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ORIGINAL ARTICLE

Bacteriological and physicochemical quality of treated wastewater of the Mzar treatment plant

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Abstract

In order to use purified wastewater on watering green spaces of Agadir city, we conducted this study to assess the bacteriological and physicochemical quality of treated wastewater in Mzar treatment plant. To realize these objectives, we analyzed four types of waters: raw water (RW), decanted water, purified water and purified water treated by the ultraviolet radiation (PWUV). The biologically analyzed parameters are fecal coliforms (FC) and fecal enterococci (FE). The physicochemical parameters are: pH, electrical conductivity, chemical oxygen demand (COD), five-day biological oxygen demand (BOD_5) and total suspended solids (TSS). The results showed a high level of bacterial contamination in all types of waters, and the average loads of FC were between 4.71×10^6 CFU/100 mL (RW) and 1.45×10^3 CFU/100 mL (PWUV), while loads of FE were between 2.62×10^5 CFU/100 mL (RW) and 7.92 CFU/100 mL (PWUV). The physicochemical parameters show a pH close to neutrality and a high electrical conductivity (3261 µS/cm) in PWUV. In all stages of wastewater treatment, values of COD, BOD_5 and TSS were under the limit values recommended by Moroccan standards. Except for the electrical conductivity and FC, all the studied parameters were under the limit values requested by the Moroccan standards. The microbiological quality of PWUV is unstable, and if these waters are reused, they can affect the microbiological and physicochemical quality of green spaces and groundwater.

Keywords Morocco · Wastewater · Green spaces · Physicochemical parameters · Thermotolerant coliforms · Fecal enterococci

Introduction

Like most local countries, Morocco suffers from scarcity and unequal distribution of water. In this context, alternative sources of water would be greatly appreciated (Ouhamdouch et al. 2016). Indeed, the water deficit can be filled mainly by treated wastewater; this resource is abundantly and continuously available. It has many advantages, notably a reasonable cost compared to the desalinating seawater or digging wells. (The water table is too deep in the Souss Massa region.) These waters are naturally rich in phosphates and nitrates that allow the minimization of industrial fertilizers needs.

Reusing treated wastewater has very important environmental aspects. In reality, once treated it protects receiving environments: lakes, rivers, estuaries and oceans. Despite the benefits of wastewater reuse, it could presents significant risks for users and the environment (eutrophication and heavy metals) (Habbari et al. 2000; Metcalf and Eddy 2003; Cha et al. 2004; Qadir et al. 2010; Fatta-kassinos et al. 2011). Actually, household sewage contains a high percentage of organic materials and pathogenic microorganisms, including bacteria, viruses and parasites. Many diseases are associated with such microorganisms including typhoid, dysentery, diarrhea, vomiting and malabsorption. Any human contact with the raw wastewater might be hazardous (Shakir et al. 2017). In Morocco, many studies have focused on this point. Sadly, just few studies have been carried out in Agadir (Mimouni et al. 2002, 2003; Alla et al. 2006; Eddabra et al. 2011), which is particularly characterized by an arid climate, and high industrial and agricultural activities. Many of the reported studies in Agadir were focalized on chemical risks (Mouhanni et al. 2011;

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Aba-aaki et al. 2013) and microbiological hazards of reuse of wastewater (Touyer et al. 1998; Mimouni et al. 2002, 2003; Eddaoudi et al. 2004; Eddabra 2011; Fonteneau et al. 2017). The purpose of this study is to evaluate the possibility of reusing treated wastewater from the Mzar treatment plant in the irrigation of green spaces. It mainly consists in studying different parameters (i.e., thermotolerant coliforms, fecal enterococcus, temperature, pH, electrical conductivity, COD, BOD_5 and TSS), which govern the reuse of wastewater and compare it with national and international standards.

Materials and methods

Description of Mzar treatment plant

The Mzar treatment plant (30°20′28.1″N, 9°35′35.0″W) is located in the south of Agadir, Morocco; it was built in 2002 inside the Souss Massa national park (Fig. 1). The purification mode, includes three successive treatment stages (Table 1), carried out as follows: a first stage in which the raw water is sedimented for 3 days in the settling basins, with a treatment capacity of 75,000 m^3/day; a second treatment stage, in which decanted water is percolated in the sand basins, which provides a treatment capacity of 30,000 m^3/day; and the third stage, which allows a treatment capacity of 30,000 m^3/day. Finally, the infiltrated water is disinfected by UV exposure (RAMSA 2002).

Samples collection

A total of 60 samples were collected over 5 months; the sampling lasted from February to June 2015. Monthly, three replicates of each sample were collected from four sampling points (Fig. 1). It included: raw water (RW) at entrance to the plant, decanted water (DW) after three sedimenting days

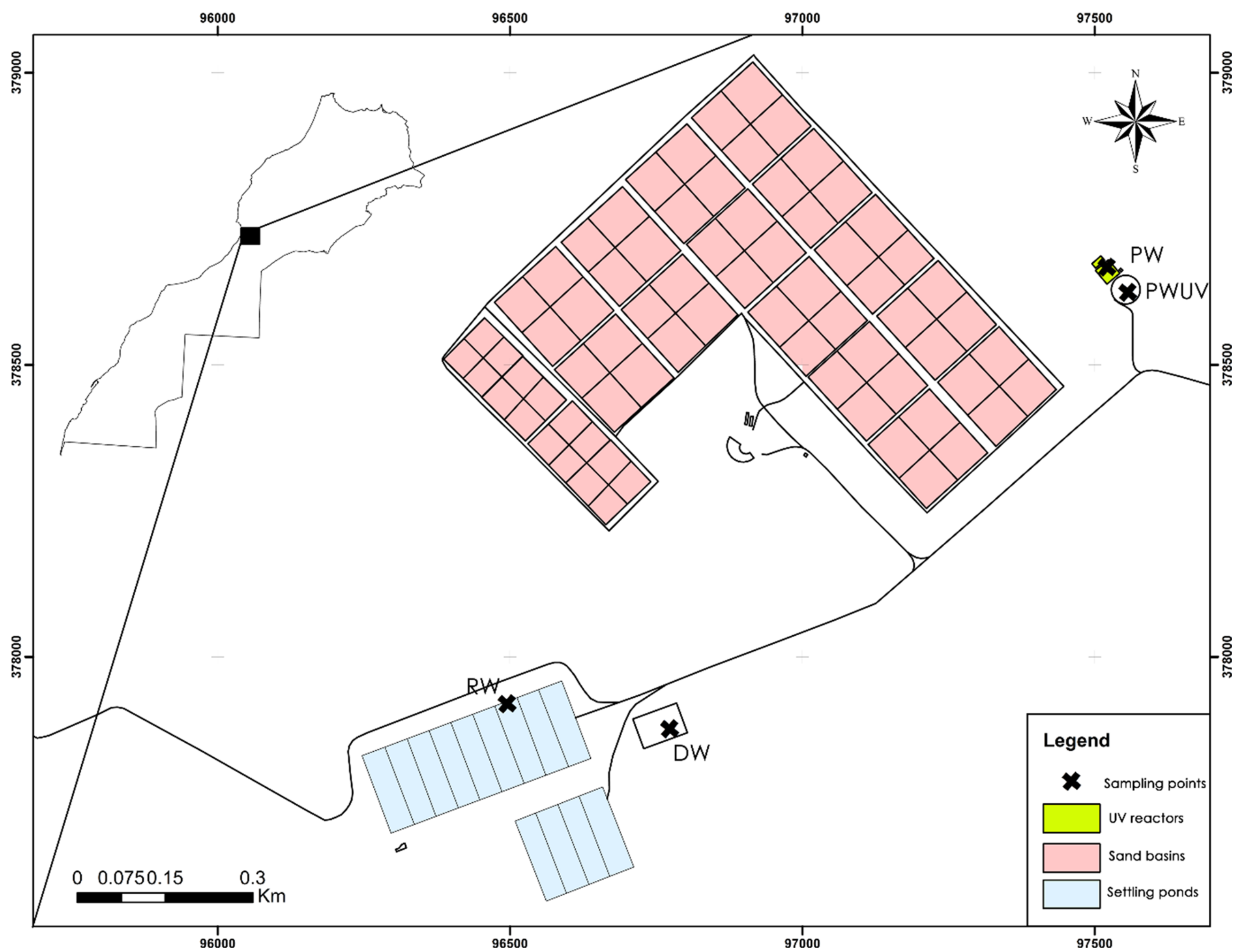

Fig. 1 Map of the Mzar wastewater treatment plant, located in the south of Agadir, Morocco. *RW* raw water, *DW* decanted water, *PW* purified water, *PWUV* purified water disinfected with ultraviolet radiation

Table 1 Physical and geometrical characteristics of the wastewater treatment process of the Mzar WWTP *Source*: RAMSA (2002)

Primary treatment: anaerobic decantation		Secondary treatment: infiltration percolation		Tertiary treatment: UV disinfection		
Flow	75,000 m^3 per day	Flow	10,000 m^3 per day	Flow		30,000 m^3 per day
Number of decanters	13	Number of filters	64	Pumps (number and unit capacity)		6 + 1 Pumps—270 m^3/h
Length of decanter	115 m	Filter surface	5000 m^2	Reactors (number and unit capacity)		6 Reactors—5000 m^3 per day
Width of decanter	35 m	Sand thickness	2 m	*UV lamps*	Number per reactor	14 lamps
Depth of the decanter at the deposit area	6.59 m	Gravel thickness	0.5 m		Wavelength	254 nm
Depth of decanter at lagoon area	4.24 m	Infiltration speed	1 m per day		Exposure dose	50 mJ/cm^2
Total volume of decanter	210,000 m^3	Filter bottom sealing material	1 mm thick of HDPE geomembrane		Service life	16,000 h
					Contact time	4 s

in the settling ponds, and purified water (PW) at the output of the sand basins, finely, purified water disinfected with ultraviolet radiation (PWUV) at the exit of the UV reactors.

Bacteriological and physicochemical analyses

Samples were taken in strict aseptic techniques to prevent any accidental contamination. Each sample was carried out in sterile flasks. Collected samples were stored in a cooler (4 °C) and then transmitted to the laboratory on the same day for analysis. They were analyzed by filtration method (100 mL on 0.45 µm membrane), according to the standards of ISO 9308-1:2014. Results were expressed by colony forming units (CFU) per 100 mL of sample.

The pH, temperature, conductivity and COD were determined in situ by a pH meter equipped with a multi-parameter probe types CONSORT C831. The total suspended solids (TSS) were identified by filtration (Whatman circular filters of 47 mm in diameter and 0.45 µm of porosity), according to French Standard Methods AFNOR 2005 (T90-105). The five-day biological oxygen demand (BOD_5) was determined by the manometric method with a respirometer (types WTW), according to AFNOR standard (NF T90-101). The oxidizable matter (OM) is calculated as follows: Oxidizable matters $= (2\mathrm{BOD5} + \mathrm{COD})/3\,\mathrm{mg/L}$.

Results

Physicochemical parameters

The pH values were semi-neutral in all types of waters (Table 2). The temperature averages ranged between 19.1 °C and 20.9 °C. The conductivity variations were important (2170–3340 µS/cm), the lowest recorded value was the one of RW and the most important was the one of PW (Table 2). For PW and PWUV, values recorded for conductivity are all higher than 3000 µS/cm, which is the limit value of direct discharge into the receiving environment. The extreme values of BOD_5 were, respectively, 1720 mgO_2/L and 11 mgO_2/L, recorded upstream and downstream the Mzar WWTP (Table 2).

The COD recorded values for the PW remain below 500 mgO_2/L. Upstream and downstream the plant, the average values are, respectively, 1821 ± 280 mgO_2/L and 43 ± 7 mgO_2/L (Table 2). For total suspended solids as for BOD_5 and COD, the values at the entry of the station are very important, and then, after the process, these values decrease until they reach the lowest values in PW and PWUV (Table 2).

Typology of Agadir's waters

Assessing the ability of wastewater to biodegrade is of primary interest for wastewater treatment. Indeed, this biodegradation ability will guide the choice of treatment process (biological or physicochemical treatment). The combination of the two global pollution parameters COD and BOD_5 allows a good approach to biodegradability, the COD representing the organic matter as a whole and the BOD the only biodegradable fraction under fixed conditions (Rodier et al. 2009). The relationship between COD, DBO_5 and TSS allows the estimation of the oxidizable matter (OM) and has a very important interest for a better appreciation of the origins, nature and biodegradability of the studied effluents (Table 3).

Table 2 The average values of physicochemical parameters of Agadir wastewater, from February to June 2015

Parameters	Unit	Water type	Minimum	Maximum	Average $n=5$	SD
pH	–	RW	7.40	7.67	7.54	0.12
		DW	7.31	7.42	7.37	0.06
		PW	7.85	8.00	7.92	0.07
		PWUV	7.93	7.99	7.95	0.03
Temperature	°C	RW	19.50	20.90	20.15	0.57
		DW	19.30	20.40	19.75	0.54
		PW	19.10	19.50	19.23	0.19
		PWUV	19.20	19.80	19.53	0.32
Electrical conductivity	µS cm^{-1}	RW	2170.00	3010.00	2520.00	352.42
		DW	2780.00	3110.00	3002.50	155.64
		PW	3240.00	3340.00	3302.50	45.00
		PWUV	3120.00	3314.00	3261.50	94.47
COD	mgO_2 L^{-1}	RW	1412.00	2045.00	1821.50	280.06
		DW	528.00	834.00	716.75	133.90
		PW	36.00	56.00	44.50	7.55
		PWUV	34.00	57.00	43.00	7.79
BOD_5	mgO_2 L^{-1}	RW	983.78	1720.14	1389.44	313.17
		DW	321.00	422.25	385.16	44.89
		PW	7.00	20.15	11.52	5.84
		PWUV	7.00	22.04	11.34	5.48
TSS	mg L^{-1}	RW	593.00	785.00	697.81	81.51
		DW	245.00	420.00	321.98	86.78
		PW	4.00	11.00	6.84	3.03
		PWUV	4.00	11.00	6.50	3.11

RW raw water, *DW* decanted water, *PW* purified water, *PWUV* purified water treated by the ultraviolet radiation, *pH* power of hydrogen ion, *EC* electrical conductivity, *CDO* chemical oxygen demand, *BOD_5* biochemical oxygen demand after 5 days, *TSS* total suspended substance

Table 3 Oxidizable matter and biodegradability of Mzar sewage effluent

Parameters studied	February 2015	March 2015	April 2015	May 2015	June 2015	Min	Max	Average $n=5$	SD
COD/BOD_5	1.45	1.35	1.44	1.11	1.37	1.11	1.45	1.34	0.14
BOD_5/COD	0.69	0.74	0.70	0.90	0.73	0.69	0.90	0.75	0.09
TSS/BOD_5	0.51	0.52	0.60	0.42	0.49	0.42	0.60	0.51	0.06
OM (mg/L)	1531.60	1695.30	1126.50	1780.40	1597.30	1126.50	1780.40	1546.20	253.00

The COD/BOD_5 ratio

The COD/BOD_5 ratio is very important to assess the biodegradability of wastewaters in the treatment plant. During the study period, the values recorded are below 3 and the average value of the COD/BOD_5 ratio is 1.34 ± 0.14 (Table 3), which means that the effluents of the great Agadir are easily biodegradable and the dominant character is that of domestic wastewaters.

The BOD_5/COD ratio

To characterize industrial pollution, we considered the BOD_5/COD ratio, which gives very interesting insights into the origin of the wastewater pollution and its treatment options (Benyakhlef et al. 2007).

The values recorded during the study period ranged from 0.69 to 0.90 (Table 3); these values show a very high organic load and confirm the possibility of an easily biological treatment, being higher than 0.3. The BOD_5/COD ratio indicates a dominance of organic matters (Bouknana et al. 2014).

TSS/BOD_5 ratio

The average TSS/BOD_5 ratio is 0.51 ± 0.06 (Table 3), which is relatively low compared to the usual value (between 1.2 and 1.5) (Ministry of Land and of Morocco 2002). This report provides additional information about organic matter quantities in the effluent, but also provides information about sludge production (Mouhanni et al. 2011).

Oxidizable matter

In wastewater, oxidizable matter is the global assessment of an organic pollution, especially for pollution tax purposes. The term "oxidizable matter" (OM) corresponds to a weighted average of two global parameters the COD and the BOD_5, by assigning a double coefficient to BOD_5 (Rodier et al. 2009).

In urban effluents, oxidizable materials represent a significant pollutant load and they are taken into account in the definition of the population equivalent. The OM is a very useful parameter for assessing the pollutant load and possibility of connection of industrial plant to the municipal sewerage network. In reality, most organic materials become polluting only when they are found in excess in the environment (Bouknana et al. 2014).

Through the study period, the values obtained of OM were very high (Table 3); the average value was 1546 ± 253 mg/L. This result, along with the reports of TSS/BOD_5 and BOD_5/COD, testifies the very high loads of organic matter carried by the effluents of Agadir city.

Enterococcus and fecal coliforms

The fluctuations of bacterial populations in different sampling points during the study period are shown in Figs. 2 and 3. The average bacterial loads of fecal coliforms are very high. With 4.71×10^6 CFU/100 mL in row water, after treatment this value is reduced to 1.45×10^3 CFU/100 mL in PWUV. However, the loads in PWUV remain above the Moroccans/WHO standard (< 1000 CFU/100 mL). Values above the standard were observed during the first 3 months of the study.

It appears that the wastewater treatment process is effective in reducing loads of the enterococcus. During the study

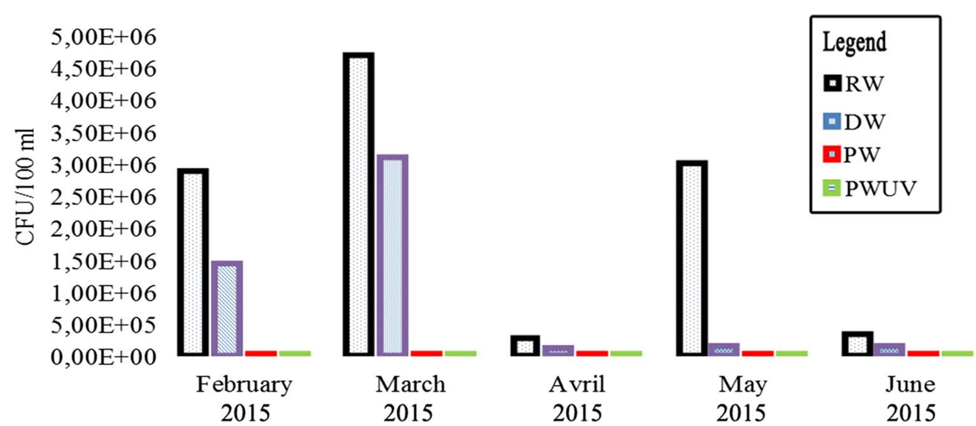

Fig. 2 Fecal coliforms levels in different types of wastewaters in Mzar treatment plant

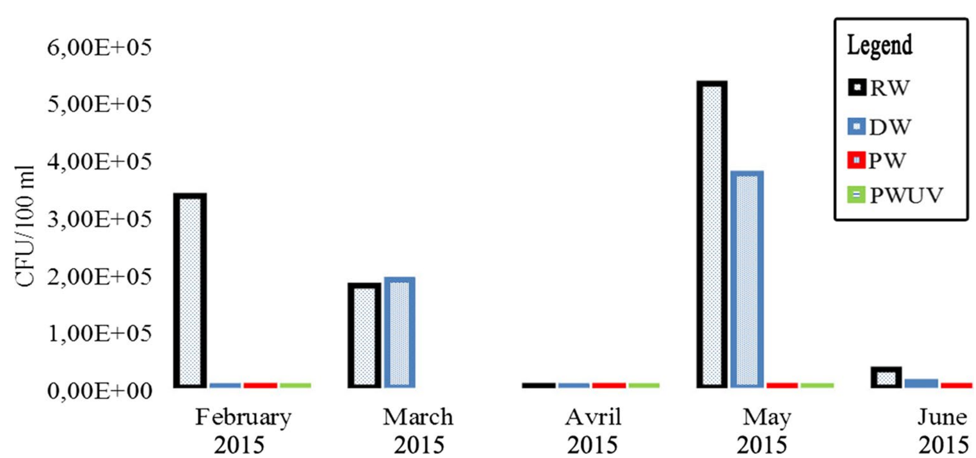

Fig. 3 Fecal enterococcus levels in different types of wastewaters in Mzar treatment plant

period, high loads of FE were recorded in RW, with an average of 2.62×10^5 CFU/100 mL. These values are reduced gradually as the processing path progresses to reach an average of 7.92 CFU/100 mL in PWUV. Throughout the study period, The FC/FE ratio was always superior to three (FC/FE > 3), which is an evidence of a human fecal contamination in all types of waters.

Discussion

The southern Morocco is the most affected by the drought and water scarcity, and available water resources are used mainly in agriculture. Reuse of treated wastewater for watering the city's green spaces seems to be a promising choice to reduce the pressure on the water tables. Currently, the PWUV of the Mzar WWTP are reused to water a golf course in Agadir city. This study aims to evaluate the bacteriological and physicochemical quality of the PWUV, to assess the effectiveness of UV disinfection and to prevent their health and environmental risks.

For studied parameters, the pH values in different types of waters are close to neutrality and were acceptable for watering green spaces according to de Moroccan standards (MS) similar to the WHO guidelines (Ministry of Land and of Morocco 2002). However, it should be noted that the pH values which are lower than 5 or higher than 8.5 affect the growth and the survival of soil microorganisms (Jeison et al. 2008).

Through the study period, the temperature in all types of waters was below 35 °C, recognized as the limit value recommended by the MS and WHO. Moreover, the temperature is an important ecological factor for the proper functioning of anaerobic sludge digestion.

The electrical conductivity of the water samples ranged from 2170 to 3340 µS/cm. Throughout the study period, higher EC was observed in treated final effluent samples, which reflects a high level of water salinity. The latter increases the osmotic pressure of the soil solution and prevents imbibition of seeds and roots absorption. The increase in electrical conductivity can be explained by: the mineralization of organic matter by bacteria during the treatment process and by the chemical and geometric properties of the sand use in percolation infiltration basins (Et-taleb et al. 2014; El Haouti et al. 2015).

Agadir region is a very active economic and industrial pole. Fisheries are the second important activity of the local population. Every year, the fish plants reject tons of brines and organic matters in sanitation system of the city (Mimouni et al. 2002; Gillet et al. 2003). Consequently, high levels of salinity, COD, BOD_5 and TSS are recorded in raw water. The latter are overloaded by fish scales, which have a very slow biodegradability. Despite the influence of industrial effluents, wastewaters of the greater Agadir remain in the category of readily biodegradable water (COD/BOD_5 ratio < 3). In addition, the Mzar treatment plant is able to reduce the COD, BOD_5 and MES levels below the limit values recommended by the Moroccan and WHO Standards.

Significant work has been undertaken to reduce the discharge of raw industrial wastewater into the city's sewage system, and to encourage industrial wastewater pretreatment. This will have a positive impact on treatment processes. Adequate wastewater treatment can make the slow filtration and the UV disinfection more efficient.

In the field of hygiene and sanitation, bacteriological analyses often involve non-pathogenic microorganisms, but the same germs that not necessarily constitute a risk in itself for public health. Indicators of fecal contamination (IFC) are associated with intestinal pathogens (bacteria and viruses) that are dangerous to human health. In general, these germs act as IFC and allow to assess the risk of contamination by fecal matter that can carry pathogenic microorganisms, or as indicators of treatment effectiveness (ITE), to assess the quality of a water disinfection treatment against pathogenic microorganisms whose presence may be feared in the raw water used (Rodier et al. 2009).

Water disinfection is a treatment that aims to reduce the presence of pathogenic microorganisms in the water. In order to meet the Moroccan standards, the Mzar WWTP uses the UV radiation to disinfect PW. The UV disinfection has many advantages: no by-products formation, short contact time, inactivation of virus and no residues. However, it also has some weaknesses: high energy demand, high cost, influenced by high levels of suspended solids, turbidity and soluble organic matter. The effectiveness of UV radiation disinfection depends on the energy dose absorbed by the organism, the time of exposure, the color and turbidity of water (Farrell et al. 2018). Actually, high loads of TSS can significantly reduce the efficiency of the UV disinfection (Sharrer et al. 2005). If the energy dose is not high enough, the organism's genetic material might only be damaged instead of being destroyed (Collivignarelli et al. 2017). In addition, several studies have reported an increased UV resistance in environmental bacteria and bacterial spores, compared to laboratory-grown strains (Hijnen et al. 2006). Previous studies have proven that some bacteria genus can easily cross the treatment process, while remaining are viable (Eddabra et al. 2011; Fonteneau et al. 2017); and this is further confirmed by the present study.

In treated wastewater, bacterial loads were deeply influenced by the initial loads in raw water, physicochemical parameters and climatic conditions. In fact, slow sand filtration is a water treatment process that is well suited for use by small water systems; the nature of the slow sand filtration causes some serious limitations on utilization of the process. An important limitation is the need for high-quality source water or appropriate pretreatment or filter modification to cope with water quality that is less than ideal (Logsdon et al. 2002).

This research showed that the UV disinfection at the Mzar WWTP was insufficient to provide water that meets the Moroccan standards. It would be necessary to combine the UV disinfection with another disinfection process in order to guarantee the safety and salubrity of the PWUV (Li et al. 2018; Sun et al. 2018). Even after treatment, wastewaters constitute a potential risk for human health and environment, and for that reason, it is necessary to keep a constant monitoring. In this study, bacteriological analyses showed significant loads of fecal coliforms. It made us wonder about the effectiveness of Mzar treatment process and the ability of UV reactors to provide waters that meet the Moroccan/WHO standards.

Currently, only one golf course is watered by the PWUV of the Mzar WWTP. Low demand on PWUV can have negative effects on the quality of this water. Indeed, long waiting times and storage conditions may be the cause of cross-contamination. In PWUV storage basins, the bacteriological contamination can be due to bacterial biofilms, accidental contamination and by the multiplication of bacteria that escape the UV disinfection (Farrell et al. 2018).

The climatic conditions play an important role in the treatment process (Chebor et al. 2018), and this becomes more apparent by monthly fluctuations of temperature. Indeed, in the coldest months of the study, significant burdens were recorded, mainly on February and March with the highest FC loads.

In the Mzar treatment plant, it seems that the initial bacterial loads and the temperature were the main factors involved in the bacteriological quality of final effluent. For FE, very low burdens were recorded during the entire study period, with slight increase in the coldest months. In Morocco, there is no standard for the enterococci. However, these organisms were used all over the world to provide additional information on fecal contamination of water (Boehm and Sassoubre 2014). Hence, there is a need for continuous monitoring to assess the effect of seasonal variations on different bacteria loads. Using these waters in green areas irrigation can hinder the quality and safety of these areas and put population at risk. The charges enumerated during the entire period of the study were superior to the Moroccan standards and WHO recommendations. The results obtained during this study corroborate and improve the results obtained previously (Eddabra et al. 2012).

The main limitations of the study were the short duration of this study, no 24/24 direct debiting system and turbidity not being measured, which is a key parameter for UV disinfection.

Conclusion

Monitoring of the microbiological and physicochemical parameters in all types of waters from Mzar treatment plant made it possible to assess their quality. The following conclusions were drawn from the current study: apart from the high conductivity and high loads of fecal coliforms, all the other parameters were in conformity with the Moroccan standards. Indeed, for fecal coliforms and conductivity, levels recorded during this study were above the Moroccan standard. Unfortunately, PWUVs distinguished for watering green spaces do not meet the criteria set by the Moroccan and WHO reuse standards. Therefore, it is necessary to take appropriate preventive measures in order to reduce the health risk and prevent further pollution of green spaces and groundwater.

As prospects, we plan to study the effectiveness of UV disinfection, to investigate the elimination of same pathogenic bacteria as *Salmonella* spp. and *Vibrio* spp. and explore the microbiological impact of PWUV reuse on the groundwater and city's green spaces.

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