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Review Article

**Current and Future Water Resources for
Agriculture in Qatar State**

Abstract:

The state of Qatar falls in one of the driest regions in the world with average rainfall of 80 mm year⁻¹, and with zero surface water, this situation puts Qatar under huge pressure to balance between available water and water demands for different uses.

The uncontrolled ground water use in agriculture causes decline in the groundwater table and results in serious environmental problems including creation of depression zones, salt intrusion in several areas and deterioration of ground water quality and quantity in 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 <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. Available data from governmental institutions deal with TSE

production; agricultural production and environmental protection were collected, analyzed and presented.

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

The Public Works Authority (PWA) has 3 main wastewater treatment plants plus other minor treatment plants that produced $634,860 \text{ m}^3 \text{ day}^{-1}$ in 2013, amount of $196,445 \text{ m}^3 \text{ day}^{-1}$ is in use for Roads and Expressways Irrigation, Local Landscaping Irrigation, Private Irrigation, Cooling, Industry (General) and Sand Washing. The remaining TSE volume $438,415 \text{ m}^3 \text{ day}^{-1}$ (50.4million 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.

Key words:

Non conventional water resource, Agricultural Crops & Reverse Osmosis

1. Introduction:

Qatar is a small peninsula in the Arabian Gulf covering an area of approximately $11,525 \text{ Km}^2$ including a number of small offshore islands. The peninsula is located between $24^{\circ} 27'$ and $26^{\circ} 10'$ north latitudes, and $50^{\circ} 45'$ and $51^{\circ} 40'$ East longitudes (Fig. 1).

The country has an extensive hydrological and meteorological data collection network which has been operative since 1972. The State of Qatar's climate is characterized as hot and arid, scanty rainfall with an annual average of about 77.6 mm over the period 1972–2010. Rainfall is extremely unpredictable and highly erratic, both in time and space. The low intensity and variability of rain considered not being reliable for supplementing irrigation and maintaining agriculture, yet it represents the main source of irrigation water in the form of recharge to groundwater. Other climatic characteristics are high temperatures during summer ($> 40^{\circ} \text{C}$), high evaporation rates with an annual average of 2 200 mm, very strong winds and high relative humidity (Abu Sukar et al., 2007 and MDPS, 2013).

Conventional (or natural) water resources in Qatar are ground water and rainfall, while non-conventional water resources are desalinated sea

78 water and Treated Sewage Effluent (TSE).The aim of this paper is to
79 review the current situation of water consumption for agricultural production
80 and suggesting alternative water resource (TSE with upgraded water quality) to
81 comply with the decree No. 20.

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83 **2. Research Review:**

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85 The fresh groundwater is provided by two main aquifers. The uppermost is a
86 chalky limestone referred to as the Rus aquifer. This overlies the important
87 Umm er Rhaduma which is a major aquifer throughout the Gulf region. The
88 salinity level of these two aquifers in northern and central Qatar varies from 500
89 to 3 000 mg/l and increases towards the sea reaching 10 000 mg/l near the
90 coasts. The average annual groundwater recharge from rainfall is estimated
91 internally at 55.9 million m³year⁻¹. In addition there is an inflow of groundwater
92 from Saudi Arabia estimated at 2.2 million m³year⁻¹, making the average total
93 renewable groundwater

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Figure1: Location of the State of Qatar (Source:FAO-AQUASTAT,2008).

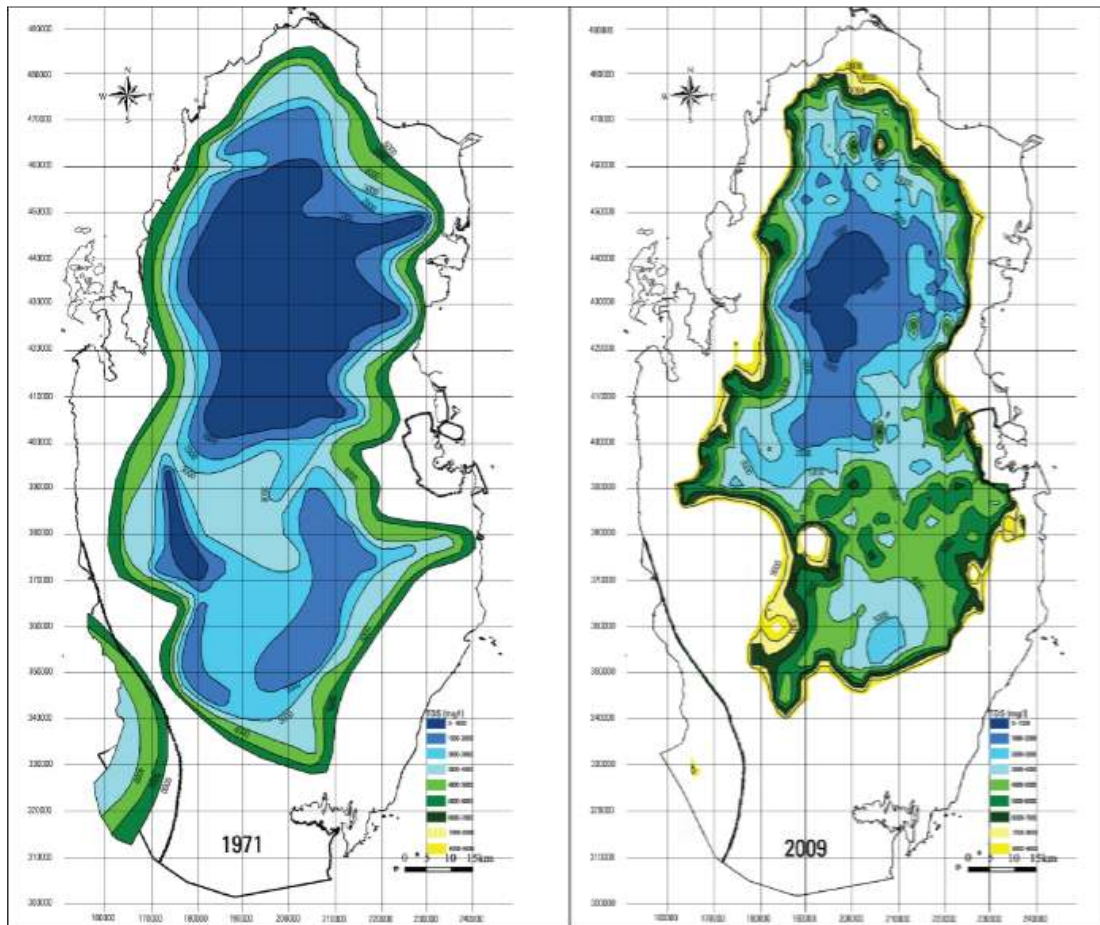
resources 58.1 million m³year⁻¹ for the period 1972-2005 (DAWR, Groundwater Unit, 2006).

110
111 It was found that available fresh groundwater in the northern and middle
112 aquifers has decreased from 15% of the total country's area in 1971 to 2% in
113 2009, and that the currently available fresh groundwater area in the country is
114 approximately 11% of that area in 1971 Figure. 2 shows the groundwater
115 depletion in 1979 and 2009.(Kamel et.al., 2008).

116
117 Throughout the remainder of Qatar, except in the extreme southwest,
118 groundwater conditions were highly varies with generally poor yields and
119 higher salinity, except in certain favourable areas where meteoric waters have
120 gained access to the two main aquifers.

121
122 The quality of groundwater has been monitored regularly since the early
123 seventies. This has shown that the quality deterioration process has been
124 continuous since then and is the result of over extraction and the subsequent
125 increase in the concentration of salts from both seawater intrusion and upward
126 migration of deep saline groundwater. Even under normal conditions prior to
127 over-abstraction, suitable groundwater for domestic consumption was limited to
128 the northern groundwater area containing waters of less than 1500 mg/l of total
129 dissolved solids. Elsewhere, groundwater was not to be supplied directly to the
130 consumer, in particular in those areas of central and southern Qatar where
131 magnesium exceeded 30 mg/l and where sulphate concentration was in excess
132 of 250 mg/l .

133
134 The groundwater is considered the main natural water resource available for
135 agriculture; in 2005, total water withdrawal was estimated at 444 million m³, of
136 which 262 million m³ or 59 percent for agricultural purposes, 39 percent for
137 municipal purposes and 2 percent for industrial use (Figure 3).the cultivated
138 land for agriculture is variable from year to year Table 1 shows that the cropped
139 area in 2010,2011 and 2012 was10,506; 9,021 and 10,259 respectively.while the
140 water demand for the same years are 240,207 and 238 mcm respectively.The
141 water require by each crop is varies table 2 shows the different water
142 requirement by each crop under different system of cultivation,vegetables that
143 grown under open field in winter require 600 m³ha⁻¹ while vegetables under
144 same system grown in summer require10,000 m³ha⁻¹ while vegetables that
145 grown in green house required8,000 m³ha⁻¹ (Amer and Almahmoud, 2003;
146 Singhal and Gupta, 2010; and Hashim, 2013).



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

Figure2: Ground water depletion in 1979-2009.

(Source: Schlumberger water service/DAWR 2009)

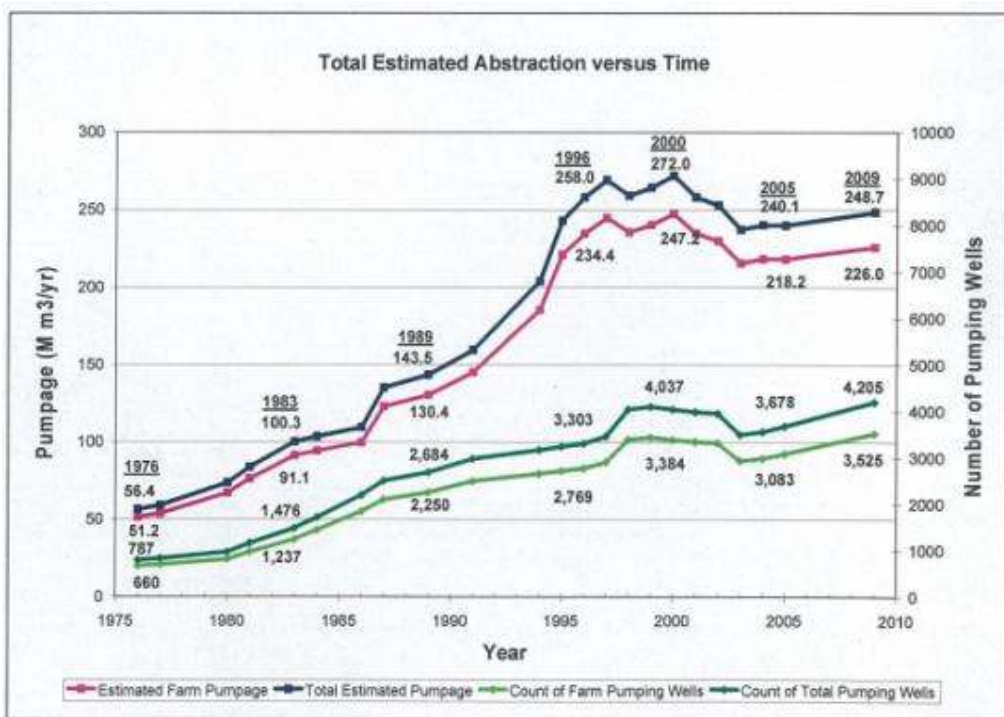


Figure 3: Ground water abstraction and number of wells for Agriculture (Source: Schlumberger Water Resources, 2009).

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

(Source: Agric. Sector, 2012)

Table 2: Estimated crop water consumption in 2012

Crop	Cropped area(ha)	Estimated Gross Irrigation req.(m ³ ha ⁻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

Increased water scarcity led to development of many technologies that can help in maintaining environmental quality and decrease the impact on natural freshwater 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 (Mohamed et al., 2012).

Reverse osmosis (RO), as one of the membrane methods, is used to separate the incoming water inflow to clean water (permeate) and a concentrate with high nutrients content. RO initially was developed for the production of potable water from saline and brackish water .However, the RO performance has been improved in recent years and begun to find applications in the treatment of water and hazardous waste, the process has also been applied for treating municipal wastewater. The RO process has been used mostly for the removal of dissolved solids since they are not removed by conventional municipal treatment processes. Moreover, the RO process can also remove organics, colour, nitrate and low total dissolved solids (TDS) concentrations (Sirkar et al., 1992; Hamidi and Mojiri, 2014). In the NEWater process, which is a significant part of future water policies in Singapore, reverse osmosis is used to treat domestic wastewater 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 (2004) for treatment of wastewater containing copper (Cu^{2+}) and cadmium (Cd^{2+}). High removal efficiency was achieved by the RO process, as 98% of the copper and 99% of the cadmium was recovered. The effectiveness of the RO membrane technology in treating wastewater containing mixed heavy metals was also tested. The result showed that the RO membrane was able to reduce initial ion concentrations of 500ppm in wastewater to 3ppm with removal efficiency equal to 99.4% (Anna, 2006; and Tomas and Gajdosova, 2009).

Available data from governmental institutions deal with TSE production, agricultural production and environmental protection were collected, 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.

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 Defence 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 presents the total flow of all sources of sewage flow.

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 $\text{m}^3\text{day}^{-1}$ in 2012. Doha South STW (DSSTW) with a capacity of 106,000 $\text{m}^3\text{day}^{-1}$ received flows ranging from 160,000-180,000 $\text{m}^3\text{day}^{-1}$ in 2012. Industrial Area STW (IASTW) has a capacity of 12,000 $\text{m}^3\text{day}^{-1}$ and receives mainly tankered flows.

Al Karaana Lagoon: since 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 m³day⁻¹.

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& 6 show the TSE standard for STWs.

Table3: Total sewage flows from all sources in 2011

Sources of Sewage Flows	Average Daily Flow (m ³ /day)	Proportion (%)
Doha West STW	180,000	77%
Doha South STW	150,000	
Doha West (Old) STW	15,000	8.7%
Industrial Area STW	9,400	
Al Khor STW	4,400	
Al Shamal STW	132	
All PTPs	8,484	
Al Karaana Lagoon	60,000	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 / Parameters
Wastewater 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
pH	-	6.0 to 8.0	7.30
Treated Sewage Effluent (TSE) Characteristics			
BOD	mg/L	<10	2
TSS	mg/L	<10	3
NH ₄ -N	mg/L	<1.0	4.3
pH	mg/L	6.0 to 8.0	7.1
Total Coliform	MPN/100 ml	<23	0 values >23
Total Residual Cl ₂	mg/L	1.0 to 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 Out	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-NH ₃ (mgN/l)	18.5	23.5	22.5	0		1.0	0.0	100%
pH	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 ₄ /T)	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				
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				
Faecal Coliforms (MPN)						ND	0	100%
Total Nitrogen (mgN/l)						10.0	5.0	100%
Dissolved Oxygen (mgO ₂ /l)						ND / 100 mL	6.3	100%
Free Chlorine (mgCl ₂ /l)						1.0	1.7	97%
Turbidity (NTU)					2.0	2.0	0.6	100%
Intestinal Nematode Eggs (/l)					0.5	<1 per L	0	100%
Enteric Viruses (PFU/l)						<1 PFU / 40L	0	100%
Giardia (cyst / 40l)						<1 cyst / 40L	0	100%

(Source :QIDMP, 2013).

Table 6: Industrial area STW influent and effluent characteristics.

Parameters	Units	Design Average Conditions (as per Contract)	Average Flow / Parameters
Wastewater 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 to 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 to 8.0	7.1
Total Coliform	MPN/100 mL	<23	0 values > 23
Total Residual Cl ₂	mg/L	1.0 to 2.0	2.9

(Source :QIDMP, 2013)

3. 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 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

321 that countries develop national standards and regulations on the use of these
 322 water resources, by adopting these guidelines or eventually adapting them to
 323 their local conditions. Table 7 shows the FAO guideline for irrigation water.
 324 Tables 4, 5& 6 display the effluent characteristic, before and after treatment for
 325 Doha south, West and industrial area. the current and Proposed Effluent
 326 Discharge Standards is need to add standard for heavy metals as in tables 8 and
 327 table 7 for FAO, later FAO have standard, allowable concentration for heavy
 328 metals in TSE as shown in Table 8.(Hanson B.R. et.al. 2006).

329 Table7: Laboratory determinations of irrigation water quality parameters

Water parameter	Symbol	Unit	Usual range in irrigation water	
SALINITY				
<u>Salt Content</u>				
Electrical Conductivity	EC _w	dS/m	0 – 3	dS/m
(or)				
Total Dissolved Solids	TDS	mg/l	0 – 2000	mg/l
<u>Cations and Anions</u>				
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	

330 (Source: FAO, 1985)

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337 Table 8: Recommended concentrations of trace elements in irrigation water for
338 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

339 (Source: FAO, 1985)

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345 Table 9: Current and proposed effluent discharge standards

Parameter	Symbol	Unit	Current Standard	Future Standard 90 %ile	Proposed Standard	
					100 %ile	Frequency
Total Suspended Solids	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
Faecal Coliforms	MPN	No/100mL	None	None	10/100mL	weekly
pH	pH	Units	6 - 9	6 – 9	5.5-9.5	weekly+
Ammonia (NH ₃ N)	NH ₃	mg/L	1	1	5	weekly
Phosphate (PO ₄)	PO ₄	mg/L	1	1	3	weekly
Total Nitrogen (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 Solids	TDS	mg/L	< 2,000	< 500	750	weekly+
Intestinal Nematodes		No/L	< 1	0	5	weekly
Enteric Viruses		PFU/40L	< 1	< 1	10	weekly
Giardia	Cysts	No/40L	< 1	< 1	5	weekly

(Source:QIDMP, 2013)

The contribution of agriculture toward food security in Qatar is about 10% self-sufficiency under area of 10,388 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 (m³/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 (Qatar statistic book, 2012). The water use (m³) to produce a ton of agricultural product as follow as in table 10:

Water use per ton = total water use/total yield

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

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 is shifted to efficient advance irrigation system such as drip irrigation, these will lead to high water productivity:

Total agriculture production (ton) = 45800 ton/year

Water use = 60.7mcm/year

The water use per ton = $60.7\text{mcm}/45800\text{ton} = 1325\text{ m}^3/\text{ton}$ and for

While for existing Greenhouse, its water use per ton in 2020 will improve 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) = 43.5mcm/year

The water use per ton = $43.5\text{mcm}/88400\text{ton} = 492\text{ m}^3/\text{ton}$

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
OF	(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
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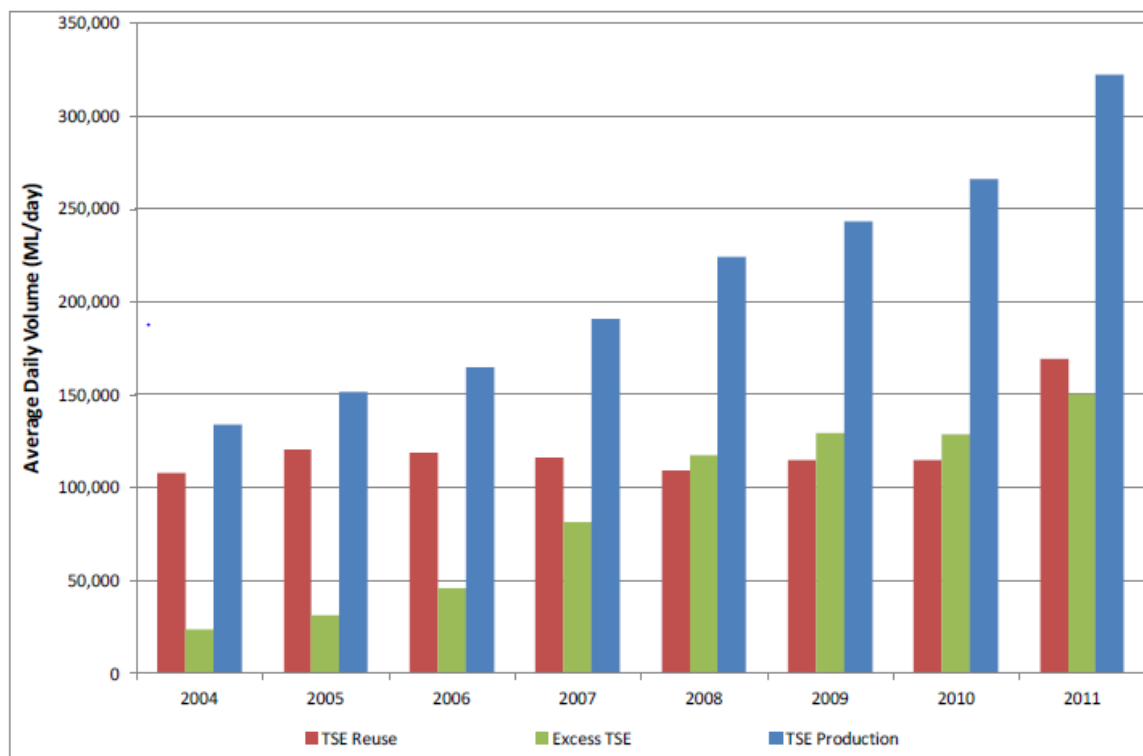
WATER USE TIMELINE	2012	2014	2015	2016	2017	2018	2019	2020
GH	(MCM/year)							
Existing producers	8.3	8.3	16.4	22.3	28.2	33.2	38.8	43.5
New producers	0	0	0.1	0.3	0.4	0.5	0.6	0.8
Total	8.3	8.3	16.5	22.6	28.6	33.7	39.5	44.3

Water requirement will increase as crop production is increasing; Total water requirements in year 2020 is estimated to be 126.2 mcm, which produces about 205,700 ton ($603.5\text{m}^3\text{ton}^{-1}$) compare to water productivity in 2012 was $1894\text{m}^3\text{ton}^{-1}$. 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 $24,000\text{m}^3\text{day}^{-1}$ in 2004 to $150,000\text{m}^3\text{day}^{-1}$ 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 $\text{Mm}^3\text{year}^{-1}$; Figure 4 shows the quantity of excess of TSE from 2004 to 2011.

The Public Works Authority (PWA) has 3 main wastewater treatment plants plus other minor treatment plants that produced $634,860\text{m}^3\text{day}^{-1}$, in 2013, out of this volume $196,445\text{m}^3\text{day}^{-1}$ is in use for Roads and Expressways Irrigation, Local Landscaping Irrigation, Private Irrigation, Cooling, Industry (General) and Sand Washing. The remaining TSE volume $438,415\text{m}^3\text{day}^{-1}$ which is equivalent to 50.42mcm (can be used for agricultural production. after



Note: 1 ML = 1,000 m³

Figure 4. TSE production, reuse and excess for the period 2004-2011.

(Source: QIDMP, 2013)

upgrading Treated Sewage Works (TSW) treatment plants to quadratic treatment using Reverse Osmosis (R.Os), these excess of TSE (438,415m³day⁻¹ = 50.4mcm) 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).

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.

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date 27-29 May 2014. Qatar.

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