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Characterization of byproducts from wastewater treatment of Medea (Algeria) with a view to agricultural reuse

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ABSTRACT

It is imperative for Algeria by virtue of its arid to semiarid climate to rationalizing the use of conventional water resources. That is why the agricultural reuse of byproducts is an alternative treatment expected to preserve the water resources, the environment and the promotion of the agricultural sector. The present work aims to search for the possibility of reusing treated wastewater and sludge resulting from the treatment plant of the city of Médéa in agriculture, through the analysis of physical, chemical and bacteriological on the samples, and the continuous monitoring of the evolution of several elements. The results showed that the treated water, despite its high salinity, can be reused for irrigation of some salt-tolerant species and on well-drained soil and leached. The sewage sludge, by the relatively low amount of organic matter it contains, is considered a fertilizer, more than organic amendment.

Keywords: Sustainable development; Sewage treatment plant; Treated wastewater; Sewage sludge; Standards; Reuse; Irrigation; Spraying

1. Introduction

The scarcity of conventional water represent for Algeria, under its arid to semi-arid Mediterranean climate, a major concern that negatively affects the well-being of citizens and threatens future generations. The agricultural reuse of treated wastewater and sludge generated by the treatment, represent the alternative intended to preserve the resource and parallel promotion of agriculture. This technique causes no additional investment, water is produced once for domestic use, and after pollution it is recovered and purified. Instead of being rejected into the natural environment, it will be used in agricultural irrigation. This additional resource is not negligible and always available. Moreover, its agronomic value is ensured by the fertilizers intake. The sludge generated by the treatment, is rich in organic matter and nutrients, instead of being landfilled or incinerated, it can be used as a support for fertilizer or organic amendment.

The majority of projects of wastewater reuse concern agricultural uses. The irrigation of crops or green spaces is the most widespread reuse path of urban

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wastewater. At world level; it is also the solution that has more of a future in the short and medium term [1]. The projects of treated wastewater reuse are concentrated around the Mediterranean and in industrialized countries, in Europe, the United States or in Australia. Some countries such as Tunisia, have a genuine national policies reuse of treated wastewater [2].

It is in this context that fits this work which focuses on the ability of treated wastewater and sewage sludge from the city of Medea for reuse in agriculture. This city located on the mountains of the Tell Atlas, is distinguished by its agricultural character, considered as a major consumer of water that must be developed without detriment to conventional resources.

2. Presentation and functioning of WWTP Medea

Realized and put into service during the month of April 2007, the wastewater treatment plant, located south of the city, is designed to treat wastewater from the city of Medea and its surroundings. This wastewater arrives gravity at the station by a single manifold, characterizing the sewerage system which is unitary. It operates at low mass load according to the extended aeration process, and also at load low mass according to the extended aeration process.

The treatment system comprises successively the following operations: pre-treatment, biological treatment, a chlorine station, thickening then sludge drying.

3. Materials and methods

The analyses of sludge and water from the Medea WWTP were made through 3 laboratories. Namely, that of WWTP and those of the National Institute of Soil, Irrigation and Drainage of K'sar Chellala and Algerian waters of Djelfa. The different parameters measured, methods and equipment used are given in Table 1.

4. Experimental results and interpretations

The analysis results are interpreted and compared to recommendations and standards. During the period of study, the results obtained for the two branches are presented and interpreted in Table 2.

4.1. Branch water

4.1.1. Temperature

The mean values of the wastewater temperature during the study period ranged from 13 at the *inlet* of the WWTP and 12 at its outlet. These values are within a range favorable to microbial activity (< 30°C). This promotes the biological treatment of wastewater and the development of vegetation in their agricultural use.

4.1.2. Electrical conductivity (EC)

The values of electrical conductivity recorded within the treatment plant vary from an average of

Table 1
Material and analytical methods

Parameter	Analysis method	Material used
Water		
Temperature	Thermometry	Multiparameter typeHach SensIon 156
pH	Potentiometry	pH-meter type Hach SensIon 1
Electrical conductivity	Conductimetry	Conductimeter type Hach SensIon 5
Total suspended solids (TSS)	Filtration, centrifugation	Centrifuge Hermle Z300—oven at 105°C
COD	Oxidation by $K_2Cr_2O_7$	Heating block Brand Behr-Labor Technik
BOD_5	Respirometric	Flasks OxiTop IS12, WTW—Enclosure 20°C
NH_4^+, NO_3^-, PO_4^{3-}	Spectrometric	Spectrophotometer HACH DR/4,000 V
Ca^{++}, Mg^{++}, K^+, Na^+, MTE	AAS	AAS Perkin–Elmer AAnalyst 200
Pathogens	Colimetry, streptometry	Ramp filtration—Oven Model Binder
SLUDGE		
Sludge index (SI)	30 min settling	Transparent test tube
Dryness	24 h drying at 105°C	Oven at 105°C Binder-Balance KERN Als 220
VSS	2 h calcination at 550°C	Oven at 550°C mark Nabertherm 30–3,000°C
Organic carbon	WALKLEY	Titration with a solution of Mohr's salt
TKN	KJELDAHL	Digester-distiller/Buchi
Assimilable phosphorus	JORET-HEBERT	Colorimeter brand JENWAY model 6051
Ca^{++}, Mg^{++}, Na^+, K^+, MTE	AAS	AAS brand Perkin–Elmer type AAnalyst 200

Table 2
Results of physico-chemical analyzes

		pH	T (°C)	EC (µS/cm)	TSS (mg/l)	COD (mg/l)	BOD_5 (mg/l)	NH_4^+ (mg/l)	NO_3^- (mg/l)	PO_4^{2-} (mg/l)
Average	Entry	7.5	13	2,449	737	588	377	23	3	2.5
	Output	7.25	12	2,305	22.5	72	9	2	15	1.6

2,449 µS/cm at the *inlet* and 2,305 μS/cm at the outlet. According to FAO 1985 [3], these values are in the range of mild to moderate restriction for the quality of irrigation water.

The effluent of the WWTP Medea belongs to classes IV, according to [4], the use of very high salinity waters, belonging to classes IV for agriculture, is possible on particularly resistant crops (Fig. 1).

4.1.3. pH

The pH of the wastewater varies from 7.5 at the inlet of the WWTP and 7.25 at the outlet. It is relatively stable in the vicinity of neutrality as is the case for most domestic wastewater. According to FAO 1985 [3], the pH is in the normal range between 6.5 and 8.4.

4.1.4. Total suspended solids

The total suspended solids (TSS) analysis shows a very significant decrease of the mean values of the inlet (737 mg/l) to the outlet (22.5 mg/l) of the station. The Medea WWTP was able to strongly reduce particulate pollution, a reduction of 96%. This still gives an idea about the effectiveness of treatment, specially if one considers that standards of TSS for discharging treated water is < 30 mg/l based on recommendations USEPA [5].

4.1.5. Biological oxygen demand

The mean values of biological oxygen demand (BOD_5) recorded within the WWTP vary from 377 mg/l at inlet and 9 mg/l to outlet, or a reduction of 97% of the organic load. This indicates that the biological treatment performed on the wastewater is very acceptable, especially if one considers that the recommendation USEPA requires $BOD_5 < 30$ mg/l.

The effects of organic matter exerted mainly on soil properties, both physical (structural stability, ventilation, water retention and economy), chemical (exchange capacity) or biological [6,7] (Fig. 2).

4.1.6. Chemical oxygen demand

The average concentrations of chemical oxygen demand (COD), shows extensive reductions in the purification process, 88% yield, justified by recording an average value of COD for raw water 588 mg/l and treated wastewater at the outlet of the station, an average value of 72 mg/l.

4.1.7. Biodegradability coefficient k = COD/BOD_5

The wastewater entering the WWTP is predominantly of domestic nature. It is deduced from the ratio $k = COD/BOD_5$ which is on average $1.56 < 2.5$, indicating that the oxidizable matter (OM) of wastewater is very easily biodegradable.

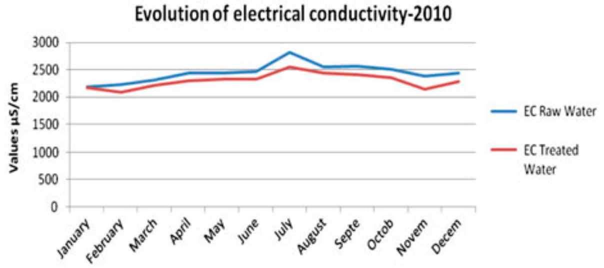

Fig. 1. Graphic representation of the evolution of the EC at the inlet and at the outlet of the WWTP.

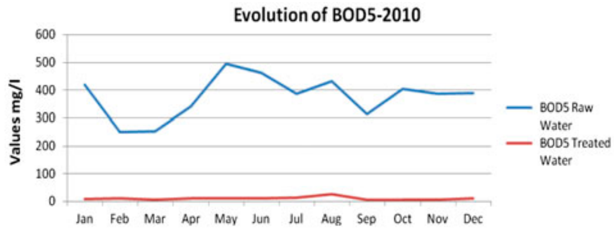

Fig. 2. Graphic representation of the evolution of BOD_5 to the inlet and the outlet of the WWTP.

Table 3
Ionic species of SAR measured

Element measured	Concentration (mg/l)	Concentration (meq/l)
Na^+	85	3.70
Mg^{++}	29	2.38
Ca^{++}	97	4.84
SAR		1.95

4.1.8. Sodium adsorption ratio

Knowing that $[SAR = Na^+/\ [(Ca^{++} + Mg^{++})/2]^{1/2}]$, the results of analysis of ionic species sodium adsorption ratio (SAR) found in our water, are given in Table 3.

As measured, the electrical conductivity of the treated wastewater at the WWTP is an average of 2305 μS/cm, thus the EC > 700 μS/cm and SAR is between 0 and 3, these values give water based on the recommendations of the FAO 1985 [3], quality unrestricted irrigation use. These waters are considered highly mineralized and may be suitable for irrigation of salt-tolerant species and well-drained soil and leached [8]. According to Catherine et al. [9], for the values of SAR and EC, the water has no influence on the rate of infiltration at the irrigated soil.

4.1.9. Fertilizers

4.1.9.1. Nitrogen. The shape of the nitrogen target is the mineral form, ammonia (NH_4^+) and nitrate (NO_3^-). The average values of nitrates range from 3 mg/l at the inlet and 15 mg/l at the exit of the WWTP (Fig. 3). Those of ammonium ranged from 23 mg/l at inlet and 2 mg/l for treated water. These results indicate slightly increasing of average content of nitrates from inlet to outlet of the WWTP. The ammonium content, by cons, decreases on the same axis.

At the entrance of the WWTP, the low nitrate content is due to the fact that nitrogen is in ammonia or organic forms, strongly present in domestic wastewater and progressively during the treatment, the latter oxidized by nitrification in the aeration basin, generating nitrates, which explains the inverse proportionality between ammonium and nitrate.

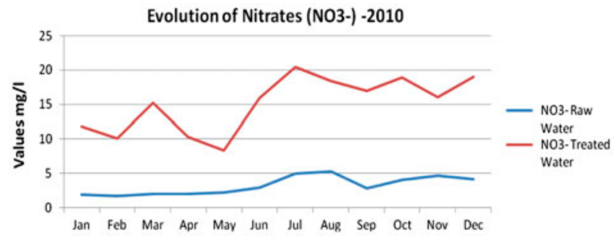

Fig. 3. Graphic representation of the evolution of NO_3^- at the inlet and the outlet of the WWTP.

Table 4
Results of bacteriological analysis of treated water of Medea

Parameters	Results (CFU/100 ml) × 10^4	WHO standards (CFU/100 ml)
Total coliform (TC)	23.03	/
Fecal coliform (FC)	17.60	⩽1,000
Fecal streptococci (FS)	8.45	/
FC/FS	2.08	/

Our purified water has an average value of nitrates located on the recommendation of the FAO 1985 cited in [3], between 5 mg/l < 15 < 30 mg/l, an interval that has a degree of restriction on agricultural use light to moderate. Some cultures are very effective to consume the nitrogen and prevent its accumulation in the soil and its migration. As nitric to groundwater, they are usually multiple cuts crops and deep rooted.

4.1.9.2. Phosphorus. The mean content of phosphates recorded, range from the highest, that at the entrance of the treatment plant (2.5 mg/l), to the lowest at the outlet (1.6 mg/l). This content is between 0 and 2 mg/l, a range usual in the irrigation water.

Phosphates according to [10] have long escaped the conventional biological sewage treatment and thus were in discharges. Therefore, the reduction of the contents of the phosphates from the entry to the exit of the station, is due to their consumption by the bacteria in the purification process.

Table 5
Results of analysis of the sludge parameters of the WWTP Medea

	MI ml/g	Dryness%	OM%	C_{org}%	N_{TK}%	P_2O_5%	K_2O%
Average value	43.16	44	28	15	2.05	0.33	0.19

4.1.9.3. Potassium. The potassium in the waste water does not cause adverse effects on plants, or on the environment. It is an essential macronutrient that favorably affects soil fertility, crop yield and their quality [8]. In our case, the potassium concentration in the treated water is 14 mg/l, a value considered normal and no adverse effects or inhibitor on the use of these waters for irrigation.

4.1.10. Metal trace elements

In fact, most of these metals are retained in the sewage sludge during wastewater treatment [11]. According to [12] we find that heavy metals important to plants and pose no health problems are the iron and manganese.

The threshold set by the FAO for irrigation water is 10 and 20 mg/l manganese and iron, respectively, for use in the short term and 0.2 and 5 mg/l for use in the long term.

The Fe and Mn in the treated water have the respective values of 1.25 mg/l and 0.12 mg/l. These contents are very negligible, and have no toxic effects on either the ground or on the plant.

According to [12], copper and zinc are classified as interesting metals to plants and pose a health problem.

The tolerable limit adopted by the FAO for irrigation water is 5 mg/l and 10 mg/l Cu and Zn, respectively, for use in the short term and 0.2 and 2 mg/l for long-term use.

Then the analyzes of treated wastewater at the WWTP Medea, also showed average grades respective Cu and Zn 0.05 and 0.16 mg/l. These concentrations are relatively minor and do not cause toxic effects in irrigation.

4.1.11. Pathogens

The average fecal coliform load of treated water is 17.60×10^4 CFU/100 ml and 8.45×10^4 CFU/100 ml for faecal *streptococci* (Table 4).

The relatively high concentrations of Fecal Coliform exceed the standard adopted by the WHO for irrigation water which is $\leqslant$1,000 CFU/100 ml. We can estimate the origin of human or animal fecal pollution from the study of values of the ratio FC/FS content in water [13]. Value of 2.08 for this factor determines the origin of the source of pollution, that is mixed type dominated human. Given the bacteriological results obtained, the sanitary quality of treated wastewater to the WWTP Medea is far from being acceptable for irrigation.

4.2. Branch sludge (see Table 5)

4.2.1. Mohlman index MI

The average value of MI found 43.16 ml/g, reflecting a modest availability of sludge decantation. There is a good decantation, when MI is between 50 and 150 ml/g.

4.2.2. Dryness of the sludge

The laboratory measurements gave an average dryness of the sludge samples of 44%, which reveals the solid character sludge of the WWTP Medea.

4.2.3. Organic matter

The amount of organic matter measured in the sludge of the WWTP Medea, represents 28% of the dry matter. It is relatively low comparing to that of a solid sludge. This value is related to the low C/N ratio of 7.32 found, thus reflecting well stabilized sludge. Then this sludge is considered a fertilizer, a more organic amendment (Fig. 4).

4.2.4. C/N

The sludge of WWTP Medea contains 15% organic carbon and 2.05% nitrogen Kjeldahl (TKN) in the dry matter, that gives a ratio C/N = 7.32. This value shows us high availability of nitrogen; it is rapidly mineralized and can undergo leaching. To prevent its leaching, the sludge must be spread over the period of plant growth, nitrogen is assimilated, and its loss through volatilization and percolating will be reduced.

4.2.5. Metal trace elements

Sewage sludge of Medea, when analyzed, gave us the results presented in Table 6.

As Table 6 shows, the contents of metallic trace elements in sewage sludge Medea are sufficiently low

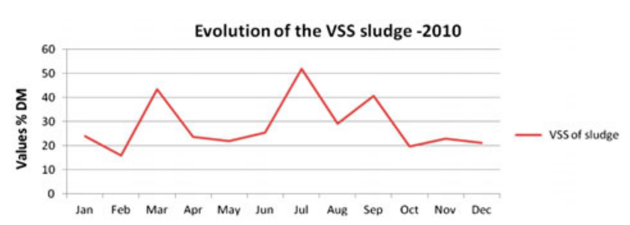

Fig. 4. Graphic representation of the evolution of the VSS sludge of WWTP Medea.

Table 6
Results of analysis of MTE in the sludge of the WWTP Medea

MTE	Concentration (mg/kg of DM)*	Concentration (mg/kg of DM)**	Regulatory limit values
Cd	0.57	/	10
Cr	10.96	/	1,000
Cu	41.96	65.89	1,000
Ni	12.13	/	200
Zn	217	425	3,000
Cr + Cu + Ni + Zn	282	/	4,000
Fe	/	1,800	
Mn	/	97.78	

*Analyzed at the central laboratory of the ONA-2010.
**Analyzed at the laboratory of the insid-2012.

and do not constitute a limiting factor for its reuse in agriculture, and can therefore be applied to land without restriction.

4.2.6. Phosphorus

Phosphorus has the advantage of not leach into the groundwater or surface water because according to [14], it remains fixed and strongly adsorbed by soil particles. Phosphorus (P_2O_5) measured in our samples, represents 0.33% of the dry matter, that is an interesting addition and can cover the needs of crops [15].

4.2.7. Potassium

The sludge samples analyzed at the laboratory gave an average concentration of potassium (K_2O) 0.19% of the dry matter. This is a low value, which by spreading high doses of sludge, does not exempt the farmer to provide potassium mineral fertilizer [16].

5. Conclusion

The main objective of our study was to evaluate the quality of treated wastewater and sludge from the WWTP of Medea, and their levels of response to the requirements and guidelines established in the context of irrigation and agricultural spraying, via their analysis to the laboratories.

The results showed that the treated water is highly mineralized (SAR = 1.95, EC = 2,305 μS/cm) and may be suitable for irrigation of salt-tolerant species and well-drained soil and leached. It has no influence on the rate of infiltration at the irrigated soil. Their nitrate content (15 mg/l) is eligible and has no harmful effect. In cases of large doses, crops at multiple cuts and deep roots are very effective to consume nitrogen and prevent its accumulation in the soil and its migration. For the MTE, the levels found are very negligible, have no toxic effect on either the ground or on the plant. The high concentration of fecal coliforms due to the suspension of the disinfection system of WWTP, fact that these waters can not be used without chlorination.

The sewage sludge with a C/N of 7.32 constitutes an important availability and rapid mineralization of nitrogen, of which leaching may be avoided by land application of the latter during the plant growth. This report is related to the relatively low amount of organic matter that it contains, thus translating a stabilized sludge, which can be considered a fertilizer, more than organic amendment. To be used in agriculture, microbiological analysis must be made on the sludge of WWTP, with results consistent with their use.

The evolution of these parameters was followed for one year. For an agricultural reuse of byproducts of Medea WWTP be it credible, we must establish a continuous control device and rigorous monitoring of these parameters, so that there will be no important variations that impede their reuse.

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