Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2015.1054310

57 (2016) 5946–5950
March

Taylor & Francis
Taylor & Francis Group

Study of the fertilizing potential of the treated wastewater of the Kolea wastewater treatment plant (Algeria)

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Received 31 January 2014; Accepted 14 May 2015

ABSTRACT

The objective of this study was to examine the wastewater of the Kolea sewage for agricultural reuse. The type of approach followed in the study of the quality of irrigation water lies generally within three broad categories: salinity, permeability, and sodium-related toxicity. Physicochemical analyses of treated water reveal conformity of the majority of the parameters of the water reuse standards in irrigation. Taking into account the Richards classification, the presence of the C3S1 class was identified at the Kolea plant. The C3S1 class relates to water that are usable without particular control for the irrigation of crops that are moderately tolerant to salt, on well-drained soils or with good permeability. This water has electrical conductivity mean values of 1,001 μS/cm, which will allow their use in a less restrictive way for irrigation. Finally, this study confirmed that this water contains significant amounts of nutrients, helping to reduce the consumption of chemical fertilizers with beneficial consequences for the environment.

Keywords: Treated wastewater; Irrigation; Fertilizing potential; Agricultural reuse

1. Introduction

Water resources in Algeria are limited, vulnerable, and unevenly distributed. For population of 35 million, the renewable water resources are 550 m^3/year per capita. This value is very low compared to other countries of the Maghreb, which is 1,250 m^3. The threshold of the scarcity of water is 1,000 m^3/person/year; therefore, Algeria is a country where water is scarce [1,2]. In these conditions, the sector of agriculture is the largest water applicant.

Ayers and Westcot [3] and Saidam [4] reported that in 2006, 900,000 ha or 10.5% of the useful agricultural area is irrigated. 78% of this area is irrigated with groundwater and 13% with surface water. Algeria focuses currently on regularization of the reuse of wastewater in agriculture. The annual volume

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Presented at the 3rd Annual International Conference on Water (CI.EAU 2013), 18–20 November 2013, Algiers, Algeria

of wastewater discharged by cities above 20,000 inhabitants is estimated at 550×10^6 m^3. The reuse of treated wastewater can be an important alternative to the use of clean and freshwater in the agricultural sector, especially in a country like Algeria, where irrigation uses up to 90% of the water consumed.

The purpose of this work was to study the wastewater of the Kolea plant for agricultural use. Comparing our results with the WHO standards [5] and FAO [6] shows that it is possible to use these treated water in agriculture. Wastewater treatment plants have certainly many attractive properties for agriculture, but their widespread use in this area is based on the lifting of a number of restrictions (e.g. salinity, permeability, etc.). This water contains significant amounts of nutrients. On the other hand, agriculture is a sector which has a high consumption of chemical fertilizers [7]. Currently, the fertilizers market experiences a rise in prices and the use of less expensive nutrient sources such as the purified water can be seen as a promising solution with a positive impact on the profitability of farmers.

2. Methods

2.1. Presentation and functioning of Kolea WWTP

The Kolea wastewater treatment plant is located in a coastal zone at 30 km west of Algiers. That activated sludge plant is sized to 58,000 eq/cap (equivalent population) with a daily flow of 82,000 m^3/d. The wastewater treatment plant, located south of the city, is designed to treat wastewater from the city of Kolea and its surroundings. The wastewater reaches the treatment plant by a combined sewer network. 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: pretreatment, biological treatment, a chlorine station, thickening then sludge drying.

2.2. Sampling and wastewater analysis

The wastewater samples were collected in one-liter polyethylene bottles. Analyses took place immediately after wastewater collection. Part of the analyses was carried out at the wastewater treatment plant laboratory, while the rest were conducted at the Water Sciences Research Laboratory at the National Polytechnic School of Algiers. The studied physicochemical parameters were the following: pH, electrical conductivity (EC), nitrate ammonium, magnesium, calcium, sodium, orthophosphates, and total suspended solids (TSS) (Table 1). Each week, 15 samples were taken and analyzed.

Each parameter was analyzed between 25 and 35 samples.

3. Results

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

Table 1
Material and analytical methods

Parameter	Analysis method	Material used
Temperature	Thermometry	Multiparameter type Hach SensIon 156
pH	Potentiometry	pH-meter type Hach SensIon 1
EC	Conductimetry	Conductimeter type Hach SensIon 5
TSS	Filtration, centrifugation	Centrifuge Hermle Z300—oven at 105℃
NH_4^+, NO_3^-, PO_4^{3-}	Spectrometric	Spectrophotometer HACH DR/4000V
Ca^{2++}, Mg^{2++}, K^+, Na^+, MTE	AAS	AAS Perkin–Elmer AAnalyst 200

Table 2
Physicochemical and better agricultural features of treated water

	pH	T (℃)	Sodium ratio absorbable (SAR)	Richards class [10]	Mineralization of water (mg/l)	EC (µS/cm)	TSS (mg/l)	NO_3^- (mg/l)	NH_4^+ (mg/l)	P_2O_5 (mg/l)	K_2O (mg/l)
Kolea plant	7–7.5	14.5	2.75	C3S1	968	1,001	14.8	5.95	2	8.69	16.38

3.1. Water temperature

The average water temperature was below 30˚C. This value was considered as direct discharge limit value in the receiving environment [8]. The average temperature of 14.5˚C is not a constraint to the reuse of wastewater in agriculture [9].

Water pH is slightly basic with a mean value of 7.36 (Table 2), lower than the WHO [5] upper limit. This pH value is used to neutralize some acidic soils of the region.

3.2. Permeability and salinity

The TSS represent the totality of the insoluble mineral and organic particles, floating or suspended, that are contained in wastewater. They are largely biodegradable [11]. The average TSS content encountered was 14.8 mg/l. It is less than irrigation standards (WHO [5] and FAO [6]) eliminating any risk of clogging of the soil, thus allowing their use in irrigation without the need of filtration.

Knowing that the sodium adsorption ratio (SAR) is given as follows:

$$\mathrm{SAR} = \frac{\mathrm{Na}^{+}}{\sqrt{\frac{\mathrm{Ca}^{2+} + \mathrm{Mg}^{2+}}{2}}} \tag{1}$$

The results of analysis of ionic species SAR found in our water are given in Table 2. When wastewater is recycled in irrigation, two important parameters are taken into consideration, including the EC and SAR that expresses the relative activity of sodium ions in exchange reactions in soils compared to calcium and exchangeable magnesium (Table 2).

In this study, the estimation of some parameters of salinity was conducted in relation to agricultural use. Analysis and interpretation of the results, according to Richards [10], allowed us to predict and assess the likely risks on the nature of soil and vegetation with regard to wastewater reuse.

The value of the EC (1,001 S/cm) and the SAR (2.75) indicate that we are in the presence of the C3S1 class (Table 2). This water is used without particular control for crop irrigation water moderately salt tolerant, on well-drained soils and with good permeability.

This water has mean values of 2,001 µS/cm. And according to Bremond and Vuichard [12], above 1,500 µS/cm, water is hardly usable for irrigation. According to FAO [13], these values are in the range of light to moderate restriction for the quality of wastewater irrigation. Anyhow, the quality of irrigation water can be established only on the basis of soil types and used crops [14].

The observed EC and salinity value lies within the range of values recommended by Ayers and Westcot limits [3] and FAO [13]. When these soils are subjected to irrigation with rich sodium exchangeable water, the latter can be substituted with alkaline earth ions of clays and deflocculating, then causing their waterproofing [3,15].

3.3. Fertilizer quantities produced by treated water

The nutrients contained in the treatment water constitute an important quality parameter for the valorization of this water in agriculture and landscape management [16]. The most common elements in this water are nitrogen, phosphorus, and potassium. These elements are in significant quantities, but in quite variable proportions. Table 3 shows the amount of fertilizer given by a volume of 1,000 m^3 of wastewater. These values are compared to those offered by Faby and Brisaud [17].

3.3.1. Nitrogen

The shape of the nitrogen-target is the mineral form, ammonia (NH_4^+) and nitrate (NO_3^-). The average values of nitrate and ammonium in station outlet are, respectively, 5.95 and 2 mg/l (Table 2). These results

Table 3
Fertilizer amounts (kg/ha) provided by a clean sheet of water 100 mm corresponding to (1,000 m^3/ha)

	Nitrogen (NO_3) (kg/ha)	Nitrogen (NH_4) (kg/ha)	K_2O (kg/ha)	P_2O_5 (kg/ha)	CaO (kg/ha)	MgO (kg/ha)	Na_2O (kg/ha)
Kolea plant	5.95	2	16.38	8.69	44.7	150.8	114
Faby and Brisaud [17]	16–62	–	2–69	2–24	18–208	9–100	27–182

indicate a slight increase in the nitrate content in output station. On the other hand, the ammonium contents decrease. At the entrance to the treatment plant, low nitrate content is due to the fact that nitrogen is in a form of ammoniac organic, strongly present in domestic wastewater and progressively during the treatment, and it is oxidized by nitrification in the aeration tank, nitrate production, which explains the inverse proportionality between ammonium and nitrate.

3.3.2. Phosphorus

The average grade of phosphate is recorded 8.69 mg/l (Table 2). Phosphates according to Rodier et al. [18] 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.

3.3.3. Potassium

The potassium in the wastewater 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 [6]. In our case, the potassium concentration in the treated water is 16.38 mg/l, a value considered normal and no adverse effects or inhibitor on the use of this water for irrigation Table 2.

A dose of irrigation of 5,000 m^3/ha/year is adopted on the basis of an estimate of the water needs of crops grown in the area and taking into account climate needs. Citrus and fruit trees grown in the Wilaya (department) of Tipaza have theoretical needs in water ranging from 4,500 to 5,500 m^3/ha/year depending on rainfall. Vegetable crops, however, are mainly represented by pepper, chilli, aubergines, fennel, and salad; their theoretical water needs are between 3,500 m^3/ha/year (wet year) and 4,500 m^3/ha/year (dry year) [19]. Inputs of fertilizers for irrigation of 5,000 m^3/ha/year are reported in Table 4.

The example shows how the integrated management of water resources, including the recycling component, can be beneficial economically, socially as well as environmentally (Table 5).

This treatment water allows the irrigation of approximately 792 ha at 5,000 m^3/ha per year (Table 5). In an agricultural soil, the assimilation of nitrogen by plants can reach 300 kg/ha/year which depends on the type of crop and the region [21]. According to Ratel et al. [22], the requirements of phosphorus plants vary in general from 30 to 80 kg/ha/year. Soing [23] reported that the needs in K_2O for fruit species range from 55 to 150 kg/ha. This water enriches the soil by an annual average intake of 40 kg/ha nitrogen, 43 kg/ha of phosphate, and 82 kg/ha of potassium, far in excess of the requirements of sensitive crops. They therefore provide significant amounts in nitrogen. Phosphorus and potassium intake may even cover all of the needs of the plants in some cases, resulting in greater productivity and substantial economic gains.

Table 4
Potential fertilizer amounts (kg) made at 5,000 m^3/ha/year of purified water

	Nitrogen (NO_3) (kg/ha)	Nitrogen (NH_4) (kg/ha)	K_2O (kg/ha)	P_2O_5 (kg/ha)	CaO (kg/ha)	MgO (kg/ha)	Na_2O (kg/ha)
Kolea plant	29.75	10	82	43	223	750	570
Faby and Brisaud [17]	16–62	–	2–69	2–24	18–208	9–100	27–182

Table 5
Potentially irrigable surfaces by the treated effluents of the Kolea plant

	Volume (treated water) (m^3/year)	Irrigated surfaces (ha) [20]
Kolea plant	3,960,000	792

4. Conclusion

Through this work, it has been shown that the modernization of irrigated agriculture can also be thought in terms of wastewater reuse. Our work brought analytical clarification on the nature of wastewater for the sewage treatment plant of Kolea. The reuse of wastewater in irrigation of crops contributes to increase the reserves of water intended for agriculture, therefore allowing increases in yield. Physicochemical analyses of the treatment water reveal conformity of the majority of the physicochemical parameters to the irrigation water reuse standards. With EC (at 25°C) and SAR values, we could identify the presence of the C3S1 class for the Kolea plant. TSS encountered levels are below standards for irrigation, thereby eliminating any risk of clogging of soil and thus allowing their use in irrigation without resorting to filtration. pH values do not exceed the WHO (OMS) [5] and FAO [6] maximum permissible values. They provide significant amounts in nitrogen. Phosphorus and potassium intake may even cover all of the needs of the plants in some cases, resulting in greater productivity and substantial economic gains. This study shows how the reuse of wastewater in an urban center allows the agricultural valorization of a large area (792 ha), which is currently competing for the same center potable or industrial needs. The new approach allows the agriculture to benefit, in addition to water, from fertilizers contained in treated water, particularly nitrogen, phosphorus, and potassium that improve crop yields without increasing production costs.

Acknowledgments

This work has been conducted at the Water Sciences Research Laboratory at the Polytechnic National School of Algiers (Algeria), in collaboration with the laboratory of the National Office of Sanitation (ONA). The authors wish to acknowledge the support of ONA for accommodating a part of the research and by supporting some samplings and analyses in this project.

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