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Greywater production in airports: Qualitative and quantitative assessment

Eduardo de Aguiar do Couto*, Maria Lúcia Calijuri, Paula Peixoto Assemany, Aníbal da Fonseca Santiago, Isabella de Castro Carvalho

Federal University of Viçosa (Universidade Federal de Viçosa/UFV), Departament of Civil Engineering, Environmental Engineering Group – nPA, Campus Viçosa, 36570-000 Viçosa, MG, Brazil

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ABSTRACT

Airport complexes are great water consumers where the adoption of reuse practices adapted to their particular characteristics may represent significant savings of financial and environmental resources. Greywater reuse is an important alternative for reducing potable water consumption in airports. The objective of this study was to assess the quality of greywater produced in airport environments and the reuse potential of such effluent. This study was developed in a mid-size airport in Brazil, where a qualitative assessment of greywater produced by different activities was performed. The results were analyzed using descriptive and multivariate statistics. Greywater production in the administrative buildings was estimated by the application of questionnaires and interviewing employees, and compared to the non-potable demand in these buildings. The results showed that the quality of the greywater produced in the airport is similar to that produced in residences and can be easily treated for reuse purposes. In quantitative terms, greywater reuse can meet the non-potable demand and provide great savings of water and financial resources, in addition to priceless environmental benefits.

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1. Introduction

Great airport complexes worldwide consume water in the same proportion of small and mid-size cities. The Atlanta International Airport (Hartsfield-Jackson) presented, in 2009, water consumption equal to that of a city with a population of 13,000 people (HAIA, 2009). The London-Heathrow Airport consumed 1,852,000 m^3 in 2010, which equals the consumption of a city of 25,000 people, and presented passenger traffic of 66 million people (LHA, 2010). The Narita International Airport, in Japan, with over 33 million passengers in 2010, presented in the same year water consumption equivalent to that of a city of 24,000 people (NIAC, 2010).

Great part of the water necessary to maintain airport infrastructure and operation routine is destined to non-potable activities such as air cooling systems, landscape irrigation, washing of aircraft, vehicles and runways, fire control testing, and toilet flushing. Considering this scenario, airports are potential environments for implementing processes and technologies aimed at the rational use of water such as greywater reuse.

Greywater consists of effluent from lavatories, showers, bathtubs, kitchen sinks and washing machines (Ottoson and Stenstrom, 2003; Liu et al., 2010; Nazer et al., 2010; Hernández Leal et al., 2011; Hurlimann, 2011). Garland et al. (2004) and Lamine et al. (2007) state that the main factors which interfere in greywater quality are the supply water quality, the material used in the distribution system and the activities performed in a certain building or residence. According to Zhang et al. (2010) and Mourad et al. (2011) greywater is a suitable alternative water source for non-potable uses, such as toilet flushing, laundry and garden irrigation.

Regarding the quantitative aspects, the volume of greywater produced in residences and commercial or industrial activities varies according to local characteristics such as the number of employees, frequency of cleaning, existence of a dining hall, among others. These characteristics also vary according to the region, habits and purchasing power of the population. According to Al-Hamaiedeh and Bino (2010), 50–80% of the volume of effluent produced in a house is due to greywater.

The objective of this study was to assess and characterize the qualitative and quantitative aspects of greywater produced in an airport complex in order to infer about its reuse potential.

2. Methodology

2.1. Study area

The study was carried out in the Tancredo Neves International Airport (TNIA) located between 19°39′ and 19°37′ S and 43°59′ and 43°57′ W, in Confins, state of Minas Gerais, Brazil.

* Corresponding author. Tel.: +55 31 38993098; fax: +55 31 38993093.
E-mail addresses: eduardo.acouto@hotmail.com (E.A. Couto), calijuri@gmail.com (M.L. Calijuri), paula_assemany@hotmail.com (P.P. Assemany), anibalsantiago@gmail.com (A.d.F. Santiago), isakpi@yahoo.com.br (I.d.C. Carvalho).

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According to the Brazilian Airport Infrastructure Enterprise (Infraero), the TNIA complex has an area of 15 km^2 and the capacity to transport over 10 million passengers every year. In 2011, the TNIA transported over 9.50 million passengers and consumed 259,470 m^3 of water, which is 31% higher than the volume consumed in 2010 and makes it the fourth in the ranking of water consumption among all Brazilian airports (Infraero – personal communication).

The current context of high water consumption and expansion of the airport capacity justifies the development of this study since the greywater reuse potential can be considered in the planning of water resources management practices in the airport complex.

2.2. Greywater qualitative characterization

In order to assess the quality of greywater from different sources, samples from bathroom sinks, kitchen sinks and showers located in several areas of the TNIA were individually analyzed.

The sampling points where water was collected from bathroom sinks (Points 1, 2, 3 and 4) were chosen in order to represent the characteristics of the TNIA buildings including those with a fixed number of employees, those with floating population and with different hierarchy levels. With respect to the kitchen sinks, two sampling points were selected: one sink used for washing fruit and vegetables (Point 5) and one for washing dishes and kitchenware (Point 6). Samples from showers (Point 7) were collected in the locker room used by the employees of the maintenance company outsourced by Infraero.

The sampling campaigns were carried out from September 2010 to May 2011. Plastic siphons were adapted to the existing hydraulic facilities in order to divert the effluent to 50 L recipients. After each sampling campaign, the effluent was homogenized and laboratory samples were collected and conserved at 4 °C.

The analyses were performed according to recommendations of the Standard Methods for the Examination of Water and Wastewater – 21st edition 2005 (APHA, 2005), and the number of the procedure is indicated in parenthesis. The physical, chemical and microbiological variables analyzed were pH (4500-H^+ B), turbidity (2130B), temperature (2550B), total suspended solids (TSS) (2540D), total solids (TS) (2540 B), total alkalinity (Alk) (2320B), total hardness (2340C), electrical conductivity (EC) (2510A), biochemical oxygen demand (BOD) (5220B), chemical oxygen demand (COD) (5220D), dissolved oxygen (DO) (4500-0G), nitrate (NO_3^-)(4500-NO3E), ammonia nitrogen (NH_4^+) (4500-NH_3C), total kjeldahl nitrogen (TKN) (4500-Norg C), total phosphorus (TP) (4500-PA), oils and grease (5520 A) and *Escherichia coli* (*E. coli*) (Colilert®).

2.2.1. Statistical analyses

Descriptive statistics (mean and standard deviation) were obtained using the software Microsoft® Excel 2010. In addition, two multivariate statistical analyses were used: Principal Components Analysis (PCA) and Cluster Analysis. PCA is used to transform an original dataset of variables from a multidimensional space into a more concise equivalent set (Omo-Irabor et al., 2008). This technique consists of transforming the original variables into others, non-correlated, named principal components, which correspond to linear combinations of the original variables (Sarbu and Pop, 2005). This analysis was used with the objective of assessing the importance of each of the variables studied in the dynamics of the greywater quality produced in the airport complex.

The cluster analysis was used to detect similarities among the sampling points, separating them into groups according to these similar characteristics. This technique reveals the behavior of a dataset without making any prior assumptions in order to classify objects of the studied system into categories or groups, based on their similarities (Panda et al., 2006). The cluster analysis was performed in order to assess similarities/patterns in the characteristics of greywater in the sampling points and thus acknowledge the aspects related to the production of this effluent in airport environments.

These analyses were performed using the software R©, version 2.10.1, developed by the R Foundation for Statistical (R Development core team, 2009). The multivariate statistical procedures used the packages "FactoMineR" for PCA and "Cluster" for cluster analysis.

2.3. Quantification of greywater production and non-potable demand

Greywater production and non-potable demand at the TNIA were estimated from the amount of water consumed in the buildings located in the airport. The methodology based on studies carried out by Proença and Ghisi (2005) and Ghisi and Ferreira (2007), led to an estimate of the volume consumed in each building by each of the activities performed. Contributions from kitchen sinks, showers, bathroom sinks and cleaning activities were added to obtain the total amount of water produced in each building. In order to estimate the non-potable demand, the volumes consumed by activities such as toilet flushing, cleaning and irrigation were added.

The survey was carried out in eight buildings: Internal Revenue Service (IRS), Cargo Terminal (CT), Fire Section (FS), Airspace Control (AC), Fuel Area (FA), Equipment Shelter (ES), RA Group restaurant (RA) and the Infraero Maintenance Building (MB).

The estimate of water consumption in each building was performed by identifying the consumption habits of the users and assessing the specific flow for each sanitary fixture. Consumption habits were investigated by requesting employees to fill out questionnaires and by interviewing those responsible for cleaning the buildings. The questions of both questionnaires and interviews were related to frequency, form and duration of sanitary fixtures utilization and cleaning activities.

The flows of kitchen sinks and external taps used for irrigation were obtained using the direct flow measurement method. The mean value among all taps tested was used to estimate the total volume of water consumed. For toilets equipped with sanitary flushing valves, the flow of 1.7 $L\,s^{-1}$ was adopted, which is the maximum flow recommended by NBR 5626 (ABNT, 1998). The flow adopted for showers was 0.34 $L\,s^{-1}$, as suggested by a research developed by the University of São Paulo and the sanitation company of the state of São Paulo – Sabesp, for showers between 15 and 20 mwc, which is the regular water pressure for most showers in the buildings (SABESP, 1996).

After obtaining responses to the questionnaires and the specific flows for the sanitary fixtures, the water consumption was calculated for each activity in each building. In order to estimate consumption in taps, showers, toilets and urinals, Eqs. (1)–(3) were used.

$$C_1 = N_1 T Q_1 \quad \text{(taps and showers)} \tag{1}$$

$$C_2 = N_2 Q_2 \quad \text{(toilets and urinals)} \tag{2}$$

$$C_3 = (C_1 + C_2) \cdot D \tag{3}$$

where C_1: water consumption per user of taps/showers (liters/day); C_2: water consumption per user of toilets/urinals (liters/day); C_3: monthly water consumption for each employee (liters/month); N_1: frequency of utilization (number of times/day); N_2: frequency of utilization (number of flushes/day); $C_1 + C_2$: total daily consumption for each employee (liters/day); Q_1: sanitary fixture flow

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