Airport Water Consumption Footprinting

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Abstract The study focused on water consumption footprinting and development of water efficiency plan for an airport located in Turkey. Airports are facilities having large water consumption, generally for non-potable purposes such as water cooling systems, fire control, cleaning and washing of vehicles, runways and aircrafts and also public uses (WC, food service). Research period covered 12 months and consumption data obtained from 116 water meters were evaluated for water footprinting. Along a year the airport served to about 12 million passengers and 81 thousand aircrafts. These passengers and aircrafts were served by various services by airport authorities. These services were linked by water consumption directly or indirectly. Study results showed that annual water consumption was about 436000 m³/year. Irrigation, fire control system, cooling towers and terminal WC uses accounted high use with rate of 23%, 7%, 26% and 20%. While water used for WC changed between about 6-8.5 L per pax, this value was between 1-1.5 L per pax for food consumption. Therefore passenger based uses fluctuated between 6.5-10 L per pax in the airport. Based on this analysis several methods were suggested to minimize water consumption. Among them “training and education of airport staff” was proposed as the most economical solution. Furthermore “improved water consumption monitoring” system could be suggested as applicable method considering economical and physical aspects and should gain priority. Then alternative measures could be chosen based on their economical and physical applicability.

Keywords Water Footprinting, Airport Water Footprint

1. Introduction

In parallel to population growth, high demand for water resulting droughts and unpredictable climatic patterns is becoming an alarming reality in many parts of the world. Increasing concerns regarding the consequences of climate change also emphasize the need for water resources management planning in order to guarantee that current and future demands [1].

Airport environments consume large amounts of water to maintain infrastructure and operations and, they rely on available potable and reclaimed water during construction and in daily operations, on the airfield and in the terminals. In most cases, large amounts of water are consumed at during the course of daily operations to support terminal operations such as restrooms, food service, and heating, ventilating, and air conditioning; airfield services such as deicing, construction, and firefighting; and maintenance activities such as vehicle cleaning and landscaping. This volume can also be met by alternative water sources (rainwater and treated effluent, e.g) [1,2].

Water-related issues are central to environmental programs at most airports. On a regular basis, airport staff make water management decisions to support permitting, regulatory compliance, development planning, infrastructure design, asset management, operations, and maintenance efforts [3].

Water efficiency efforts are becoming more critical because of the following reasons:

- climatic changes increasing the probability of variations in water availability from year to year
- cost of potable water
- the continued growth and expansion of urban centers threatening usable water amount [2].

The development of a water minimisation plan is an important element in the ongoing process of maximising the efficient use of water [4]. Implementing water efficiency practices can reduce costs and achieve a lower water footprint.

An airport’s water footprint is the amount of fresh water which is used to provide services. Water consumption in the airports has been assessed and total consumption and index of L/passenger were calculated in annual reports of many airports in the world [1,2].

Types of facilities, end uses in the airports and total water consumption per passenger at various airports are presented in Table 1 and 2.

Retrofit programs can greatly improve water efficiency at airports. Basic measures, such as water monitoring and water efficient amenities, are generally applicable to all
airports while more complex and capital-intensive measures such as rainwater reuse and greywater recycling should be considered with detailed cost-benefit analysis in the context of the individual airport [5].

The study focused on water consumption footprinting and development of water efficiency plan for an airport located in Turkey.

Table 1. Types of facilities and end uses in the airports [2]

| Facility                  | Example of End Uses                                      |
|---------------------------|---------------------------------------------------------|
| Terminals                 | Toilets, urinals, bathroom and kitchen faucets, dishwashers |
| Office Buildings          | Window cleaning, Interior plant watering, toilets, urinals, faucets |
| Rental Car Center         | Fleet vehicle washing, outdoor irrigation                |
| Ground Transportation     | Vehicle washing                                         |
| Parking                   | Snow removal, street cleaning                            |
| Fire and Police Stations  | Fleet vehicle washing, fire suppression                  |
| Hotels                    | Toilets, showers, ice machines, swimming pools, spas, laundry |
| Central Heating/Cooling Plant | Boiler, cooling                                      |
| Maintenance and Services  | Runway rubber removal, employee break rooms and restrooms |
| Airlines/Aircrafts/Cargo | Aircraft cleaning, on-board aircraft water, de-icing    |

Table 2. Total water consumption per passenger at various airports in the World

| Airports          | L/passenger | Reference |
|-------------------|-------------|-----------|
| Bristol Airport   | 9.4         | [6]       |
| Amsterdam Airport | 13.3        | [7]       |
| Gatwick Airport   | 17.08       | [8]       |
| Frankfurt Airport | 21.7        | [9]       |
| Porto Alegre Airport | 23       | [1]       |
| Salvador Airport  | 23          | [1]       |
| Madrid Barajas Airport | 23.09   | [10]      |
| Recife Airport    | 24          | [1]       |
| Heathrow Airport  | 29          | [11]      |
| Lisbon Airport    | 43          | [1]       |

2. Study Area

Study area comprises 4 terminals namely Domestic, International, VIP and CIP. Monthly terminal passenger capacities and number of flights as of 2016-2017 are presented in Table 3. From March 2016 to February 2017 the airport served to about 12 million passengers and 81 thousand aircrafts. These passengers and aircrafts were served by various services by airport authorities. These services were linked by water consumption directly or indirectly.

The study aimed to design “Water Efficiency Plan” for the airport. In this scope firstly water consumption footprinting has been implemented. Then water efficiency plan was developed. The main target was to determine the most water consumed activities/ facilities within the airport and propose efficiency plan to minimise these uses.

Overall objective was water saving considering climate change effects in near future in this region and also economic aspects. Research period covered 12 months and consumption data obtained from 116 water meters were analysed. Since frequency of the records of these water meters (installed to water supply line and water distribution line) showed difference, water uses in whole facility was evaluated by examining annual total consumptions. Data was presented in Table 4.

3. Passenger based Water Consumption of the Terminals

Water is supplied to domestic and international terminals via different lines. However, there was water transfer between terminals (for WC use). Since both terminals are linked, food providing companies in terminals served to whole passengers (domestic and international). Therefore water footprinting of WC and food service uses has been conducted based on the total water consumption value and also total number of passengers in the airport.

Number of passenger versus water consumption rates (WC use and water consumption of food services in total) was plotted (see figure 1) and the graphic showed that there was a linear correlation between both variables ($R^2=0.85$). Monthly change of L per pax (liter per passenger) values for WC use and food consumption together are shown in Figure 2.
### Table 3. Monthly terminal passenger capacities and number of flights [12]

| March     | Domestic  | 792.962 | International | 117.422 | Total       | 910.384 | Domestic  | 5292 | International | 996 | Total       | 6288 |
|-----------|-----------|---------|--------------|---------|-------------|---------|-----------|------|--------------|-----|-------------|------|
| April     | Domestic  | 814.659 | 136.144 | 950.803 | 5169 | 996 | 6364 |
| May       | Domestic  | 873.803 | 188.190 | 1.061.993 | 5510 | 1425 | 6935 |
| June      | Domestic  | 813.950 | 192.792 | 1.006.742 | 5270 | 1593 | 6863 |
| July      | Domestic  | 825.257 | 305.005 | 1.130.262 | 5473 | 2404 | 7877 |
| August    | Domestic  | 894.152 | 323.756 | 1.217.908 | 5492 | 2396 | 7888 |
| September | Domestic  | 827.882 | 260.469 | 1.088.351 | 5400 | 2023 | 7423 |
| October   | Domestic  | 856.320 | 206.113 | 1.062.433 | 5582 | 1608 | 7190 |
| November  | Domestic  | 831.378 | 94.264  | 925.642  | 5382 | 722  | 6104 |
| December  | Domestic  | 820.920 | 96.878  | 917.798  | 5488 | 734  | 6222 |
| January   | Domestic  | 800.479 | 89.773  | 890.252  | 5218 | 693  | 5911 |
| February  | Domestic  | 764.176 | 80.199  | 844.375  | 5087 | 628  | 5715 |
| Total     | Domestic  | 9.915.938 | 2.091.005 | 12.006.943 | 64363 | 16417 | 80780 |

### Table 4. Annual water consumption rates of the water supply and distribution line

| Water supply line | Water consumption m³/yr | Water distribution line | Water consumption m³/yr | % share |
|-------------------|-------------------------|-------------------------|-------------------------|---------|
| WM-1 (from surface water) | 106600 | WD-1 (water to out of terminal area) | 68258 | 0.157 |
| WM-2 (from surface water) | 103770 | WD-2 (water to domestic terminal) | 7005 | 0.016 |
| WM-3 (from ground water) | 63295 | WD-3 (water to cooling towers) | 112175 | 0.257 |
| WM-4 (from ground water) | 63728 | WD-4 (water to reservoirs used for WC) | 9150 | 0.021 |
| WM-5-6-7-8 (from ground water directly to irrigation) | 98267 | WD-5 (water to aircraft) | 372 | 0.001 |
| WM-6 (water to international terminal offices) | 2006 | WD-6 (water to international terminal) | 20530 | 0.047 |
| WM-7 (water to international terminal) | 20530 | WD-8 (water to Irrigation) | 98267 | 0.226 |
| WM-9 (water to international terminal) | 4417 | WD-9 (water to international terminal) | 4417 | 0.010 |
| WM-10 (water to domestic terminal) | 84813 | WD-10 (water to domestic terminal) | 84813 | 0.195 |
| Unaccounted amount (water to fire control system) | 28667 | | | 0.066 |
| Total | | | | 435660 |

### Figure 1. Relationship between number of passengers and water consumption values (WC+Food consumption)
While water used for WC changed between about 6-8.5 L per pax, this value was between 1-1.5 L per pax for food consumption. Therefore passenger based uses was fluctuated between 6.5-10 L per pax in the airport (see Figure 3). Monthly change in water consumption for WC use and food consumption was quite similar to changes in number of passangers (see Figure 4-5)
4. Water Efficiency Plan for the Airport

Water meter records were evaluated and results showed that within the airport, there were number of particularly high users/activities which are presented in Table 5. Irrigation, cooling towers and wc use comprised about 76% of the total use. Therefore priority should be given minimization of the consumption for these activities. These measures and their applicability in terms of economical and physical factors are presented in Table 6.

Table 5. High water users/activities in the airport

| Water users/activities | Annual consumption (m3) | Share in total consumption (%) |
|-----------------------|-------------------------|-------------------------------|
| Irrigation            | 98267                   | 0.23                          |
| Fire system           | 28667                   | 0.07                          |
| Cooling towers        | 112175                  | 0.26                          |
| Terminal WC use       | 87968                   | 0.20                          |

Table 6. Water efficiency solutions and their applicability

| Water users/activities | Water efficiency solutions                                                                 | Economical applicability | Physical applicability |
|-----------------------|-------------------------------------------------------------------------------------------|--------------------------|------------------------|
| Irrigation            | Use of artificial grass                                                                   | 1*                       | 5                      |
|                       | Automatic irrigation systems installation (Available)                                      | 3                        | 5                      |
|                       | Rainwater harvesting for irrigation                                                        | 3                        | 2                      |
|                       | Use of sub-surface irrigation (Available)                                                  | 3                        | 3                      |
| Fire system           | Collection of fire testing water for re-use or re-purposing for non-potable use is proposed. (Available) | 3                        | 3                      |
| Cooling towers        | Changing chillers                                                                         | 1                        | 1                      |
|                       | Optimising cooling tower makeup water consumption, convert open loop evaporative humidifiers with closed loop versions, replace open loop water cooled condensers by air cooled, or closed-loop water cooled condensers | 1                        | 1                      |
| Terminal WC use       | Increasing rainwater and greywater capacity                                               | 3                        | 1                      |
|                       | Replacing restroom fixtures with high-efficiency ones                                      | 2                        | 5                      |
| General comments      | Use gray water for landscaping; capture and collect rain water for non-potable uses       | 1                        | 1                      |
|                       | Training and education of airport staff                                                   | 5                        | 3                      |
|                       | Improved water consumption monitoring                                                    | 3                        | 3                      |

* 1: very low  2: low  3: medium  4: high  5: very high
5. Conclusions

During the research period (from March 2016 to February 2017) the facility served to about 12 million passengers and 81 thousand aircrafts. These passengers and aircrafts are served by various services by airport authorities. These services are linked by water consumption directly or indirectly. Annual water consumption was about 436000 m³/year in total.

Within the Airport, there were a number of particularly high users/activities:

- Irrigation (23% of the total use)
- Fire control system (7% of the total use)
- Cooling towers (26% of the total use)
- Terminal WC use (20% of the total use)

While water used for WC changed between about 6-8.5 L per pax, this value was between 1-1.5 L per pax for food consumption. Therefore passenger based uses was fluctuated between 6.5-10 L per pax in the airport. This value was below world average rates.

Based on this analysis, the airport authority should consider following projects in near future:

- Use of artificial grass
- Rainwater harvesting for irrigation
- Changing chillers
- Replacing restroom fixtures with high-efficiency fixtures
- Increasing rainwater and greywater capacity (for WC use)
- Revising the operations of cooling towers
- Use gray water for landscaping; capture and collect rain water for non-potable uses
- Training and education of airport staff
- Improved water consumption monitoring

Economical and physical applicability of these methods were also assessed based on judgement of airport technical staff. It was concluded that the most economical measure was “training and education of airport staff” to minimise water consumption. Furthermore physical applicability of “replacing restroom fixtures with high-efficiency ones and use of artificial grass” were relatively higher than the other proposed methods.

6. Discussion

Airports are potential environments for implementing programs aiming conserving water due their large consumption, generally for non-potable purposes such as water cooling systems, fire control, cleaning and washing of vehicles, runways and aircrafts and also public uses. The study focused on water consumption footprinting and development of water efficiency plan an airport located in Turkey. Research period covered 12 months and consumption data obtained from 116 water meters were analysed for water footprinting. (WC, food service). Annual water consumption was about 436000 m³/year in total. Results of the footprinting study showed that irrigation, fire control system, cooling towers and terminal WC uses accounted high use rated with 23%, 7%, 26% and 20 %. While water used for WC changed between about 6-8.5 L per pax, this value was between 1-1.5 L per pax for food consumption. Based on these results water efficiency plan was developed. In this plan several methods were suggested to minimize water consumption. Among them “training and education of airport staff” was proposed as the most economical solution. Furthermore “improved water consumption monitoring” system could be suggested as applicable method considering economical and physical aspects and should gain priority. Then alternative measures could be chosen based on their economical and physical applicability.

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