PN-ADC-272

وزارة المياه والري

USAID

WEPIA

Water Efficiency and Public Information for Action

مشروع الكفاءة المائية والتوعية

AED

Author:	[illegible]
Descriptive Title:	[illegible]
Program:	Water Efficiency and Public Information for Action Project
Strategic Objective:	SO2
Sponsoring USAID office:	USAID/Jordan, Operating Unit WRE; Cooperative Agreement No.: 278-A-00-00-00201-00
Contractor Name:	Academy for Educational Development
Date of Publication:	[illegible]
Key Words:	NGOs, Water Conservation, Jordan, [illegible]
Delivery:	Shera Bender sbender@aed.org

PN-ADC-272

Water Audit

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Submitted to

The Academy For Educational Development

The Water Efficiency And Public Information For Action (WEPIA)

May,2001

INTRODUCTION

One of the goals of the project on water conservation between WEPIA and Queen Rani AlAbdallah Center for Environmental Science and Technology (QRCEST) is to conduct water audit for the various departments at Jordan University of Science and Technology (JUST) and to investigate the feasibility of installing water saving devices (WSD) in these places. The water audit survey will be conducted by JUST students. Prior to the water audit, students from various disciplines at JUST will be trained in a special training workshop. Six workshops will be held throughout the period of the project, which will last for two years. In each workshop about 30 students will be trained. Since the university is large, it was divided into six parts so that each part will be water audited after each workshop. Therefore the whole university will be audited at the end of the last workshop.

WATER AUDIT RESULTS

The first workshop was held in April 10-12, 2001 and attended by 32 students most of them were Engineering students (Civil, Chemical, Mechanical, Architecture...etc). Other faculties were also involved such as the Agriculture and the Faculty of Science. The audit included measuring the flow rates through faucets in the various places in the Engineering building such as bathrooms, kitchens, laboratories....etc. The students were also asked to identify the users, type of the faucets and the faucets through which leaks take place. The same audit was also carried out for the bathrooms and urinals. It should be noted that no showers are present in the analysis. Table 1-4 summarizes the auditing results

Table 1: Water audit data for automatic sinks/faucets in the Engineering building at JUST

# of Faucets	Location	User	Flow Rate L/min	Leaks	Brand
4	Architecture	Students	7	0	Mira
8	Geology	Students	8	0	Mira
8	Civil	Students	11	0	Mira
5	Civil	Employees	15	0	Mira
15	Mechanical	Students	11	0	Mira
13	Electrical	Students	6	0	Mira
4	Nuclear	Students	12	0	Mira
3	Nuclear	Employees	10	0	Mira
3	Chemical	Both	6	0	Mira
2	B3/L3	Employees	11	0	Mira
2	L3	-	15	0	Mira
2	B5/L3	-	11	0	Mira
2	B7/L3	-	17	0	Mira
2	B9/L3	-	15	0	Mira
2	B3-Bath	-	15	0	Mira
2	B2/L3	-	4	0	-
2	L1	Students	15	0	-
2	L1	Employees	10	0	-
2	L1	Students	3	0	-
2	L1	Employees	10	0	-
2	L1	Students	10	0	-
2	L1	Students	12	0	-
2	L1	Employees	20	0	-
1	L1	Employees	20	0	-
2	L1	Students	12	0	-
2	L1	Students	10	0	-
2	L1	Students	9	0	-
2	C1	-	7.5	0	Mira
2	C2	-	6.7	0	Mira
2	C3-L1	-	6.7	0	Mira
1	C5	-	7.5	0	Mira
1	C5	-	5	0	Mira
2	G	-	6	0	Mira
2	A1	-	5	0	Mira
2	A2	-	7.5	0	Mira
3	A3	-	6	0	Mira
1	A3	-	4.3	0	Mira
2	A3	-	4	0	Mira
4	President	Employee	6	0	Mira
20	L2	Both	4	2	Mira
6	L2 (kitchen)	Employee	6	0	Jordanian
Total =148					

Table 2: Water audit data for manual sinks/faucets in the Engineering building at JUST

# of Faucets	Location	User	Flow Rate L/min	Leaks	Brand
2	Geology	Students	7	0	-
0	Civil	-		1	-
0	Mechanical	-		0	-
1	Electrical	Students	6	0	-
3	Nuclear	Employees	10	1	-
3	Chemical	Both	6	0	-
1	A4/L3	Employees	8	2	-
2	B3/L3	-	5	0	Mira
1	L3	Employees	8	0	-
4	B5-1L3	-	11	Yes	-
1	C68/L3	Employees	3	0	Mira
1	B97/L3	Employees	3	Yes	-
2	B2/L3	-	7	Yes	-
2	L1	Employee	20	0	-
1	C2-L1	Employee	20	0	-
2	C3-L1	Employee	15	0	Mira
6	Lab/Civil	Students	30	0	-
4	Civil Eng.	Students	4	0	-
10	Civil Eng.	Students	30	0	-
1	Agriculture	Students	15	0	-
1	Agriculture	Students	30	0	-
1	Mech/Lab	Students	12	0	-
1	Mech/Lab	Students	30	0	-
6	Agr., Eng...	Employee	30	0	-
2	QRAEST	Employee	30	0	-
6	Kitchens	Employee	10	0	-
				0	Jordanian
Total = 64					

Table 3: Water audit data for urinals in the Engineering building at JUST

Location	# of Urinals	Users	No of Leaks	Brand	Comments
Archeticture	2	Students	2	Mira	Automatic
Geology	5	Students	0	Mira	Automatic
Civil	4	Students	0	Mira	Automatic
Civil	2	Employees	0	Mira	Automatic
Mechanical	8	Students	0	Mira	Automatic
Electrical	4	Students	0	Mira	Automatic
Nuclear	4	Employees	0	Mira	Automatic
Nuclear	2	Students	0	Mira	Automatic
Chemical	3	Students	0	Mira	Automatic
L2	16	Students	3	DAL	Automatic
L3	28	Students	0	DAL	Automatic
L1/C5, G, A1, A3, presidency	17	-	0		Automatic

Table 4: Water audit data for bathrooms in the Engineering building at JUST

Location	# of Toilets	User	Leaks	Brand	Notes
Architecture	4	Students	3	Mira	
Geology	7	Students	2	Mira	
Civil	8	Students	2	Mira	
Civil	4	Employee	0	Mira	
Mechanical	15	Students	0	Mira	
Electrical	11	Students	1	Mira	
Nuclear	4	Employee	0	Mira	
Nuclear	3	Students	0	Mira	
Chemical	3	Both	0	Mira	
L1/CH, E, N	24	Students	0	-	3 are Arabic style
L1/C1	1	-	0	DAL	Arabic, Automatic
L1/C1	3	-	0	DBP	Automatic
L1/C2	1	-	0	DAL	Arabic, Automatic
L1/C2	2	-	0	DBP	Automatic
L1/C3	1	-	0	DAL	Arabic, Automatic
L1/C3	3	-	0	DBP	Automatic
L1/C5	1	-	0	DAL	Arabic, Automatic
L1/C5	2	-	0	DBP	Automatic
L1/G1	1	-	0	DAL	Arabic, Automatic
L1/G1	2	-	0	DBP	Automatic
L1/A1	1	-	0	DAL	Arabic, Automatic
L1/A1	1	-	0	DBP	Automatic
L1/A2	1	-	0	DAL	Arabic, Automatic
L1/A2	1	-	0	DBP	Automatic
L1/A3	1	-	0	DAL	Arabic, Automatic
L1/A3	3	-	0	DBP	Automatic
Presidency	2	-	0	-	Automatic
L3	38	-	0	-	Automatic
L2	22	Both	0	DAL	Automatic
Total	170				

ESTIMATION OF THE TOTAL WATER CONSUMPTION

In order to perform water saving calculations, it is necessary to estimate the amount of water consumed by various water users in the university including visitors. The Engineering faculty has 5550 students, 750 employees. To estimate the amount of water consumed per year for sinks and faucets the following assumptions were made.

1. Each student receives one visitor per year and each employee receives 5 visitors per year. Hence the number of visitors was estimated to be 9300 visitors
2. 218 working days for students and 212 working days for employees. Note that students come to the university on Saturdays for exams whereas employees do not work on Saturdays. The working days are estimated as follows:

   For students: 365 day/year – 52 Fridays/year – 27 Working Saturdays/year - 68 holidays and between semesters = 218 days.

   For employees: 365 day/year – 104 Saturdays and Fridays – 45 holidays/year = 212 days
3. Students and employees use water 2 times per day where visitors use it once per visit. Note that one visit per year is assumed. Moreover the use of the sink lasts for 25 seconds.
4. The average flow rate through the tap or the faucet is 10 L/min

The total amount of water consumed can be calculated from the following equation

For students: $$TC = N \times NU \times DU \times V \times WS \times f$$

For employees: $$TC = N \times NU \times DU \times V \times WE \times f$$

Where **TC** is the total water consumed by a catergory, **N** is the number of users, **NU** is the number of uses per day which is assumed to be 2, **DU** is the duration of the use which is assumed 25 seconds/use, **V** is the average volumetric flow rate through the tap and assumed to be 10 L/min, **WS** is the working days of students/year, **WE** is the working days of employees/year and **f** is a factor to convert units to m^3/year and equals 1/60000. Table 5 summarizes the amount of water consumed by the various users in the engineering building at JUST.

Table 5: Estimated amount of water consumed / year by the various users in the engineering building at JUST.

Users	TC (m^3/year)
Students	10082
Employees	1325
Visitors*	39
Total amount	11446

* note that visitors use the sinks 1 time/year. Hence W is 1.

WATER SAVING CALCULATIONS

1. Faucets and Taps

Assuming that the recommended flow rate through a faucet is 6 liters / minute then Table 6 below shows the amount of savings that can be made by installing WSD on the faucets. From Tables 1 and 2 we notice the followings

- There are 53 taps allocated for the employees
- There are 159 taps allocated for the students
- Taps which are used by both the students and employees are assumed to be used by the students

- Taps of which the users are not known and indicated by "-" are assumed to be used by students
- Visitors can only use student's taps
- The total amount of savings, TS, that can be made by installing WSD's on taps is calculated as follows:

For students:

$$\mathbf{TS = NT \times S \times NS \times DU \times NU \times WS \times f}$$

For employees:

$$\mathbf{TS = NT \times S \times NE \times DU \times NU \times WE \times f}$$

For visitors:

$$\mathbf{TS = NT \times S \times NV \times DU \times NU \times f}$$

Where **NT** is the number of taps, **S** is the amount of water saved upon installing the WSD in L/min and equal to the flow rate before installing the WSD – 6 L/min, **NS** is the number of students/tap and equal to 5550 student/159 tap = 35 student/tap, **NE** is the number of employee/tap = 750 employee/53 tap = 14 employee/tap, **NV** is the number of visitors/tap = 9300 visitor/159 tap = 59 visitor/tap and **DU**, **NU**, **WS**, **WE** and **f** are as defined before. We should remind the reader that the visitors use the taps one time per year. The results of the calculations are shown in Table 6, 7 and 8 below.

Table 6: Shows the amount of water that can be saved upon installing WSD on the automatic and manual faucets used by students.

NT	Location	S (L/min)	TS (m^3/year)
4	Architecture	1	25
8	Geology	2	102
8	Civil	5	254
15	Mechanical	5	477
13	Electrical	0	0
4	Nuclear	6	153
3	Chemical	0	0
2	L3	9	114
2	B5/L3	5	64
2	B7/L3	11	140
2	B9/L3	9	114
2	B3-Bath	9	114
2	B2/L3	0	0
2	L1	9	114
2	L1	0	0
2	L1	4	51
2	L1	6	76
2	L1	6	76
2	L1	4	51
2	L1	3	38
2	C1	1.5	19
2	C2	0.7	9
2	C3-L1	0.7	9
1	C5	1.5	10
1	C5	0	0
2	G	0	0
2	A1	0	0
2	A2	1.5	19
3	A3	0	0
1	A3	0	0
2	A3	0	0
20	L2	0	0
0	Architecture	0	0
2	Geology	1	13
0	Civil	0	0
0	Mechanical	0	0
1	Electrical	0	0
3	Chemical	0	0
2	B3/L3	0	0
4	B5-1L3	5	127
2	B2/L3	1	13

Table 6 continues

6	Lab/Civil	24	916
4	Civil	0	0
10	Civil	24	1526
1	Agriculture	9	57
1	Agriculture	24	153
1	Mech/Lab	6	38
1	Mech/Lab	24	153
Total			5025

Table 7: The amount of water that can be saved upon installing WSD on the automatic and manual faucets used by employees.

NT	Location	S (L/min)	TS (m^3/year)
5	Civil	9	111
3	Nuclear	4	30
2	B3/L3	5	25
2	L1	4	20
2	L1	4	20
2	L1	14	69
1	L1	14	35
4	President	0	0
6	L2 (Kitchen)	0	0
3	Nuclear	4	30
1	A4/L3	2	5
1	L3	2	5
1	C68/L3	0	0
1	B97/L3	0	0
2	L1	14	69
1	C2-L1	14	35
2	C3-L1	9	45
6	Agr Eng.	24	356
2	QRACEST	24	119
6	Kitchens	4	59
Total			1031

Table 8: The amount of water that can be saved upon installing WSD on the automatic and manual faucets used by visitors.

NT	Location	S (L/min)	TS (m^3/year)
4	Architecture	1	0.10
8	Geology	2	0.39
8	Civil	5	0.98
15	Mechanical	5	1.84
13	Electrical	0	0.00
3	Chemical	0	0.00
2	L3	9	0.44
2	B5/L3	5	0.25
2	B7/L3	11	0.54
2	B9/L3	9	0.44
2	B3-Bath	9	0.44
2	B2/L3	0	0.00
2	L1	9	0.44
2	L1	0	0.00
2	L1	4	0.20
2	L1	6	0.29
2	L1	6	0.29
2	L1	4	0.20
2	L1	3	0.15
2	C1	1.5	0.07
2	C2	0.7	0.03
2	C3-L1	0.7	0.03
1	C5	1.5	0.04
1	C5	0	0.00
2	G	0	0.00
2	A1	0	0.00
2	A2	1.5	0.07
3	A3	0	0.00
1	A3	0	0.00
2	A3	0	0.00
20	L2	0	0.00
0	Architecture	0	0.00
2	Geology	1	0.05
0	Civil	0	0.00
0	Mechanical	0	0.00
1	Electrical	0	0.00
3	Chemical	0	0.00
2	B3/L3	0	0.00
4	B5-1L3	5	0.49
2	B2/L3	1	0.05
6	Lab/Civil	24	3.54

Table 8 continues

4	Civil	0	0.00
10	Civil	24	5.90
1	Agriculture	9	0.22
1	Agriculture	24	0.59
1	Mech/Lab	6	0.15
1	Mech/Lab	24	0.59
Total			19.43

From the above data it can be noticed that the total amount of water that can be saved is 5025 + 1031 + 20 = 6076 m^3/year. This value represents 6076/11446 = 53% of the total water consumed and can be saved by installing WSD's.

According to the ministry of water and irrigation the price of 1 m^3 of water is 0.550 JD. The cost of sewer water is 0.23 JD/m^3. Therefore the amount of saving in JD is 6076 x (0.55 + 0.23) = 4739 JD/year.

2. Bathrooms

In order to perform water saving calculations for bathrooms the following assumptions are made:

1. 1.5 L of water is saved per flush
2. Each student or employee use the toilets one time per day.
3. All the toilets are available for both the students and the employees. Note that toilets assigned for employees are only used by the heads of the departments, hence that number is ignored.
4. Visitors use the toilets one time per year.

The total amount of water saved upon installing WSD's or inserting an object in the toilet's tank to conserve 1.5 L/flush can be calculated from the following equation

For employees and students: $TS = N_{toilet} \times NSE \times NF \times S \times W/1000$

For visitors: $TS = N_{toilet} \times NV \times NF \times S/1000$

Where **TS** is the total saving in m^3/year, N_{toilet} is the number of toilets, **NSE** is the number of students and employee/toilet = (5550+750)/170 = 37 employee and student/toilet, **NF** is the number of flushes/day-student and employee which assumed to be equal to 1, **S** is the amount of savings/flush and it is assumed to be equal to 1.5 L/flush, **W** is the working days for the students or the employees which is assumed equal to **WS** = 218 day/year and **NV** is the number of visitors/toilet = 9300/170 = 55 visitor/toilet. Table 9 below summarizes the amount of water that can be saved upon either installing WSD's in toilets or inserting an object in the toilet's tank to save 1.5 L/flush.

Table 9: Total savings in m^3/year that can be achieved in toilets upon either installing WSD's or inserting an object in the toilet's tank to save 1.5 L/flush.

Location	N_{toilet}	TS, m^3/year (Students & Employees)	TS, m^3/year (Visitors)
Architecture	4	48	0.33
Geology	7	85	0.58
Civil	8	97	0.66
Civil	4	48	0.33
Mechanical	15	181	1.24
Electrical	11	133	0.91
Nuclear	4	48	0.33
Nuclear	3	36	0.25
Chemical	3	36	0.25
L1/CH, E, N	24	290	1.98
L1/C1	1	12	0.08
L1/C1	3	36	0.25
L1/C2	1	12	0.08

Table 9 continues

L1/C2	2	24	0.17
L1/C3	1	12	0.08
L1/C3	3	36	0.25
L1/C5	1	12	0.08
L1/C5	2	24	0.17
L1/G1	1	12	0.08
L1/G1	2	24	0.17
L1/A1	1	12	0.08
L1/A1	1	12	0.08
L1/A2	1	12	0.08
L1/A2	1	12	0.08
L1/A3	1	12	0.08
L1/A3	3	36	0.25
Presidency	2	24	0.17
L3	38	460	3.14
L2	22	266	1.82
Total	170	2057	14

Table 9 above shows that 2071 m^3/year can be saved upon either installing WSD's in toilets or inserting an object in the toilet's tank to save 1.5 L/flush.

3. Urinals

No calculations for urinals are performed since it is assumed that urinals are installed according to water consumption standards

CASH FLOW ANALYSIS

The total number of faucets that need WSD = 139 faucet

Cost of WSD = 3 JD x 139 = 417 JD

Cost of WSD for toilets = 0 since object will be inserted in toilets' tanks

Installation = 0.4 x 417 = 167 JD (assumed to be 40% of the WSD cost)

Maintenance = 0.2 x 417 = 42 JD/year (assumed 10% of WSD cost)

Total initial cost = 417 + 167 = 584 JD

Revenues = 4739 JD/year (see water saving calculation section)

Table 6 below shows the cumulative cash position

Table 10: Cumulative cash position table.

Beginning of Yea	Investment	Revenue	Cumulative Cash Position
1	-584	0	-584
2	-42	4739	4113
3	-42	4739	8810
4	-42	4739	13507

The above data are presented in Fig 1 below.

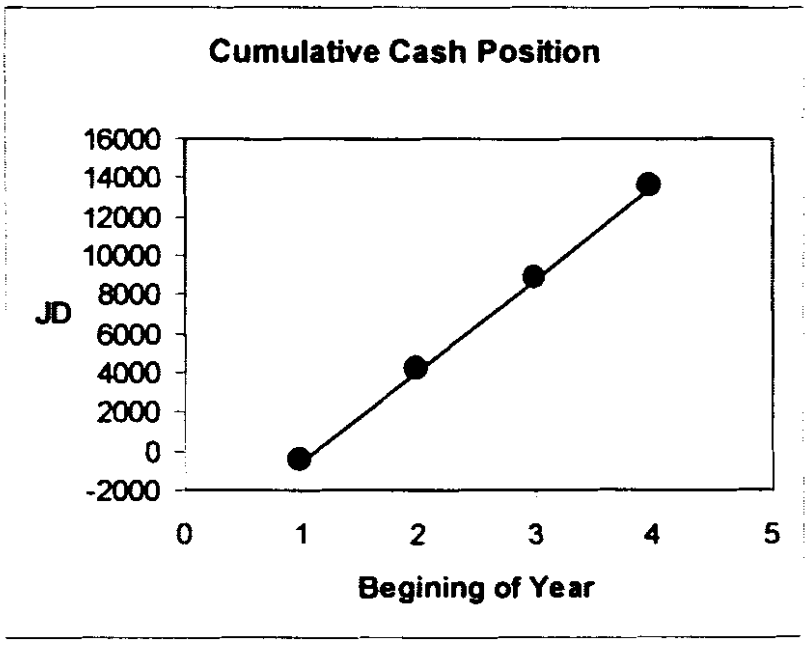

Table 10 and Fig 1 show that the pay out period is 52 days. Assuming that 70% of the students care to flush then the pay out period becomes 73 days. Therefore it is strongly recommended to install WSD on the taps used in the various utilities of the university.