International Journal of Architectural, Civil and Construction Sciences
ISSN: 2415-1734
Vol:6, No:11, 2012

Response of King Abdulla Canal Water to the upgrade of As Samra WWTP

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Abstract**—**The response of King Abdulla Canal (KAC) water to the upgrade of As Samra Wastewater Treatment Plant which discharges its effluent to the Zarqa River is investigated. Time series quality data that extends between October 2005 and December 2009 obtained by a state of the art telemetric monitoring system were analyzed for COD, EC, TP and TN at two monitoring stations located upstream and downstream of the confluence of the Zarqa River with KAC. The samples' means and the t-test showed that there has been significant improvement in the quality of the KAC water for COD, and TP. However, the improvement in the TN was found statistically insignificant, whereas the EC of the KAC was unaffected by the upgrade. Comparing the selected parameters with the standards and guidelines for using treated wastewater in irrigation showed that the KAC water has improved towards meeting the required standards and guidelines for treated wastewater reuse in irrigation.

Keywords**—**As Samra wastewater treatment plant, Telemetric monitoring system, Treated wastewater, Water quality monitoring, Zarqa River watershed.

I. INTRODUCTION

THE Jordan Valley is strategically important to Jordan as it produces most of Jordan's fruits and vegetables. Due to its temperate climate, the valley is cultivated year around with different types of crops which makes it the food basket for Jordan. The Jordan Valley extends from northern Jordan at the Syrian border to southern Jordan near Aqaba. The part of the Jordan Valley that is covered by this study is from northern Jordan to the Dead Sea.

The Jordan Valley is connected to the Amman Zarqa basin via the Zarqa River which is a main source of irrigation water to the Valley. The Zarqa River is the third largest river in Jordan after the Jordan River and the Yarmouk River [1]. King Talal Dam (KTD), the capacity of which is 86 Million Cubic Meter (MCM) was constructed on the Zarqa River to regulate the river flow to the Jordan Valley [2]. During summer, the Zarqa River is dry upstream of the confluence of the river with As Samra Wastewater Treatment plant (WWTP) whereas during winter, the river flow consists of flood water upstream of As Samra and a mixture of flood water and as Samra effluent downstream of As Samra confluence with the Zarqa River.

Due to the importance of irrigated agriculture in the Jordan Valley to the social and economic development in Jordan, many studies were conducted to optimize irrigation water use and management and to investigate the impact of climate change on irrigated agriculture in the valley as well ([3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14], [15], [16], [17], [18], [19], [20]).

As Samra WWTP, which originally consisted of; aerobic, facultative and anaerobic lagoons in series, started operation in 1985. It was then designed to treat about 67,000 m^3/d of the wastewater generated in Amman and Zarqa cities. Due to the return of large number of Jordanians from the Gulf in the wake of the Gulf war in 1990, in addition to the high natural population growth rate, the plant became quickly overloaded and as a result, the quality of its effluent deteriorated over time, which led to the deterioration of the Zarqa River water quality as evidenced by the high Chemical Oxygen Demand (COD), the high Total Nitrogen (TN) and Total Phosphorus (TP) which raised concerns about the irrigation water quality in the Jordan Valley. Due to the severe environmental impacts of As Samra WWTP as a result of the deteriorated quality of its effluent, the government of Jordan decided to upgrade the plant to a mechanical system that is capable of bringing its effluent to the international standards for discharging treated wastewater to surface water bodies which should reflect positively on the irrigation water quality in the Jordan Valley. Due to the lack of funds, it was not until 2004 that the upgrade of As Samra WWTP started. The operation of the upgraded plant started partially in June of 2007. The objective of this paper is to investigate the impact of As Samra WWTP upgrade on the King Abdulla Canal (KAC) water quality by analyzing quality data obtained by the telemetric monitoring system. Parameters that have been investigated are COD, TN, TP, and EC.

II. IRRIGATION SYSTEM IN THE JORDAN VALLEY

KAC, the backbone of the transfer system in the Jordan Valley, passes through the Jordan Valley north to south which ends several kilometers before the Dead Sea. KAC receives fresh water from three sources at its northern end which are: the Yarmouk River, the Mukheiba wells, and Lake Taiberia. KAC receives the effluent of As Samra WWTP in the middle Jordan Valley through the Zarqa River. The water in KAC upstream of the confluence of the Zarqa River and KAC is

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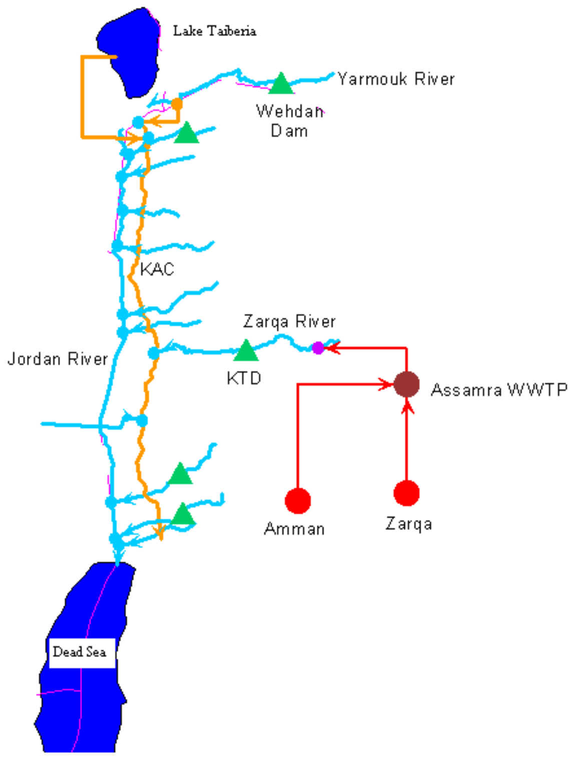


Fig. 1 Irrigation system in the Jordan valley (not to scale)

Fresh, which is used for drinking and for irrigation in the Northern Jordan Valley, however, downstream of the confluence of KAC with the Zarqa River, KAC water is a mixture of fresh water and treated wastewater which is used for irrigation in the middle and southern Jordan Valley. Fig. 1 shows the irrigation system in the Jordan Valley.

III. The Telemetric Monitoring Stations

A state of the art telemetric monitoring system that consists of thirteen completely automated monitoring stations distributed on the Zarqa River, the KAC, the Yarmouk River and the Jordan River started operation in 2005. Each of the thirteen monitoring stations is equipped to automatically collect and analyze samples for pH, Temperature, Electrical Conductivity (EC), Turbidity, COD, TN, and TP. Hourly results are obtained for all the parameters except for the TP and the TN which are obtained every six hours. For the purpose of this study, data for monitoring stations 5 and 6 which are located on the KAC upstream and downstream of the confluence with the ZR respectively were used. The telemetric monitoring system is accredited by the United Kingdome Accreditation Services (UKAS). In addition, biweekly samples for all the monitored parameters are tested in other accredited laboratories such as the Water Authority of Jordan (WAJ) laboratories and the results are compared with those obtained by the telemetric system.

IV. Statistical Treatment of the Data

Monitoring data were downloaded from the internet daily or every other working day in some instances for the period between October 2005 and December 2009 which corresponds to random sampling from a population. The downloaded data were divided into two sets for each parameter, the first set represents pre June 2007 and the second set represents post June 2007. Time series plots were prepared for each parameter, in addition to trend lines for the two data sets which were obtained by linear regression for a significance level of 0.05. Descriptive statistics i.e. mean and standard deviation was performed on each data set for all the monitored parameters. For the purpose of testing whether the means for the monitored parameters pre and post June 2007 are statistically different, the t-test was performed on the two data sets for each parameter at monitoring station 6. Outliers at monitoring station 6, were identified and excluded from the analysis by the box plot as the occurrence of these outliers is attributed to reasons other than As Samra upgrade such as accidental disposal of sewage to the river and input of pollutants to the river due to agricultural runoff during floods. Each data set was tested for normality by the normality plot as normality is a necessary condition for the validity of the t-test. Statistical analyses were performed by the Minitab software [21].

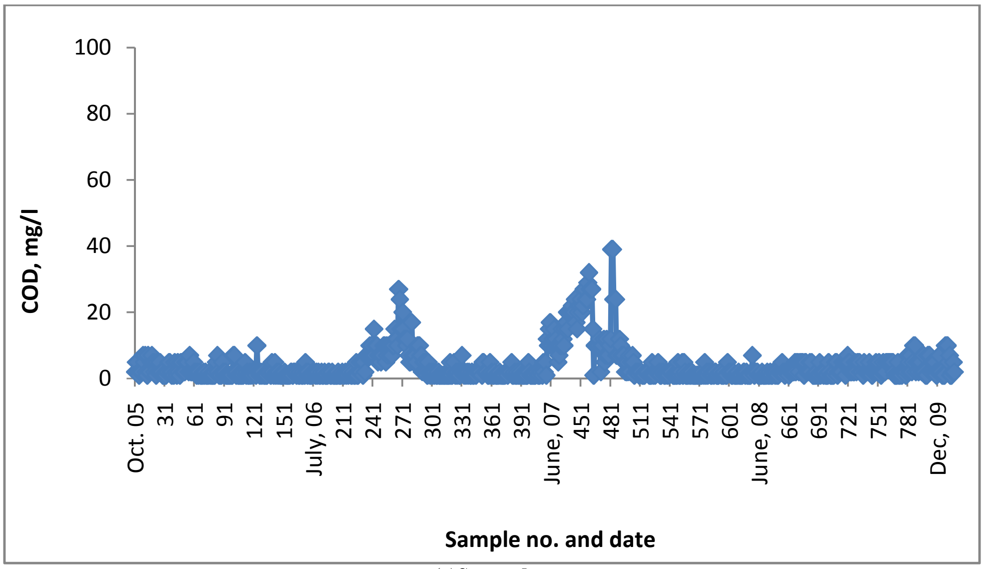
V. Results and Discussion

Figs. 2 through 4 and Table I show reductions in the COD, the TN and the TP concentrations at station 6 post June 2007, however, at station 5, increases in these three parameters were observed by different percentages (Table 1) which means that the reductions at station 6 are a result for the reductions in the water from the Zarqa River which is directly related to As Samra upgrade. The t-test results showed that the reductions in the COD and the TP are statistically significant whereas the reduction in the TN is statistically insignificant (Table 2). Fig. 5 shows that no change is observed in the KAC EC post June 2007 at both monitoring stations supported by the t-test (Table 2), which means that the upgrade of As Samra WWTP did not have any significant impact on the EC of the KAC water.

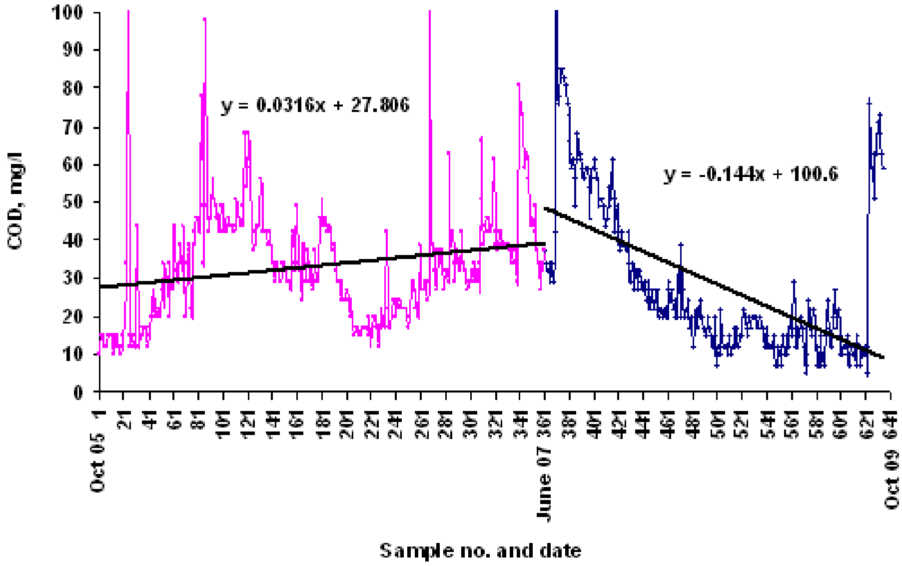
Figs 2 through 4 show occasional higher than usual increases in the COD, the TN and the TP concentrations at both monitoring stations, these occasional increases are most probably due to non point sources of pollution from the surroundings to KAC and/or from the surroundings of the river, i.e. agricultural runoff. These occasional increases might have also been associated with the disposal or spill of domestic sewage to the river which happens form time to time ([22], [23]).

In addition, Fig. 5 shows several peaks and dips in the EC at both monitoring stations which are most probably due to heat waves in the summer and to floods in the winter respectively.

Fig. 5 shows seasonal variation in the EC at both monitoring stations which is attributed to the seasonal variation in the temperature, good correspondence between the temperature and the EC is observed at both monitoring stations.

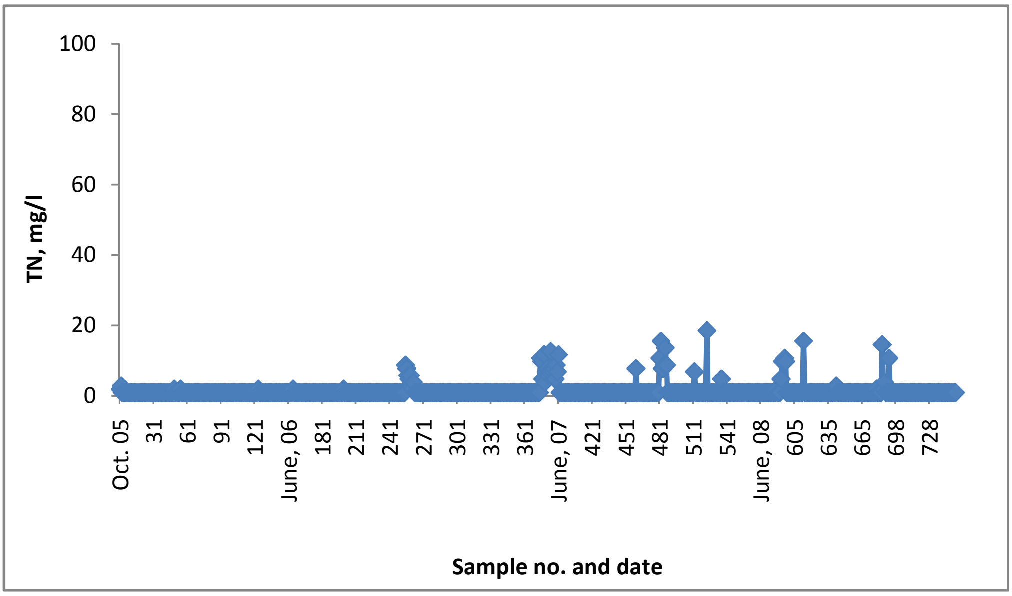


(a) Station 5

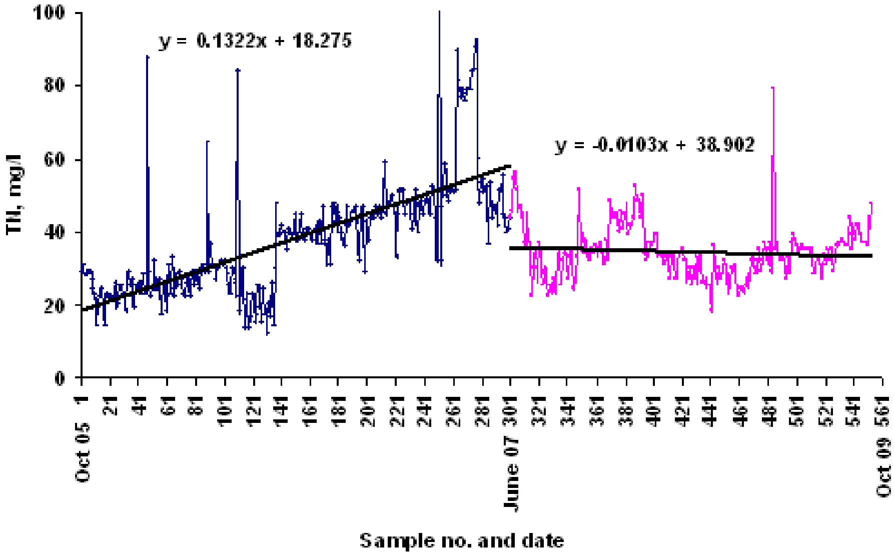


(b) Station 6

Fig. 2 COD at stations 5 & 6 for the monitoring period

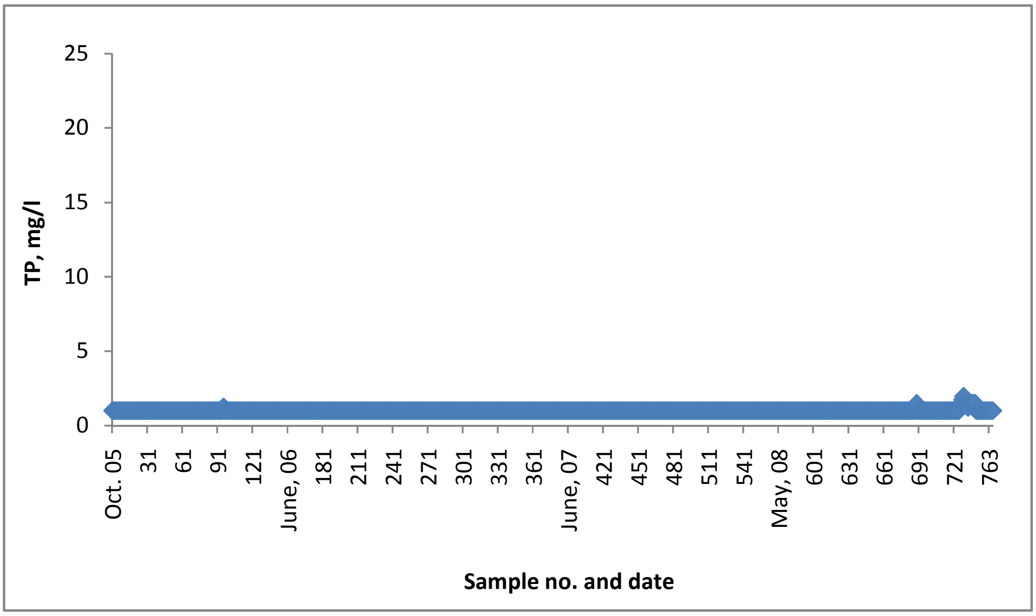


(a) Station 5

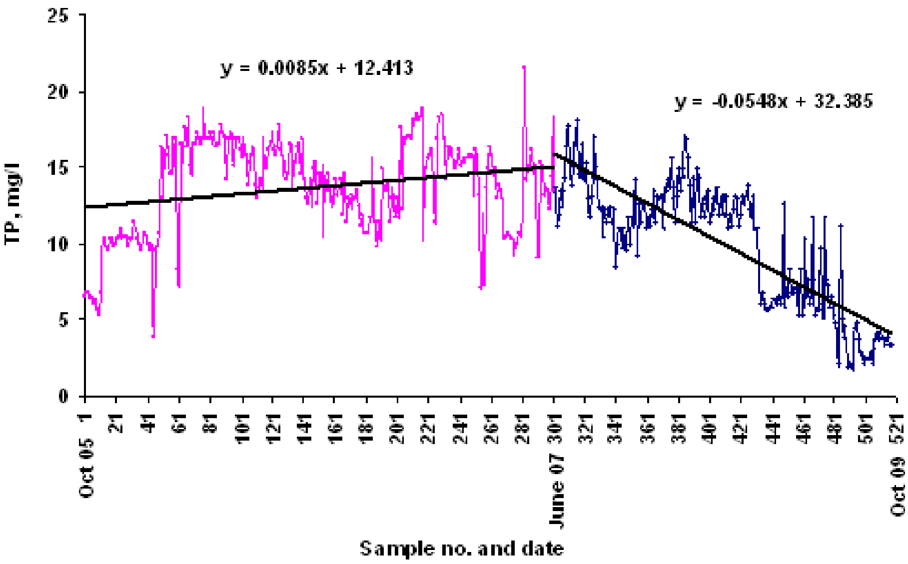


(b) Station 6

Fig. 3 TN at stations 5 & 6 for the monitoring period

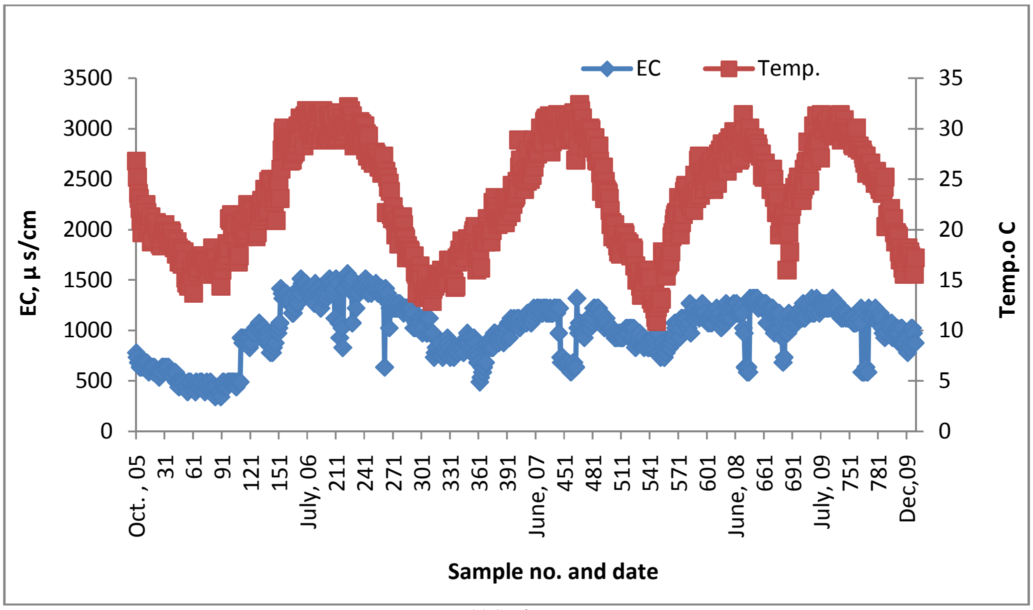


(a) Station 5

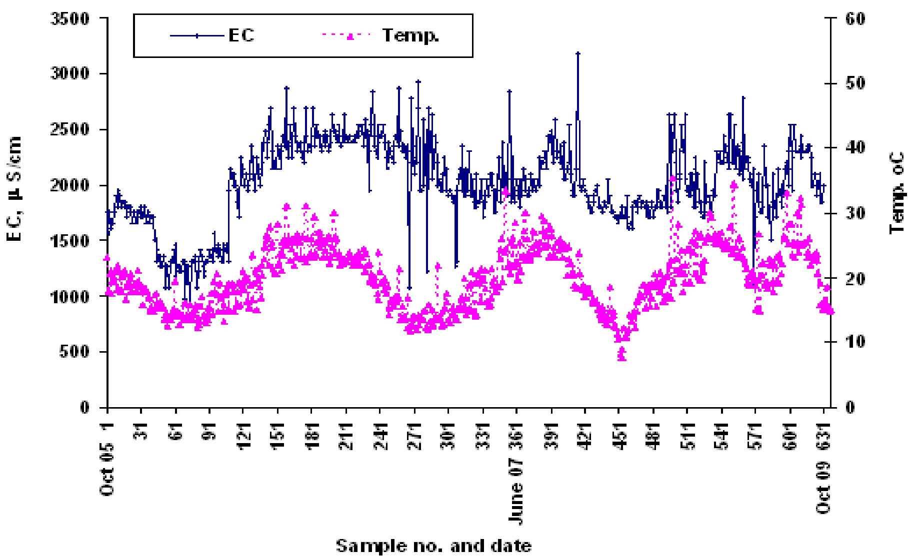


(b) Station 6

Fig. 4 TP at stations 5 & 6 for the monitoring period



(a) Station 5



(b) Station 6

Fig. 5 EC and water temp. at stations 5 & 6 for the monitoring period

TABLE I
BASIC STATISTICS FOR MONITORING STATIONS 5 AND 6 AT KING ABDULLA CANAL

Parameter	Sample no.	No. of observations	Mean	% difference	St. dev.	P-value for the normality test
			Station 6			
COD, mg/l	1	352	32.20		12.4	< 0.005
	2	211	18.97	-41.09	8.35	< 0.005
EC, μS/cm	1	361	2005.00		434.7	< 0.005
	2	267	2024.00	0.95	238	< 0.005
TN, mg/l	1	283	35.33		11.3	< 0.005
	2	240	33.52	-5.12	5.78	< 0.005
TP, mg/l	1	300	13.73		3.06	< 0.005
	2	216	9.97	-27.39	4.16	< 0.005
			Station 5			
COD, mg/l	1	421	3.16		3.61	
	2	407	4.85	53.48	6.39	
EC, μS/cm	1	313	1110.00		243	< 0.005
	2	374	1086.00	-2.16	138	< 0.005
TN, mg/l	1	391	1.41		1.65	
	2	353	1.53	8.51	2.29	
TP, mg/l	1	391	1.00		0.01	
	2	363	1.02	2.00	0.1	

TABLE II
SUMMARY OF THE T-TEST RESULTS FOR MONITORING STATIONS 5 & 6 AT KING ABDULLA CANAL

Parameter	95% CI for the diff.	Est. diff. in the mean	t-value	P-value	Decision
			Station 6		
COD	[11.536,14.974]	13.26	15.15	< 0.005	Reject Ho
EC	[-73.1,33.4]	-19.80	-0.73	0.47	Fail to reject Ho
TN	[0.297,3.31]	1.80	2.35	0.02	Fail to reject Ho
TP	[3.104,4.416]	3.76	11.27	< 0.005	Reject Ho
			Station 5		
EC	[-7.10, 53.7]	23.3	1.5	0.133	Fail to reject Ho
TN	[-0.406,0.173]	-0.117	-0.79	0.430	Fail to reject Ho

VI. PRACTICAL SIGNIFICANT OF THE REDUCTION IN THE TESTED PARAMETERS

To evaluate the improvement of the KAC water quality due to As Samra upgrade from a practical point of view, the suitability of KAC water for irrigation pre June 2007 and post June 2007 was evaluated by comparing the COD, the TN and the EC concentrations before and after the upgrade (Table 1) to the Jordanian standards for reclaimed wastewater reuse in irrigation [24] and to the Ayers and WestCot Guidelines for interpretations of water quality for irrigation [25] (Table 3). The result of the comparison is summarized in Table 4 which shows that the KAC water downstream of the confluence of the Zarqa River was suitable for irrigating fruit trees, sides of roads inside city limits, and green areas and became suitable for irrigating cooked food, parks, play ground, and sides of roads inside city limits due to As Samra upgrade.

VII. CONCLUSION

The improvement in the quality of KAC water as a result of As Samra WWTP upgrade was investigated by analyzing quality data obtained at two telemetric monitoring stations located at KAC. Analysis of the time series data and the t-test results showed that the COD, the TN and the TP of the KAC water have improved. However, the reductions in the COD and the TP were found statistically significant, whereas the reduction in the TN was found statistically insignificant. Furthermore, no reduction in the EC of KAC was observed. From a practical point of view, the suitability of KAC water for irrigation has also improved from class B to class A.

TABLE III
STANDARDS AND GUIDELINES FOR EVALUATING THE QUALITY OF TREATED WASTEWATER FOR REUSE IN IRRIGATION

Jordanian standards (Maximum limit mg/l)					Ayers and Westcot guidelines			
Parameter	A	B	C	D	Unit	None	Slight to moderate	Severe
TN	45	70	100	70	mg/l	< 5	5-30	> 30
COD	100	500	500	50	NA	NA	NA	NA
EC	NA	NA	NA	NA	ds/m	< 0.7	0.7-3.0	> 3.0
TP	NA	NA	NA	NA	NA	NA	NA	NA

TABLE IV
SUMMARY OF THE KAC WATER SUITABILITY FOR IRRIGATION

Parameter	Station 6		Standard or guideline
	Before	After	
TN	B	A	Jordanian
COD	A	A	Jordanian
EC	No restriction	No restriction	Ayers
Overall	B	A	

A Cooked food, parks, play ground, sides of roads inside city limits
B Fruit trees, sides of roads inside city limits, green areas,
C Field and industrial crops and forest trees
D Flowers

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