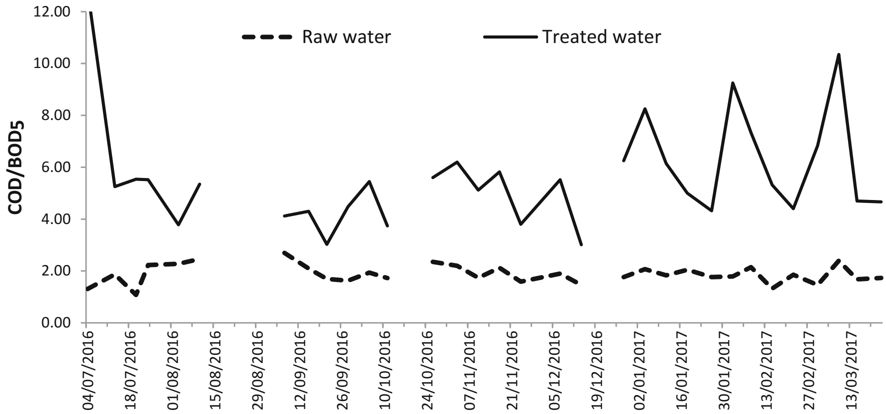

Fig. 9 Temporal COD/BOD_5 variations of raw and treated waters

These value ranges meet the JORA limit of 120 mg O_2 L^{-1} for wastewater discharged into the receiving environment.

The correlation between COD and BOD_5 in wastewater ($r = 0.64$) indicates the presence of biodegradable matter that is easily oxidable [24].

The COD/BOD_5 ratio is a measure of how much easily total biodegradable organic matter is present in the effluent. This biodegradability index is also very useful for monitoring the effectiveness of biological treatments [29].

The following rules are generally used:

– $COD/DBO_5 < 3$ easily biodegradable effluent
– $3 < DCO/DBO_5 < 5$ medium biodegradable effluent
– $DCO/DBO_5 > 5$ effluent and is not readily biodegradable or even nonbiodegradable [29]

Calculated COD/BOD_5 ratio (Fig. 9) varies from 1.08 to 2.70 (average, 1.83) in raw water, indicating that these effluents are easily biodegradable. After treatment, this ratio reaches values varying between 3.03 and 12.85 (average, 5.29), and then effluents remain in general not readily biodegradable.

3.8 *Total Nitrogen*

Nitrogen present in urban wastewater comes mainly from human waste. Urines contribute largely to this intake especially in the form of urea, uric acid, and ammonia. In addition, kitchen waters carry proteins containing amino acids and certain surfactants (detergents, softeners) which include in their molecules nitrogenous radicals [30]. Total nitrogen in the wastewater prior to treatment was from 32.5 to 80 mg L^{-1} (average, 50.6 mg L^{-1}; SD, 12.2 mg L^{-1}) (Fig. 10). The treatment

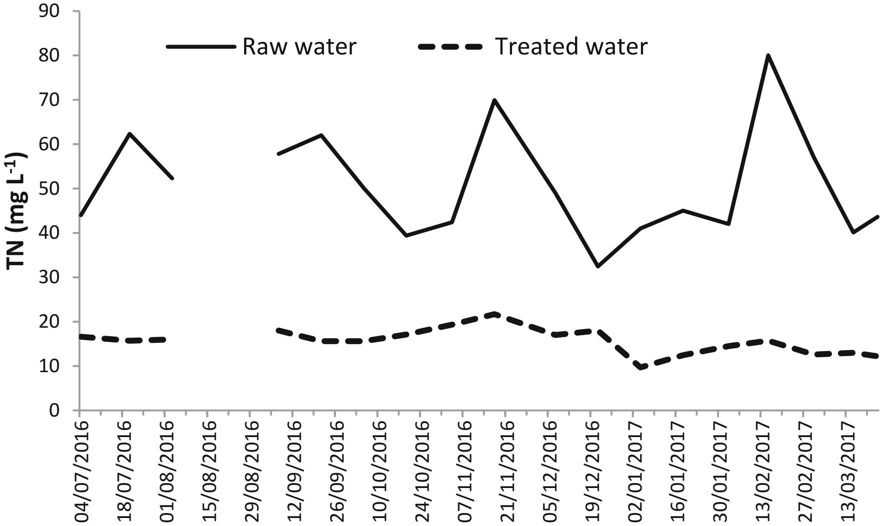

Fig. 10 Temporal TN variations of raw and treated wastewater

requirement had a significant influence on lowering the NT content from 9.7 to 19.4 mg L^{-1} (average, 15.6 mg L^{-1}; SD, 2.9 mg L^{-1}) (Fig. 10).

3.8.1 Total Kjeldahl Nitrogen (TKN)

Kjeldahl nitrogen does not represent all nitrogen but only all of its reduced organic and ammoniacal forms [29]. It is an indicator of environmental pollution, and its control makes it possible to follow the evolution of contaminations [29].

At the WWTP entrance, the NTK oscillates between 31.81 and 79.42 mg L^{-1} (average, 50.5 mg L^{-1}; SD, 12.3 mg L^{-1}). These values were recorded during December and February, respectively, (Fig. 11).

TKN values of treated wastewater are low compared to that of wastewater with contents varying between 3.01 and 11.4 mg L^{-1} (average, 7.7 mg L^{-1}; SD, 2.4 mg L^{-1}) (Table 1 and Fig. 11).

In addition, they are less than 30 mg L^{-1}, considered to be the limit value for direct release into the receiving medium according to JORA and to the lower limit of (20–60 mg L^{-1}) of the WHO standard as for their use for irrigation purposes.

3.8.2 Nitrites (NO_2^-)

Nitrites only started to be analyzed in January 2017. Their concentrations in the wastewater at the WWTP entrance vary between 0.073 and 0.7 mg L^{-1} (Fig. 12), with an average and a standard deviation of 0.2 mg L^{-1} (Table 1). There is not a

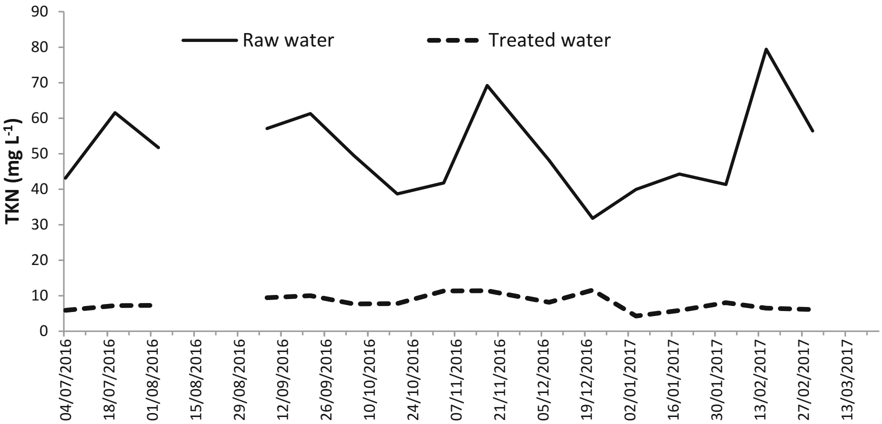

Fig. 11 Temporal TKN variations of raw and treated wastewater

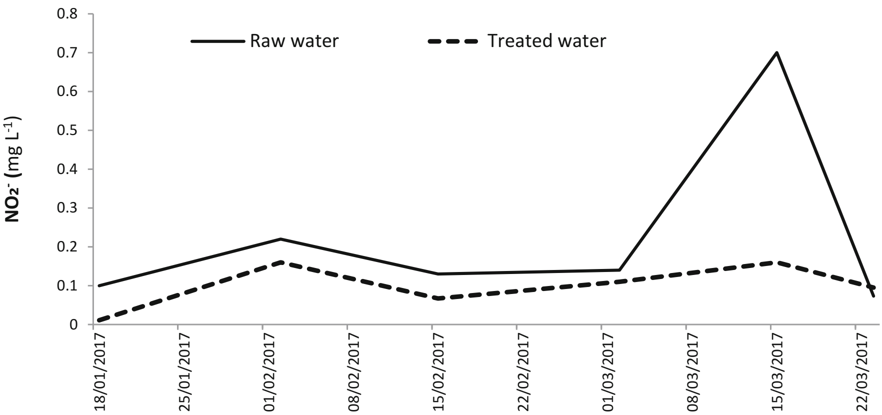

Fig. 12 Temporal NO_2^- variations of raw and treated wastewater

considerable variation in nitrite contents after purification. In cleaned water they range from 0.011 to 0.16 mg L^{-1} (Fig. 12) with an average of 0.1 mg L^{-1} and a standard deviation of 0.6 mg L^{-1} (Table 1).

The low concentrations of nitrite encountered in the studied wastewater could be explained by the fact that the nitrite ion (NO_2^-) is an intermediate compound, unstable in the presence of oxygen, whose concentration is generally much lower than that of the two forms related to it, nitrate and ammonium ions [21].

3.8.3 Nitrates (NO_3^-)

The monitoring of nitrate variation in raw wastewater from the WWTP of the Aïn Témouchent city (Table 1 and Fig. 13) shows that their NO_3^- contents vary between

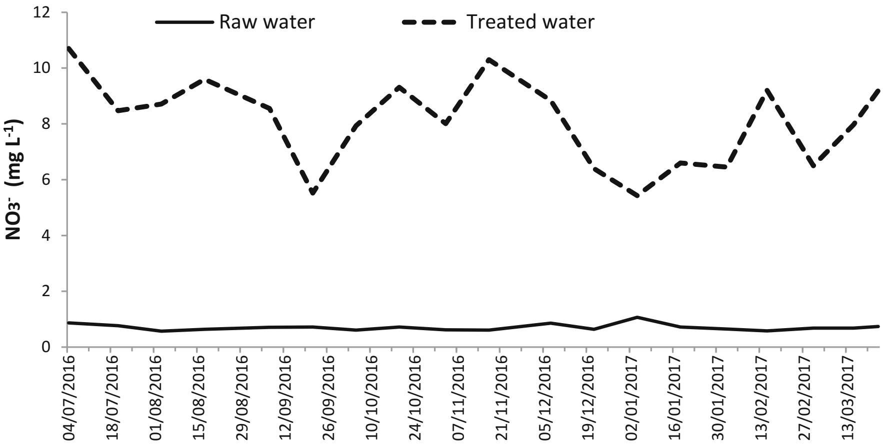

Fig. 13 Temporal NO_3^- variations of wastewater and treated water

0.57 and 1.07 mg L^{-1}, with an average of 0.7 mg L^{-1} and a standard deviation of 0.12 mg L^{-1}.

The nitrate concentrations recorded at the outlet of the WWTP (Table 1 and Fig. 13) vary considerably. They range from 5.43 to 10.7 mg L^{-1}, with an average of 8.1 mg L^{-1} and a standard deviation of 1.5 mg L^{-1}.

The comparison of the nitrate concentrations of the wastewater analyzed with the water quality standard for irrigation shows that they comply with the FAO standard [31] and present a slight to moderate restriction for irrigation water.

3.8.4 Ammonium (NH_4^+)

The ammonium contents in the wastewaters at the WWTP entrance (Table 1 and Fig. 14) range from 19.35 to 64.37 mg L^{-1}, with an average of 39 mg L^{-1} with a standard deviation of 10 mg L^{-1}.These ammonium concentrations decrease after purification (Table 1 and Fig. 14) to values between 0.21 and 2.9 mg L^{-1}, with an average of 1.1 mg L^{-1} and a standard deviation of 0.6 mg L^{-1}.

The variations in the ammonium content recorded in the purified water could be explained by better oxygenation leading to the oxidation of ammonium to nitrate ion.

3.9 Total Phosphorus and Orthophosphates

Total phosphorus is present in a sample in the form of phosphates or organic phosphorus compounds. In wastewater, phosphorus can come from human metabolism, washing and cleaning products, and orthophosphates from the hydrolysis of inorganic phosphate. Phosphorus release from wastewaters into watercourses can

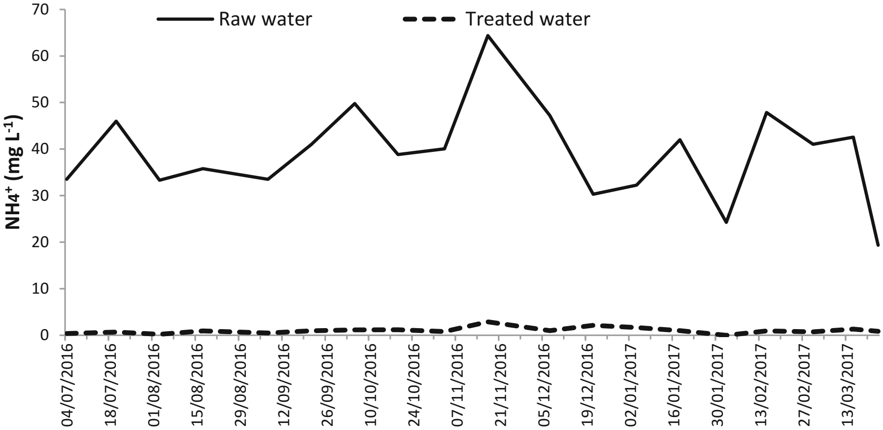

Fig. 14 Temporal NH_4^+ variations of wastewater and treated water

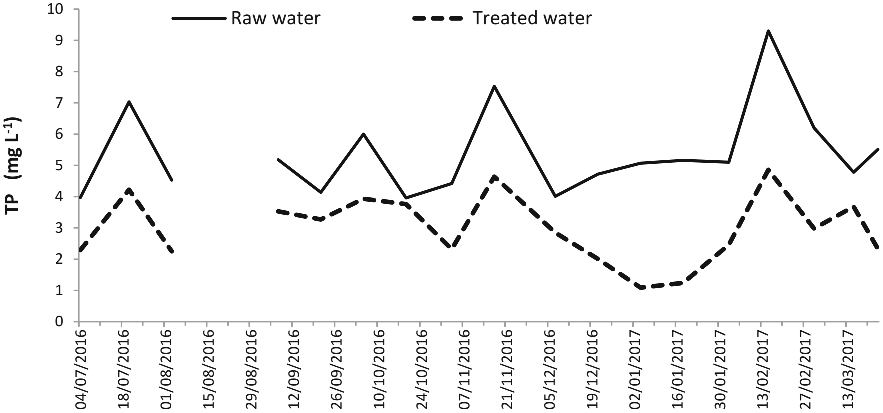

Fig. 15 Temporal TP variations of raw and treated wastewater

cause undesirable effects, such as eutrophication and its related effects [32–35] which leads to profuse algal blooms, excessive growth of aquatic plants, deoxygenation, and water purification problems [36, 37].

The results of raw wastewater analyses (Table 1 and Fig. 15) show that total phosphorus contents vary between 3.96 and 9.3 mg L^{-1} (average, 5.4 mg L^{-1}; SD, 1.4 mg L^{-1}). After purification, the TP values in treated water decreased (Table 1 and Fig. 15) to record contents ranging from 1.09 to 4.86 mg L^{-1} (average, 3.0 mg L^{-1}; SD, 1.1 mg L^{-1}).

These TP concentrations are below 10 mg L^{-1}, the direct release limit value in the natural environment according to JORA, and are generally below the lower limits of

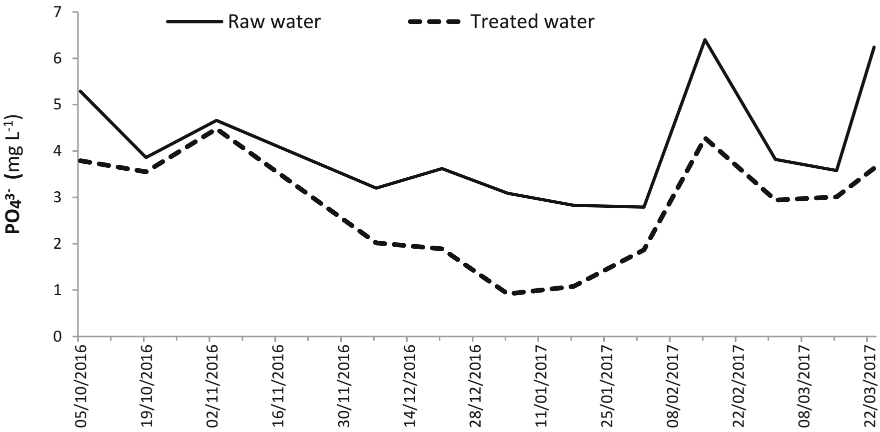

Fig. 16 Temporal PO_4^{3-} variations of wastewater and treated water

the WHO and the FAO [31] standards and can therefore be used for irrigation purposes.

The recorded orthophosphate levels do not vary considerably during the sampling cycle carried out (Table 1 and Fig. 16). Their values vary between 2.79 and 6.4 mg L^{-1} with an average of 4.1 mg $L^{-1}$and a standard deviation of 1.3 mg L^{-1}.

The concentrations of orthophosphate wastewater decreased after treatment (Table 1 and Fig. 16), reaching values of 0.92 and 4.48 mg L^{-1} (average, 2.8 mg L^{-1}; SD, 1.2 mg L^{-1}).

4 Conclusions

Temperatures and pH values at the inlet and outlet of the WWTP show no significant differences and are generally in compliance with wastewater discharge in receiving mediums and reuse standards for irrigation use. Wastewater conductivity values are between 1,240 and 2,730 μS cm^{-1}. They vary after purification to reach values ranging from 1,460 to 2,730 μS cm^{-1} and can therefore be used for crop irrigation according to the standard recommended by WHO.

The values of the COD/BOD_5 ratios for approximating the biodegradability of organic matter in a given effluent indicate that this wastewater is domestically dominant and, in general, easily biodegradable. This biodegradability is well evidenced by the values of the ratios COD/$BOD_5$and which vary between 1.08 and 2.70.

The analyses also revealed significant decreases in BOD_5 and COD. In treating water, they are between 2–8 mg L^{-1} and 18.7–43 mg L^{-1}, respectively, and therefore remain in compliance with JORA discharge standards and those recommended by the WHO for irrigation wastewater reuse. We note, however, an increase in the dissolved oxygen concentration of treated water (6.49–9.63 mg L^{-1}) compared to that of wastewater (0.46–4.46 mg L^{-1}).

Elevated suspended matter content in wastewater (84 to 464 mg L^{-1}) decreases in low concentrations in treating water. The values of the SM concentrations in the latter, between 2 and 17 mg L^{-1}, meet the JORA water discharge standard.

The analyses also revealed significant nitrogen pollution. The high Kjeldahl nitrogen concentrations in raw water (31.81–79.42 mg L^{-1}) decrease after treatment to reach values between 3.01 and 11.6 mg $L^{-1}$and are therefore within the standards of discharge in the environment and that of wastewater reuse in crop irrigation.

Phosphorus is present in treating water with concentrations ranging from 1.09 to 4.86 mg L^{-1}. These values are in line with the JORA effluent discharge standards and the FAO and WHO standards for irrigation use.

5 Recommendations

It is well-known that wastewater should be disposed of in a manner that it should not be harmful to the environment and human health. Currently, although implemented devices allow the elimination of pollutants contained within this effluent, reuse of wastewater from WWTP could cause unhealthy problems. It is necessary to ensure the performance of the treatment techniques used by performing complete physical, chemical, and bacteriological analyses of the treated water.

As for reuse for irrigation, a monitoring and frequent testing of the clean water should be made to ensure the international standards and maximum safety levels. For instance, it was observed that helminth eggs, which constitute a health risk to the human population, might remain in the outlet water, while the separation should be almost total. An increase of awareness at all levels with particular emphasis on WWTPs among farmers is required to mitigate the risks that may be incurred by the population. Farmers should use appropriate crops with treated water and suitable irrigation techniques.

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