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Water Audits of Academic Institutions in Water Stressed Countries; the Case of the Jordan University

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Abstract

Water use efficiency is considered as a step forward towards water auditing for assessing the financial, social, and environmental benefits. The diversity of activities and water end-use in the university can be considered as significant as in a small city where residential, commercial, and industrial uses are present. The end-use analysis is important for understanding the reduction in water demand due to retrofit fixtures to a more efficient one. A mixed-methods study used qualitative methods such as the questionnaire's distribution, and quantitative methods such as physical flow rate measurement for the sanitary fixtures and the laboratory equipment. Sanitary installation-plumbing supply fittings standard JS 1945:2011 was used as a benchmark. In addition to the feasibility study. Eighty percent of the volume of water consumption went to the schools and the administrative offices. The main internal use of water was the toilet with percent reached 64%. Adopting water use efficiency would reduce the water demand to 13.7%, and this would be reflected in money savings that would be 19911 ($/quarter). Retrofitting fixtures indoors on the university campus is not enough and should concern changing behaviors in the university community by incorporating water conservation in the academic curriculum.

Keywords: Water Audit, Water end-use Analysis, Water Flow Rate, Water-saving Devices, Water Scarcity, Water use Efficiency.

1. Introduction

The world is facing an increasing water deficit that is intensified by the impacts of climate change. This is especially true in arid and semi-arid regions. For that, many countries are adopting the concept of sustainability, water demand management, water use efficiency, and water audit or (Water End-use Analysis) towards managing and sustaining this precious source. The main source for water in Jordan is groundwater with about 59% of all sources (MWI, 2017). Groundwater depends mainly on annual rainfall, besides the type and distribution of the rainfall storms in the whole year, but rainfall fluctuates from year to year and even is suffering from declining trends due to climate change. The management of water resources in Jordan has serious challenges. The most viable short-term option available to the Government of Jordan is to manage its water demand. Decreasing the waste of water will decrease the depletion and pollution of water resources Velazquez et al., 2013). Water efficiency is considered one of the key futures available to water sector administrators to address water scarcity issues (El-Nwsany et al., 2019), also water audits can help by keeping a check on the losses and finding out ways to minimize them (Irene et al., 2019). In addition, social responsibility is a key component of sustainable development (El-Nwsany et al., 2019). The behavior patterns of water users will also need to be adjusted toward greater water conservation practices and more efficient water use. A water audit or water end-use analysis is necessary for managing water demand that can provide yield financial and environmental benefits. It presents the potential for water conservation and reducing the annual water demand by 30.85% through adopting and retrofitting water-saving devices in sanitary places (Oduro-Kwarteng et al., 2009). The water end-use analysis was defined that the ways customers use water daily by different sanitary fixtures with frequency use (Oduro-Kwarteng et al., 2009). Universities may be considered as small cities in terms of population, size, and daily activities that generate direct and indirect impacts on the environment (Alshuwaikhat and Abubakar, 2008). Besides, institutions of education in Jordan are among the large consumers of water representing about 14% of the commercial water consumption (MWI, 2012 a). This is since there are 32 public and private universities and academies housing about 350 thousand students, about 20 thousand administrative employees, and 11.5 thousand faculty members (MoHE, 2020). In general, water audit studies are very few, even though they are a very important tool to be a reference for managing water at any institution. This study aimed to characterize the water consumption pattern at the University of Jordan and evaluate to address the water deficit and high consumption and cost in the university.

2 Materials and Method

2.1 Study area

The University of Jordan is located in the residential and commercial districts of Amman, and its coordinates are (E: 35.869952 and N: 32.015621) as shown in Figure 1. Some of its facilities provide services to local communities and surrounding areas. The University of Jordan is characterized by a large number of utilities including research centers

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and faculties. The Water, Energy, and Environment Center helped in achieving this study by providing the main information about the total area of all buildings in the University of Jordan campus around 120,000 m^2. In 2019, the number of employees and all students at the University of Jordan was 50 thousand people containing schools of science, arts, and humanities. The University of Jordan has three major research centers, a printing house, a sports club, a mosque, and many restaurants. The irrigated green area of the university is about 550,000 m^2. There are four female residences (two international residences that enjoy high standards in terms of facilities furniture and services, and two other standard residences), the number of workers and female students in those residences is around 964 people. The main source of water is from the municipality network. According to the billing data by the Amman water utility (Miyahuna company), the average quarterly (three months) consumption in 2018 was 47,427 m^3.

Figure 1. The University of Jordan Location

2.2 Methodology

The Water Audit for the University of Jordan was carried out between 3/31- 9/4/2019. A mixed-methods study used such as qualitative and quantitative tools. The qualitative study was included the distribution of questionnaires for female students in the residences, and interviews with employees. Two questionnaires were developed and provided to the university before doing a water audit. One questionnaire was for all facilities of the university, with information related to the number of people (students, academics, and employees) using the facilities and the number of occupancy days. The other questionnaire was for the female students in the residences.

There are two types of female residences inside of the Jordan university campus, the international residence where each room has its utility of a small kitchen and bathroom, while the female students of the residents shared the utilities for each floor. One hundred seventy-seven students filled out questionnaires from both types of residences. Recorded data about the amount of water leakage and the number of leakage incidents were obtained from the maintenance department in the university and were included in the calculations. The data from local female residences has been directly measured.

The quantitative method used was the physical flow rate which was measured manually by using the beaker and the timer for the sanitary fixtures and some equipment in the laboratories except for those that had fixed volume for each use such as the equipment in the dental clinic.

Quarterly billing water data was used as a reference during calculations of the water audits for all utilities that got water from the same meter, such as the residences, printing house, mosque, nursery, etc. Sanitary fixtures rate measurement was done in each building on the campus randomly, and the average flow rate of each sanitary fixture was accredited for each utility in the calculation. In addition, the number of people that occupy those buildings daily was estimated. The assumed behavior used in the calculations in the water audit depended on the data obtained from the previous two questionnaires. Equation (1) explain the volume of consumed water in each fixture

$$V = f \times oc \times t \times su \times 60 \qquad (1)$$

Where,

V is the volume of consumed water in each fixture (m3/quarter)

f is the measured flow rate (l/min)

oc is the number of people who occupied the utilities

t is the number of times used

su is the assumption of the rate of fixture use each time

The number (60) is the assumed occupancy days in each quarter

The water consumption in the residences and the utilities inside the university campus could not be validated since the university does not have sub-meters in its building to monitor the water consumption and the leakage.

On the other hand, the water consumption for green areas was estimated after interviewing the agricultural engineers of the university and based on the water landscape guide for the Ministry of Water and Irrigation (MWI, 2012b), the source of irrigated water, times, and period for irrigating. These estimates were then compared with water irrigation amount information provided by the Water, Energy and Environment Center - The University of Jordan.

Sanitary installation-plumbing supply fittings standard JS 1945:2011 was used as a benchmark to assess water flow rate by fittings after measuring it, and the potential of water-saving. Data analysis included the corresponding statistics used to analyze the data generated and collected. An excel spreadsheet was used in the calculation. The potential percent savings are calculated as the difference between baseline average water use for fixtures and the benchmarks water use for fixtures. Each potential percent saving for fixture type was multiplied with the water used in the fixture to get the potential water saving as explained in equation (2).

$$PWS = \left(\frac{A-B}{A} \times 100\right) \times V \qquad (2)$$

Where;

PWS is the potential of water-saving (m^3/quarter)

A is baseline average water use for fixtures (l/min)

B is the benchmarks water use for fixtures (l/min)

V is the volume of consumed water in each fixture (m^3/quarter) in equation (1)

The feasibility study was done depending on its water resource, cost of water cubic meter, and the number of fittings that should need water-saving devices as explained in equation (3).

$$PMS = PWS \times C \qquad (3)$$

PMS is the potential of money-saving ($/quarter)

PWS is the potential of water-saving (m^3/quarter) in equation (2)

C is the cost of one cubic meter

3. Results

The results were built through information obtained as open files from the water, energy, and environment center, the questionnaire analysis which was distributed to the female students' residents that the percentages of female students in the international and the local residences that responded were 48%, 13% respectively, and the flow rate measuring for fixtures and equipment in whole the Jordan university campus.

3.1 Sanitary fixtures flow rates for the university buildings

The water flow rate per each type of sanitary fixture was measured manually by using a beaker and timer. There were variations in the flow rate of the same type of fixture within the schools and administrative offices of the university. Table (1) shows the average water flow rate per type of fixture for the faculties in the university and the female students' residence.

Table 1. Average flow rate of different sanitary fixtures

	Kitchen sink (l/min)	Lavatory (l/min)	Toilet (l/flush)	Bidet (l/min)	Shower (l/min)
Faculties	9	8	5	6	*16.5
Female students residence	10.5	8.8	5	7	7.5

*For swimming pool

Table (2) shows the benchmarks water flow rate for each fixture in the Jordan standard (JS 1945:2011), while Figure 2 shows the comparison of actual fixtures flow rates with the Jordan Standard. Table (3) shows the deviation of the flow rate of fixtures from the benchmark.

Table 2. Sanitary installation-plumbing supply fittings Jordan standard (JS 1945:2011)

Fixture	Toilet	Urinal	Bidet	Lavatory	Showerhead	Sink
Jordan Standard	6	1.9	4	4.5	7.6	8.3

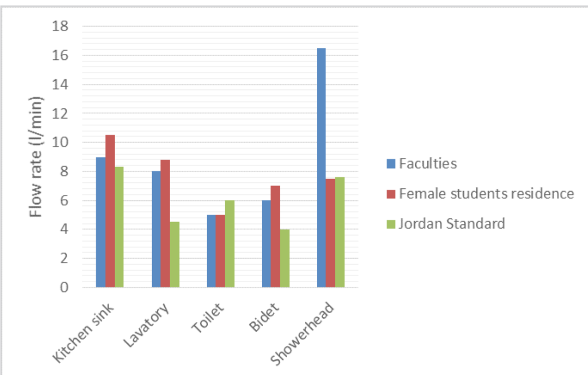

Figure 2. Comparison between the actual fixtures flow rates and the Jordan Standard (JS 1945:2011)

Table 3. The deviation of actual flow rate from the Jordan standard (JS 1945:2011)

Fixture	Toilet	Lavatory	Bidet	Sink	Showerhead
Faculties	-	44%	33%	8%	54%
Female students residence	-	49%	43%	21%	-

3.2 Potential of water-saving

Depending on water end-use analysis and reference of sanitary installation-plumbing supply fittings standard JS 1945:2011, the percentage of potential saving from the installation of water-saving devices is 13.7% as shown in Figure 3.

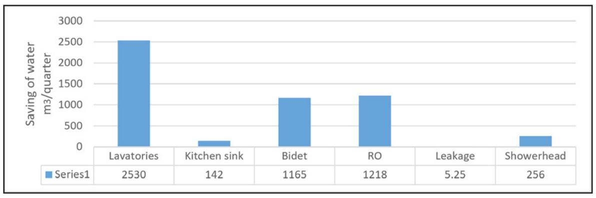

Figure 3. The amount of savings in cubic meters per quarter if the Jordanian standards are applied

3.3 Water end-use analysis

The amount of water consumption depends on many factors. The main factors are the volume of the occupied area, number of employees and students, type of irrigation for landscapes, type of fixtures, and flow rates. By analyzing the collected data, the percentage of water consumption for the schools and the administrative offices was 80% of the total volume of water consumption, and for other utilities was 20%. The 20% of total water consumption was distributed between the utilities of the University as shown in Figure 4.

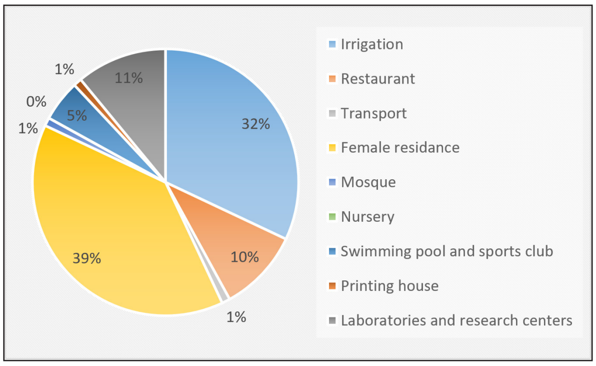

Figure 4. Water consumption percentages in the utilities of the University of Jordan

The distribution of water use within the academic and administrative buildings of the university and within the female students' residences is shown in Figure 5 and Figure 6 respectively. Toilets were shown to be the most important internal use of water with 64% in the schools' buildings and 29% in the female residences.

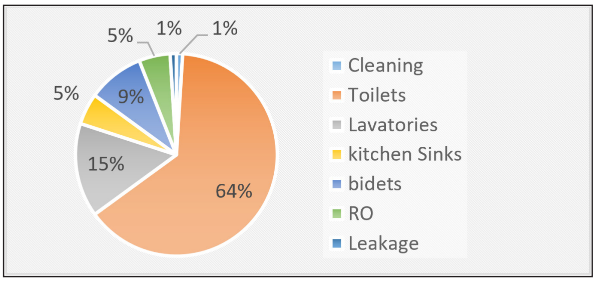

Figure 5. Percentage distribution of water consumption per each type of sanitary fixture in schools buildings

3.4 Feasibility study for water-saving devices

The goal of the study was to recognize the consumption characteristics of the different utilities within the University of Jordan campus, evaluate the water consumption per each type of sanitary fixture for the university using water end-use analysis, estimate the potential of water-saving and assess the cost-effectiveness of using water-saving devices after adopting water demand management approach to decrease the volume of water used for different sanitary fixtures.

The high consumption of some sanitary fixtures was a result of their high flow rate. Therefore, implementing the standard flow rates will lead to saving in both water and money. Tables (4), and (5) are examples of the feasibility study.

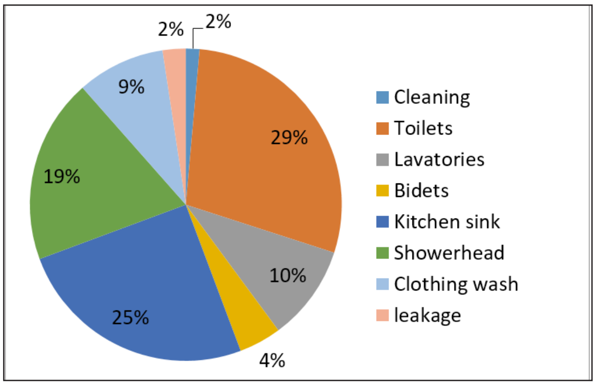

Figure 6. Percentage distribution of water consumption per each type of sanitary fixture in the female residences

Table 4. Feasibility study for Lavatories faucets of schools and administrative buildings

Average lavatories flow rate (l/min)	8
The volume of consumed water by lavatories (m^3/quarter)	5783
Potential of water-saving after installing water-saving devices (m^3/quarter)	2530
Price of one cubic meter ($)	3.056
Potential of money-saving after installing water-saving devices ($/quarter)	7732.394
Number of water-saving devices that needed to install on the lavatories	386
Cost of one water-saving device ($)	2.816
The total cost of water-saving devices for all lavatories ($)	1086.976
Payback period (months)	1

Table 5. Feasibility study for showerheads for the swimming pools of the sports club

Average Showerheads flow rate (l/min)	16.5
The volume of consumed water by showerheads (m3/quarter)	475
Potential of water-saving after installing water-saving devices (m3/quarter)	256
Price of one cubic meter ($)	3.056
Potential of money-saving after installing water-saving devices ($/quarter)	783.098
Number of water-saving devices that needed to install on the lavatories	15
Cost of one water-saving device ($)	2.816
The total cost of water-saving devices for all showerheads ($)	42.24
Payback period (months)	1

The price of water depended on the source of the supplied water, the water tariff of one cubic meter by the network was around $3.056. Table (6) shows the summary of the potential amount of water-saving and the potential of money-saving in the university as a whole.

Table 6. Summary of potential water and money-saving

Utilities	The volume of water consumption (m^3)	Potential water saving (m^3)
Schools and administrative offices	37700	5118
Female students' residences	3824	559
Mosque	63.7	19.4
Restaurant	939	57.8
Transport	72	-
Irrigation	3118	-
Nursery	51.7	-
Swimming pools-sport club	474.7	256
Printing house	117.8	-
Laboratories and research centers	1046.7	504.5
Total	47407.6	6514.7
Potential money-saving ($/quarter)	19911	

4. Discussion

Increasing water use efficiency remains the key strategy to conserve water without deteriorating the lifestyle of people or service level (Oduro-Kwarteng et al., 2009). Efficient sanitary fixtures can reduce water demand from 30-50% (EC, 2006). In the USA too, the water-saving devices program was implemented for 10 years from 1985-1996, the results of the program showed that reducing water demand reached 25% (Kanakoudis, 2002). When the University of Jordan implemented water use efficiency in its campus, the water demand would be reduced to 13.7%.

On the other hand, Toilets are considered the most important internal use of water with 64% in the schools' buildings at the University of Jordan. For validation of the University of Jordan study, Australia has significantly decreased the volume of water used for flushing water closets from an average of 11-13 liters per flush to less than 4 liter per flush, due to the development of the dual flush WCs (White, 1999; Day and White, 2003). And in 1996, the Australian authorities made standards for reducing the dual flush to 3/6 liters (Sharma, 2004). Jordan standards and metrology organization made Sanitary installation-plumbing supply fittings standard JS 1945:2011 in 2011. Accordingly, the study has used this standard as a benchmark to assess water flow rate by fittings after measuring it, the volume of flush in the toilet of the University of Jordan was 5 (l/flush). Besides, Oduro-Kwarteng et al. 2009 (Oduro-Kwarteng et al., 2009) explained the average daily number of bathes and WC flushing per respondent was 1.72 and 2.12 respectively. The average daily number of WC flushing was 2.53 for females and 2.01 for males. The frequency fixture used was estimated, duration was determined by the female student residence questionnaire especially, then they were used in the simple equation after multiplying them with the number of students and employees. For leakage; Velazquez et al., (2013) showed that 89% of leakage resulted from human behavior and just 11% of leakage was resulted due to technological failures. The leakage in Jordan University is controlled. Quantifying leakage is important to understand the level of awareness of the university community (Velazquez et al., 2013). Otherwise, wasting water by bathing could be attributed to the fact that some of the showerheads have high flow rates and students spend a lot of time bathing. Hence, the questionnaire results for 177 girls in four in campus female students' residences of the Jordan university showed that 34.5% of those females bathe daily, the average time for bathing was around 26 minutes. 44.1% of them do not close the showerhead during bathing. It is recommended to increase awareness and create educational programs to address water scarcity issues for all students in all stages are important. EL-Nwsany et al. (2019) explained that involving university students in water conservation will help in focusing on social responsibility, where social responsibility is a key component of sustainable development. Retrofitting with water-saving devices has been practiced in several countries to conserve water. In the USA, a residential water end-use study explained the potential water conservation due to showerheads and toilets alone was estimated to be up to 32% (Dickinson et al., 2003). Moreover, the water management indoor the university campus plays the main role in saving water. Water tariffs and the price of efficient fixtures play a main role in the financial benefits. For that, Velazquez et al., (2013) found in his study that the payback period of the retrofit inefficient fixture is very long and the cost-effectiveness is not feasible, but depending on water end-use analysis results for the University of Jordan that was shown in the tables (4 and 5), it was proven that the outcome is the opposite and the cost-effectiveness is reachable and payback period usually takes few months or less. In general and regardless of benefit-cost analysis of fixtures retrofitting, water value, and saving that summarized in table (6) have financial benefit more than the costs of implementing a comprehensive demand management program (UK Environmental Agency, 2006).

5. Conclusions

The end-use analysis for water consumption for large consumers including universities and academic institutions is important for understanding the reduction in water demand due to retrofit fixtures to a more efficient one. The high rates of water consumption of some sanitary fixtures are due to the high flow rate of water in some of these fixtures. Therefore, adopting the recommended flow rate in the JS1945:2011 will result in both water and money savings. A comprehensive assessment of the water supply and financial costs and benefits are important to the successful adaptation of water demand management. Water-saving translates into cost savings. Retrofitting of fixtures indoor the university campus is not enough and should be accompanied by changing behaviors in the university community. Measures that could be used to promote water conservation on the campus are retrofitting with water-efficient fixtures, awareness campaigns on water conservation practices on campus, and incorporation of water conservation in the academic curriculum (RPI, (2006); PU, (2006); UoM, (2006). In addition, installing water sub-meters for every building or green area on the campus to monitor the volume of water consumption and to control the leakage that recognizes the actual water consumption and to estimate an exact water demand (Avishek et al., 2020).

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