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Current and Future Water Resources for Agriculture in Qatar State

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Authors' contributions

This work was carried out in collaboration between all authors. Author HOA designed the study, performed the statistical analysis, wrote the protocol, wrote the first draft of the manuscript and managed the literature searches. Authors HOM, YIH and AAAM managed the analyses of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

The state of Qatar is a peninsular Arab country, as a small, hot and dry peninsula with an average rainfall of around 80 millimeters per annum, which is placed Qatar among countries of the lowest levels of rainfall in the world. There are no surface perennial streams in Qatar. Direct and indirect recharge from rainfall to the groundwater is the sole natural water resource in the country. The recharge takes place from the direct infiltration of heavy rainfall (>10 mm) through the fractures surrounding the water basins (watersheds) .Indirect recharge is the main recharge to groundwater and it has a complicated mechanism which comprises run-off from surrounding catchments, ponding in depressions, evaporation from water surfaces and percolation of the remainder after the soil deficit has been satisfied.

The groundwater is considered the main natural water resource available for agriculture in Qatar; about 99% of the abstracted groundwater is used for irrigation. This continuous abstraction from

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groundwater leads to quality and quantity deterioration in the groundwater table and several production wells.

In 2007 the government has issued the ministerial decree No. 20 on “Rationalizing the use of groundwater and preventing its deterioration” the decree banned the digging of new production wells to prevent this over extraction, in 2008 the Qatari government set its goals to protect and sustain its natural environment. The decree was amended and a proposed banning of the existing wells in the specific areas under a groundwater salinity of less than 2000 ppm for irrigating fodder crops, this amendment is intended to be a short-term solution till the issuance of the National Water Act.

This paper aims to review the current situation of water consumption for agricultural production and suggesting alternative water resources (Treated Sewage Effluent TSE with upgraded water quality) to comply with the decree No. 20. Gathering the available information and secondary data about TSE; agricultural production and environmental protection from governmental authorities and analyzed and presented in this paper.

The current total agricultural irrigated area, and water demand (excluding TSE) in the State of Qatar are 10,388 ha and 238 mcm respectively.

The Public Works Authority (PWA) has 3 main wastewater treatment plants plus other minor treatment plants that produced 634,860 m^3 day^{-1} in 2013, amount of 196,445 m^3 day^{-1} is in use for Roads and Expressways Irrigation, Local Landscaping Irrigation, Private Irrigation, Cooling, Industry (General) and Sand Washing. The remaining TSE volume 438,415 m^3 day^{-1} (50.4 million cubic meter), can be used for agricultural production after upgrading Treated Sewage Works (TSW) treatment plants to quadratic treatment using Reverse Osmosis (R.Os) which will cover about 21.3% of current agriculture water requirements. If all of the reaming volume of TSE will be available for Agriculture then above 95% percent of water demand by 2020 for agriculture will be covered.

Keywords: Non conventional water resource; agricultural crops and reverse osmosis.

1. INTRODUCTION

The state of Qatar is a peninsula of an area of about 11,525 Km^2 having a several offshore islands. The peninsula is located between 24° 27′ and 26° 10′ north latitudes, and 50° 45′ and 51° and 40′ East longitudes (Fig. 1) [1].

The country has an extensive hydrological and meteorological data collection network which has been operative since 1972. The State of Qatar lies in the northern hemisphere desert , of hyper arid degree of aridity, the rainfall is unpredictable and erratic in quantity, time and distribution, the average rainfall from the year 1972 to 2010 was about 78 mm. The uneven distribution and small quantity of the rainfall make it unreliable source for agriculture in the state of Qatar. Qatar has a mild winter of an average temperature of 15.8℃ and very hot summer of over 40℃ as a maximum temperature. The wind speed is low during winter and high speed during summer with a high mean annual relative humidity all year around [2,3].

Conventional (or natural) water resources in Qatar are ground water and rainfall, while non-conventional water resources are desalinated sea water and Treated Sewage Effluent (TSE).The aim of this paper is to review the current situation of water consumption for agricultural production and suggesting alternative water resource (TSE with upgraded water quality) to comply with the decree No. 20.

2. RESEARCH REVIEW

The aquifers that provide fresh water in the state of Qatar are Rus and Umm er Rhaduma aquifers. Umm er Rhaduma aquifer is a big aquifer in almost all the Gulf area. These two aquifers are of salinity range from 500 to 3000 milligram per liter, the salinity might reach about 10000 milligram per liter toward the sea coast.

There are two separate and distinct groundwater regions: the northern half, where groundwater occurs as a freshwater 'floating lens' on brackish and saline water and the southern half where no such lens exists and where water quality is generally brackish with only a thin veneer of freshwater at the top of the water table.

The total annual recharge for the period from 1972 to 2005 came from the rainfall to the groundwater is a round 58.1MCM (million cubic meter),which is came as a share between internal rainfall and inflow from Saudi Arabia as 55.9MCM and 2.2 MCM respectively [4].

It was found that available fresh groundwater in the northern and middle aquifers has decreased from 15% of the total country's area in 1971 to 2% in 2009, and that the currently available fresh groundwater area in the country is approximately 11% of that area in 1971 Fig. 2 [5] shows the groundwater depletion in 1979 and 2009 [6].

Throughout the remainder of Qatar, except in the extreme southwest, groundwater conditions were highly varies with generally poor yields and higher salinity, except in certain favourable areas where meteoric waters have gained access to the two main aquifers.

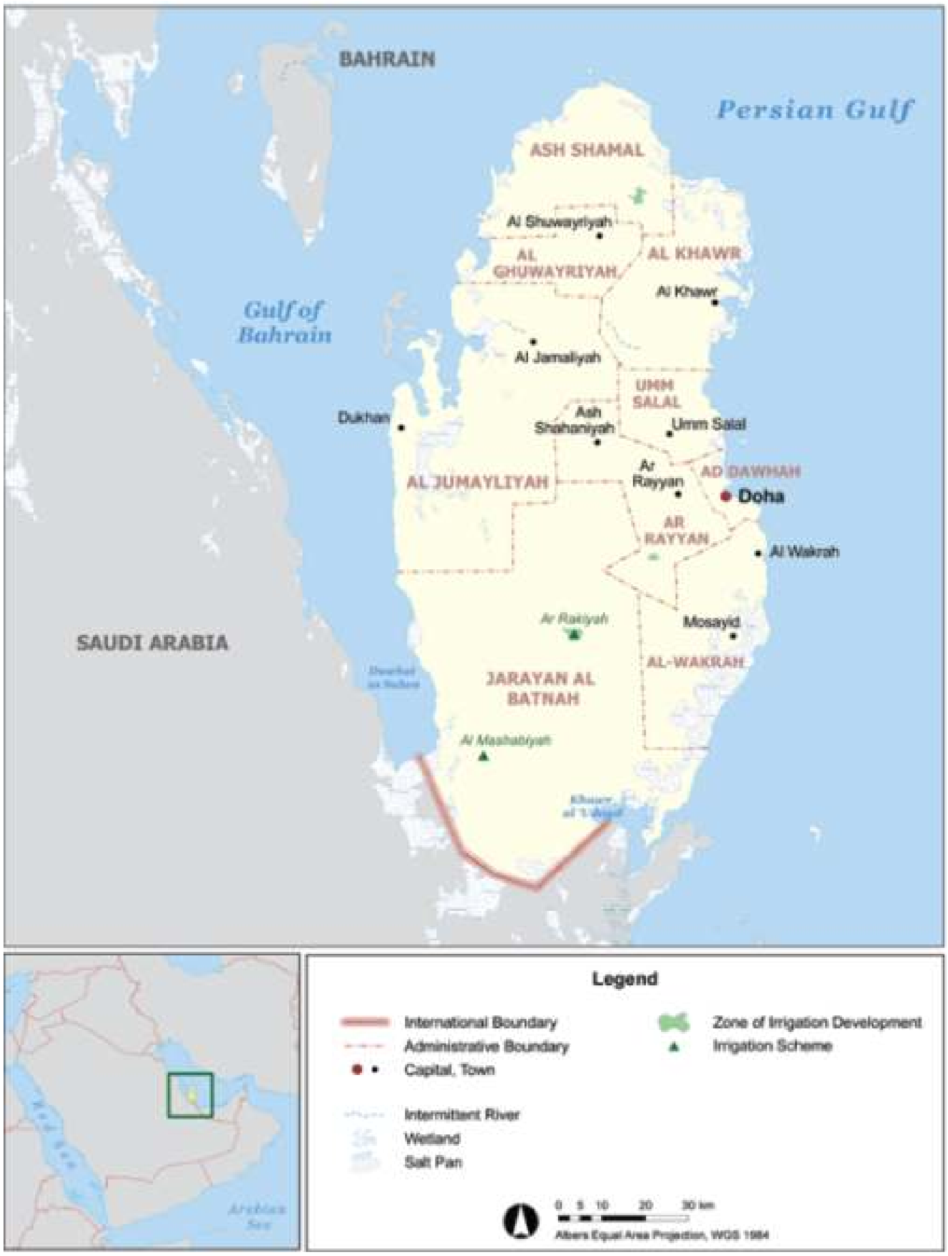
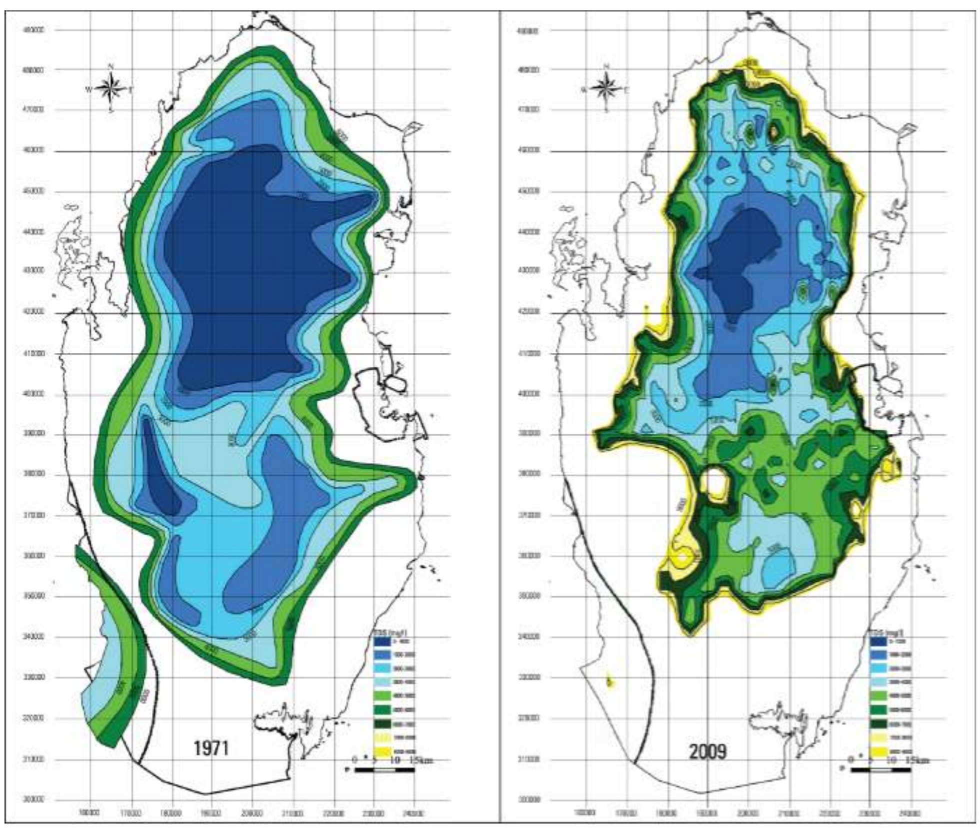


Fig. 1. Location of the State of Qatar
(Adopted from FAO-AQUASTAT, 2008)

The quality of groundwater has been monitored regularly since the early seventies. This has shown that the quality deterioration process has been continuous since then and is the result of over extraction and the subsequent increase in the concentration of salts from both seawater intrusion and upward migration of deep saline groundwater. Even under normal conditions prior to over-abstraction, suitable groundwater for domestic consumption was limited to the northern groundwater area containing waters of less than 1500 mg/l of total dissolved solids. Elsewhere, groundwater was not to be supplied directly to the consumer, in particular in those areas of central and southern Qatar where magnesium exceeded 30 mg/l and where sulphate concentration was in excess of 250 mg/l.

The groundwater is considered the main natural water resource available for agriculture in Qatar; the total water withdrawal in 2005 was estimated to be around 444 MCM, more than half (59%=262MCM) of this total water withdrawal is gone for agriculture, less than 40% (~39%=173 MCM) gone to municipal uses and less than 5% (~2%= 9MCM) use by the industry as shown in Fig. 3 [5]. The cultivated land for agriculture is variable from year to year Table 1 [7] shows that the cropped area in 2010,2011 and 2012 was10,506; 9,021 and 10,259 respectively.while the water demand for the same years are 240,207 and 238 mcm respectively.The water requires by each crop is varies Table 2 shows the different water requirement by each crop under different system of cultivation,vegetables that grown under open field in winter require 600 m^3ha^{-1} while vegetables under same system grown in summer require10,000 m^3ha^{-1} while vegetables that grown in green house required 8,000 m^3ha^{-1} [8,9,10].



15% of country area underlain with TDS<1,000 mg/L
** Sufficient freshwater reserves to 2 years of current demands (2013)*

2% of country area underlain with TDS<1,000 mg/L

SOURCE: *Schlumberger Water Services; Ministry of Environment*

Fig. 2. Ground water depletion in 1979-2009
(Adopted from Schlumberger water service/DAWR, 2009)

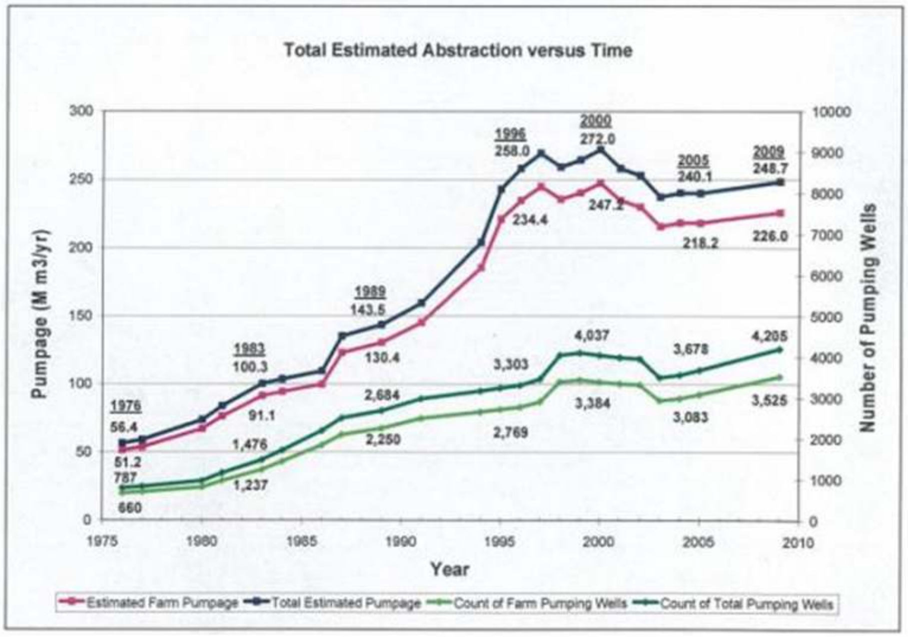


Fig. 3. Ground water abstraction and number of wells for agriculture
(Adopted from Schlumberger Water Resources, 2009)

Table 1. Agricultural land use from 2010 to 2012

Type	2012	2011	2010
Total arable area (ha)	65000	65000	65000
Number of the registered farms	1318	1281	1275
Total area of the registered farms (ha)	44591.2	43047.2	44421.6
Total arable area of the registered farms (ha)	26754.7	25828.3	26653
Number of active farms	833	831	822
Cultivated area for open field crops in the active farms (ha)	10388.2	8555.7	9961.7
Cropped area in active farms (ha)	10259.2	9021.3	10505.9

(Adopted from Agric. Sector, 2012)

Table 2. Estimated crop water consumption in 2012

Crop	Cropped area (ha)	Estimated gross irrigation req. (m^3ha^{-1})	Estimated water consumption (MCM)	Percentage of water consumption (%)
Openfield (winter vegetables)	1,448	600	8,688	3.65
Openfield (summer vegetables)	412	10,000	4.12	1.73
Green house vegetables (cooled & uncooled)	129	8,000	1,032	0.43
Fruits	424	24,000	10,176	4.28
Dates	2,479	20,000	49,58	20.83
Cereal	313	6,000	1,878	0.79
Forages	5,183	30,000	155,49	65.83
Wind break trees			7,036	2.95
Total	10,388		238	100

Several Technologies have been developed to overcome the water shortage and to keep the quality of the environment and mitigate the deterioration of fresh water resources. Reuse of wastewater is therefore crucial to overcome shortage in natural water sources. non-conventional water resource (TSE in particular) can be an excellent alternative for agricultural irrigation [11].

There are many types of membrane methods one of them is named Reverse osmosis (RO), the RO is do improve the water quality by removing the salts and other unwanted nutirients and impurities from the incoming water inflow to maintain good water quality. The purpose of developing reverse osmosis is to purified brakish water from dissolved salts and nutrients and become healthy water to drink. Recently the RO is approved to be used in treating other inpure water like muncipal waste water,sewage effluent water and hazdardous watse water. The RO is efficient in removing dissolved soild, organics, colour, nitrate and low total dissolved soild concentrations [12,13]. The future of water policies in Singapore, is to treat domestic wastewater by RO before discharging the effluent water back into reservoirs.membrane separation processes were introduced to treat secondary and tertiary municipal wastewater. In wastewater treatment applications, membranes are currently being used for the removal of dissolved salts, organic compounds, phosphorus, colloidal and suspended solids, heavy metals and human pathogens, including bacteria, protozoan cysts, and viruses. The application of RO technology was also investigated by Qadis and Moussa [14] for treatment of wastewater containing copper (Cu^{2+}) and cadmium (Cd^{2+}). The RO showing high efficiency of removing of copper and cadmium as 98% and 99% efficiency respectively. The good result for treating wastewater containing mixed heavy metals would be obtained by using the technology of RO membrane. The RO membrane showed high efficiency in reducing initial ion concentrations of 500 ppm in wastewater to 3 ppm, [15,16]. Data concerning TSE production were collected from governmental institutions, agricultural production and environmental protection and then analyzed and presented in this study.

The State of Qatar, during the last two decades,has provided sewerage treatment for most of the wastewater. The first sewage water treatment plant was installed in 1971 to cater for the flow generated by a population of 65,000.

3. SEWAGE TREATMENT WORKS (STWs)

Greater Doha, as the capital city and only sizeable population centre in Qatar, is currently served by three STWs. Doha South at Naijah, Doha West at Saliya and the Industrial Area. These are supported by a number of PTPs serving specific users such as the Qatar Defense Force. The only other STW is located in Al Khor in the north of Qatar. A number of new STWs are planned and / or under construction.

More than twelve small plants are in operation in villages, housing and industrial complexes.The total volume of treated sewage effluent (TSE) in Doha South and Doha West STW (Sewage Treatment Works) amounted to 140,000 m^3/day (51.1 MCM) in 2006 and increased to 117.66 MCM in 2011. Table 3 [17] presents the total flow of all sources of sewage flow [17].

3.1 STWS Capacity

In the capital, Doha West STW (DWSTW) which has a capacity of 175,000 m^3/day, received flows ranging from 200,000- 220,000 m^3day^{-1} in 2012. Doha South STW (DSSTW) with a capacity of 106,000 m^3day^{-1} received flows ranging from 160,000-180,000 m^3day^{-1} in 2012. Industrial Area STW (IASTW) has a capacity of 12,000 m^3day^{-1} and receives mainly tankers flows.

Al Karaana Lagoon: **s**ince early 2007 sewage tankers have been discharging untreated sewage, trade and some industrial waste effluents into the Al Karaana lagoon. Formerly an open quarry site, Ashghal constructed some rock/sand filled bunds to create a series of 4 interlinked cells approximately 500 x 2,000 m each in area. At the time of construction it was envisaged that the lagoon would accept effluent flows amounting to about 20,000 m^3day^{-1} [17].

3.2 TSE Standards

The treatment process adopted by Ashghal as a standard for foul water treatment includes biological nutrient removal followed by ultra-filtration, ultra-violet and chlorination. This process will produce a very high quality recycled water which is comparable to Class A+ water in Australia (allowable for use for inside and outside use by residential customers) and a much higher standard than adopted in many places in the world for irrigation. Tables 4, 5 and 6 [17] show the TSE standard for STWs.

Table 3. Total sewage flows from all sources in 2011

Source of sewage flows	Average daily flow (m3/day)	Proportion (%)
Doha West STW	180,000	77
Doha South STW	150,000	77
Doha West (old) STW	15,000	8.7
Industrial area STW	9,400	8.7
Al Khor STW	4,400	8.7
Al Shamal STW	132	8.7
All PTPs	8,484	8.7
Al Karaana Lagons	60,00	14.3
Total all sources	427,416	100

(Source QIDMP, 2013)

Table 4. Doha South STW influent and effluent characteristics

Parameters	Units	Design average conditions (as per contract)	Average flow/ Parameter
Water influent characteristics			
Average raw sewage flow	m^3/day	112,000	139,678
TSS	mg/L	<275	161
BOD	mg/L	<275	197
COD	mg/L	<600	371
Conductivity	µS/Cm	<4000	1.551
NH_4-N	mg/L	<50	24
p^H	-	6.0-8.0	7.30
Treated sewage effluent (TSE) characteristics			
BOD	mg/L	<10	2
TSS	mg/L	<10	3
NH4-N	mg/L	<1.0	4.3
pH	mg/L	6.0-8.0	7.1
Total Coliform	MPN/ 100 mL	< 23	>0 values 23
Total residual Cl_2	mg/L	1.0-2.0	2.7

(Source: QIDMP, 2013)

Table 5. Doha West STW influent and effluent characteristics

Parameters	Raw water				Treated sewage effluent			
	Indicative sewage characteristics		Actual average	Days cut	Effluent requirements		Actual average	Compliance
	Min	Max			Min	Max		
Flow inlet/outlet (m^3)		135,000	171,210	31			132,371	100%
TSS (mg/l)	90	205	192	0		5.0	0.4	100%
BOD_5 (mgo_2/l)	125	280	190	0		5	1	100%
COD (mgo_2/l)	275	710	477	0		50	18	100%
N-NH3 (mgN/l)	18.5	23.5	22.5	0		1.0	0.0	100%
p^H	7.0	7.8	7.5	0	6.0	9.0	7.2	100%
TP (mgp/L)	4.3	6.2	3.6	31		2.0	0.4	100%
Phosphate (mgP-PO_4T-1)	11.8	17.3	9.6	31			1.0	
Alkalinity (mg as $CaCO_3$)	200	280	25.8	0				
COD/BOD_5	2.0	2.8	2.5	0				

Table 5 continued…..

$BOD_{5/TN}$	5.0		6.7	0				
$BOD_{5/TP}$	35		53	0				
TSS/BOD_5	0.6		1.0	0				
Salinity as TDS (mg/L)	965	1,865	2,059	31				
Chloride		600	682	31				
Fecal coliform (MPN)						ND	0	100%
Total nitrogen (mgN/l)						10.0	5.0	100%
Dissolve oxygen (mg O_2/L)						ND/ 100 mL	6.3	100%
Free chlorine (mg Cl_2/L						1.0	1.7	97%
Turbidity (NTU)					2.0	2.0	0.6	100%
Intestinal nematode egg (/L)					0.5	<1 per L	0	100%
Enteric Viruses (PFU/L)						<1 PFU/40 L	0	100%
Giardia (cyst/40L)						<1 Cyst/40 L	0	100%

(Source: QIDMP, 2013)

Table 6. Industrial area STW influent and effluent characteristics

Parameters	**Units**	**Design average condition (as per contract)**	**Parameters**
Water influent characteristics			
Average raw sewage flow	m^3/day	112,000	9,243
TSS	mg/L	<275	175
BOD	mg/L	<275	22
COD	mg/L	<600	451
Conductivity	µS/Cm	<4000	996
NH_4-N	mg/L	<50	47
pH	-	6.0-8.0	7.30
Treated sewage effluent (TSE) characteristics			
BOD	mg/L	<10	2
TSS	mg/L	<10	6
NH_4-N	mg/L	<1.0	3.4
pH	mg/L	6.0-8.0	7.1
Total coliform	MPN/100 mL	< 23	0 values>23
Total residual Cl_2	mg/L	1.0-2.0	2.9

(Source: QIDMP, 2013)

4. RESULTS AND DISCUSSION

The opportunity for safeguarding and sustaining the agriculture sector is offered by the availability of non-conventional water resources and of advances in technology that permit the safe use and management of these valuable and limited resources. Putting the available non-conventional water resources into use would complement the renewable conventional resources for sustaining the present area under irrigation. The value added from putting treated wastewater into use would also compensate for part of the treatments costs and at the same time protect the environment.

The Food and Agriculture Organization of the United Nations (FAO) and the World Health Organization (WHO) have developed guidelines for the safe use of treated wastewater in agriculture. The two organizations further recommend that countries develop national standards and regulations on the use of these water resources, by adopting these guidelines or eventually adapting them to their local conditions. Table 7 shows the FAO guideline for irrigation water. Tables 4, 5 and 6 [17] display the effluent characteristic, before and after treatment for Doha south, West and industrial area. the current and Proposed Effluent Discharge Standards is need to add standard for heavy metals as in Tables 8 and 7 [18,19,20,21] for FAO, later FAO have standard, allowable concentration for heavy metals in TSE as shown in Table 8 [20,22].

The contribution of agriculture toward food security in Qatar is about 10% self-sufficiency under area of10, 388 ha and irrigation water of 238mcm respectively (AS.2012). The Qatar Food Security Program (QNFSP) is planning for increasing the self-sufficiency of agriculture up 70% by 2020.

Water requirement for crop production (m^3/ton) is high in the State of Qatar. The consumption of water in agriculture in 2012 was 60.2 MCM these amount of water produce about 43,565 ton of agricultural product as indicated in the Table 10 [7]. The water use (m^3) to produce a ton of agricultural product as follow and presented in Table 10:

Water use per ton = total water use/total yield.

Table 7. Laboratory determinations of irrigation water quality parameters

Water parameter	Symbol	Unit	Usual range in irrigation water	
Salinity				
Salt content				
Electrical conductivity	EC_w	dS/m	0 – 3	dS/m
(or)				
Total dissolved solids	TDS	mg/l	0 – 2000	mg/l
Cations and anions				
Calcium	Ca^{++}	me/l	0 – 20	me/l
Magnesium	Mg^{++}	me/l	0 – 5	me/l
Sodium	Na^{+}	me/l	0 – 40	me/l
Carbonate	CO^{--}_3	me/l	0 – .1	me/l
Bicarbonate	HCO_3^-	me/l	0 – 10	me/l
Chloride	Cl^-	me/l	0 – 30	me/l
Sulphate	SO_4^{--}	me/l	0 – 20	me/l
Nutrients			/	
Nitrate-nitrogen	NO_3-N	mg/l	0 – 10	mg/l
Ammonium-nitrogen	NH_4-N	mg/l	0 – 5	mg/l
Phosphate-phosphorus	PO_4-P	mg/l	0 – 2	mg/l
Potassium	K^+	mg/l	0 – 2	mg/l
Miscellaneous				
Boron	B	mg/l	0 – 2	mg/l
Acid/basicity	pH	1–14	6.0 – 8.5	
Sodium adsorption ratio	SAR	(me/l),	0 – 15	

(Source: Pedrero F. [18]; Enrique, et al. 2007; FAO [19]; Oster and F. Schroer. [20])

Table 8. Recommended concentrations of trace elements in irrigation water for long and short use

Element	Long term use (mg/l)	Short term use (mg/l)
Aluminium (Al)	5	20
Arsenic (As)	0.1	2
Beryllium (Be)	0.1	0.5
Cadmium (Cd)	0.01	.05
Chromium (Cr)	0.1	1
Cobalt (Co)	0.05	5
Copper (Cu)	0.2	5
Fluoride (F)	1	15
Iron (Fe)	5	20
Lead (Pb)	5	10
Lithium (Li)	2.5	2.5
Manganese (mg)	0.2	10
Molybdenum (Mo)	0.01	0.05
Nickel (Ni)	0.2	2
Selenium (Se)	0.02	0.02
Vanadium (V)	0.1	1
Zinc (Zn)	2	10

(Source: FAO, 1985)

Qatar planning for improving the water use efficiency in agricultural sector. The improvement in water will result from using advanced technology in irrigation in the open-field and cooling system in the greenhouse.

Tables 11 and 12 show the improvement of the water requirement for open field crops including existing farms and new concessions as follows:

Water use per ton in 2020 for existing farms which will shift to an efficient advance irrigation system such as drip irrigation, these will lead to high water productivity:

Total agriculture production (ton) =45800 ton/year

Water use = 60.7 mcm/year= 60700000 m^3/ year

The water use per ton=60.7 mcm/ year / 45800 ton/year = 1325 m^3 / ton =0.001325 mcm/year

While for existing Greenhouse, its water use per ton in 2020 will be improved due to drought tolerant seeds, system of cooling such as mechanical and dry cooling and other practices, these will result in improvement of water productivity as follow:

Total agriculture production (ton) =88400 ton/year

Water use (mcm) =43.5 mcm/year

The water use per ton=43.5 mcm/88400 ton= 492 m^3/ton

Table 9. Current and proposed effluent discharge standards

Parameters	Symbol	Unit	Current standard	Future standards 90% ile	Proposed standards	
					100% ile	Frequency
Total suspended solid	TSS	mg/L	5	5	10	Weekly
Biochemical oxygen demand	BOD_5	mg/L	5	5	10	Weekly
Chemical oxygen demand	COD	mg/L	50	50	100	Weekly
Fecal coliform	MPN	No/100 mL	None	None	10/100 mL	Weekly
p^H	PH	Units	6-9	6-9	5.5-9.5	Weekly+
Ammonia (NH_3N)	NH_3	mg/L	1	1	5	Weekly
Phosphate (PO_4)	PO4	mg/L	1	1	3	Weekly
Total nitorgen (N)	TN	mg/L	10	5	10	Weekly
Dissolved oxygen	DO	mg/L	2	2	NA	Weekly+
Free residual chlorine	Cl_2	mg/L	0.5-1	0.5-1	2*	Weekly+
Turbidity		NTU	2	2	5	Weekly+
Total dissolved solid	TSD	mg/L	<2.000	<500	750	Weekly+
Intestinal nematode		No/L	< 1	0	5	Weekly
Entric viruses		PFU/40 L	< 1	< 1	10	Weekly
Giadia	Custs	No./40 L	< 1	< 1	5	Weekly

(Source: QIDMP, 2013)

Table 10. Local agricultural production and water use per ton in 2012

Activities	Yield (ton)	Water consumption (mcm)	Water use per ton (m^3/ton)
Open field	31764	60.2	1894
Greenhouse	11801	8.3	703.56
Total	43565	68.5	2597.28

Qatar statistic book, 2012

Table 11. The estimated local production from the open field agriculture and corresponding water requirement form 2014 to 2020

Production timeline	2012	2014	2015	2016	2017	2018	2019	2020
Open field				**(kt/year)**				
Existing producers	31.8	31.8	34.1	36.4	38.8	41.1	43.5	45.8
New producers	0	0	10.7	21.3	32	42.7	53.3	64
Total	31.8	31.8	44.8	57.8	70.8	83.8	96.8	109.8
Water use timeline	**2012**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
Open field				**(MCM/year)**				
Existing producers	60.2	60.2	61.4	58.7	58.8	58.4	60.1	60.7
New producers	0	0	3.5	7	10.6	14.1	17.6	21.1
Total	60.2	60.2	64.9	65.7	69.3	72.5	77.7	81.9

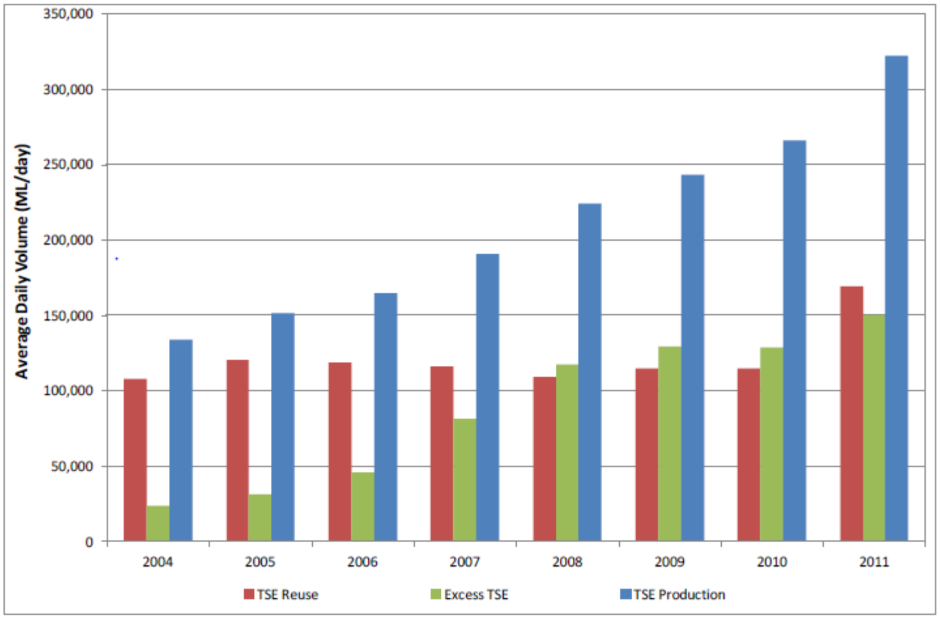
Table 12. The estimated local production from the Greenhouse agriculture and corresponding water requirement form 2014 to 2020

Production timeline	2012	2014	2015	2016	2017	2018	2019	2020
GH				**(kt/year)**				
Existing producers	11.8	11.8	24.57	37.33	50.1	62.86	75.63	88.4
New producers	0	0	1.21	2.42	3.63	4.84	6.05	7.3
Total	11.8	11.8	25.8	39.7	53.7	67.7	81.7	95.6
Water use timeline	**2012**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**
GH				**(MCM/year)**				
Existing producers	8.3	8.3	16.4	22.3	28.2	33.2	38.8	43.5
New producers	0	0	0.1	0.3	0.4	0.5	0.6	0.8
Total	8.3	8.3	16.5	22.6	28.6	33.7	39.5	44.3

Water requirement will increase as crop production will increase; Total water requirements in year 2020 is estimated to be 126.2 MCM, which produces about 205,700 ton (603.5 m^3ton^{-1}) compare to water productivity in 2012 was 1894 m^3ton^{-1}. The reduction in total water use with increasing agriculture production is due to modernizing the existing farms by using high efficient irrigation system pulse adding new concessions using advance technology in agriculture productions, these modernizing current production system and new advance production technology, will lead to increase the self-sufficiency for agriculture production to about 70%.

As the ground water is the scarce resource and highly depleted, looking for alternative resource of water is a crucial, one of the non-conventional water resources is TSE. Ashghal's proposal for upgrading TSE to level 4 using ROs will improve TSE quality as portable water.

During the period from 2004 to 2011; the TSE reuse volumes have remained fairly stable until 2011 with major increases. production corresponding to an increase in excess TSE; the increase in flows to the STWs from Doha development has resulted in a major increase in excess TSE, from around 24,000 m^3day^{-1} in 2004 to 150,000 m^3day^{-1} in 2011, or a total annual volume of 8.751 to 54.789 Mm^3 (8,751 to 54,789 ML); TSE to lagoons (both local STW and Abu Nahkla) is increasing again since the introduction of the groundwater injection system. In 2012 the discharge to lagoons was approximately 30 Mm^3year^{-1}; Fig. 4 [3] shows the quantity of excess of TSE from 2004 to 2011.



Note: 1 ML = 1,000 m^3

Fig. 4. TSE production, reuse and excess for the period 2004-2011
(Source: QIDMP, 2013)

The Public Works Authority (PWA) has 3 main wastewater treatment plants plus other minor treatment plants that produced 634,860 m^3 day^{-1}, in 2013, out of this volume 196,445 m^3 day^{-1} is in use for Roads and Expressways Irrigation, Local Landscaping Irrigation, Private Irrigation, Cooling, Industry (General) and Sand Washing. The remaining TSE volume 438,415 $m^3 day^{-1}$ which is equivalent to 50.42 mcm (can be used for agricultural production. After upgrading Treated Sewage Works (TSW) treatment plants to quadratic treatment using Reverse Osmosis (R.Os), these excess of TSE (438,415 $m^3 day^{-1}$=50.4 mcm) of TSE would cover about 67% of current water demand for agricultural crop, while for year 2020 the excess will cover 75% water demand for agricultural crop in open field and green house 2020. Extension to a new treated plant to allocate the excess that discharge to lagoon will also participate to the 2020 agricultural water demand (depending on Ashghal strategy and other users demand).

5. CONCLUSION

If Ashghal's proposal of upgrading TSE quality to level 4 using ROs is applied then this TSE can contribute to cover 67% of the estimated water requirement for current agricultural production. The excess of TSE in 2020 will be 203 MCM which will cover over 95% of water demand for agricultural production by 2020.

More research to be carried out on Socio - economic aspects and Environmental impact on using TSE on fresh vegetables.

DISCLAIMER

This manuscript was presented in the conference.
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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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