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Evaluations of on-site wastewater reuse alternatives for hotels through water balance

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ABSTRACT

Reusing of treated wastewater may contribute to solving water-related problems in touristic regions while contributing to sustainable tourism. Water saving potential of reuse will be mainly dependent on the size of hotel, size of irrigated landscaped area, length of irrigation season and servicing time of hotel. As the most appropriate solution is generally case specific and a long-term flow measurement for set of water consumption activities is needed, a model for common hotel configurations can contribute to use of treated wastewater at hotels. In this study, long-term monitoring data of two pilot hotels were assessed for water balance between the potential wastewater sources and demand for various individual reuse purposes. As a result, a decision tree for an optimized wastewater reuse is developed for the hotels in Mediterranean region. Our study suggests that to acquire the highest water saving, mixed domestic wastewater reuse may be the best suitable alternative for hotels which have more than 250 rooms, large irrigated landscaped area of bigger than 100 m^2 per room, and operated seasonally. However, for hotels which are operated throughout the whole year, having limited irrigated landscaped area and under design or construction, grey water reuse may be the best suitable alternative for the highest water saving.

1. Introduction

Hotels are one of the sectors, having a high rate of water consumption. Although water requirement of the sector is very high, the summer season is virtually dry in Turkey and in most of the Mediterranean Countries underlining the importance of water management in the sector. Reusing treated wastewater reduces exploitation of water resources and may contribute to solve water-related problems in the touristic regions. However, practical water management strategies and examples for the sector are still inadequate. At this stage, the question is which wastewater source can be reused for which purposes in a hotel? Following that the second question is; can the same alternative be used for any hotels? The answer of the both questions will be based on same principle; the interpretation of wastewater reuse for an individual hotel should be depended on water balance between the available source, which is generated wastewater, and the demand, which is need for secondary quality water. Therefore, selection of the appropriate solution is generally case specific. Steps that should be followed to get a decision on wastewater reuse are (i) preliminary assessment of potential alternatives, (ii) measurement of water consumption for each of individual purposes, (iii) assessment of water balance for each of the alternatives and (iv) comparison of the water saving potentials. In a recent study done by Joustra and Yeh (2014) a prioritization framework based on demand and source balance is presented for integrated building water management. Similarly, Couto et al. (2013) assessed the balance between grey water production and non-potable water demand for an international airport. In another study done by Kasim et al. (2014), a framework based on Reducing, Reusing, Reaching and Recycling was proposed highlighting the importance of water management of hotels.

Water consumption of hotels are influenced by the physical properties of hotel; such as class of hotel, size, age of facility, availability of jacuzzi in rooms, swimming pools, golf course, sauna etc., and operational features; such as availability of environmental management system and strategies to reduce water consumption etc. (Bohdanowicz and Martinac, 2007; Tortella and Tirado, 2011).

There is a large difference in average water consumption for per guest in different studies (Gössling et al., 2012). For example, in a survey conducted by Bohdanowicz and Martinac (2007), average water consumption of Hilton Hotels located in different countries for per guest were 516 ± 334 L/day, while it was 216 ± 59 L/day for Scandic Hotels. These kinds of differences in the literature may be attributed to the fact that, all of the water consuming activities may not be directly affected by the number of accommodating guests in

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hotels such as landscape or golf course irrigation, swimming pool feedings and cleaning of public areas. Therefore, water consumption data for set of activities may be necessary, not only for better understanding of water consumption statistics of guests, but also for building up water balance for reuse alternatives.

In this context, the objective of this study was to provide a better understanding of key factors effecting water consumption in hotels and in accordance to develop an integrated water and wastewater management model for the sector. For this purpose, a long term water consumption data of two hotels were collected daily along with the accommodating guest number. The results were analyzed and evaluated for optimized wastewater reuse through the water balance between potential wastewater sources and demand for various individual reuse purposes. Finally, a decision tree for an optimized wastewater reuse is developed for the hotels in Mediterranean region.

2. Materials and methods

2.1. Study area

Data collection study was carried out with two big sized 5 star hotels having similar physical properties located at different cities. Amount of the water consumed at different levels and generated grey water were measured daily for one year. At the same time, daily accommodating guest numbers were also recorded. General properties of the hotels relevant to water consumption are presented in Table 1.

2.2. Estimation of water consumption and wastewater flow rate

Total daily water consumptions of the both hotels were measured by water meters located at point of connection from city network to the facility (indicates overall water withdrawn from city network). Furthermore, to breakdown the other water uses, three additional water meters were installed at different locations of the Hotel 1, one at the point of pipeline serving to inside of the building (indicates the total indoor water consumption), the second and third are at the point of swimming pool feeding and of irrigation pipelines. The both hotels have segregated wastewater pipelines as grey and black water. Daily flow rates of the grey water were measured by flowmeters. During the study, numbers of guests staying in the both hotels were also recorded daily. These records enabled the water consumption figures for per guest, while contributing to determine breakdown of the water usage.

Total water consumption consisted of sum of the indoor and outdoor usages. The indoor usage consisted of grey water use, toilet flushing and other usages (kitchen, laundry, public area etc.), while outdoor usage consisted of irrigation and swimming pools feeding. As a control point, the differences between overall water withdrawn from city network and indoor usages were compared to the sum of swimming pools feeding and irrigation. The water that could be consumed for toilet flushing was estimated by using toilet reservoir volume of the hotels (it is assumed that, the flush may be used 11 times per day, 5 times for 6 L, 6 times for 3 L).

2.3. Scenarios and development of the decision tree

Two scenarios based on on-site wastewater treatment and reuse were compared in terms of water saving potentials through water balance between the amount of available wastewater that can be potentially reused, and the need for reclaimed water. The compared scenarios were as Scenario 1: collection/treatment and reuse of mixed domestic wastewater for landscape irrigation, Scenario 2: grey water segregation and reuse for toilet flushing and/or landscape irrigation. The Hotel 1 was operated seasonally, while the Hotel 2 is open during the whole year. Therefore, the scenarios were evaluated for the both hotels to compare effect of operation length so that the results may be representative for the both type hotels. Schematic illustration of the scenarios is given in Fig. 1. Finally, a decision tree is developed by comparing the water saving potential of variable size of hotels and irrigated landscaped areas. The potential water savings were estimated by using the equations developed in this study.

3. Results and discussion

3.1. Water consumption profiles

Average occupancy rate (per bed) of the Hotel 1 and Hotel 2 were 0.47 and 0.54 respectively during the evaluation period. It varied from 0.2 to 0.64 for the Hotel 1 and from 0.4 to 0.64 for the Hotel 2. Daily average total water consumptions were 390 m^3/day for the Hotel 1 and 400 m^3/day for the Hotel 2, which varied from 110 to 780 m^3/day and from 250 to 650 m^3/day respectively. Water Use Indexes (WUI) which shows the amount of water usage per sqm of hotels total area was 2.5 m^3/m^2 for the Hotel 1 and 1.9 m^3/m^2 for the Hotel 2. These values were lower compared with average WUI, 5.1 m^3/m^2 for five star hotels (Deng and Burnett, 2002). Reason of the lower WUI may be explained with larger total floor area of the both hotels which are in average about 106 m^2/room for the Hotel 1 and 158 m^2/room for the Hotel 2.

The water consumption values for per guest and comparison with the literature are given in Table 2. In general, the total water consumption values for per guest were slightly higher than reported values for the both hotels, which may be attributed to the large irrigated landscape areas (Tortella and Tirado, 2011; Hadjikakou et al., 2013; Bohdanowicz and Martinac, 2007). Yearly average of daily water consumption for per guest of the Hotel 1 was calculated as 830 L, while it was 735 L for the Hotel 2. If the average daily water consumption for per guest in summer season is compared between the two hotels, it can be seen that the water consumption for per guest in the Hotel 2 (965 L) is higher than that of in the Hotel 1. The reason of the difference may be dependent on two factors, (i) water used for irrigation in the Hotel 2 may be slightly higher than that of the Hotel 1, as irrigated landscaped area is%15 higher compared to the Hotel 1, (ii) daily indoor use for per guest may be higher in the Hotel 2 than the Hotel 1 possibly due to different habits of guests accommodating in a resort and a business hotel. The second reason is coinciding with the amount of generated grey water which is one of the indoor water consuming activates. In general, a guest staying in a resort hotel spends all day in beach and/or pool, take shower there and he or she usually takes a very short shower at room. On the other hand, a guest staying in a 5 star business hotel may want to stay longer in shower and/or fill the bathtub and relax. However, there is a need for social studies for better understanding of the difference between the behaviors.

The seasonal variation of total water consumption for per guest in the Hotel 2 is illustrated in Fig. 2. As seen from the figure, the water consumption for per guest is higher in the summer season. The consumption start to increase in May and reach to highest value in July and then started to decrease slightly till the mid of September during the observation period. This could be mainly explained by irrigation of the large landscaped area in summer time.

Variations of the water consumption profiles by occupancy rate of the Hotel 1 are illustrated in Fig. 3. As expected, the total and indoor water consumptions are directly related to the occupancy rate (Fig. 3a). When the occupancy rate increases, both consumptions increase as well. However, the total water consumption by the occupancy rate is deviated more than that of the indoor consumption. The reason may be attributed to outdoor water consuming