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Impact and assessment of As-Samra wastewater treatment plant on the water quality of the Zarqa River: A review

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ABSTRACT

The purpose of this review was investigated of the impact and assessment of As-Samra wastewater treatment plant (WWTP) on the water quality of the Zarqa River (ZR). The As-Samra WWTP is the largest wastewater treatment plant in Jordan discharges around 110 m^3/ year of effluent municipal wastewater to Zarqa River. The assessment of the As-Samra WWTP considers influent, effluent reclaimed wastewater and treatment efficiency. The main pollutants released to the river are organics, nutrients, phosphorous, microbial contamination, pharmaceutical compounds, and solid waste. Characterization of wastewater was evaluated the influent and effluent of the As-Samra WWTP. The maximum treated of the As-Samra treatment plant all parameters are above 90%. In concluded, this review shows that the effluent treated water before reuse in agriculture irrigation needs advanced treatment to prevent its impact on environment and then human health.

KEYWORDS

Wastewater; As-Samra plant; Zarqa River; Characteristics of wastewater; Treated wastewater reuse; Environmental impact.

INTRODUCTION

The lack of freshwater is a significant issue in the world. Indeed, it is probably the most of humanity is currently facing because problems connected to it affect the lives of millions of people. The lack of freshwater is worsened by the continued population growth in Jordan caused by natural population growth and the successive influxes of refugees from neighboring countries such as Palestine, Kuwait1, Iraq, Syria, Libya and Yemen[6]. One way that Jordan has overcome its freshwater problem is by making use of treated wastewater alternative water resources, for example, using recycled treated wastewater for agricultural irrigation purposes[9]. In Jordan, the increase in water demand, in addition to water shortage has led to growing interest in treated wastewater reuse. The scarcity of water has led to the broad use of nonconventional water resources around 13% of the water resources in Jordan come from these nonconventional resources[23]. The use of treated wastewater resources is expected to increase considerably to minimize the gap between supply of and demand for water[5].

The aims of this review investigated of quantify the degree of contamination in the As-Samra WWTP by evaluating the characteristics variations of pollution indicators and to determine the impacts of these pollutions on Zarqa River water quality for agricultures irrigation. Evaluated of quality of the As-Samra WWTP reclaimed wastewater was compared with Jordanian standards to determine its suitability for reuse. Furthermore, investigate the impact of the As-Samra WWTP upgrade on the Zarqa River water quality and the impact of reduction in contaminant concentrations.

AS-SAMRA WWTP

Background

In 1985, As-Samra wastewater treatment plant by stabilization ponds method the largest natural treatment plant in Jordan and Middle East. It was constructed to serve the capital city (Amman), Zarqa and Rusiefeh town. It services a population of approximately 2.27 million people mainly in Amman city and Zarqa. As-Samra WWTP designed to reclaimed water for irrigation purposes and supports various activities such as agriculture, industry and recycles to ground water in the Jordan Valley. The management system of the wastewater for the Amman and Zarqa includes the collection, conveyance, and treatment of wastewater generated in the Amman Zarqa basin where 60% of the populations of Jordan live. In Amman where 80% of the households, the wastewater generated connected to a sewage network, is transported over about 40 km to As-Samra wastewater treatment plant by gravity through a conveyor pipeline. Wastewater is under high pressure when transfer to the plant due to difference in elevation and turbines have been installed to run on upstream wastewater flow. The same process is repeated after treatment where the effluent is used to power discharge hydraulic turbines generating additional energy before the water is released towards the King Talal Reservoir (KTR) with its 86 MCM storage capacity.

In 2008, As-Samra treatment plant was upgraded to mechanical and chemical treatment (Figure 1). Due to the low performance of the old treatment system, the plant was upgraded to mechanical treatment system using activated sludge. At the present time, the As-Samra plant generated is more than 110 MCM/year[14]. As-Samra plant now treats all wastewater and the effluent water released into Zarqa River and the quality water is better than the water released during the initial stages of the plant. Despite the average influent in As-Samra plant is always lower (267,000 m^3/d) than its design capacity (364 000 m^3/day), it represents 71% of the total reclaimed wastewater in Jordan[24].

Location

The site located in Khirbeh As-Samra area within Al Hashimiyya in Zarqa Governorate 13Km North of Zarqa and 36 Km to Downtown Amman.

Wastewater treatment process

The main purpose of wastewater treatment process is to removal pollution of the receiving watercourse, and to protect human health and the environment. Reclaimed water is applied on soil, on cultivated as well as marginal areas in various facilities such as industry, agriculture and recharge of ground water. In Jordan, twenty-seven domestic wastewater treatment plants were evaluated over periods ranging from two to fifteen years of operation. Eight wastewater treatment plants used waste stabilization pond system, eight plants used activated sludge system, four plants used trickling filter system and two treatment plant used mixed technology activated sludge and trickling filter. The activated sludge and trickling filter systems were found to have better performance than the waste stabilization pond systems. Al-Mahamid, (2005) was found the activated sludge and trickling filter system is higher removal efficiencies for BOD_5, COD and TSS and produced good quality of the final effluents.

As-Samra WWT plant was consisted of stabilization ponds, and the influent flow rate was always exceeding the plant's design capacity (67,000 m^3/d). It was rehabilitated and upgraded in August 2008 (Figure 1). Main objective of As-Samra WWTP is to increase the hydraulic capacity from 67000 m^3/d to 365,000 m^3/d and provide an adequate treatment of wastewater improving its effluent quality for suspended solids, biological materials and other critical pollutants[20]. TABLE 1 summarizes the characteristics of the As-Samra WWTP, including the treatment technology used, operating date, design flow capacity and design biological loading (BOD_5). The average influent BOD_5 is estimated at 650 mg/l which is a very high organic load imposing operational problems in this plant[1]. From Figure 2 can be seen the improvement of the effluent quality parameters is significant in terms of BOD_5, TSS, and TN compared to the influent water parameters. As shown in TABLE 2 the water quality changes between inlet and outlet.

Wastewater treatment line

As shown in Figure 2 the As-Samra wastewater *treatment processes* include biological and sludge treatments. It aims a brief of description of the schematic's treatment methods, designs and specifications of wastewater treatment.

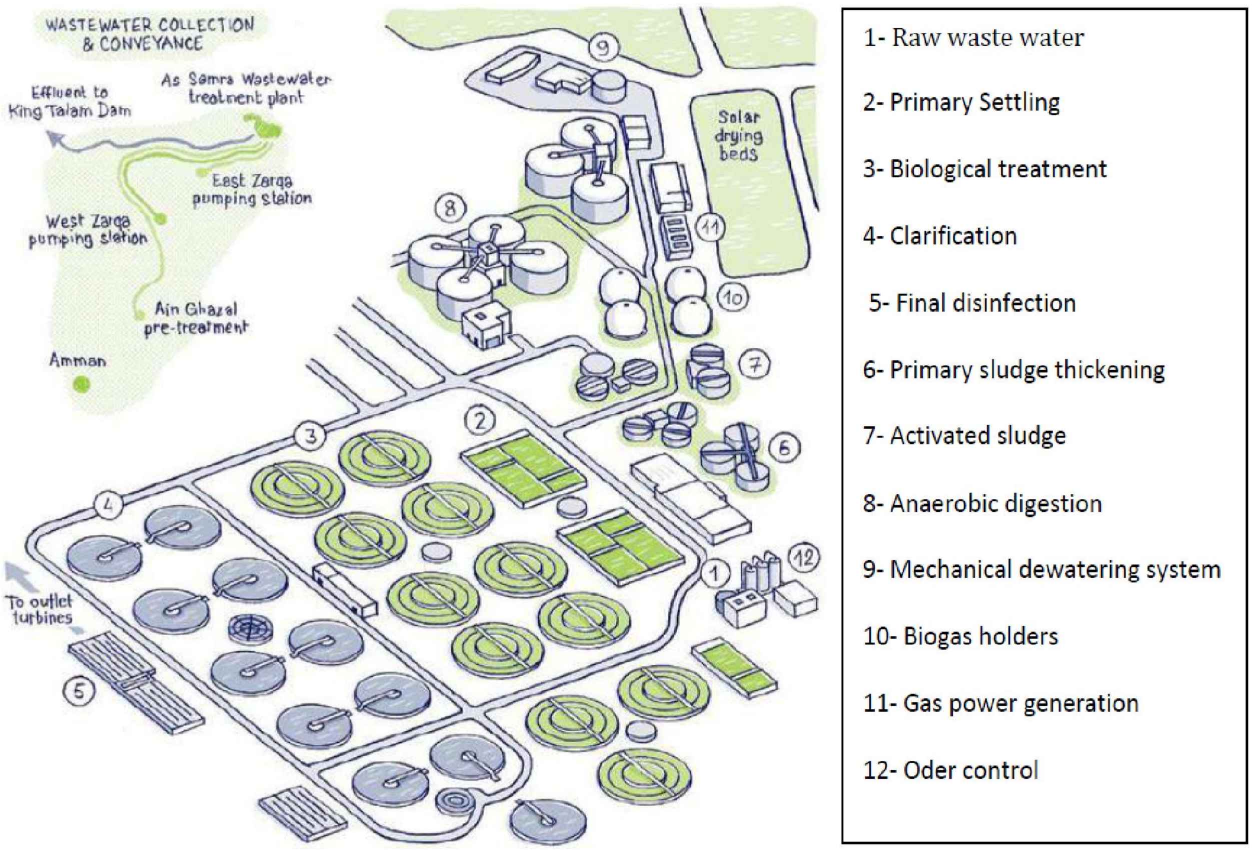

Figure 1: Scheme of As-Samra WWTP's configuration. Source: Modified from[28]

TABLE 1: Design criteria for the As-Samra wastewater treatment plant

Parameters										
Year of operation	Design flow (m^3/day)	Actual hydraulic load in (m^3/d)	Average influent (m^3/day)			Sludge (m^3/day)	Design BOD_5 (mg/L)	Efficiency	Treatment system	Serviced population
			2013	2015	2016			2014*		
1984	67,000	249740	230	294	304	3 000	650	97.3	WTP AS	2,265,000
2008	364,000		606	862	357					

Source: DOS, 2016

TABLE 2: As-Samra WWTP water quality parameters: Inlet, outlet and values

Inlet water		Outlet water	
BOD_5	637–708 mg/l	BOD_5	5–30 mg/l
COD	1,449 mg/l	COD	53 mg/l
TSS	649–682 mg/l	TSS	15–30 mg/l
Total Nitrogen	100–107 mg/l	Total Nitrogen	15–30 mg/l
F- Coliforms	10^8 MPN/100 ml	F-Coliforms	<1000 MPN/100ml

CHARACTERIZATION OF AS-SAMRA WWT

The purpose of the characterization of effluent As-Samra WWT to investigate the feasibility of utilizing treated wastewater for agricultural purposes. Characterization of As-Samra wastewater treatment was evaluated in terms of measuring BOD_5, COD, TN, TP, NO_3, NH_4, TDS, TSS and heavy metals values for the

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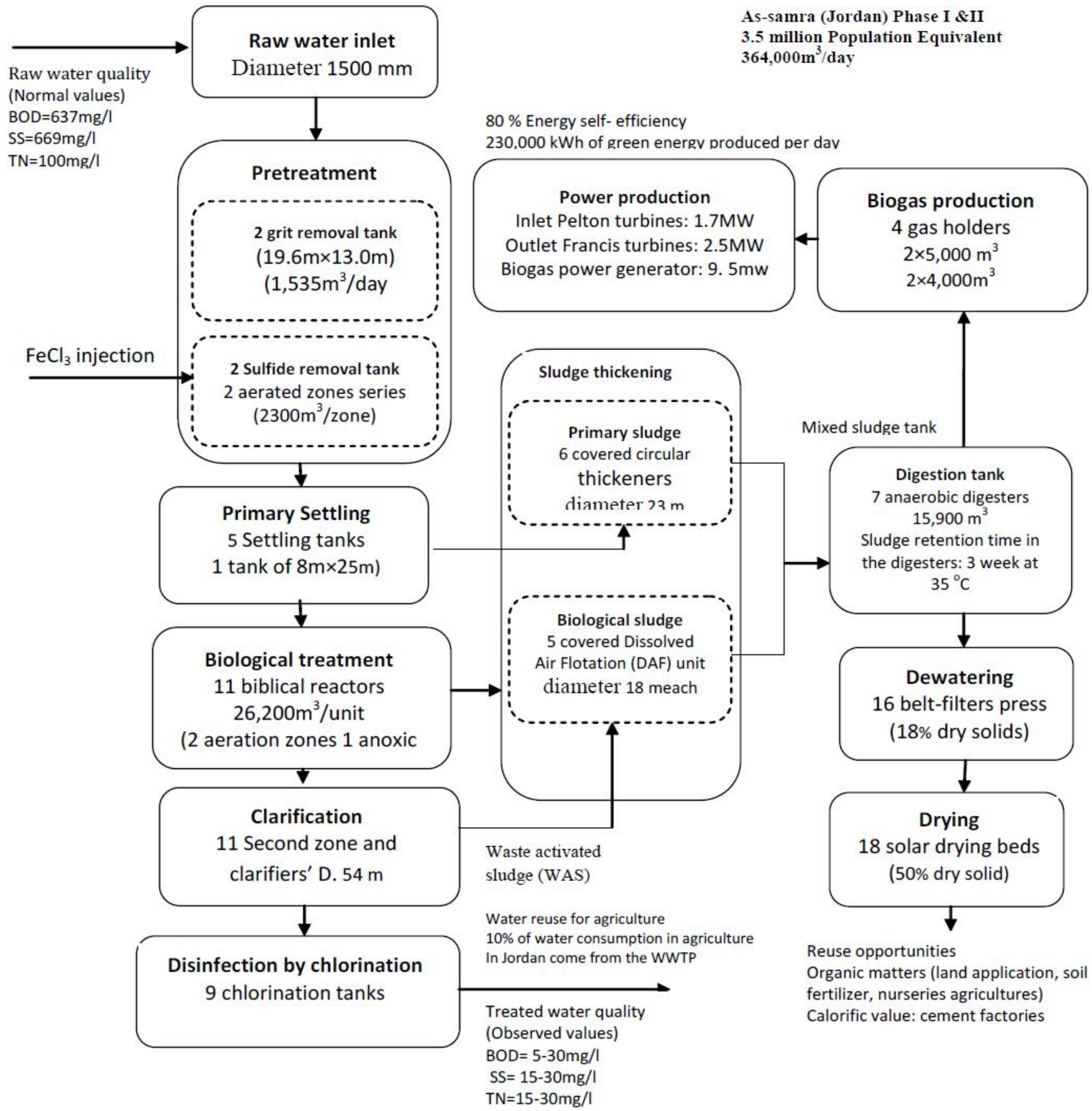

Figure 2: Wastewater treatment lines in As-Samra wastewater treatment plant after first expansion[4]

influent and effluent from the plant at different years. The efficiency assessment of As-Samra WWT based on effluent quality standards for irrigation reuse was investigated. TABLES 3, 4 and 5 illustrates the characteristics of wastewater that influent and effluent of the As-Samra WWT during the selected years.

Raw wastewater

As-Samra raw wastewater was characterized as high salinity. The high strength is due to the low per capita consumption of water, caused by shortages in water resources. The high salinity of wastewater (TDS more than 1000 mg/l) is caused by the salinity of domestic drinking water reached to 580 mg/l value[12]. A number of initial water quality parameters may affect the use of treated water for irrigation and the yield of irrigated crops in the Jordan valley. TABLE 2 shows the influent BOD_5, COD, TN, TP, NO_3, NH_4, TDS and TSS values for As-Samra WWTP at different stages. Myszograj, Qteishat[25] were observed the values in of BOD_5, COD, TN, TP and TSS concentrations for the influent wastewater are 650, 1238, 100, 16 and 571 mg/l, respectively.

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TABLE 3: Some of the previous works carried out on influent for As-Samra wastewater treatment plant

Years	Parameters											
	BOD_5	COD	H_2S	TN	TP	NH_4	TDS	TSS	PO_4	NO_3	pH	Ref.
	mg/l											
1998	708	1789		104	20	85	1153	556				[12]
2001	798	2288					1286	799				[22]
2006	552.6	14416				70.58		549.9			7.09	[11]
2008	705	1890				90		591				[10]
2008 (mg/dm^3)	686	1350						706				[25]
2009 (mg/dm^3)	673	1238						671				[25]
2015	652	1,449	40	130				551				[29]
2017 S1	620	517		96	11.4			480				[7]
S2	540	1183		98	11.3			501				[7]

TABLE 4: Some of the previous works carried out on effluent for As-Samra wastewater treatment plant

Years		Parameters													
		BOD_5	COD	TP	TN	NH_4	TDS	TSS	DO	PO_4	NO_3	*E. coli*	PH	EC	Ref.
		(mg/l)										(MPN/ 100 ml^{-1})		µS/cm	
1990		105	321	19	110		1144	177							[22]
1995		144	355	12	80		1219	125							[22]
2000		139	497	18	89		1220	146							[22]
2003		101			94		1141	92		4.0		37,000			[12]
2005*	S8		224.40	19.45	112.60									2153.00	[8]
	S10		88.11	11.81	112.50									2115.00	[8]
2006		118.2	335			86.16		118					7.89		[11]
2008		140	605			97		117	1.8						[10]
2009*	S8		68.75	11.18	99.19									2171.00	[8]
	S10		50.54	7.08	69.92									2056.00	[8]
2011		152.4	385.9			129.6				35.63	28.00	$<16\times10^6$	7.86	2.04 dS/m	[5]
2011		9.91	71.09		20.17		1109.82	17		15.84		18	7.85		[30]
2014		8.36	53.96		14.80	1.23	902.33	17.71		7.77	38	8	7.42		[1]
2014		< 2	75			< 45	888	15	53		37		7.36		DOS, 2014
2015		6	41			9	935	9	41		54		7.53		DOS, 2015
2017	S1	8	117	2.2	12.2			18.0							Othman et al., 2019
	S2	5	44.5	6.5	14.4			10.0							
JS (G. A)*		30	100		45			50	>2		30	100	6-9	100	[3]

JS (G. A)*: Jordanian Standard, group A

TABLE 5: Some of the previous works carried out on effluent for As-Samra wastewater treatment plant

	Heavy metals																						
	Al	As	Be	Cu	Fe	Mn	Mo	Ni	Pb	Se	Cd	Zn	Cr	Hg	Ca	Mg	Na	K	Cl	V	Co	B	CN	Ref.
Years	(mg/l)																							
2001	0.9	0.005	0.01	0.27	0.38	0.12	<0.02	0.03	0.02	0.014	0.005	0.08	0.043	0.001						<0.1	0.05		0.04	[19]
2011																	261.14	31.32	364.61			0.91		G. Carr et al., 2011
2014	<0.7												<0.02		74	24	193		263					DOS, 2014
2015	<0.7												<0.02		75	19	207		288					DOS, 2015
JS (G.B)	5.0	0.1	0.1	0.2	5.0	0.2	0.01	0.2	5.0	0.05	0.01	5.0	0.1		230	100	230			0.1	0.05	1.0	0.1	[3]

Source: DOS

The raw wastewater of As-Samra plant is comparatively low in toxic pollutants such as heavy metals, pesticides and toxic organic compounds. This is due to the low level of industrial discharges to sewage treatment plants. It is estimated that 10% of the biological load comes from industrial discharges[1].

Treated wastewater

Characterization of treated water from As-Samra plant was evaluated in terms of measuring BOD_5, COD, TP, TN, NH_4, TDS, NO_3, CO_3, SO_3, EC and TSS values. The average temperature of influent flow is 24°C. TABLE 6 shows the some of the previous works carried out on effluent for As-Samra WWT plant. It can be seen the best removal of BOD_5, COD, and TSS values are 8 and 44, 10 mg/l respectively. The efficiency of BOD_5 removal in waste stabilization ponds (efficiency removal 80%) system is lower than the activated sludge (efficiency removal ranges from 92.5 to 95.75%) system. The capacity of the As-Samra WWT plant for Pollution parameters removal was observed (TABLE 4). The poor COD removal efficiencies for As-Samra WWT range from 58 to 83% were found in waste stabilization ponds system, while the COD removal efficiencies range from 92 to 97% were found in activated sludge system. In the case of TSS, the highest efficiencies of removal after upgraded of As-Samra treated wastewater plant. The values reduction after upgraded of the As-Samra plant all pollution parameters is above 90%. The As-Samra plant before upgrading 2008 has a low efficiency regards to BOD, NH_4, and COD removal because it depends on natural treatment (stabilization ponds), so it is affected by seasonal variation of climate parameters such as temperature, pressure, and sunshine hours. Main pollution parameters in the effluents of As-Samra WWT working on waste stabilization pond system of BOD, COD and TSS were 144 mg/l, 356 mg/l and 126 mg/l, respectively and the effluent treated wastewater contains a high concentration of NH_4[26]. TABLE 4 shows the As-Samra treatment plant after upgraded 2008 the effluent of parameters such as BOD_5, COD, TN, TP, NH_4 and TSS are complies with Jordanian standards for treated wastewater discharge to streams, recharge of groundwater and reuse for irrigation of agriculture.

TABLE 5 compares the concentrations of heavy metals in Jordanian wastewater to the Jordanian standards. As-Samra wastewater treatment plant characterized insignificant heavy metals and low concentrations toxic organic compounds due to the low level of industrial discharges because industrial wastewater treated for toxins and partly recycled before reaching the As-Samra plant[18]. Cadmium, copper, nickel are often present in wastewater and can be mobilized easily and absorbed by plants. Despite the fact that present heavy metals levels are not high, these contaminants could build up in the soil with time[12]. From TABLE 5, it is found that the levels of trace elements and metals are much lower than the concentrations specified by the Jordanian Standards. In concluded, the capacity of the As-Samra WWT plant was assessment and the quality of the reclaimed wastewater was compared with Jordanian standards. It's should be suitability for irrigation reuse.

WASTEWATER REUSE

In Jordan, about 63% of the Jordanian population makes use of services of wastewater collection and treatment provided to them by the government in 2013. This leads to the production of about 137 MCM of treated wastewater annually a quantity that Jordanians reuse in agriculture. The amount that the mixed water irrigates is about 20,000 ha in the middle and lower Jordan Valley[27]. This replaces its dwindling freshwater flow. It is expected that the volume of As-Samra treated wastewater will increase due to the growth of population and the increase of the sewered areas. For this purpose, the government established the expanded As Samra wastewater treatment plant in October 2015 to provide Jordan with up to 133 MCM of treated water per year. According to Drechsel[16] treated water represents 13% of the country's entire renewable water resources. This helps fresh water to be devoted for more valuable uses.

The farmers who directly used this method recognized that the continuous supply of reclaimed water from the wastewater treatment plant enabled them to cultivate throughout the year[5]. After upgrading the As-Samra WWTP in 2008, the quality of the Zarqa River water considerably improved. There were gradual but significant reductions in chemical oxygen demand and TP[8]. This had positive effects on irrigation practices which, in turn, produced its habitats. El-Rawy, et al.[17] noted the high concentrations of the pollution parameters in As-Samra plant. This has been attributed to a number of variables such as local pollution from agricultural runoff with pesticides and fertilizers and illegal discharge of pollutants from untreated industrial wastes. Al-Ansari et al.[2] observed the that the impacts of irrigation by As-Samra treated wastewaters plant have been used for only a limited period of time, and that there were no adverse health impacts. Furthermore, reclaimed water should be controlled because of environmental issues such as Zarqa River, groundwater and yield crops.

SOCIO-ECONOMIC, HEALTH AND ENVIRONMENTAL EFFECT

The positive effects of the As-Samra wastewater treatment plant highly improved the quality of domestic and industrial wastewater effluents entering ultimately surface water bodies (364,000 m^3/day). The treatment plant significantly helps in the reduction of disposal of raw sewage, risks of groundwater pollution and the spread of excreta-related diseases. Since the upgrading in 2008, As-Samra treated water quality in the Zarqa River has significantly improved despite certain recontamination[8]. The As-Samra WWTP secures about 170–180 new jobs, which are used almost exclusively by national staff. Only 3% of all female employees were contacted in order to encourage the participation of women in public consultations about job opportunities and to examine the obstacles towards women employment. Further, the reclaimed water secures about 10,000 jobs in agriculture, industry, and economic development. As-Samra also produces 103,000 kwh of green energy per day. This makes the plant 90–95% energy self-sustainable. It also enables the production of biogas during the on-sight digestion of sludge used for heating. The As-Samra WWTP has its own indirect uses for the whole country such as the following: improvements in wastewater use, the delivery of fresh water, savings of treated wastewater use by 2.26 million people, the reduction of aquifer extractions, the support of the tourism sector jobs, food security, the saving of the use of synthetic fertilizers (reclaimed water is rich in plant nutrients) and the adaptation to the risks related to climate change and migration[13].

CONCLUSION

In Jordan the reuse of reclaimed water for irrigation is a valuable strategy to maximize available water resources, but the quality of the treated water is agricultural challenges. The assessment of the As-Samra wastewater treatment plant of considers influent, effluent and treatment efficiency. The contaminants reduction after upgraded of the As-Samra plant all parameters is more than 90%. The characterization of treated wastewater from As-Samra WWTP was evaluated in terms of measuring of the pollution parameters values such as BOD, COD and TSS. The capacity of the As-Samra WWTP for COD and TSS were high removal observed. The effluent of As-Samra wastewater treatment plant can be characterized insignificant toxic organic compounds and heavy metals due to the low level of industrial discharges to the As-Samra plant. The effects of agriculture irrigation by As-Samra reclaimed waters have been used limited period and no more adverse health impacts.

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