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de Aguiar do Couto, Eduardo; Peixoto Assemany, Paula; Calijuri, Maria Lúcia; da Fonseca Santiago, Aníbal; Gripp Simões Alves, Luna

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REUSE OF TREATED SEWAGE EFFLUENT IN AIRPORTS: IRRIGATION OF ORNAMENTAL PLANT NURSERY

Eduardo de Aguiar do Couto, Paula Peixoto Assemany*, Maria Lúcia Calijuri, Aníbal da Fonseca Santiago, and Luna Gripp Simões Alves

Department of Civil Engineering, Federal University of Viçosa, Brazil

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Abstract: Airports consume significant amounts of water which can be compared to the volume consumed by mid-size cities, thus practices aimed at reducing water consumption are important and necessary. The objective of this study was to assess the reuse potential of sewage effluent produced at a mid-size international airport for nursery irrigation. The sewage treatment system consisted of a facultative pond followed by a constructed wetland, which were monitored during one hydrological year and the parameters COD, pH, solids, nitrogen, phosphorus and Escherichia coli were analyzed. Removal efficiencies of 85% and 91% were achieved for COD and solids, respectively. Removal efficiencies for ammonia nitrogen and total phosphorus were 77% and 59%, respectively. In terms of E. coli concentration, the treated effluent met the recommendations by the World Health Organization for reuse in irrigation with the advantage of providing high levels of residual nutrient. The ornamental species Impatiens walleriana was irrigated with treated sewage effluent and plant growth characteristics were evaluated. The experiment showed that reuse can enhance plant growth without significantly affecting leaf tissue and soil characteristics. This study highlighted the importance of simple technologies for sewage treatment especially in countries which still do not present great investment in sanitation and proved that effluent reuse for landscape irrigation can provide great savings of water and financial resources for airport environments.

Keywords: Airport environments; reuse; constructed wetlands; ornamental plant

* Correspondence to: Paula Peixoto Assemany. E-mail:

INTRODUCTION

Airports consume significant amounts of water in order to maintain their infrastructure and operational routine, and a considerable portion of such volume is destined to activities which do not require drinking water quality (Moreira Neto, 2012). Thus an integrated approach regarding water resources management in airports is necessary, including the implementation of measures aimed at the rational water use such as the reuse of treated sewage effluent. Wastewater reuse has recently been looked up as a potential option to cope up with the increasing water stress. In addition, because of its stable quantity it could be a reliable alternative water resource (Jamwal & Mittal, 2010).

Many airports worldwide show initiatives towards the rational water use such as water saving sanitary fixtures and programs for reducing consumption (ADR, 2009; NIAC, 2010; HKIA, 2010; SA, 2009; FRAPORT AG, 2010 and MNA, 2007). However, more audacious alternatives such as effluent reuse, which need greater intervention in airport infrastructure, are usually implemented only in the construction of new terminals or under scarcity situations.

Among the airport activities which do not require drinking water (toilet flushing, washing of vehicles and paved areas, fire control and others), landscape and nursery irrigation stands out due to its high water demand (Lubello *et al*., 2004). Such demand can be perfectly supplied by reuse of the sewage effluent produced in the airport.

The use of treated sewage effluent for irrigation of plants and crops has become a common practice worldwide (Angelakis *et al*., 1999). This represents an alternative water source to minimize scarcity problems and provide other important advantages such as the reduction of drinking water consumption (Singh *et al*. 2012), the adequate destination for great volumes of effluent – which is even more relevant in developing countries and has direct implications on public health (Rutkowski *et a*l., 2006) – and the reduction on fertilization costs by taking advantage of the residual nutrients found in the effluent (Lubello *et al*., 2004).

The objective of this study was to evaluate the reuse of sewage effluent produced in airports for irrigation of a nursery used for maintaining a harmonious landscape in the airport, in order to provide tools and alternatives which contribute to an efficient management of the water resources in such environments.

MATERIALS AND METHODS

The study was carried out in the Tancredo Neves International Airport, located between longitudes 43°56′W and 43°56′W and latitudes 19°38′S and 19°38′S, in the city of Confins, 35 km from Belo Horizonte, capital of the state of Minas Gerais, Brazil. According to the Brazilian Airport Infrastructure Enterprise – INFRAERO (personal communication), the TNIA has an area of 15 km² and the capacity to transport over 10 million passengers every year.

According to the Köppen classification, the climate of the region belongs to the Awi category, characterized by a hot climate in which the coldest month has temperatures above 18°C, and alternating rainy (summer) and dry (winter) seasons, with a maximum range of 5°C between the coldest and warmest monthly averages (Ribeiro, 1995). The average annual precipitation is 1286.5 mm, with 58% of the total concentrated within the months from November to January. The dry period is usually from May to September, and represents less than 8% of the annual precipitation (CPRM, 1998).

In 2011, the airport transported 9 534 986 passengers and consumed 259 470 m³ of water, which is 31% more than the volume consumed in 2010. From the total airport water consumption, approximately 7% was used for landscape irrigation.

The airport is currently served by groundwater, which is relevant given that it is located in a karstic area with an extremely vulnerable environment and it is currently undergoing the negative impacts from anthropic actions (Calijuri *et al*., 2012). Thus treated sewage effluent reuse and the resulting reduction in drinking water consumption can represent not only financial gains but also priceless environmental benefits.

Sewage treatment experimental unit

The TNIA has a wastewater treatment plant which consists of a facultative pond (FP) followed by a maturation pond and treats all sewage produced in the airport before discharge into the water bodies. The experimental unit made use of the FP from the original treatment plant and a constructed wetland (CW) was proposed for the post-treatment instead of the MP.

The FP has a total surface area of 2.2 ha, average inflow of 345 $m^3.d^{-1}$, and a hydraulic retention time (HRT) of 66 days. The option for using the original FP in this study was mainly motivated by the fact this is a low cost technology of easy implantation and operation.

The CW was built in order to polish the FP effluent so that it would be adequate for ornamental plant irrigation. CW systems are considered a potential alternative for the post-treatment of biologic reactors such as stabilization ponds. Kaseva (2004) states that the CW systems have important characteristics such as the use of natural processes and easy construction, operation and maintenance. El-Khateeb *et al*. (2009) highlight that such systems are an interesting solution due to their capacity to meet the most stringent standards of effluent discharge, in addition to being economically feasible and having great applicability in isolated or decentralized situations.

Part of the FP effluent was pumped to the pilot scale CW system, which consisted of a rectangular tank with a total surface area of 16 m^2 (8 m x 2 m) filled with medium gravel (range 12.5–25 mm, 50% of porosity) up to the height of 50 cm and the water depth was 45 cm. The HRT was 4 days, the mean inflow rate was 1.0 $m^3.d^{-1}$. The macrophyte planted in the tank was the *Typha domingensis* Pers, which is found in natural wetlands in the area where the experiment was carried out. Thus the choice for *Typha* was based on the adaptability of the species to the region, which facilitated management, planting and growth.

In order to guarantee the maturation of the filter bed (gravel) and the adaptation of the macrophyte, sampling campaigns started one year after the construction of the CW and were carried out throughout a hydrological year. Samples were collected every two weeks and analyzed for pH (4500–H^+B), chemical oxygen demand – COD (5220 D), total suspended solids – TSS (2540 D), ammonia nitrogen – N-NH_4^+ (4500-NH3C), total phosphorus – TP (4500-P) and *Escherichia coli* (Colilert®). The analyses were performed according to the Standard Methods for the Examination of Water and Wastewater (APHA, 2005).

Reuse of treated effluent for the irrigation of ornamental species

An experimental nursery was built near the wastewater treatment pilot unit in order to evaluate the effects of effluent reuse on the growth of ornamental plants. The species used in the nursery was the *Impatiens walleriana*, which was selected for being widely used in landscaping projects in the TNIA and because they bloom all year round (Liebsch & Acra, 2002).

A total of 72 seedlings were planted in 3 experimental plots (2 rows each) in containers filled with dystrophic haplic cambisol, which is the soil found in the region and commonly used in the airport's nursery. The first plot was irrigated with CW effluent, the second with FP effluent, and the third with drinking water, as shown in **Fig. 1**.

The plants were manually irrigated with 5 L of effluent or drinking water 3 times a week, for 3 months, which is how long the plants are usually kept in the nursery before being planted into soil.

Plant growth was monitored by measuring stem height and by counting the number of leaves and flowers. Additionally, analyses of soil and leaf tissue were performed. The variables monitored for soil were: soil–water pH, Ca^{2+}, Mg^{2+}, Na^+, cation exchange capacity, sum of bases, total acidity, aluminum saturation, organic carbon, organic matter, and phosphorus. The variables Na^+, Mg^{2+} and Ca^{2+} were used for obtaining the soil sodium adsorption ratio (SAR). For leaf tissue, Na, B, Cu, Mn, Zn, N, P, K, Ca, Mg and S were monitored.

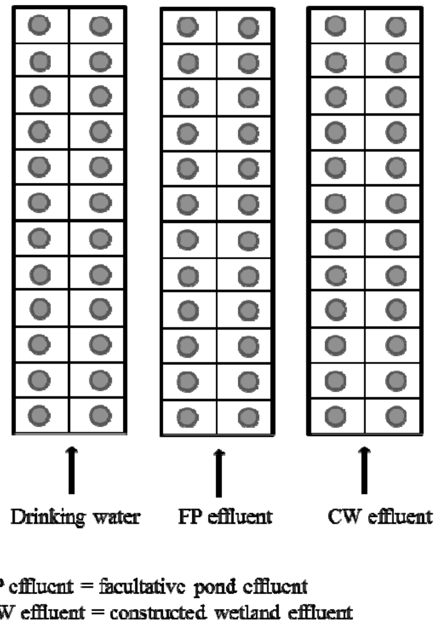

Fig. 1 Illustration of the experiment arrangement.

The results of the soil and leaf tissue analyses were submitted to the Student's t-test for two independent means and unknown variances at the 5% significance level. The test was performed by comparing irrigation sources two by two (CW × FP, CW × drinking water and FP × drinking water), in order to identify the possible effects from using effluent for irrigation. In addition, the values found for soil variables were compared to those recommended by Ribeiro *et al.* (1999) for classes of soil interpretation based on concentrations considered typical for a certain condition. These recommendations are specific for the edaphic conditions of the region where the study was performed given the great regionality of this natural element.

RESULTS

Removal of organic matter and suspended solids

The FP–CW system achieved an overall COD removal efficiency of 85% (57% for the FP and 66% for the CW, separately). With respect to TSS concentrations, the FP presented an average reduction of 60% whereas the CW removed 76%, with an overall removal efficiency of 91% for the system. **Figures 2** and **3** show these results.

The removal of settleable, suspended or dissolved organic matter in wetlands occurs by sedimentation and filtration by the filter bed (porous medium), roots and rhizomes, followed by microbial degradation. Sedimentation occurs because of the low flow rate and filtration depends on the growth of microorganisms in the filter bed (Kadlec, 2004). As for the biological process, the degradation of colloidal solids and particulate and dissolved organic matter is performed by bacteria which develop in the liquid medium and mostly by the biofilm adhered to the filter bed (Truu *et al.*, 2009).

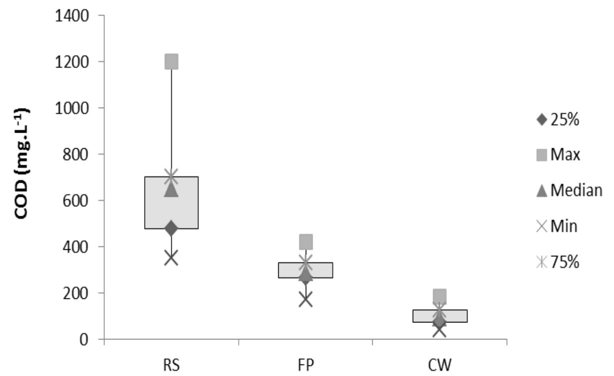

Fig. 2 COD concentration for raw sewage (RS), FP effluent and CW effluent.

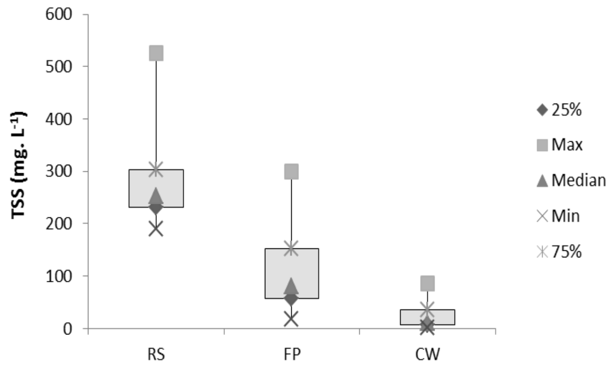

Fig. 3 TSS concentration for raw sewage (RS), FP effluent and CW effluent.

Steinmann *et al*. (2003) assessed the performance of CWs after stabilization ponds and state that the removal efficiency for COD and TSS can be attributed to the continuous removal of algae produced in the FP, which corroborates the potential of CWs as a post-treatment for such system.

Bastos *et al*. (2010) used CWs for the post-treatment of UASB effluent in southeastern Brazil, under climate conditions similar to the ones in the present study, and obtained average removals of 70 and 60% for TSS and COD, respectively. The authors also assessed the efficiency of a MP compared to a CW. The MP achieved a removal efficiency of 70% for COD and an addition of TSS concentration due to the high proliferation of algae, which is common in this type of unit.

Nutrient removal (ammonia nitrogen and total phosphorus)

The FP reduced in 71% the ammonia nitrogen concentration. According to Senzia *et al.* (2002) the main routes for nitrogen transformation in ponds are nitrification, denitrification, ammonia volatilization, net loss to sediments, uptake by microorganisms and mineralization. The CW presented a removal efficiency of 22.3% and the overall removal for the system was 77% (**Fig. 4**).

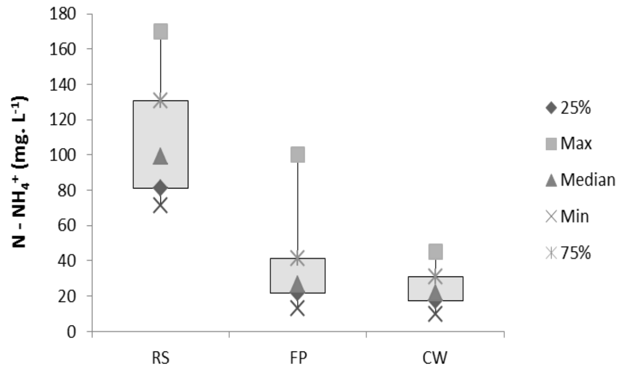

Fig. 4 Ammonia-N results for the raw sewage (RS), facultative pond (FP) and constructed wetland (CW).

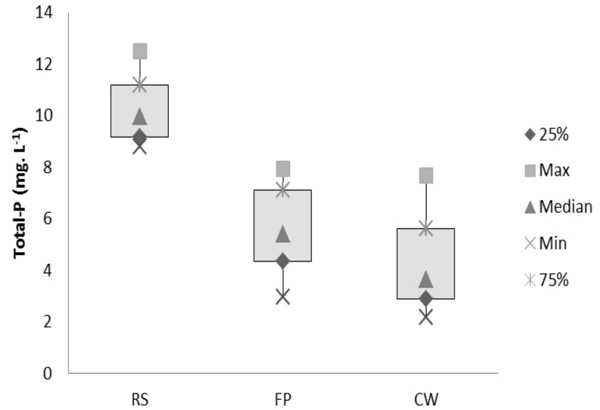

Fig. 5 Total phosphorus results for the raw sewage (RS), facultative pond (FP) and constructed wetland (CW).

Literature reports different information in terms of ammonia nitrogen removal in CWs. Kaseva (2004) obtained a 23% removal of ammonia-N, which is similar to the results obtained in the present study. Kadlec (2003) obtained an average removal efficiency of 61% for this variable.

The main mechanisms for nitrogen removal in CWs are the same as those described for stabilization ponds, with the addition of plant uptake (if frequent pruning is performed) and adsorption in the filter bed (USEPA, 2004). On the other hand, Borin & Solvato (2010) state that there are uncertainties regarding the prevailing removal mechanisms because they also depend on a series of factors such as plant species, system configuration and climatic conditions. This complexity of factors which intervene in nutrient removal efficiency can justify the wide range of distinct results.

Total phosphorus removal in stabilization ponds is mostly attributed to adsorption of the element in the settled sludge (Peng *et al*., 2007). The total phosphorus concentration was reduced in 46% by the FP. The removal of total phosphorus in the CW was 24% and the overall removal of the whole system was 59% (**Fig. 5**).

For total phosphorus, the available results in literature are also distinct. Kadlec (2003) obtained higher removal efficiencies compared to this study, achieving 48%. Steinmann *et al.* (2003) presented results of average reduction in total phosphorus concentration of only 15%. Yousefi & Mohseni-Bandpei (2010) studied nutrient removal in subsurface flow wetlands installed in small communities and planted with *Iris pseudacorus*. The average total phosphorus removal efficiency ranged from 52 to 78%. Similarly to what was discussed for ammonia nitrogen, the identification of a prevailing mechanism for phosphorus removal is not precise since many factors influence such process. However, Dunne & Reddy (2005) point out as the main forms phosphorus retention in CW: sorption on wetland substrates, accumulation in vegetal and microbiological biomass and precipitation of insoluble compounds. These authors state that these processes are saturable and only removal by plant uptake could be relatively easily controlled by frequent pruning of the plants, which was frequently performed during the monitoring of the system.

Carr *et al*. (2011) state that the substantial amount of nutrients are acceptable in the treated effluent once they reduce the need for chemical fertilizers used to increase crop productivity. Thus, despite the low nutrient removal efficiency obtained in the present study, the CW effluent can be considered appropriate for agricultural reuse, considering the nutrient cycling in the soil (Tidåker *et al*., 2007).

Escherichia coli

The raw sewage samples presented *E. coli* concentrations of 10^7 MPN/100mL. The FP presented a reduction of 2 logarithmic units in 18% of the samples, whereas the other 82% presented reductions of 3 logarithmic units or more. **Figure 6** shows these results.

The CW removed between 2 and 3 logarithmic units with an effluent concentration of 10^2–10^4 MPN/100mL (**Fig. 7**). The oscillatory behavior of the results can be observed for FP effluent as well as for the effluent of the CW. Such fact can be explained by the variability of the inflow. This variation in raw sewage quality can be associated to the place where the experiment was installed. Because this study was performed in an airport, the floating population (passengers and visitors) is significant and causes great variation in quality and quantity of sewage inflow.

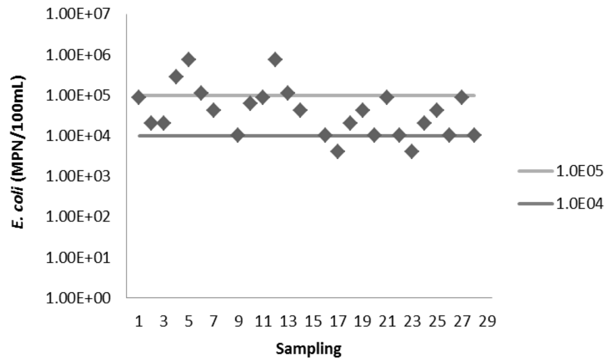

Fig. 6 *E. coli* results for the FP.

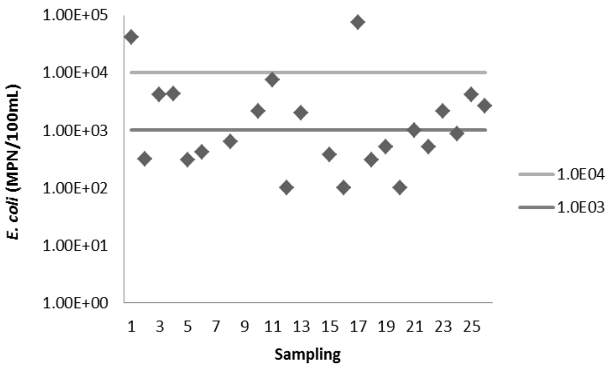

Fig. 7 *E. coli* results for the wetland effluent.

Molleda *et al*. (2008) highlight that sedimentation associated with adsorption to particulate matter play an important role in the reduction of many organisms in subsurface flow wetlands. Boutilier *et al*. (2009) studied the main *E. coli* removal mechanisms in CWs (adsorption, sedimentation and inactivation) and concluded that if a wastewater has undergone significant pre-treatment (i.e. settling lagoon or septic tank), inactivation by natural processes was the main removal mechanism of this organism. Bastos *et al*. (2010) obtained results similar to the ones in this study, with effluent *E. coli* values in the range of 10^2–10^4 MPN/100mL (geometric mean). El-Khateeb *et al*. (2009) obtained even better results, removing up to 5 logarithmic units in a subsurface flow wetland in series with a surface flow one.

pH values

The average pH values for the influent and effluent of the FP were 7.5 and 8.1, respectively. **Figure 8** presents the pH values obtained during the monitoring of the system. This pH elevation can be attributed to the biomass photosynthetic activity in the pond environment. An effluent with pH values over 8.5 can compromise the dynamics of the receiving waters. Moreover, high pH values can damage the macrophyte roots, when CWs are used as post-treatment. The CW effluent presented mean

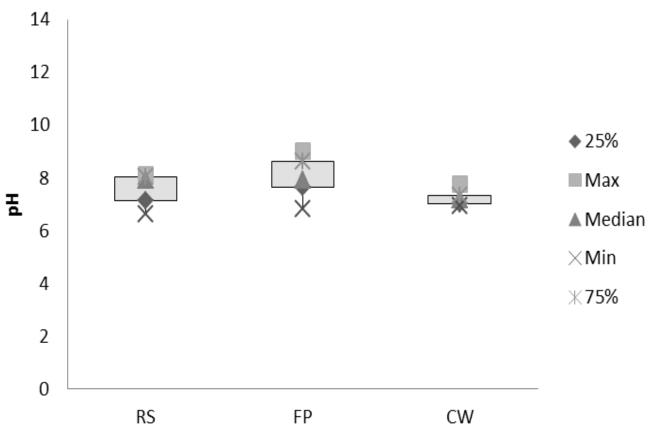

Fig. 8 pH results for the raw sewage (RS), facultative pond (FP) and constructed wetland (CW).

pH value of 7.2 with a small range from 6.9 to 7.8. The results of the FP influent and the CW effluent are similar. The algal biomass removal by the CW and the consequent decrease in chlorophyll production can explain the attenuation of the FP pH values by the CW (Katsenovich *et al.*, 2009).

Attaining limit values and standards

The "Guidelines for the safe use of wastewater, excreta and greywater" by the World Health Organization (WHO, 2006) establishes limits for unrestricted and restricted irrigation. Unrestricted irrigation relates to leaf or roof crops which receive some other form of removal/protection such as the normal household washing of food and drip irrigation. The restricted irrigation relates to planting systems where there is human contact with soil and crop such as the non-mechanized planting.

The treated effluent met the WHO recommendations for unrestricted irrigation in most of the samples. Approximately 91% percent of them presented *E. coli* concentrations below or equal 10^3 MPN/100mL. The remaining samples (9%) met the recommendations of the same guide for restricted irrigation. Thus the CW proved efficient in removing biological contamination indicators, producing an effluent which can be used for the irrigation of ornamental plants in the TNIA.

Reuse of treated effluent for the irrigation of ornamental species

Effects on plant growth

Figures 9−11 present the growth results for plants irrigated with effluent from the FP, CW and drinking water. With respect to the stem height, we observe that the plants irrigated with FP effluent presented higher growth, followed by those irrigated with effluent from the CW. Considering the number of leaves and flowers, plants irrigated with CW effluent presented greater development with time.

It is important to highlight that the use of treated effluent was better for plant growth than using drinking water. These results corroborate other studies which demonstrated that the use of wastewater can increase productivity of vegetal species, mainly because of their significant amount of nutrients (Yadav *et al.*, 2002; Lubello *et al.*, 2004; Asgharipour & Azizmoghaddam, 2012; Singh *et al.*, 2012).

Effects on the characteristics of soil and plant leaf tissue

Although the use of effluent can improve plant growth, problems arising from the excessive use of sanitary sewage in the soil and plants cannot be neglected, as many studies have identified damages originated from such practice (Johnson & Parnell, 1998; Devitt & Neuman, 2003; Rutkowski *et al.*, 2006; Pedrero & Alarcón, 2009). Given this information, analyses of macro and micronutrients were performed, in addition to analyses of heavy metal concentrations on plant leaf tissue and on the soil used in the nursery. The results are described in **Tables 1** and **2**.

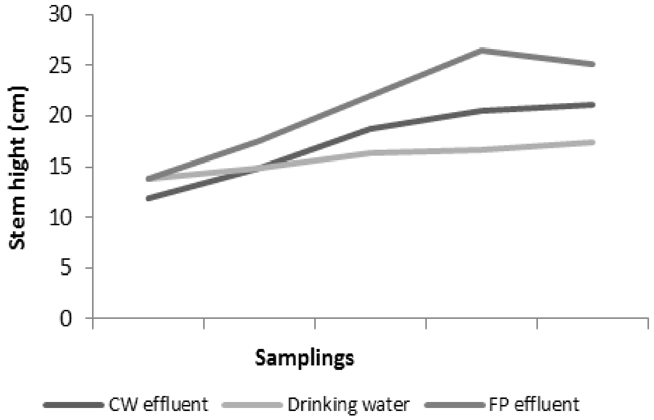

Fig. 9 Stem height of plants irrigated with different water sources.

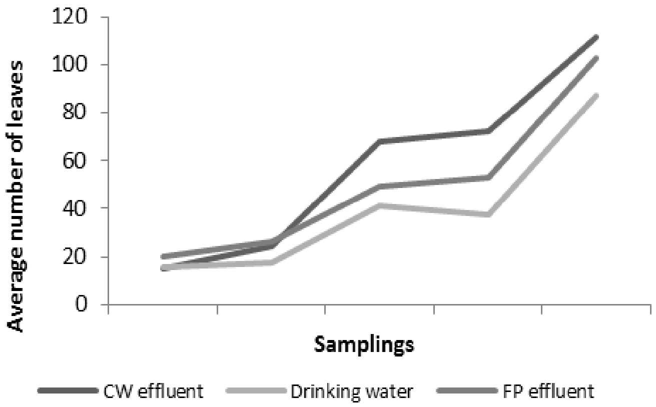

Fig. 10. Number of leaves of plants irrigated with different water sources.

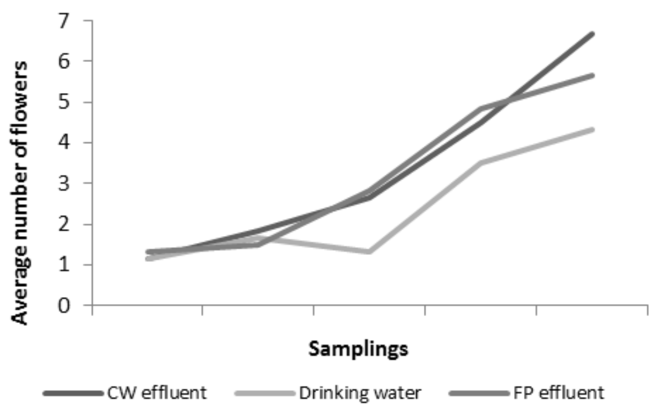

Fig. 11 Number of flowers of plants irrigated with different water sources.

Table 1 Characterization of leaf tissue of plants irrigated with different water sources

Variables	Units	Mean ± Standard deviation		
		CW	FP	Drinking water
N	$dag.kg^{-1}$ (%)	2.55±0.31	2.19±0.53	1.96±0.63
P	$dag.kg^{-1}$ (%)	0.15±0.05	0.19±0.04	0.18±0.05
K	$dag.kg^{-1}$ (%)	1.51±0.48	1.06±0.14	1.76±0.62
Ca	$dag.kg^{-1}$	2.04±0.62	2.16±0.54	2.07±0.53
Mg	$dag.kg^{-1}$	0.23±0.06	0.28±0.06	0.25±0.02
S	$dag.kg^{-1}$	0.27±0.08	0.33±0.06	0.51±0.26
Zn	$mg.kg^{-1}$	23.48±7.22	24.34±7.97	23.02±3.46
Fe	$mg.kg^{-1}$	696.9±713.1	641.9±325.4	528.7±212.7
Mn	$mg.kg^{-1}$	351.8±170.0	354.9±214.6	401.6±268.0
Cu	$mg.kg^{-1}$	3.38±2.93	3.44±2.15	2.20±1.55
B	$mg.kg^{-1}$	26.38±11.40	33.53±10.39	24.37±3.00

Table 2 Quality variables of the soil used in the nursery for plants irrigated with different water sources

Variables	Units	Mean ± Standard deviation		
		CW	FP	Drinking water
pH	-	5.05±0.37	5.02±0.30	5.23±0.29
P	$mg.dm^{-3}$	5.16±3.22	5.24±1.88	4.14±1.53
K	$mg.dm^{-3}$	96.40±54.05	136.60±48.54	54.40±18.45
Al^{2+}	$cmol_c.dm^{-3}$	0.97±0.70	0.96±0.36	0.79±0.48
H + Al	$cmol_c.dm^{-3}$	9.08±0.99	9.34±0.72	9.06±1.14
SB	$cmol_c.dm^{-3}$	2.83±1.04	2.76±0.69	2.91±0.77
t	$cmol_c.dm^{-3}$	3.79±0.52	3.72±0.48	3.70±0.48
T	$cmol_c.dm^{-3}$	11.91±0.59	12.10±0.22	11.97±0.62
V	%	23.68±8.42	22.78±5.64	24.44±6.94
m	%	26.86±22.16	26.64±12.45	21.90±13.83
OM	$dag.kg^{-1}$	3.89±0.21	4.12±0.08	4.07±0.21
P-rem	$mg.L^{-1}$	12.96±2.47	13.04±2.15	13.78±2.31

SB: Sum of bases; t: Cation Exchange Capacity; T: Cation Exchange Capacity at pH 7.0; V: Base Saturation Index; m: Aluminum Saturation Index; OM: Organic Matter; P-rem: Remaining phosphorus.

Considering the results presented for leaf tissue, the Student's t-test for two independent means showed that the means of all variables did not statistically differ for all comparisons proposed (CW x FP, CW x drinking water and FP x drinking water). Because we did not reject the null hypothesis, the means of the studied variables are statistically equal for all comparisons, and thus irrigation using treated effluent did not influence the characteristics of plant leaf tissue at the 5% significance level.

With respect to soil variables, the t-test presented the same results found for leaf tissue, thus the means of the three different irrigation forms did not differ for any of the monitored variables, which allows us to say that at the 5% significance level, soil characteristics are not affected by irrigation with treated sewage effluent.

In addition, the comparison of the results obtained in this study with the classes proposed by Ribeiro *et al.* (1999) showed that the use of treated effluent only interfered in soil acidity (making it more acid) and in increasing potassium (K) concentrations, as shown in **Table 3**. A "Very bad" classification means that the concentration of the respective variable in the soil addresses a very bad soil condition whereas a "Very good" classification means that the concentration of that variable is beneficial for soil condition.

It is important to highlight the negative effects of soil acidification such as the reduction in soil fertility, and water, nutritional and photosynthetic damages for the plants. In order to minimize these effects, practices such as using salt-tolerant crops and building drainage systems are mandatory. It is also necessary to constantly monitor the salts concentration in the soil in order to verify salt accumulation with time and facilitate measures to decrease salinity in the root zone of the plants (FAO, 2005).

Besides the variables presented in **Table 2**, Na^+, Ca^{2+} and Mg^{2+} concentrations were monitored in order to obtain the SAR.

Figure 12 shows that the soil SAR increased with the use of sewage effluent for irrigation, due to the high sodium concentration if compared to calcium and magnesium, which can reduce the soil water infiltration rate and, in the long-term, jeopardize plant growth.

Table 3 Classification of the variables for soil irrigated with different water sources

Variables	Unit	Classes		
		CW	FP	Drinking water
pH	-	High acidity	High acidity	Average acidity
P	$mg.dm^{-3}$	Very bad	Very bad	Very bad
K	$mg.dm^{-3}$	Good	Very good	Average
Al3+	$cmol_c.dm^{-3}$	Average	Average	Average
H + Al	$cmol_c.dm^{-3}$	Very bad	Very bad	Very bad
SB	$cmol_c.dm^{-3}$	Average	Average	Average
T	$cmol_c.dm^{-3}$	Average	Average	Average
T	$cmol_c.dm^{-3}$	Good	Good	Good
V	%	Bad	Bad	Bad
M	%	Good	Good	Good
OM	$dag.kg^{-1}$	Average	Good	Good

SB: Sum of bases; t: Cation Exchange Capacity; T: Cation Exchange Capacity at pH 7.0; V: Base Saturation Index; m: Aluminum Saturation Index; OM: Organic Matter.

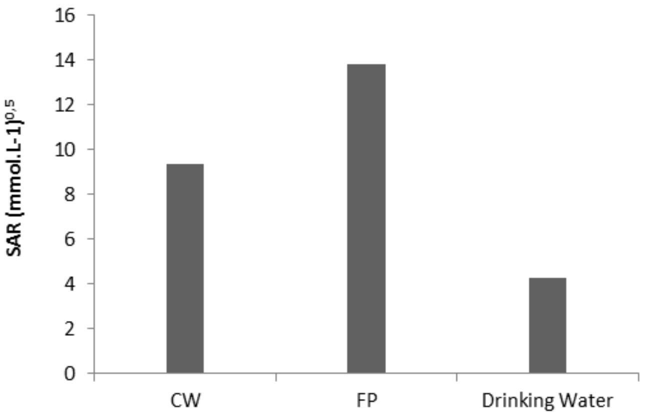

Fig. 12 Sodium adsorption ratio for soils irrigated with different water sources.

However, Lado *et al*. (2009) state that high K^+ and NH_4^+ concentrations in the water can reduce soil affinity for Na^+ and, as a consequence, the percentage of available sodium will not be as high as expected. Thus the undesired effects of high sodium concentrations can be minimized so that they do not impede effluent reuse for plant irrigation, once K^+ and NH_4^+ are present. In addition, although the SAR has increased with the use of effluent, for all irrigation water sources the values were within the normal range for irrigation using drinking water, which is from 0 to 15 mmol L^{-1} (FAO/UNESCO, 1973). The results corroborate those obtained in similar experiments carried out worldwide which agreed on the advantages of using sewage effluent for irrigation (Meli *et al*., 2002; Lubello *et al*., 2004).

The present study shows that the reuse of treated effluent for the irrigation of ornamental plants can optimize plant growth without compromising the chemical characteristics of soil and plants. Therefore, it is an attractive option due to the potential savings of water and fertilizers. Considering the reality of the airports where high volumes of water are consumed for the maintenance of harmonious landscape through the irrigation of green areas, effluent reuse, according to the results presented here, can represent great savings of financial resources.

It is important to mention that, despite the quality results for soil and leaf tissue do not indicate variations regarding irrigation source, the reuse of FP effluent is not recommended because health related factors (fecal contamination indicator organisms) did not meet quality standards for such activity. However, if CWs are used for the post-treatment of such effluent, reuse becomes feasible and can provide all the advantages previously discussed.

CONCLUSIONS

Sewage effluent produced in the airport was satisfactorily treated by a system which consisted of a facultative pond followed by a constructed wetland, and presented overall removal efficiencies of 85%, 91%, 77% and 59% for organic matter, suspended solids, ammonia nitrogen and total phosphorus, respectively. We emphasize the importance of the technologies used in this research (cheap and easy operation) mostly for developing countries which still need great investments in sanitation.

The treatment system evaluated also provided good removal of fecal contamination indicator organisms. An average removal of 3 log units in the CW effluent enables its use for irrigation, according to recommendations by WHO. The study also showed that treated effluent reuse optimizes the growth of ornamental species without significantly affecting soil and leaf tissue characteristics. Such findings allow us to state that sewage effluent reuse for irrigation with landscaping purposes can be considered in the strategic planning of airports worldwide, given the benefits from its use such as increased plant growth and the cycling of the nutrients found in the sewage. In addition to that, reuse itself can provide the mitigation of environmental liabilities and the consequent savings of drinking water, becoming one of the main ways to reduce water consumption in airports.

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