

Overview on:

KAHRAMAA Drinking Water

Quality Requirements

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Content

1.	Introduction	6
Table 1	Desalination Plants Capacity	6
2.	Water Quality Requirements & Standards	8
Table 2	Drinking Water Quality Requirements/KAHRAMAA	9
Table 3	Required Maximum Permitted Level for Organic Compounds in Drinking Water	45
Table 4	Additional Water Quality Parameters with Maximum Permitted Contaminant level for Guidance (MCL)	46
3.1	Water Producers Monitoring	46
3.	Overview Monitoring Activities	46
3.2	Operational Performance Monitoring	46
3.3	KAHRAMAA Water Quality Monitoring Plan, Sampling Points & Frequency	47
3.4	Requirements for Compliance with Standards	47
3.5	Other Water quality Requirement and Conditions	48
Table 5	Annual Frequency of Monitoring Water Quality in Distribution System	49
Table 6	Analysis Frequency & Analysed Parameters	50
Table 7	Minimum number of samples for microbial testing required for population served (from WHO, 2011)	52
Table 8	Minimum number of samples for physico-chemical parameters required for population served (from WHO, 2011).	53
3.6	Limits of detection Methods	53
Table 9	Recommended Methods and Detection Limits – Health	54
Table 10	Recommended Methods and Detection Limits – Aesthetics and other factors	56
4.	References	57
5.	Abbreviations	57




Introduction

KAHRAMAA (The Qatar General Water and Electricity Corporation) is responsible by the decree Law No. 45 / 2009 for the drinking water supply in Qatar. Drinking water is produced by desalinating sea-water and groundwater. There are mainly seven thermal seawater desalination plants, six of these plants use thermal Multi-Stage-Flash (MSF) and one uses Multi Effect distillation (MED) process and all together have production capacity of around 325 Million gallons per day (Table 1). The water is distributed to a population of approximately 1.8 million and it covers all the area of the State of Qatar that constitutes around 7,180 Km². More than 99.6% of the water is supplied by KAHRAMAA distribution network and the rest (0.4%) is supplied by water tankers. There are three Reverse Osmosis (RO) desalination plants, two with small capacity of ≤ 1000 cubic meters per day and are used to desalinate brackish water wells and one a seawater plant with a capacity of 35,000 cubic meters per day (still under commissioning stage). KAHRAMAA desalination strategy for future involve expanding the use of RO technology as feasible.

Table 1. Desalination Plants Capacity, 2014

Desalination Plants (MSF/MED)	Capacity MIGD	Capacity Cubic Meters /Day
Ras Abu Fontas A, (RAF 'A')	55	250035
Ras Abu Fontas B, (RAF 'B')	33	150021
Ras Abu Fontas B2, (RAF 'B2')	29	131837
Ras Abu Fontas A1, (RAF 'A1')	45	204574
Ras Laffan Power Com., (RL 'A')	40	181844
Ras Laffan Q- Power Com, (RL 'B')	60	272766
Ras Laffan C, (RL 'C')	63	286404
Total	325	1477480
RO plants		
Abu Samra	0.15	675
North Camp	0.15	675
RO Pearl	7.7	35.000
Total	333	968393

One imperial gallon per day=0.00454609188 cubic meter per day



A safe drinking-water supply is a fundamental pre-requisite of public health. Safe drinking water is a main responsibility of the water supplier and safety imply that water does not represent any significant risk to health over lifetime of consumption and exposure based on present scientific knowledge. Acknowledging the tight link between water and health, The World Health Organization has published since 1953 Guidelines for Drinking Water Quality, these guidelines include values for water characteristics and constituents that represent reference points for ensuring safety. The guideline is kept up to date through a process of rolling revision and the latest published was the fourth edition in 2011. Most countries including the Gulf countries commonly use this reference in setting their national drinking water quality standards.

KAHRAMAA, policy and strategy dictate that water quality should not only be safe to drink but also to be reliable and sustainable and of high aesthetic quality. Accordingly KAHRAMAA developed its own Drinking Water Quality Requirements & Conditions, providing an authoritative reference to the water supply industry on what defines safe, good aesthetic quality water **and how it can be achieved, controlled and be assured**. The requirements are part of a framework for good management of drinking water supplies from source until customer tap. The requirements address both the health and aesthetic aspects of supplying good drinking water quality.

KAHRAMAA continuously update its water quality requirements and conditions for better management of drinking water quality in Qatar. The overall objective for the update takes into account:

1. Advances that are being made internationally in the management of drinking water quality (in particular the risk-based approach to water quality management)
2. The local conditions that are unique to Qatar, including environmental, legal and economical conditions.

This document provide an overview on “*Drinking Water Quality Requirement to ensure the water supply system performance in Qatar*” – and it summarizes the following:

1. Maximum permitted levels of water quality parameters in distribution system & until customer connection point notably the standards and monitoring requirements.
2. Maximum permitted levels of water quality parameters as indicated in The updated draft Version of the GSO standard No. 149/2009 for “Un-bottled Drinking Water published on web 2012.
3. Criteria used by KAHRAMAA in setting its annual plans for monitoring water quality in distribution system (from desalination plants until customer connection point).
4. Minimum Water Quality testing requirements for water Tankers.
5. Maximum permitted levels of water quality parameters & monitoring requirements set by KAHRAMAA for water producers.
6. Analytical test methods recommended for use.
7. Basis for setting parameters maximum limits and the occurrence of these parameters in GCC ambient environment.

These water quality, monitoring and analytical requirements, standards and procedures have been developed based on Qatar’s present water supply system infrastructure and characteristics, and is periodically reviewed by KAHRAMAA or when new developments occur such as changes to treatment or distribution systems or the emergence of new water quality hazards or scientific knowledge.

This booklet notably covers only the testing & monitoring requirements and standard levels and constitute only a part of KAHRAMAA water quality requirements & conditions where additional documents are set based on risk analyses to control any activity that may impact water quality.



Drinking Water Quality Requirements & Standards

Table 2. list the water quality parameters and their permitted level as been developed by KAHRAMAA. There are also statements of justification and guidelines for interpretation of these requirements/standards level. The GSO parameters and their standard values have been included for comparative purposes and where they are applicable for water at customer tap and used by official surveillance body (Supreme Council of Health) for ensuring drinking water quality.

The water quality parameters listed and the standards levels have been developed based on review of the existing water quality standards in Qatar (GSO, 2009 and its update), the WHO (2011) drinking water guidelines, the WHO (2009) guidelines for desalination, other international drinking water quality standards and guidelines (including those for the United States/EPA, Australia, and other Gulf nations). In addition, the results of a comprehensive water quality risk assessment completed for the Qatar water supply system (GHD, 2009) were used.

For most water quality parameters, two requirements are set by KAHRAMAA :

1. Water quality Requirements at Treatment Outlet : these are the water quality targets for water at the point at which it leaves the water treatment plant. (These requirements are part of water quality management requirements set by KAHRAMAA for water producers to adhere with, such as water safety plan implementation, intake water monitoring and etc.,)

2. Water Quality Requirements at Entry Point-to-Property : these are the water quality targets in distribution system until the entry points of KAHRAMAA's water supply system to properties.

Table 2. Drinking Water Quality Requirements / KAHRAMAA

Parameter	Units	GSO/Qatari Standard	KAHRAMAA Requirements for Water Quality Produced by Desalination Plants at Outlet Point		KAHRAMAA Requirements for Water Quality in Distribution System	Comments & Technical Details
			Minimum-Maximum permitted level	Frequency of Testing	Minimum-Maximum Permitted level	
Aesthetic & Physical Water Quality Characteristics						
Taste and odor	-	Free from any material that impact taste, odor	Acceptable	D	Acceptable	<p>Basis for limit: water should be palatable and acceptable with respect to taste and odor.</p> <p>Occurrence: Generally immediately after treatment desalinated water does not have taste and odor, although with a very low concentration of salts it can have a flat and unpleasant taste. It is possible for taste and odor to originate from natural inorganic and organic or biological sources or processes (e.g., aquatic microorganisms such as algal blooms), from contamination (e.g. by petroleum hydrocarbons or synthetic chemicals), from corrosion or as a result of water treatment (e.g., chlorination). Taste and odor may also develop during storage and distribution due to microbial activity.</p> <p>The potential for taste and odor is highest for compounds that may carry over in a thermal desalination process, and that are not completely vented as part of the distillation process. Monoaromatic hydrocarbons such as ethyl benzene are of potential concern, as is geosmin (associated with algae) which has an odor threshold measured in ng/L.</p> <p>Taste and odour in drinking water may also be indicative of some form of pollution or of a malfunction during water treatment or distribution. It may therefore be an indication of the presence of potentially harmful substances. The cause for odor should be investigated promptly, particularly if there is a sudden or substantial change.</p>
Color	True (Pt.Co)	Free from any particles visible to naked eye	15	D	15	<p>Basis for limit: Most people can detect colors above 15 true color units (TCU) in a glass of water. Levels of color below 15 TCU are usually acceptable to consumers, but acceptability may vary.</p> <p>Occurrence: Color should be very low in desalinated water. It is possible that an elevated apparent color will occur if there is ingress of dust and dirt (e.g. at storage tanks) or infiltration of dirty water in the distribution system. Color that can be detected by naked eye or during testing should be directly investigated.</p>

Temperature	C°	Acceptable	Acceptable (less than 45°C)	D	Acceptable	<p>Basis for limit: Cool water is generally more palatable than warm water, and temperature will impact on the acceptability of a number of other inorganic constituents and chemical contaminants that may affect taste. High water temperature can increase the growth of certain microorganisms (Pseudomonas and Legionella species) and may increase taste, odor, color and corrosion problems.</p> <p>In Qatar there is general acceptance that the water can be hot, however 45°C is the highest acceptable at desalination plants delivery point. Historical data indicated that this level has never been reported at delivery point, and only in very few occasions been exceeded in the network. High temperature could not be controlled easily in distribution system therefore no limit has been adopted.</p> <p>Occurrence: The ambient temperature in Qatar can be extremely hot, and this results in water with a high temperature being delivered to customers. Also to consider that further increase in temperature may occur through storage in roof tanks.</p>
Turbidity	NTU	No Standard Value	1.0 (at disinfection point)	C/D	4.0	<p>Basis for limit: turbidity should be below 1 nephelometric turbidity units (NTU) for effective disinfection, and unusual increases in turbidity need to be investigated as they can indicate ingress of pollution (e.g. contaminated storm water or sewage). Some deterioration due to corrosion in pipes is normal prior to customer taps and up to 4 to 5 NTU is usually acceptable in water from sample taps at the entry point to a customer's property.</p> <p>No health-based guideline value for turbidity has been proposed by WHO. However, as the Qatar desalination plants thermal or filtration plant produces water of very low turbidity a limit 1.0 NTU has been set after remineralisation and at disinfection point.</p> <p>Occurrence: Suspended solids should not be present in desalinated water, and the presence of turbidity could indicate corrosion or leakage is occurring. remineralisation using limestone chips will result in an increase of turbidity (e.g. to 0.4 NTU), but should be less than 1.0 NTU in any case. Suspended solids can occur in the distribution system from corrosion of piping systems, microbiological activity, and ingress of windblown dust in storage tanks.</p>

General Chemical Parameters						
pH	units	6.5-8	7.0 to 8.3	C/d	6.5 to 8.5	<p>Basis for limit: For effective disinfection with chlorine, the pH should preferably be less than 8.5 and greater than 7.0. A lower pH than this will mean the water is likely to be corrosive & within the distribution system pH to be ideally less than 8.5. WHO has set no limit for pH as of no health significance.</p> <p>Occurrence: The pH of the water supplied to customers is the result of controlled addition of lime or other reagents to balance the requirements to avoid corrosion (low pH), scaling (high pH), reducing the effectiveness of disinfection (high pH), and uncontrolled rise through leaching from cement lined pipes and concrete tanks where water sits for long periods of time. pH is used also as an indicator for operational performance and any change to be investigated for causes & measures to be taken.</p>
TDS / Electrical Conductivity	TDS: mg/l EC us/cm	100-1000 No standard value	110 – 250 (TDS) 150 – 500 (EC)	D C/D	110-250 (TDS) 150-500(EC)	<p>Basis for limit: Reliable data on possible health effects associated with the ingestion of total Dissolved solids (TDS) in drinking water are not available, and no health-based guideline value is proposed by WHO. Limits on TDS are set with respect to taste and nutritional aspects. The palatability of water with a TDS level of less than 600 mg/L is generally considered to be good; drinking-water becomes significantly and increasingly unpalatable at TDS levels greater than about 1000 mg/L. The presence of high levels of TDS may also be objectionable to consumers, owing to excessive scaling in water pipes, heaters, boilers and household appliances. Very low concentrations of TDS (e.g. < 20 mg/L) can give rise to a flat and insipid taste, and the water may be corrosive.</p> <p>For desalination plants the product water EC and TDS are the main indicators of performance, a standard for this parameter has been set on the basis of assuring treatment plant performance with allowance for increase in TDS and EC in the distribution system.</p> <p>Occurrence: The concentration of dissolved salts in desalinated water is dependent on the efficiency of the desalination plant in removing dissolved salts. EC is a Critical Control Point (CCP) and product water leaving the distillation/ filtration process usually has an EC <20, with system shutdown if the EC exceeds 100. After mineralization treated water normally will have an EC<500 and TDS <250. After Reverse Osmosis of the brackish bore water in Qatar the EC is usually <500 in the final disinfected product water and failure is indicated if it is >500.</p> <p>The EC is used also as an indicator for operational performance and any change to be investigated for causes & measures to be taken.</p>

Hardness	mg/l as CaCO ₃	No Standard Value	65-120	D	<150	<p>Basis for limit: Alkalinity and hardness can be considered together.</p> <p>A low alkalinity is an indication that a water will tend to be corrosive to metals and will leach calcium from cement lined pipes. The alkalinity and the pH of treated water entering the distribution system need to be kept within an optimal range to avoid these corrosion effects and minimize costs for treatment chemicals. That is, higher levels of alkalinity are of no significant benefit..</p>
Alkalinity	mg/l as CaCO ₃	No Standard Value	60- to 120	D	60-120	<p>Calcium and magnesium are the main contribute to the level of hardness in water but sodium, chloride and sulphates will also contribute to the total hardness.</p> <p>Water with a high hardness has a poor taste and requires greater use of soap when cleaning. Water with a hardness above 200 mg/L will usually also cause scale deposition in kettles, in industrial boilers and on electric immersion heaters, reducing their performance and shortening their life.</p> <p>A maximum hardness of 150 mg/L (as CaCO₃) has been set for hardness for pleasant tasting water. A lower range is proposed at the desalination or water treatment plant outlet, because some increase in the distribution system can occur and a minimum value has been set to ensure water will not induce corrosion in distribution system. WHO has set no guideline value for Alkalinity as of no health significance.</p> <p>Although not proposed as a standard, the corrosion and scaling potential of the water leaving the treatment plant should be controlled to an acceptable range. There are various indices and measures that can be applied, such as Calcium Carbonate Precipitation Potential (CCPP) and the Langelier Index. Typically the objectives can be:</p> <p>Langelier Index – aim -0.3 to 0 and, CCPP – aim for -4 to 0 mg/L., The appropriate targets can be set by an appropriate test program.</p> <p>Occurrence: hardness and alkalinity is added generally by the addition of lime. Hardness can increase in the distribution system through the dissolution of lime from cement-lined pipes, particularly where new pipes have been installed and the detention time in the pipes is long. Hardness and Alkalinity to be kept at optimum range neither to induce corrosion or produce scaling and any change to be investigated to ensure proper performance of supply system.</p>

Calcium	mg/l	No Standard Value	80	D	80	<p>Basis for limit: Calcium is an important determinant of water hardness and alkalinity, and it also functions as a pH stabilizer, because of its buffering qualities. Calcium also gives water a better taste. It occurs in water in the form of calcium carbonate/bicarbonate. Calcium regulates many body activities, and in order to stimulate these body functions a daily intake of about 1000 mg of calcium is recommended for adults. This may be achieved by diet and calcium concentration in water may assist as a supplement in strengthening bones and teeth & may also decrease the risk of heart conditions. However, WHO has set no guideline value as of no health significance yet indicates that a level of ≥ 30 mg/l will be optimal for ensuring nutrient level in water for health.</p> <p>Occurrence: Calcium level found in water as Ca^{2+} ions is dependent on the hardness/alkalinity level and is generally added by lime, in the mineralization step at desalination plant. In desalination plants/delivery point calcium ranges between 6-35 mg/l indicating it is low and will not tend to scale on heating as the case with hard water forming deposits of calcium carbonate scale.</p>
Magnesium	mg/l	No Standard Value	10	W	30	<p>Basis for limit: Magnesium is a determinant of water hardness. A review of epidemiological studies suggests that there is an inverse (beneficial) relationship between water hardness and cardiovascular mortality. The best correlations were usually with magnesium. Studies indicated that effects at about 10 mg/L were significant (WHO, 2006, 2007). However, inherent weaknesses in the ecologic studies design limit the conclusions that can be drawn from them and accordingly WHO has set no guideline value for magnesium as of no health significance.</p> <p>Hardness is added in a remineralisation step in desalination on the basis of avoiding corrosion, the studies referred to above suggest that, of the hardness added, at least 10 mg/L should be magnesium.</p> <p>Occurrence: Magnesium level found in water as Mg^{2+} ions is dependent on the hardness level and is generally added by lime in the mineralization step at desalination plant and therefore is usually lower than 10 mg/l unless it is deliberately added.</p>

Sodium	mg/l	No Standard Value	50 MSF/MED <25 mg/L after distillate	D	80	<p>Basis for limit: Sodium imparts a salty taste to water. A health-based limit is not set by WHO or GSO for sodium as of no health significance . The WHO recommended a guideline value for sodium at 200 mg/L. In Australia using surface and ground water for drinking a guideline value of 180 mg/L is being adopted</p> <p>With respect to sodium, sodium is essential for adequate functioning of human physiology although the requirement of infants for sodium is lower than for children and adults, and high sodium intake may lead to hypernatraemia. This is a problem for bottle-fed infants and is the reason why sodium levels in infant formulae have been reduced significantly over time. There have been concerns expressed about the importance of sodium intake for increasing hypertension across populations. On the other hand hyponatraemia can be a serious including fatal acute risk if significant perspiration causes high loss of sodium and there is inadequate sodium intake from the total diet. .</p> <p>Occurrence: The concentration of sodium is dependent on the degree to which the desalination plant removes dissolved salts. For thermal systems low concentrations of sodium can be achieved. The concentration of sodium will be related to the concentration of chloride in the distillate and hence the limit will be site specific. A low value of around 25 mg/L is required for an efficient desalination system. A higher value would suggest a treatment process failure. For RO plant the sodium removal depend on the filters efficiency and is less than in thermal desalination plant and the limit set is 80 mg/l.</p> <p>Natural seawater contains around 11,000 mg/L of sodium. The concentration of sodium can increase if leakage occurs between salt water and the distillate, and also during disinfection (depending on the reagent used for disinfection). A change in sodium concentration indicate a change in system performance require investigation.</p>
Potassium	mg/l	No Standard Value	2	W	4	<p>Basis for limit: The range found internationally in drinking water is between <1-8 mg/l. However there is no evidence that potassium levels in treated drinking water, even water treated with potassium permanganate, or with softeners are likely to pose any risk for the health of consumers. WHO find out that It is not considered necessary to establish a health-based guideline value for potassium in drinking-water.</p> <p>Occurrence: potassium usually found in very low concentration in water, however treatment with potassium permanganate or using salt for treatment may add some potassium levels to water. Desalinated water usually contain low concentrations. A maximum of 2 mg/l is considered an upper range. In distribution system a higher value is set at 4 mg/l.</p>

Chloride	mg/l	No Standard Value	MSF/ MED<50 For RO<80	D	<80	<p>Basis for limit: Taste thresholds for the chloride anion depend on the associated cations calcium, sodium and potassium and is in the range of 200–300 mg/L. Concentrations in excess of 250 mg/L are increasingly likely to be detected by taste. The WHO sets no guideline value as of no health significance for levels found in drinking water yet an upper value of 250 mg/L has been recommended.</p> <p>For desalination plants the high level of chloride can indicate failure of the treatment process, and a more stringent standard has been set for desalination plants, <50 for MSF/MED and <80 for RO plants..</p> <p>Occurrence: The concentration of chloride is dependent on the degree to which the desalination plant removes dissolved salts; it can increase if leakage occurs between salt water and the distillate. And in RO plants chloride level depend on the raw water quality, system used and filtration performance. Any change in chloride level dictate the investigation regarding system performance & potential causes.</p>
Bromide	mg/l	No Standard Value	<0.1	Q	<0.1	<p>Basis for limit: Bromide occur in sea water, ground water and any leakage of this water during distillation or treatment can cause presence of bromide. Bromide can be involved in the reaction between chlorine and naturally occurring organic matter in drinking-water forming brominated and mixed chloro-bromo byproducts, such as trihalomethanes or halogenated acetic acids, or it can react with ozone to form bromate. The levels of bromide that can result in the formation of these substances are well below the health-based values of 2mg/l and been set at 0.1 mg/l.</p> <p>Occurrence: bromide occur in drinking water in low concentrations. Ensuring levels are low is a precautionary measure to ensure disinfectant byproducts will not be formed in levels exceeding the standards.</p>

Flouride	mg/l	<p>1.5</p> <p>(Flouride at a minimum: 0.34/x)</p> <p>$X=0.038+(0.0062\{T^9/5+32\})$</p>	1.5	Q	1.5	<p>Basis for limit: Fluoride is absorbed quickly following ingestion. It is not metabolised, but diffuses passively into all body compartments. Fluoride has an affinity for mineralising tissues of the body: in young people, bone and teeth; in older people, bone.</p> <p>Skeletal fluorosis, characterised by hyper mineralisation and thus brittle bones, has occurred in association with high fluoride concentrations in drinking water, and also with occupational exposure to fluoride containing dust. It generally occurs after prolonged exposure (several years) and is reversible: if the exposure is removed, the fluoride levels in bones gradually decline.</p> <p>There is no substantiated epidemiological evidence that fluoride or fluoridation causes cancer. The International Agency for Research on Cancer has concluded that the available data for fluoride provide inadequate evidence of carcinogenicity in humans. (WHO,2004)</p> <p>Because fluoride is widely dispersed in the environment, all living organisms are exposed to it and all tolerate modest amounts. It has been claimed that fluoride is an essential trace element for humans, but this is difficult to establish conclusively, and no data are available on the minimum amount needed. Below about 1 mg/L fluoride is beneficial as it helps prevent tooth decay and significantly reduces the cost of visits to the dentist. However, high levels of fluoride (ie >4 mg/L) can be a health hazard. The WHO guideline value of 1.5 mg/L has been adopted (based on high quantities of water consumed > 2 L/day).</p> <p>Occurrence: Natural Seawater contains around 0.7 to 1.3 mg/l fluoridie. Desalination will reduce fluoride naturally present in seawater and groundwater to a very low level. In many countries fluoride is added to achieve about 0.5 to 1mg/L in the treated water to improve dental health of the community. The presence of unsafe high levels of Fluoride is considered to be a very low risk in the Qatar system rather a low level is expected. However, like chlorine disinfectant a small residual level in the drinking water would have health benefits.</p>
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Ammonia	mg/l as NH ₃	No standard value	0.5	M	0.5	<p>Basis for limit: The threshold odor concentration for ammonia at alkaline pH is approximately 1.5 mg/L. EPA set a limit of 0.5mg/l as a secondary parameter. Australia sets an ammonia limit of 0.5 mg/L based on corrosion of copper fittings. The WHO does not set a limit for ammonia as of no health significance yet can be used as an indicator of water quality and contamination.</p> <p>Ammonia is usually present at significant levels (e.g. 0.5 to 1 mg/L) when it is added with chlorine in chloramination disinfection systems. In systems such as Qatar where ammonia is not added in the treatment process, the presence of ammonia can indicate cross connection to recycled water systems or entry of contaminated groundwater. Because of this, the concentration of ammonia in the distribution system should not exceed the concentration at delivery point to distribution system.</p> <p>Occurrence: Ammonia is at very low levels in natural seawater, ie <0.01 mg/L and would be negligible in distillate water. Increased concentrations of ammonia could indicate leakage of contaminated groundwater into the water supply system. Ammonia is expected to pose a low risk to water quality in the Qatar water supply system.</p>
Phosphate	mg/l	No standard value	0.01	M	0.01	<p>Basis for limit: Phosphate can stimulate biofilms growth and algae growth where sunlight is present in roof and ground tanks at customer properties. This may result in potential health risks if blue green algae or pathogenic microbes (e.g. Naegleria fowleri) emerge.</p> <p>There are no recommended levels for phosphate in the international drinking water guidelines. A low level is set for Qatar emanated from levels usually found in desalinated water.</p> <p>Occurrence: Usually phosphate will be present at low concentrations in desalinated water (<0.01 mg/L); however, polyphosphate can be added to water to minimize the corrosive effect of the treated water on water supply assets. A level is set to ensure no phosphate is presents in levels to induce biofilm.</p>
Sulfate	mg/l	No standard value	50 (at distillate MSF/MED <5 mg/l)	W	50	<p>Basis for limit: Taste thresholds have been found to range from 250 mg/L for sodium sulfate to 1000 mg/L for calcium sulfate. It is generally considered that taste impairment is minimal at levels below 250 mg/L. WHO or GSO has set no Guidance/Standard level.</p> <p>The concentration of sulphate in a distillate water is expected to be <5 mg/L.</p> <p>Occurrence: The concentration of sulphate is dependent on the degree to which the desalination plant removes dissolved salts. For thermal systems low concentrations of sulphate can be achieved. The concentrations of sulphate can increase if leakage occurs between salt water and the distillate, and also during disinfection (depending on the reagent used for disinfection). Natural seawater contains about 3000 mg/L of sulphate</p>

Hydrogen Sulphide	mg/l	No standard value	Not detectable	NR	Not detectable	<p>Basis for limit: The odor threshold of hydrogen sulfide in water is estimated to be between 0.05 and 0.1 mg/L. The presence of detectable sulphide in desalinated water may indicate the entry of contamination and the requirement has been set that it should not be detectable. The presence of sulphide can also indicate that anaerobic conditions are occurring, and this can be associated with increased levels of corrosion and heavy metals.</p> <p>Occurrence: Hydrogen sulphide can be present if contamination enters the system, or if organic matter accumulates in stagnant areas and there is depletion in dissolved oxygen levels. Very low risk in Qatar Water System.</p>
Asbestos	Million Fiber/l	No standard value	7 fibers	NR	7 fibers	<p>Basis for limit: WHO set no limits on Asbestos, as no scientific evidence is provided to indicate that ingested asbestos impact health. EPA adopt 7 Fibers/Million for drinking water.</p> <p>Occurrence: there is no/low risk of having asbestos in desalinated water in Qatar, yet asbestos may be found in demolition of construction sites and in cement & may enter the water distribution system. The EPA value has been adopted.</p>
Foaming Agents	Mg/l	No standard value	0.5	NR	0.5	<p>Basis for limit: WHO set no limits on Foaming agents. EPA adopted a level of 0.5 mg/l. KAHRAMAA adopt the same level.</p> <p>Occurrence: There is no risk from foaming agents in water. However contamination may enter the water system. The EPA value has been adopted.</p>

Nitrate as NO ³	mg/l	50	10 <0.1 at distillate MSF/ MED	M	10	<p>Basis for Limit: The toxicity of nitrate to humans is thought to be solely due to its reduction to nitrite in the stomach. Nitrite can react with haemoglobin in f bottle fed infants under 3 months old causing methaemoglobinemia unabling to transport oxygen to body. laboratory experiments suggest that neither nitrite nor nitrate acts directly as a carcinogen. There is concern that nitrite may react with foods rich with secondary amines to form N-nitroso compounds in the stomach: Many of these compounds are known to be carcinogenic in animals. Some epidemiological evidence suggests a relationship between nitrate and gastric cancer in humans, but this has not been confirmed in with more definitive analytical studies (NHMRC, 2004).</p> <p>The WHO and NHMRC have set a guideline value for nitrate of 50 mg/L (expressed as NO₃), and for nitrite 3 mg/L (expressed as NO₂). The WHO has also suggested a provisional long term guideline for nitrite of 0.2 mg/L on the basis that the potential for health effects from long term exposure is uncertain. A rise in nitrates in the distribution system can indicate contamination of drinking water by sewage, were ammonia could be transformed to nitrate..</p> <p>Occurrence: Chloramination (addition of chlorine and ammonia) may give rise to the formation of nitrite and nitrate within the distribution system if the formation of chloramine is not controlled properly. The increase in nitrite and ultimately nitrate is as a consequence of microbial activity in biofilms in the pipe network oxidizing ammonia. The extent depends on how much ammonia is present. Nitrification in distribution systems can increase nitrite levels, usually to around 0.2–1 mg/L. WHO, 2011 advice is that the occurrence of nitrite in the distribution system as a consequence of chloramine use will be intermittent, and average exposures over time should not exceed the provisional guideline value. Chloramine is not used as a disinfectant in Qatar and accordingly it is not expected to present in values >0.1 mg/l.</p>
Nitrite as NO ²	mg/l	short term 3	0.1	M	0.1	
Trace and Heavy Metals						
Iron	mg/l	No standard value	0.1	W	0.3	<p>Basis for limit: At levels above 0.3 mg/L, iron stains laundry and plumbing fixtures. There is usually no noticeable taste at iron concentrations below 0.3 mg/L, although continued low concentrations may result in the build up and sloughing of slimes and the occurrence of severe dirty water events.</p> <p>The WHO value of 0.3 mg/L has been adopted.</p> <p>Occurrence: Iron concentrations in desalinated water should be very low, unless corrosion of metal systems and pipework is occurring. The concentration of iron at the customer taps can provide a measure of the extent of corrosion that is occurring in the distribution system. Iron is a low risk in the Qatar system as pipelines are mostly made from PE.</p>

Copper	mg/l	2	0.05	W	1.0	<p>Basis for limit: Copper is an essential trace element for humans. It is estimated that adult requirements are about 2-3 mg per person per day. High doses of copper (above 50 mg/kg bodyweight) can be lethal. Copper poisoning has resulted in cirrhosis of the liver and, in extreme cases, death. Other less severe symptoms associated with the consumption of water containing 3-5 mg/L copper are gastrointestinal symptoms such as nausea, abdominal pain and vomiting. Infants are thought to be most susceptible. International Programme on Chemical Safety concluded that the upper limit of the acceptable range of oral intake in adults is uncertain but is most likely in the range of several (more than 2 or 3) milligrams per day in adults. (WHO, 2011).</p> <p>The WHO guideline value of 2 mg/L is a realistic value for a health-based standard. An increase in copper levels in desalinated water may indicate other more hazardous water quality conditions are present, e.g. chromium or leakage of seawater into distillate. KAHRAMAA adopt much lower limit of 0.05 mg/L for treated water at the desalination plant outlet. However a 1.0 mg/l has been adopted in distribution system by the GSO standards and by KAHRAMAA as well. Beside health considerations, staining of laundry and sanitary ware occurs at copper concentrations above 1 mg/L. At levels above 5 mg/L, copper also imparts a color (blue water) and an undesirable bitter taste to water. Copper is at very low levels in seawater (<0.002 mg/L).</p> <p>Copper in a drinking-water supply usually arises from the corrosive action of water leaching copper from copper pipes. Desalinated water would be very aggressive to copper if pH was not increased by adding an alkali before distribution to customer properties. Copper in drinking water may increase due to the corrosion of galvanized iron and steel fittings due to galvanic action of copper particles lying on the iron or steel surfaces. A value of 1 mg/L at entry to customer properties has been set for copper on the basis of avoiding staining and higher values would indicate excessive corrosion of copper pipes and fittings.</p> <p>Occurrence: elevated concentrations of copper can occur through corrosion of piping and other metallic fittings. It can be exacerbated by microorganisms, and maintaining a disinfectant residual can reduce this. Copper is a low risk in the Qatar system as pipelines are mostly made from PE.</p>
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Manganese	mg/l	0.4	0.05	Q	0.05	<p>Basis for limit: At levels exceeding 0.1 mg/L, manganese in water supplies causes an undesirable taste in beverages and stains sanitary ware and laundry. Even at a concentration of 0.05 mg/L, manganese will often form a coating on pipes, which may slough off and make the water appear dirty and can cause staining of clothing in washing machines. Consequently, a low value of 0.03 mg/L at the treatment plant outlet should trigger action to find the cause and eliminate it</p> <p>The WHO value of 0.4 mg/L has been adopted at the entry to properties by the GSO standard. Manganese affect the appearance, taste or a dour of the water & a more stringent value has set for water at delivery point and in distribution system <0.05 mg/.</p> <p>Occurrence: Manganese concentrations in natural seawater are very low (<0.003 mg/L), unless corrosion of metal systems is occurring. Manganese is a low risk in the Qatar system.</p>
Zinc	mg/l	No standard value	0.05	M	3.0	<p>Basis for limit: Zinc imparts an undesirable as-tstringent taste to water at a taste threshold concentration of about 3 mg/L (as zinc sulfate). At the water treatment plant a detectable level of zinc would indicate corrosion may be occurring, which could release other heavy metals or be a result of leakage of untreated seawater into the distillate.</p> <p>The WHO has set no guideline value as of no health significance at concentrations normally found in water. A value of 3 mg/L has been adopted at the entry to properties, which above it water may not be acceptable to consumers and a more stringent value of <0.05 mg/L was set for delivery point.</p> <p>Occurrence: Zinc concentrations in desalinated water should be very low, unless corrosion of metal systems (particularly galvanized products) is occurring. It is possible for zinc concentrations to exceed the limit if water is stored in galvanized tanks. Zinc can be expected to present a low risk in the Qatar system.</p>
Nickel	mg/l	0.07	0.02	M	0.07	<p>Basis for limit: In humans, long-term exposure may result in toxic effects to the kidney. Nickel is known to be a common skin allergen and can cause dermatitis, particularly in younger women. The International Agency for Research on Cancer has concluded that nickel compounds are carcinogenic to humans (NHMRC, 2004)</p> <p>The WHO guideline value of 0.07 mg/L has been adopted. Because nickel can be an indicator of corrosion, a lower limit has been set for the outlet of the desalination plant.</p> <p>Occurrence: Nickel should not be present in desalinated water, unless occurring through corrosion of metals that have high nickel content or are nickel plated.</p>

Aluminum	mg/l	No standard value	0.1	M	0.2	<p>Basis for limit: The presence of aluminum at concentrations in excess of 0.2 mg/liter often leads to "dirty water" complaints by consumers.</p> <p>Occurrence: The main source of aluminum is from the use of aluminum-based coagulants. This coagulant is usually added to remove suspended matter and discoloration from untreated surface water.</p> <p>Qatar's Desalination Processes processes do not involve the addition of coagulants. If in the future coagulation were to be included with RO systems, it can be expected that an iron-based rather than aluminum-based coagulants would be used as iron-based coagulants are more effective in seawater and brackish water. Aluminum is a low risk for Qatar.</p>
Lead	mg/l	0.01	0.01	Q	0.01	<p>Basis for limit: Adverse effects associated with exposure to high amounts of lead include kidney damage, interference with the production of red blood cells, and interference with the metabolism of calcium needed for bone formation. The IARC has concluded that lead is possibly carcinogenic to humans (NHMRC, 2004).</p> <p>The WHO sets a guideline value of 0.01 mg/L, and this has been adopted.</p> <p>Occurrence: Lead is not expected to be present in desalinated water, and if detected its presence would be expected to have resulted from household plumbing systems containing lead in pipes, solder, fittings or the service connections to homes. The amount of lead dissolved from the plumbing system increases with standing time of water that is soft and acidic. It is expected to pose a low risk in the Qatar system.</p>
Mercury ((total	mg/l	for 0.006 Inorganic mercury	0.001	Q	0.001	<p>Basis for limit: Various reports indicate that inorganic mercury binds to, and damages, mammalian DNA. Some evidence of carcinogenicity in rats has been reported. However the health impacts of organic (methyl) mercury are more severe, through organic mercury is unlikely to be present in uncontaminated waters. The main effects of methyl mercury poisoning are severe irreversible neurological disorder and mental disability (NHMRC, 2004).</p> <p>The WHO has set a value of 0.006 mg/L. The USEPA has adopted 0.002 mg/L and KAHRAMAA adopted a value of 0.001 mg/L because of its significant health importance.</p> <p>Occurrence: Mercury is used in the electrolytic production of chlorine, which could be relevant if chlorine is produced using electrolytic methods. Mercury can be associated with petroleum production. Methylation of inorganic mercury has been shown to occur in fresh water and in seawater. Because mercury is volatile, the extent of removal in a thermal desalination system can be uncertain. Mercury is expected to pose a low risk in the Qatar system.</p>

Boron	mg/l	2.4	0.5 (MSF/MED) For 1.0 RO	Q W if RO technology is used	1.0	<p>Basis for limit: Boron, as soluble borate (borax) or boric acid, is rapidly and completely absorbed after ingestion. It is widely distributed throughout the body and up to 90% is excreted in urine as unchanged compound.</p> <p>There have been a number of reported cases of poisoning following the ingestion of high doses of boron. Symptoms include gastrointestinal disturbances, skin eruptions, and central nervous system stimulation and depression. Long-term occupational exposure to boron can lead to similar symptoms.</p> <p>Short-term studies with rats and dogs reported testicular atrophy at high doses (5000 mg/kg bodyweight) of boric acid and borate. This condition was also observed in longer-term studies with rats, mice and dogs over 2 years. Reproductive studies reported that rats became sterile at the highest doses. However, no increase in the incidence of tumours was observed in long-term studies using mice. (NHMRC, 2004).</p> <p>WHO (2006) suggests a health-based limit of 0.3 mg/L but considers that this is difficult to achieve in treatment systems and sets a provisional level of 0.5 mg/L for protection of human health on the basis of practicability. New WHO health guideline value/ WHO 2011 was set at 2.4 mg/l as recently reported that health based evidences are not available on its toxicity beyond this level.</p> <p>Boron can affect the growth of plants (ie act as a herbicide) if present in irrigation water above 1.0 mg/L (Environment Australia, 2000), particularly in areas where rainfall is so low as to not cause leaching of salts from soils such as can occur in Qatar. Australia has set a health-based limit of 4 mg/L.</p> <p>Taking into account practicability, a value of 0.5 mg/L is set for MSF and 1 mg/L as a provisional value for RO supplies.</p> <p>Occurrence: Boron is found naturally at relatively high levels in seawater (4 to 5 mg/L) and in brackish groundwater. Concentrations of less than 0.5 mg/L should be achieved by thermal desalination systems, but can be difficult to achieve by a RO system, and it may require a two-pass system. Boron poses a moderate risk in the Qatar system.</p>
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Cadmium	mg/l	0.003	0.001	Q	0.003	<p>Basis for limit: In humans, long-term exposure to cadmium can cause kidney dysfunction leading to the excretion of protein in the urine. This may occur, in a certain proportion of people, if the amount of cadmium exceeds 200 mg/kg renal cortex tissue; about 10% of the population is estimated to possess this sensitivity. Other effects can include osteomalacia (softening of the bones). Cases of Itai-Itai disease have been reported in Japan among elderly women exposed to highly contaminated food and water. Symptoms are similar to osteomalacia accompanied by kidney dysfunction characteristic of cadmium poisoning.</p> <p>The International Agency for Research on Cancer has concluded that there is evidence that cadmium is carcinogenic by the inhalation route. However, there is no evidence of carcinogenicity by the oral route and no clear evidence for the genotoxicity of cadmium (WHO, 2011).</p> <p>The WHO guideline value of 0.003 mg/L has been adopted for distribution system and a more stringent value of 0.001 mg/l been adopted for water at delivery point</p> <p>Occurrence: Cadmium is unlikely to be present after desalination and is very low in natural seawater (<0.0003mg/l), However, it could be present as a trace contaminant in the limestone chips used in some desalination plants for remineralisation of the distillate water. Also, corrosion of solders and impurity in some plumbing fittings or dissolution of piping materials can be a source. The risk associated with cadmium is low for the Qatar system.</p>
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Barium	mg/l	0.7	0.7	Q	0.7	<p>Basis for limit; The degree of absorption of barium from the gastrointestinal tract depends on the solubility of the barium compound, and on other factors including age. In a study using rats, barium was absorbed more effectively in very young rats compared with older rats. After absorption, barium is deposited in bone and teeth. It can cross the placenta in humans.</p> <p>At high concentrations, barium causes Increase in blood pressure, strong vasoconstriction (constriction of blood vessels), peristalsis (contractions of the alimentary canal), convulsions and paralysis.</p> <p>Repeated exposures to contaminated table salt in China are believed to have caused recurrent outbreaks of transient paralysis known as 'Pa-Ping' disease.</p> <p>There is no evidence that barium is carcinogenic or mutagenic. Barium has been shown to cause nephropathy in laboratory animals, but the toxicological end-point of greatest concern to humans appears to be its potential to cause hypertension (WHO, 2011)..</p> <p>The WHO value of 0.7 mg/L is adopted by GSO and KAHRAMAA.</p> <p>Occurrence: Barium is generally naturally occurring in water and is present in seawater at low levels (<0.02mg/l). Non-occupational exposure is generally through food, though drinking water is a possible source. Barium will be rejected by desalination systems, and poses a low risk in the Qatar system.</p>
Molybdenum	mg/l	0.07	0.07	Q	0.07	<p>Basis for limit: Molybdenum is an essential trace element for humans and other animals. Data on the health impacts of this element is rare and no relevant data are available on the carcinogenicity of molybdenum. (The WHO guideline limit of 0.07 mg/L has been adopted.</p> <p>Occurrence: Molybdenum is found naturally in soil and is used in the manufacture of special steels and in the production of tungsten and pigments, and molybdenum compounds are used as lubricant additives and in agriculture to prevent molybdenum deficiency in crops. Natural seawater usually contains around 0.005 to 0.02 mg/L. Consequently, Molybdenum is not expected to be present in desalinated water, unless arising from the corrosion of materials that include molybdenum, such as stainless steel. Molybdenum constitute a low risk in the Qatar system.</p>

Cyanide	mg/l	0.07	0.07	HY	0.07	<p>Basis for limit: Cyanide is highly toxic. It is rapidly absorbed by the gastrointestinal tract and metabolised to thiocyanate. Cyanide effects on the thyroid gland and particularly the nervous system. Cyanide may deplete vitamin B12 and result in a deficiency that can cause goitre and cretinism. People most at risk are those with a nutritionally inadequate diet.</p> <p>No data are available on the carcinogenic properties of cyanide. Tests for mutagenicity with different strains of bacteria have been mostly negative.</p> <p>The WHO guideline value of 0.07 mg/L has been adopted.</p> <p>Occurrence: Food and drinking water (particularly in developing countries) are the main sources of exposure to cyanide, particularly through industrial contamination, and also from certain foods such as cassava. Effects on the thyroid and particularly the nervous system have been observed in some populations as a consequence of the long-term consumption of inadequately processed cassava containing high levels of cyanide. (WHO. 2011). Accordingly, cyanide poses a low risk in the Qatar system.</p>
Antimony	mg/l	No standard value	0.006	Q	0.02	<p>Basis for limit: Antimony in soluble forms is considered carcinogenic to humans but evidence is weak that the specific soluble form, potassium antimony tartrate, could ever be present in drinking water.</p> <p>The WHO value of 0.02 mg/l is adopted in distribution system. EPA adopted a value of 0.006 mg/l and KAHRAMAA adopt this value at delivery point.</p> <p>Occurrence: Exposure may arise from leaching corrosion from antimony-tin solder and hard alloys of copper, lead and tin. As the most likely source is dissolution of metal plumbing, best control will usually be by the control of plumbing products and corrosivity of drinking water. Antimony can be expected to pose a low risk in the Qatar system as the drinking water is stabilised.</p>

Arsenic	mg/l	0.01	0.01	Q	0.01	<p>Basis for limit: The health considerations apply mainly to the inorganic arsenic compounds, as they are more likely than the organic compounds to be present in drinking water supplies. There is no evidence of arsenic being essential for humans.</p> <p>Soluble arsenic salts are readily absorbed by the gastrointestinal tract. After absorption inorganic arsenic binds to haemoglobin, and is deposited in the liver, kidney, lungs, spleen, and skin. Inorganic arsenic does not appear to cross the blood-brain barrier but can cross the placenta.</p> <p>There is overwhelming evidence from epidemiological studies that consumption of elevated levels of arsenic through drinking-water is causally related to the development of cancer at several sites, particularly skin, bladder and lung (WHO, 2011). The International Agency for Research on Cancer has concluded that arsenic is carcinogenic to humans.</p> <p>The WHO value of 0.01 mg/L is adopted. Note that Australia adopts a value of 0.007 mg/L that was derived by a different method to the one used by WHO.</p> <p>Occurrence: Arsenic is occasionally present in drinking water (mainly from groundwater sources) at levels that are a significant cause of health effects. As such, arsenic is considered to be a high-priority substance for screening in drinking-water sources, particularly groundwater sources. Concentrations in groundwater are often highly dependent on the depth to which the well is sunk, and can increase over time as drawdown occurs. Arsenic is usually at very low levels in seawater (i.e. <0.002 mg/L) and will have a high rejection in desalination systems and hence pose a low risk to the Qatar system.</p>
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Chromium (total)	mg/l	0.05	0.05	Q	0.05	<p>Basis for Limit: The absorption of chromium after ingestion is low and depends on the valence state. Hexavalent chromium is more readily absorbed from the gastrointestinal tract than trivalent compounds.</p> <p>Epidemiological studies have found an association between inhalation of hexavalent chromium compounds and lung cancer, especially in humans occupationally exposed during chromate production.</p> <p>There is no evidence that organs other than the lung are affected or that ingestion of hexavalent chromium compounds can cause cancer.</p> <p>The International Agency for Research on Cancer has concluded that hexavalent chromium is carcinogenic to humans (WHO, 2011). The trivalent chromium is not classifiable as to its carcinogenicity to humans due inadequate evidence in humans and limited evidence in animals.</p> <p>The WHO guideline value of 0.05 mg/L has been adopted.</p> <p>Occurrence: Chromium is very low in seawater (<0.0003 mg/L). However, it is present in stainless steels that are extensively used in MSF desalination plants. Corrosion is minimized by addition of corrosion inhibitors and careful selection of the correct stainless steels. The risk in the Qatar system is low.</p>
Selenium	mg/l	0.04	0.01	Q	0.01	<p>Basis for Limit: Selenium is an essential element for many species, including humans. Signs of selenium deficiency in humans are not well established but may include a chronic disorder of the heart muscle, other heart diseases and cancer. There have been a number of reports of ill effects attributed to short- and long-term exposure to selenium; most of these have resulted from occupational exposure or accidental poisoning; acute or chronic nutritional toxicity is comparatively rare. The International Agency for Research on Cancer has concluded that selenium is not classifiable as to its carcinogenicity in humans. The WHO guideline value of 0.04 mg/L has been adopted by GSO standards and KAHRAMAA adopt a value of 0.01 mg/l..</p> <p>Occurrence: Selenium is not expected to be present in the Qatar system, and it may not be necessary to monitor it if initial monitoring shows it is absent.</p>
Beryllium	mg/l	No standard value	0.004	Q	0.004	<p>Basis for limit: Beryllium is an inorganic metallic element in the periodic table. Because it is an element, it does not degrade nor can it be destroyed. Compounds of beryllium are either white or colourless and do not have a particular smell. According to EPA some people who drink water containing beryllium well in excess of the maximum contaminant level (MCL) for many years could develop intestinal lesions.</p> <p>WHO has no guideline value as it is unlikely to occur in drinking water. EPA set a limit of 0.004 mg/l. KAHRAMAA adopt EPA standard value.</p> <p>Occurrence: Beryllium is used in making metal alloys used in industrial purposes. Beryllium pose no /low risk for contaminating Qatar water system.</p>

Silver		No standard value	0.1	HY	0.1	<p>Basis for limit: WHO has no guideline value as data do not permit derivation of a guideline value. Silver may be used in conjunction with disinfection aspects, yet doses to be within guidance values. EPA adopt a 0.1 mg/l maximum permitted level, KAHRAMAA adopt a 0.1 mg/l level where no risk is tolerated at this level.</p> <p>Occurrence: Silver may be used in disinfection activities, however low/No risk is expected in Qatar water system as currently there is no use of such types of disinfectants..</p>
Thallium		No standard value	0.001	HY	0.002	<p>Basis for limit: According to EPA, some people who drink water containing thallium well in excess of the maximum contaminant level (MCL) for many years could experience hair loss, changes in their blood, or problems with their kidneys, intestines, or liver problems. EPA set a limit of 0.002 mg/l. WHO has no guideline value as it is unlikely to occur in drinking water. KAHRAMAA adopt EPA standard value of 0.002 mg/l in distribution system for guidance and a lower level at 0.001 mg/l at delivery point.</p> <p>Occurrence: The major sources of thallium in drinking water are leaching from ore-processing sites; and discharge from electronics, glass, and drug factories. Not expected to be found in desalinated water of Qatar.</p>
Uranium	mg/l	0.03	0.015	Y	0.015	<p>Basis for limit: In humans, the main toxic effect of short-term exposure to high concentrations of uranium is inflammation of the kidney. Little information is available on the effects of long-term exposure. Studies have shown high specific activity uranium isotopes to be carcinogenic in animals, causing malignant tumours in mice and bone sarcomas in rats. Similar studies using natural uranium (uranium-238) have not shown similar effects, possibly due to the lower radiation doses involved. Epidemiological data are inadequate to show whether exposure to uranium in drinking water will lead to an increased risk of cancer.. third edition adopted a value of 0.015 and the fourth edition was increased to 0.03 mg/l. USEPA adopted a guideline of 0.03 mg/L Only chemical aspects of uranium has been addressed. KAHRAMAA adopt the lower WHO value of 0.015mg/l.</p> <p>Occurrence: The possibility of uranium in seawater would mainly arise from discharges from activities occurring in countries in the region. Uranium is likely to precipitate in seawater and would be expected to be present at only low levels, and would be effectively removed in a desalination system. Uranium may indicate presence of radioactive contamination. Uranium is expected to pose a low risk in the Qatar system.</p>

Organic Chemical Parameters						
Organotins (Tributyltin oxide / Di- alkyltins)	mg/l	No standard value	0.001	HY	0.001	<p>Basis for Limit: Tributyltin is part of the organotins, few data are available on the absorption and distribution of organotins in the body, but animal studies have reported that some of the compounds are poorly absorbed, and distributed primarily to the liver and kidney (NHMRC, 2004). The dialkyltins another constituents of the organotins have low general toxicity. Carcinogenicity bioassays with animals have been inconclusive. No data are available on the ingestion of tributyltin oxide in humans in drinking water, although occupational information and dermal exposure are known to cause irritation.</p> <p>The significance of the immunotoxicity to humans remains questionable (NHMRC, 2004). According to WHO The data available is insufficient to permit the setting of guideline values for dialkyltins. A limit of 0.001 mg/L is set for tributyltin and for dialkyltins (NHMRC, 2004).</p> <p>Occurrence: Dialkyltins are stabilizers in plastics and may leach from PVC water pipes at low concentrations for a short time after installation. Tributyltins are biocides used as antifouling agents on boats and hence may be present in sediments and seawater where boats and ships are maintained. Raw water intakes should avoid such areas.</p> <p>Such compounds are highly unlikely to pass through a desalination plant and pose a low risk in the Qatar supply.</p>

Ethyl Benzene	mg/l	300	0.3	HY	0.3	<p>Basis for Limit: long-term toxicity or carcinogenicity are available. Ethylbenzene has shown no evidence of genotoxicity in in vitro or in vivo systems (WHO, 2011).</p> <p>Ethylbenzene is readily absorbed from the human gastrointestinal tract. It can be stored in fat and is metabolised to mandelic and phenylglyoxylic acids and excreted in the urine. It can cross the placenta. No data are available on the health effects in humans after oral exposure, and inhalation data are limited to short-term studies.</p> <p>Ethylbenzene is almost completely converted to soluble metabolites, which are excreted rapidly in urine. The acute oral toxicity is low. No definite conclusions can be drawn from limited teratogenicity data. No data on reproduction,</p> <p>The WHO guideline value of 0.3 mg/L has been adopted. Ethylbenzene has an aromatic odour. the odour threshold for ethylbenzene in drinking water (0.002 mg/litre).The lowest reported odour threshold is 100-fold lower than the health-based guideline value of 0.3 mg/l</p> <p>Occurrence: Ethylbenzene is present in petroleum products, and could result in seawater following a spill of petroleum hydrocarbons into the Gulf waters. If present it would be expected to be accompanied by benzene, and benzene would be limiting with respect to human health effects. Trace levels could pass through a MSF desalination process. Ethylbenzene is considered to be a low-moderate risk in the Qatar system.</p>
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Benzene	mg/l	0.01	0.005	HY	0.01	<p>Basis for limit: Benzene is rapidly and efficiently absorbed and widely distributed throughout the body. It is metabolised predominantly into phenol by the liver, and also by bone marrow.</p> <p>Human health data are mainly from studies where benzene had been inhaled. Exposure to high concentrations in air can cause death. Lower concentrations can induce toxic effects, with white blood cells being most sensitive. There is considerable evidence that occupational exposure to low benzene concentrations for periods as short as 12 months may result in leukaemia (WHO,2011).</p> <p>Acute exposure of humans to high concentrations of benzene primarily affects the central nervous system. At lower concentrations, benzene is toxic to the haematopoietic system, causing a continuum of haematological changes, including leukaemia (WHO, 2011).</p> <p>The WHO value of 0.01 mg/L is adopted. The Australian Drinking Water Guidelines (NHMRC, 2004) apply an additional safety factor and set a health limit of 0.001 mg/L.</p> <p>Occurrence: Benzene is present in petroleum products, and could occur after a spill of petroleum hydrocarbons into the Gulf waters. Having a boiling point similar to water, it may not be effectively removed in a desalination plant. Benzene is considered to be a moderate risk to the Qatar system.</p>
PAH (Polycyclic aromatic Hydrocarbons) Total	µg/l	No standard value	0.2	HY	0.2	<p>Basis for limit: Some PAH compounds have been found to be carcinogenic by non-oral routes, but others are known to have low potential for carcinogenicity. The International Agency for Research on Cancer has concluded that BaP (a type of PAH) is probably carcinogenic to humans (NHMRC, 2004)</p> <p>The EPA value of 0.2µg/l has been adopted. Because PAHs should not be present in desalinated water and their presence would indicate that contamination has occurred, a lower limit has been set for the outlet of the desalination plant.</p> <p>Occurrence: The main source of PAH contamination in drinking water is usually the coal-tar coating of drinking-water distribution pipes, used to protect the pipes from corrosion. Such coatings are not in use in Qatar. PAHs could occur in seawater if spills of petroleum hydrocarbons occur. PAHs pose a low risk in the Qatar system.</p> <p>Occurrence: The main source of PAH contamination in drinking-water is usually the coal-tar coating of drinking-water distribution pipes, used to protect the pipes from corrosion. Fluoranthene is the most commonly detected PAH in drinking-water and is associated primarily with coal-tar linings of cast iron or ductile iron distribution pipes. PAH constitute low/no risk in Qatar Water system</p>

PCB's Polychlorinated (biphenyls)	µg/l	No standard value	0.5	HY	0.5	<p>Basis for limit: PCB's causes Skin changes; thymus gland problems; immune deficiencies; reproductive or nervous system difficulties; increased risk of cancer. EPA set a limit of 0.0005 mg/l. KAHRAMAA adopt this level.</p> <p>Occurrence: PCB's can be a result of Runoff from landfills or from discharge of waste chemicals. There is no risk for presence of PCB's in Qatar Water System.</p>
Toluene	mg/l	0.7	0.7	HY	0.7	<p>Basis for limit: In humans, toluene is readily absorbed from the gastrointestinal tract after ingestion, and is distributed preferentially in adipose tissue, then the kidneys, liver and brain. It is rapidly metabolised by the liver to benzyl alcohol, benzoic acid, and to a lesser extent, phenols. The International Agency for Research on Cancer has concluded that toluene is not classifiable as to its carcinogenicity in humans (NHMRC, 2004).</p> <p>The WHO guideline value of 0.7 mg/L has been adopted. The reported taste threshold for toluene ranges from 0.04 to 0.12 mg/L. The reported odour threshold for toluene in water ranges from 0.024 – 0.17 mg/L. Toluene may therefore affect the acceptability of water at concentrations below its health-based guideline value.</p> <p>Occurrence: Toluene is present in petroleum products, and could result in seawater following a spill of petroleum hydrocarbons into the Gulf waters. If present it would be expected to be accompanied by benzene, and benzene would be limiting with respect to human health effects. Trace levels could pass through a MSF desalination process. Toluene is considered to be a low-moderate risk in the Qatar system.</p>
Xylene	mg/l	0.5	0.25	HY	0.5	<p>Basis for limit: The International Agency for Research on Cancer has concluded that xylenes are not classifiable as to their carcinogenicity in humans (NHMRC, 2004).</p> <p>The WHO guideline value of 0.5 mg/L has been adopted. The reported taste threshold for xylene is 0.02 mg/L, xylene may therefore affect the acceptability of water at concentrations below its health-based guideline value.</p> <p>Occurrence: Xylene is present in petroleum products, and could result in seawater following a spill of petroleum hydrocarbons into the Gulf waters. If present it would be expected to be accompanied by benzene, and benzene would be limiting with respect to human health effects. Trace levels could pass through a MSF desalination process. Xylene is considered to be a low-moderate risk in the Qatar</p>

TOC	mg/l	No standard value	<2	W	4	<p>Basis for limit: TOC is used as an indicator of the total organic carbon present in water and the performance of treatment/desalination plants. Increase in TOC in presence of chlorination may increase the potential of producing Halogenated organic compounds of carcinogenic characteristic. Volatile organic carbons is part of the TOC, when present may cause odor problems. No limits has been set by WHO. KAHRAMAA adopt a limit of <2 at delivery point and 4 mg/l in distribution system.</p> <p>Occurrence: Organic carbon in water can be natural from vegetation, algae growth, or from contamination with sewage or industrial pollution. There is low risk for Qatar water supply system.</p>
Disinfectants and Disinfectant By-products						
Residual Chlorine	mg/l	5 For effective 0.5 ppm after at least 30 minutes contact time .at pH < 8.0	1.0	C/D Upon use	0.2-1.0	<p>Basis for limit: Most individuals are able to taste or smell chlorine in drinking water at concentrations well below 5 mg/L, and some at levels as low as 0.2 mg/L. At a residual free chlorine concentration of between 0.6 and 1.0 mg/L, there is an increasing likelihood that some consumers may object to the taste.</p> <p>It is critical to add sufficient chlorine to achieve disinfection. Concerns relating to taste and odour should not be a basis for permitting inadequate disinfection. Chlorine also can react with organic compounds or inorganic s to form byproducts with signifocance health importance as the Tri-Halo-methanes.</p> <p>A target of achieving at least 0.2 mg/L in distribution system and entry point to customers has been set.</p> <p>Occurrence: Chlorine is added as a disinfectant, and the concentration of chlorine that is present will depend on the amount added and the extent to which it depletes. A level of 0.2 mg/l as a minimum is required to be available for water safety while not inducing odor or increasing disinfectant byproducts in water.</p>
Monochloramine	mg/l	3	3	C/D Upon use	3	<p>Basis for limit: Monochloramine, dichloramine and trichloramine are considered by-products of drinking-water chlorination, being formed when chlorine and ammonia are added to water. Monochloramine, the most abundant chloramine, is recognized as a less effective disinfectant than chlorine and is used as a secondary disinfectant to maintain a residual in distribution systems.. The use of chloramines for disinfection instead of chlorine reduces the formation of THMs in drinking-water supplies. Only monochloramine has been considered for development of a health-based guideline value by WHO at 3 mg/l.</p> <p>Occurrence: Usual monochloramine concentrations when used as a disinfectant range between 0.2-2mg/l. A 3.0 mg/l is adopted as a guideline value. Monochloramine is not used currently as a disinfectant in Qatar Supply System and thus imply no risk in Qatar water system.</p>

Chlorine dioxide	mg/l	No standard value	0.7	C/D Upon use	0.7	<p>Basis for limit: Chlorine dioxide is used as a disinfectant to reduce the formulation of disinfectant byproducts produced on using the hypochlorite. Significant depression of thyroid hormones has also been observed in rats and monkeys exposed to it in drinking-water studies.</p> <p>The WHO does not set a guideline value for chlorine dioxide because of its rapid hydrolysis to chlorite and because the chlorite provisional guideline value is adequately protective for potential toxicity from chlorine dioxide (WHO, 2011). The Australian health-based guideline (NHMRC, 2004) for chlorine dioxide is 1 mg/L and 0.4 mg/L for aesthetics (taste and odour). EPA set a limit of 0.8 mg/l.</p> <p>As chlorine dioxide is easier to measure than chlorite and chlorate it is a good operational target at the treatment plant outlet, and a value of 0.7 mg/L has been set at the treatment plant outlet.</p> <p>Occurrence: Qatar uses chlorine dioxide as a disinfectant at desalination plants. A level of 0.7mg/l is adopted as maximum permitted level, usual concentration used range between 0.3-0.4 mg/l. Chlorine dioxide seems to have a high/moderate risk in Qatar water system as mentioned in the basis for limit.</p>
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Dibromo-chloro-methane	µg/l	100	80	W	100	<p>Basis for limit: The components that make up the total THM value (i.e. dibromochloromethane, chloroform, bromoform, and bromodichloromethane). Trihalomethanes are rapidly and efficiently absorbed following ingestion. They are metabolised primarily to carbon dioxide and/or carbon monoxide, and rapidly exhaled. They are fat soluble, and accumulate in tissues with the highest lipid content (such as adipose tissue, brain, kidney and blood).</p> <p>In animals, the trihalomethanes are central nervous system depressants and liver and kidney toxicants. Chloroform and bromoform are also known to cause central nervous system depression in humans. Some epidemiological studies have reported associations between the ingestion of chlorinated drinking water (which typically contains THMs) and increased cancer mortality rates.</p> <p>The International Agency for Research on Cancer has concluded that chloroform and bromodichloromethane are possibly carcinogenic to humans, and bromoform and dibromochloromethane are not classifiable as to their carcinogenicity to humans due inadequate evidence in humans and limited evidence in animals (WHO, 2011).</p> <p>The USEPA specifies that the average total THM over summer should be < 0.08 mg/L. The WHO set a guideline that the sum of the ratios of the concentrations of the components that make up the total THM value (i.e. dibromochloromethane, chloroform, bromoform, and bromodichloromethane) compared to their respective guideline level should be <1. This approach provides guidance on maintaining the concentration of total THMs at an acceptable level, and the WHO approach has been adopted for Qatar as follows:</p> <p>(Concentration of Bromoform / Max limit allowed for Bromoform) + (Concentration of Dibromochloromethane / Max limit allowed for Dichloromethane) + (Concentration of Dichloromethane / Max limit allowed for Dichloromethane) ≤1.</p> <p>Occurrence: Trihalomethanes (THMs) result from the chlorination of organic matter, typically present in raw water sources. Chlorination of seawater can lead to elevated THM concentrations; however, after desalination the concentrations of THMs should be low. THM concentrations in the distribution system will on the remineralisation and disinfection practices.</p> <p>A lower chloroform/bromoform and THM limit at the outlet of the water treatment plant is set because some increase may occur in the distribution system as a result of booster chlorination to maintain adequate chlorine residual in the network.</p>
Dichloro-methane	µg/l	20	5	W	20	
Bromo di-chloro-methane	µg/l	60	60	W	60	
Bromoform	µg/l	100	100	W	100	
Chloroform	µg/l	300	150	W	200	
THM	µg/l	Sum of the ratio of THM's compounds to their respected guideline values <1	Sum of the ratio of THM's compounds to their respected guideline values <1 Total THM: 80	W	Sum of the ratio of THM's compounds to their respected guideline values <1 Total <100	

Bromate	µg/l	10	10	W	10	<p>Basis for limit: Bromate is rapidly absorbed from the gastrointestinal tract of rats. Although bromate was not subsequently detected in tissue, bromide concentrations were significantly increased in plasma, red blood cells, pancreas, kidney, stomach and small intestine.</p> <p>Most cases of human poisoning from bromate are due to accidental or intentional ingestion of home permanent-wave neutralizing solutions and dying of textiles, which can contain 2–10% bromate. Toxic effects include nausea, abdominal pain and diarrhoea, central nervous system depression and pulmonary oedema, most of which are reversible. Irreversible effects include kidney failure and deafness.</p> <p>The International Agency for Research on Cancer concluded that although there is inadequate evidence of carcinogenicity in humans, there is sufficient evidence for the carcinogenicity of potassium bromate in experimental animals to consider bromate as possibly carcinogenic to humans. (NHMRC, 2004).</p> <p>The WHO sets a provisional health-based guideline of 0.01 mg/L; this has been reduced from a provisional value of 0.025 mg/L set in the 1993. The guideline is provisional on the basis of limitations in treatment and analytical methods, which limit the adoption of a more stringent value. The Australian health-based guideline is 0.02 mg/L.</p> <p>For Qatar 0.01 mg/L has been considered, and a value of 0.01mg/l is proposed for the treatment plant outlet, and customer connection point. Observation indicate bromate concentrations may increase in distribution system under certain conditions.</p> <p>Occurrence: Bromate is not naturally present in seawater or brackish bore water, but may be formed during disinfection by reaction of bromide with ozone or hypochlorite. Seawater contains around 50 to 80 mg/L of bromide. Excessive amounts of bromate can also be if chlorine used in disinfections is produced by electrolysis of seawater or if sodium hypochlorite solution dosed to the water do contain bromate. Chlorine dioxide is mainly used as a disinfectant in Qatar and this negate formation of any bromate and accordingly bromate poses a medium risk in the Qatar system.</p>
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Chlorite	µg/l	700	700	W	700	<p>Basis for limit: The IARC has concluded that chlorite is not classifiable as to its carcinogenicity to humans. The primary and most consistent finding arising from exposure to chlorite is oxidative stress resulting in changes in the red blood cells. This end-point is seen in laboratory animals and, by analogy with chlorate, in humans exposed to high doses in poisoning incidents. Studies with human volunteers for up to 12 weeks did not identify any effect on blood parameters at the highest dose tested, 36 mg/kg of body weight per day.</p> <p>The WHO guideline value of 700 µg/l has been adopted.</p> <p>Occurrence: Chlorate is a DBP resulting from the use of chlorine dioxide as a disinfectant and for odor/taste control in water. There is a risk in the Qatar system as Chlorite also is found in hypochlorites used for disinfection of water. However concentration of chlorine dioxide permitted for use are satisfactory to control any increase in chlorite/chlorate in water.</p>
Chlorate	µg/l	700	700	W	700	<p>Basis for limit: Similar to chlorite, the primary concern with chlorate is oxidative damage to red blood cells. Also like chlorite, a chlorate dose of 36 mg/kg of body weight per day for 12 weeks did not result in any adverse effects in human volunteers. Although the database for chlorate is less extensive than that for chlorite, a recent well-conducted 90-day study in rats is available. A long-term study is in progress, which should provide more information on chronic exposure to chlorate. (WHO, 2011)</p> <p>The WHO guideline value of 700 µg/l has been adopted.</p> <p>Occurrence: Chlorite is a Disinfectant Byproduct resulting from the use of chlorine dioxide as a disinfectant and for odor/taste control in water. Chlorate also may be found in Hypochlorites used for disinfection. The risk in the Qatar system is medium and emanate from the use of chlorine dioxide for disinfection.</p>
Haloacetic Acid	mg/l	DCA: 0.05 MCA: 0.02 TCA: 0.2	DCA: 0.05 MCA: 0.02 TCA: 0.2	Q	DCA: 0.05 MCA: 0.02 TCA: 0.2	<p>Basis for limit: Chloroacetic acids are formed when chlorine reacts with acetic acid compounds. A similar picture to that for THMs has emerged regarding carcinogenic properties. There are three acids of concern: onochloroacetic acid (MCA), dichloroacetic acid (DCA), and trichloroacetic acid (TCA).</p> <p>The WHO guidelines set MCA at 0.02 mg/L, DCA at 0.05 mg/L and TCA at 0.25 mg/L. The Limits have recently been set by the USEPA on the total of the haloacetic acids in drinking water at 0.06 mg/L. The WHO guideline values have been adopted.</p> <p>Occurrence: the haloacetic acids are expected to pose a low risk in the Qatar system.</p>

Perchlorate	µg/l	No standard value	6	Q	6	<p>Basis for limit: Perchlorate may have adverse health effects because scientific research indicates that this contaminant can disrupt the thyroid's ability to produce hormones needed for normal growth and development. WHO did not set a guideline value. EPA regulate monitoring for Perchlorate recently, the only other state to have a drinking water standard for perchlorate is California, which set 6 ppb or less as an allowable concentration. KAHRAMAA adopt California standard for perchlorate.</p> <p>Occurrence: Perchlorate is both a naturally occurring and man-made chemical that is used to produce rocket fuel, fireworks, flares and explosives. Perchlorate can also be present in bleach and in some fertilizers. Perchlorate pose no or low hazard to Qatar water system.</p>
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Radiological Characteristics						
Radio-nuclides: Total Activity of Alpha Rays	Bq/l	As WHO Guideline Value for Each Radioisotope	0.5	Q	0.5	<p>Basis for limit: The process of identifying individual radionuclides in drinking-water and determining their concentration is time-consuming and expensive. Because, in most circumstances, the concentrations are low, such detailed analysis is normally not justified for routine monitoring. A more practical approach adopted by WHO is to use a screening procedure, where the total radioactivity present in the form of alpha and beta radiation is first determined, without regard to the identity of specific radionuclides.</p> <p>The WHO guideline values for total alpha and beta radionuclides have been adopted. The values provided here as standard values serve only as “screening” requirements that may indicate harmful levels of radioactivity in the water. Further guidance on the recommended response to monitoring results that exceed these values is provided in WHO (2011).</p> <p>Occurrence: Desalinated water should generally not contain radionuclides in concentrations greater than the screening values, although sometimes groundwater can naturally contain elevated concentrations. It is possible that activities in neighboring countries involving nuclear energy could lead to elevated concentrations of radionuclides in seawater that might not be adequately removed in the desalination process. The potential presence of radionuclides poses a low to medium-high risk to the Qatar system.</p>
Radionuclides: Total Activity of Beta Rays	Bq/l		1.0	Q	1.0	
Radium	pCi/L		5	Y	5	<p>Basis for Limit: Radium in water may pose a hazard to human health when the water is used for drinking or cooking. Only a small portion of ingested radium is absorbed from the digestive tract and distributed throughout the body. Internally deposited radium emits alpha particles that may then damage surrounding tissue, cause depression of the immune system, anemia, cataracts, and fractured teeth. Exposure to high levels of radium also has shown an increased incidence of bone, liver and breast cancer.</p> <p>The U.S. Environmental Protection Agency (USEPA) has established a maximum contaminant level (MCL) for radium in public water supplies of 5 picoCuries per liter (pCi/L). The MCL for radium has been set well below levels for which health effects have been observed and is therefore assumed to be protective of public health.</p> <p>Occurrence: Radium can be present in ground or surface water, not expected in desalinated water. Low or no risk is expected in Qatar drinking water system.</p>

Microbiological Characteristics						
Total Coliforms	Organisms per 100 mL	0 / <1	0 / <1	D	Nil in 99% of tested samples	<p>Basis for limit: coliform group is not a health threat in itself; it is used to indicate whether other potentially harmful bacteria may be present. Total coliform bacteria include a wide range of aerobic and facultative anaerobic, Gram-negative, non-spore-forming bacilli and which are capable of growing in the presence of Total coliforms. Hence, total coliform is not useful as an indicator of faecal pathogens, but they also can be used to assess the cleanliness and integrity of distribution systems and the potential presence of biofilms.</p> <p>Occurrence: Total coliform bacteria occur in both sewage and natural waters. Some of these bacteria are excreted in the faeces of humans and animals, but many coliforms are heterotrophic and able to multiply in water and soil environments. Total coliforms can also survive and grow in water distribution systems, particularly in the presence of biofilms.</p> <p>Total coliforms should not be present after disinfection, and the presence of these organisms indicates inadequate treatment. The presence of total coliforms in distribution systems and stored water supplies can reveal regrowth and possible biofilm formation or contamination through ingress of foreign material, including soil or plants. KAHRAMAA target for compliance is no detection in 99% of samples tested monthly.</p>
E. coli	Organisms per 100 mL	0 / <1	0 / <1	D	Nil	<p>Basis for limit: Though some strains of E. coli can be pathogenic, these organisms are intended to serve as indicators of faecal contamination in the water.</p> <p>The WHO guideline is that no E. coli should be detected, and notably for good water supply system; not detected in 95% of samples collected from distribution system.</p> <p>Occurrence: While absence of these indicators can imply good water quality, it cannot guarantee that the water is absent of pathogens. These pathogens are best managed through a combination of compliance with these standards plus reliable disinfection and activities and works to prevent recontamination of the treated water such as always maintaining a positive pressure in the pipe network of >1.5 bar. KAHRAMAA key performance indicator for Coliform is Nil in 99% of tested samples.</p>

Total Bacterial Count		No standard Value	<10	Recommended Daily	100	<p>Basis for limit: HPC measurement detects a wide spectrum of heterotrophic microorganisms, including bacteria and fungi. The tests detect only a small proportion of the microorganisms that are present in water. The population recovered will differ according to the method and conditions applied. The test has little value as an indicator of pathogen presence but can be useful in operational monitoring and as a treatment and disinfectant indicator, where the objective is to keep numbers as low as possible. In addition, HPC measurement can be used in assessing the cleanliness and integrity of distribution systems and potential presence of biofilms.</p> <p>Occurrence: Heterotrophic microorganisms include both members of the natural (typically nonhazardous) microbial flora of water environments and organisms present in a range of pollution sources. After disinfection, numbers would be expected to be low; for most uses of HPC test results, however, actual numbers are of less value than changes in numbers at particular locations. In distribution systems, increasing numbers can indicate a deterioration in cleanliness, possibly stagnation and the potential development of biofilms. HPC can include potentially “opportunistic” pathogens such as Acinetobacter, Aeromonas, Flavobacterium, Klebsiella, Moraxella, Serratia, Pseudomonas and Xanthomonas. However, there is no evidence of an association of any of these organisms with gastrointestinal infection through ingestion of drinking-water in the general population. Qatar water is desalinated and there is little potential for microbial regrowth, a maximum level of 100 cfu/ml has been adopted as a guidance level in distribution system in case of suspecting water quality and action required, and 10 cfu/ml for water at desalination plants delivery point.</p>
Harmful Viruses	Organisms per 100 mL	No standard Value	Nil /<1	-	Nil	<p>Basis for limit: Viruses and pathogenic protozoa can cause gastro-intestinal illnesses and other communicable diseases in humans. Severe doses can result in death. Immuno-compromised persons, children and the elderly are most susceptible.</p>
Chlorine Resistant Protozoa (Cryptosporidium)	Organisms per 100 mL	No standard Value	Nil /<1	-	Nil /<1	<p>The GSO Standard (Section 4.8) refer to microbes of faecal origin and that they should not be present in the water. However, due to limitations in analytical methods sampling alone cannot be relied upon as verification that the water poses an insignificant risk from these microbes.</p> <p>WHO (2011) advocates development of a Water Safety Plan (a water quality management plan) to control harmful microbes such as viruses and/or cryptosporidium to a level that delivers a negligible risk of infection due to consumption of drinking water. Although these micro-organisms are not required to be routinely tested yet are of importance in cases where water is suspected of being contaminated or for verifying that water is free from these micro-organisms.. Qatar water is desalinated and there is little potential for the presence of these microorganisms unless water is contaminated with sewage during distribution.</p>

Legio- nella	Organ- isms per 100 mL	No standard Value	Nil /<1	-	Nil /<1	<p>Basis for limit: These organisms can cause gastro-intestinal illnesses and other communicable diseases in humans. Immuno-compromised persons, children and the elderly are most susceptible.</p> <p>The GSO Standards refer only to microbes of faecal origin and that they should not be present in the water. There are no specified guidelines for these organisms and should be managed by developing a dedicated water quality management plan that should be verified by testing that shows no or these micro-organisms are not required to be routinely tested yet are of importance in cases where water is suspected of being contaminated or for verifying that water is free from these micro-organisms.</p> <p>occurrence: These organisms can be present in hot waters such as occur in the Qatar distribution system. A management strategy that has been effective in piped system similar to Qatar is to maintain a Chlorine dioxide level of >0.05 mg/l or residual chlorine of 0.2 mg/l chlorine residual of 0.2 mg/L throughout the network combined with an adequate chlorine contact time while reducing stagnation and storage time of water. As the temperature of Qatar's water can be in the vicinity of 35-45 °C, legionella, Pseudomonas and N. floweri presents a medium risk for the water system. N. fowleri is to better understood regarding its potential presence.</p>
Pseudo- monas Aeurugi- nosa		No standard Value	Nil /<1	-	Nil /<1	
N. fowleri	Organ- isms per 100 mL	No standard Value	Nil /<1	-	Nil /<1	
<p>Note: *: Parameters radioactivity guidance level is as indicated in latest edition of WHO Guidelines.</p>						



Other Organic & Inorganic Compounds

Table 3. is a list of organic pollutants with their maximum permitted level as indicated in the GSO standard No. 149/2009 for Un-Bottled Drinking Water (Under update). These levels are adopted from the Fourth Edition of WHO Guidelines for Drinking Water Quality, 2011. KAHRAMAA adopt this list of requirements for water at delivery point and at customer connection points. Table 3. Also List chemical compounds with their maximum permitted limits and which are not listed in the GSO Standard or WHO Guidelines for drinking Water Quality and adopted by KAHRAMAA as Guidance levels.

There is no requirement for routine monitoring for these compounds, listed in table 3 & 4. However in any case water is suspected of having any of these compounds; the Water Producer shall analyse water to ensure compliance.

Table 3. Maximum Permitted Level for Organic Compounds in Drinking Water

ORGANIC POLLUTANTS	MAXIMUM LEVEL	PESTICIDES AND INSECTICIDES	MAXIMUM LEVEL
Carbon tetrachloride ($\mu\text{g/l}$)	4	Alachlor ($\mu\text{g/l}$)	20
Diethylhexyl phthalate ($\mu\text{g/l}$)	8	Aldicarb ($\mu\text{g/l}$)	10
Dichlorobenzene, 1, 2 ($\mu\text{g/l}$)	1000	Aldrin and Dieldrin ($\mu\text{g/l}$)	0.03
Dichlorobenzene 1,4 ($\mu\text{g/l}$)	300	Atrazine ($\mu\text{g/l}$)	2
Dichloroethane 1,2 ($\mu\text{g/l}$)	30	Carbofuran($\mu\text{g/l}$)	7
Dichloroethene 1,1 ($\mu\text{g/l}$)	30	Chlordane ($\mu\text{g/l}$)	0.2
Dichloroethene 1,2 ($\mu\text{g/l}$)	50	Chlorotoluron ($\mu\text{g/l}$)	30
Dichloromethane ($\mu\text{g/l}$)	20	Cyanazine ($\mu\text{g/l}$)	0.6
Hexa chloro butadiene ($\mu\text{g/l}$)	0.6	2,4 dichlorophenoxy acetic acid($\mu\text{g/l}$)	30
Nitrilotriacetic acid ($\mu\text{g/l}$)	200	2,4 D-B ($\mu\text{g/l}$)	90
EDTA ($\mu\text{g/l}$)	600	1,2 Di bromo,3 chloropropane ($\mu\text{g/l}$)	1
Pentachlorophenol ($\mu\text{g/l}$)	9	1,2 Dibromoethane ($\mu\text{g/l}$)	0.4
Styrene ($\mu\text{g/l}$)	20	1,2 Dichloropropane ($\mu\text{g/l}$)	40
Tetrachloroethane ($\mu\text{g/l}$)	40	1,3 Dichloropropane	20
Trichloroethane ($\mu\text{g/l}$)	20	Dichloroprop ($\mu\text{g/l}$)	100
Cyanogens chloride ($\mu\text{g/l}$)	70	Dimethoate($\mu\text{g/l}$)	6
Dibromoacetonitrile ($\mu\text{g/l}$)	70	Endrin($\mu\text{g/l}$)	0.6
Trichloroplenol, 2, 4,6 ($\mu\text{g/l}$)	200	Finoprop($\mu\text{g/l}$)	9
Acrylamide ($\mu\text{g/l}$)	0.5	Isoproturone($\mu\text{g/l}$)	9
Epichlorhydrine ($\mu\text{g/l}$)	0.4	Lindane ($\mu\text{g/l}$)	2
Benzoalphapyrine ($\mu\text{g/l}$)	0.7	MCPA ($\mu\text{g/l}$)	2
Phenyl chloride ($\mu\text{g/l}$)	0.3	Micoprope ($\mu\text{g/l}$)	10
Dichloroacetonitrile ($\mu\text{g/l}$)	20	Methoxychlor ($\mu\text{g/l}$)	20
Dioxin 1,4 ($\mu\text{g/l}$)	50	Metolachlor ($\mu\text{g/l}$)	10
		Molinate ($\mu\text{g/l}$)	6
Permethrine($\mu\text{g/l}$)	300	Pentadimethalin ($\mu\text{g/l}$)	20
Peroxyfen ($\mu\text{g/l}$)	300	Simazine ($\mu\text{g/l}$)	2
Chloropyrifos ($\mu\text{g/l}$)	30	2,4.,5 T ($\mu\text{g/l}$)	9
DDT ($\mu\text{g/l}$)	1	Terbutylazine ($\mu\text{g/l}$)	7
		Trifluraline ($\mu\text{g/l}$)	20
Microstatin L-R ($\mu\text{g/l}$)	1		

Table 4: Additional Water Quality Parameters with Maximum Permitted Contaminant level for Guidance (MCL)

Organic Parameters	MGL		MGL
2- Chlorotoluene ($\mu\text{g/l}$)	140	1,2,4 Trichlorobenzene –total ($\mu\text{g/l}$)	70
4- Chlorotoluene or p-chlorotoluene ($\mu\text{g/l}$)	140	Naphthalene ($\mu\text{g/l}$)	100
p-Isopropyltoluene ($\mu\text{g/l}$)	70	Petrol in Water (mg/l)	<MDL
1,2 ,3- Trichloropropane ($\mu\text{g/l}$)	0.005	Kerosene in Water (mg/l)	0.1
Bromochloromethane or (Methylene bromochloride (mg/l)	0.5		
1 ,1 ,2 -Trichloroethane ($\mu\text{g/l}$)	5		
Monochlorobenzene ($\mu\text{g/l}$)	70		
Isopropylbenzene mg/l or n-propyl benzene ($\mu\text{g/l}$)	260	Inorganic Parameters	
1, 2 ,4-Trimethylbenzene ($\mu\text{g/l}$)	330	Strontium (mg/l)**	4
1 ,3, 5 -Trimethylbenzene ($\mu\text{g/l}$)	330	Cobalt (mg/l)**	0.002
s-Butylbenzene ($\mu\text{g/l}$)	260	Lithium (mg/l)	0.05
T-butyl benzene ($\mu\text{g/l}$)	260	Silica (mg/l)	0.05
**= NO Guidance Level indicated by WHO for the above listed parameters. MGL's indicated are referenced to EPA/OEHHA levels.* MDL: Method detection limit.			

3. Overview /Monitoring Activities

3.1 Water Producers Monitoring

KAHRAMAA purchase water from private water producers companies in accordance to contracts signed between the two parties. The contract cover requirements for water quality management and specifications to be reached as indicated in table 2-4. Water producers are required to submit daily water quality reports to KAHRAMAA to indicate water quality test performed and their results. These reports are checked daily by KAHRAMAA for compliance.

3.2 Operational Performance Monitoring

For operational and performance monitoring of the Water quality at desalination Plant (e.g. continuous monitoring of EC, disinfectant level at outlet point) are fed into a centralised Supervisory Control and Data Acquisition (SCADA) system at KAHRAMAA and used as an indicator for potential losses of control, or, to identify significant changes in water quality or treatment performance, and to signaled where correctional action may be required. “Alert levels”, notifications, correctional actions, and a listing of the responsible person for undertaking correctional activities, is outlined in a Water Quality Control Plan developed to ensure water desalination performance. Online monitoring system is checked routinely with data collected manually to ensure proper system calibration.

3.3 KAHRAMAA Water Quality Monitoring Plan, Sampling Points & Frequency

Table 5 and 6 summaries the water quality-monitoring plan that has been developed by the Water Quality Lab/HSEd KAHRAMAA for implementation along with the recommended locations and frequency of sampling and analysis. The guidance provided by WHO (2011), table 7 & 8 for sampling and analyses are generally considered; however, desalinated seawater in the high water temperature environment of Qatar has particular aspects that require a different approach in some areas.

For monitoring water quality at the points of supply to the customer property, KAHRAMAA categorizes sampling based on a water quality zones, where systems are divided into discrete zones for the purposes of monitoring and reporting. The Zones are divided mainly in relation to their supply source and notably to a particular reservoir. The sampling also take into consideration the following; extent of population served by each reservoir, critical location of importance, critical parameters of importance, reservoirs/network design and retention times, network age and type, water quality complaint areas beside any others that are applicable to certain locations and cases.

Table 9 &10 Also summaries the water quality analysis methods that are used by KAHRAMAA. These are validated by comparative testing with other laboratories, and it confirm that the limit of detection is in the range that will allow confirmation that the analyte is not at concentrations that exceed the standard.

The methods of analysis particularly pertain to the analysis of treated water of low salinity and low input of the analytes (such as metals), monitoring of the treated water should form a primary check that substances are not present at levels of potential concern.

3.4 Requirements for Compliance with Standards

Monitoring results are reviewed frequently to assess performance against the water quality requirements at delivery point & in distribution system. Where results show that standards/requirements have been exceeded or deviated from, corrective actions are undertaken. Also monitoring aim to provide KAHRAMAA with results of a planned monitoring program to assess the long-term performance of the water supply system over a given period (typically monthly-yearly), and to be able to confirm that the quality of the water complies with the standards and provides a reliable treated water product specification to industry. Nevertheless, to ensure continuous improvement on water quality challenging targets has been set by KAHRAMAA as key performance indicators based on the executed monitoring results as follows:

- For microbiological samples representative of the quality of water supplied to consumers, performance can be regarded as satisfactory if monthly: at least the minimum number of routine samples has been tested for Total coliform (or thermotolerant coliforms), and at least 99% of scheduled samples (as distinct from repeat or special purpose samples such as complaint, new projects and etc.,) contain no coliforms.
- For physical characteristics, notably turbidity performance can be regarded as satisfactory if 98% of the samples tested monthly were in compliance with requirements of <4 NTU.
- For chemical and radiological parameters: for all chemical characteristics, performance can be regarded as satisfactory if 99% of individual results lie within the water quality requirement level.
- For disinfectant level in distribution system, an operational performance parameter, 99% of individual samples to comply with required level set by KAHRAMAA.

Certain parameters of no health significance such as EC TDS, alkalinity, hardness and which are not part of GSO standards can be waived from compliance upon approval of top management and were a definite plan and minimum maximum limits has been set during the exemption period and until their compliance.

The proposed frequency of monitoring has the objective of establishing at the outset whether certain

water contaminants are of concern or not in the Qatar supply system. For some analytes, it may be that after carrying out the analysis for one or two years and with reference to the potential for the analyte to be present, confidence is gained that the analyte is very unlikely to be present at concentrations greater than the standard. This might be the case, for example, for analytes such as arsenic and cadmium where it is not expected that there would be a source within the supply system, and the nature of the desalination system is such that it provides a high level of assurance that the substances will not be present in the treated water. In such cases, it is justified as been adopted to reduce the frequency of sampling and analysis, perhaps to once per year or less. In other cases and based on new advances a new emergent pathogen or contaminant is gaining importance for its potential presence in water and its health impact, monitoring frequency for this analyte can be increased in order to gain more information on its potential impact in local environment.

Results from routine operational and drinking water quality monitoring are evaluated monthly and annually. Results are documented appropriately and a system of regular reporting of results to relevant staff, departments and external stakeholders such as Supreme Council of Health is implemented.

3.5 Other Water quality Requirement and Conditions

KAHRAMAA control over water quality extend to all activities that may impact its quality, this include:

- treatment & disinfection technologies and procedures
- chemicals and materials used in contact with water,
- water supply operation; reservoirs design and retention time and disinfection management,
- new mains and reservoir disinfection and commissioning procedures,
- monitoring strategy; online and manual,
- water quality reporting,
- water quality emergency plans,
- water quality research and studies,
- awareness programs,
- water tankers monitoring, licencing and control,
- risk assessment and management,
- water quality lab results and assurance,
- sanitary inspection activities and etc.,

KAHRAMAA has set rules & conditions controlling all the above activities to ensure performance for better quality and public health. The conditions set are part of a water safety plan that the private producers have to set and adhere to it in accordance to the contractual agreements signed between them & KAHRAMAA. KAHRAMAA in turn also adhere in its routine activities to all these conditions and rules and continuously update these rules relevant to experience, new data or information related to water quality.

Table 5. Annual Frequency of Monitoring Water Quality in Distribution System

Sample Source	No. of Sampling Points	Collected samples	Monthly/Quarterly Samples	Annual Samples
Desalination Plant MSF/ MED	7	6	42	504
Desalination Plant (R.O Plants)				
R.O plant (Abu Samra)	2	6	12	144
R.O plant (Abu Samra)Well Water	1	6	6	24
Reservoirs				
Reservoirs Monthly Routine	65	3	195	2,340
Reservoirs Quarterly Routine	65	2	Every Quarter	520
Reservoirs (Trace Metals)	65	1	Annually	65
Hydrants				
Hydrants Fixed Points				
Hydrants Fixed point**	94	4	376	1,504
Hydrants Fixed point (Trace Metals)	94	1	Annually (over 3 months period)	94
Hydrants Fixed point (TOC) 94		1	Semi Annually (over 3 months period)	188
Hydrants Fixed point**	63	2	125	1,504
Hydrants Variable Points				
Hydrants Variable point	238	2	476	5,712
Tankers	50	2	100	1,200
Total				13799

** Fixed hydrants to be collected within 3 months period (4 times a year). Hence; on monthly base; only the assigned portion of the fixed hydrants are monitored.

Table 6. Analysis Frequency & Analysed Parameters

No	Parameter	Method	Unit	Water Network Hydrants (fixed point)	Desalination Plant & R.O Plant	Reservoirs
01. Physical						
1.1	Temperature	-	°C	Daily @ site	Monthly	Monthly
1.2	pH	SM 4500-H+	-			
1.3	Electric Conductivity	SM 2510	µS/cm @ 25°C			
1.4	TDS	SM 2510 B	mg/l			
1.5	Turbidity	SM 2130	NTU/FNU			
02. Biological						
2.1	Total Coliform	SM 9223B SM 9222B	P/A or MPN per 100ml cfu per 100 ml	Daily	Monthly	Monthly
2.2	E. coli	SM 9223B SM 9222D	P/A or MPN per 100ml cfu per 100 ml			Monthly
2.3	Heterotrophic Plate Count (HPC)	SM 9215 D ISO 6222	cfu per 100ml MPN per ml	In case of contamination		
2.4	Pseudomonas aeruginosa	ISO 16266 Idexx Pseudolert	cfu per 100ml MPN per 100ml			
2.5	Yeast and Mold	-	cfu per 100ml			
2.6	Enterococcus	EPA 1600	P/A or MPN per 100ml			
2.7	Salmonellae	SM 9260B	cfu per 100ml			
03. Disinfectants						
3.1	Chlorine Residual	SM 4500 Cl, F	mg/l	Daily @ site	Monthly	Monthly
3.2	Chlorine Dioxide	SM 4500 (A+B) CLO2	mg/l			
04. Disinfectant by-product						
4.1	Bromate	EPA 300(A+B)	µg/l	Monthly*	Monthly	Monthly
4.2	Chlorite	EPA 300(A+B)	µg/l			
4.3	Chlorate	EPA 300(A+B)	µg/l			
05. Trihalomethane						
5.1	Chloroform	524.2 EPA	µg/l	Monthly*	Monthly	Monthly
5.2	Bromoform	EPA 524.2	µg/l			
5.3	Bromodichloromethane	EPA 524.2	µg/l			
5.4	Dibromochloromethane	EPA 524.2	µg/l			
5.5	Total THM	EPA 524.2	µg/l			

06. Inorganic						
6.1	Alkalinity as CaCO ₃ .T	SM 2320 (A+B)	mg/l	Semi Annual	Monthly Quarterly Monthly	Quarterly
6.2	Hardness as CaCo ₃	EPA 300(A+B) 2340 A	mg/l			
6.3	Calcium as Ca	EPA 300(A+B) 2340 C	mg/l	Monthly*		
6.4	Magnesium as mg	EPA 300(A+B) 2340 B	mg/l			
6.5	Lithium	-	mg/l			
6.6	Sodium	EPA 300(A+B)	mg/l			
6.7	Potassium	EPA 300(A+B)	mg/l			
6.8	Ammonium	EPA 300(A+B)	mg/l			
6.9	Chloride	EPA 300(A+B)	mg/l			
6.10	Sulfate	EPA 300(A+B)	mg/l			
6.11	Nitrate	EPA 300(A+B)	mg/l	Monthly*		
6.12	Nitrite	EPA 300(A+B)	mg/l			
6.13	Bromide	EPA 300(A+B)	mg/l			
6.14	Fluoride	EPA 300(A+B)	mg/l			
6.15	Boron	SM 4500 B, C	mg/l			
07. Trace Metals						
7.1	Arsenic	SM 3120 B	mg/l	Annually (over three months period)	Monthly	Annual
7.2	Selenium	SM 3120 B	mg/l			
7.3	Barium	SM 3120 B	mg/l			
7.4	Beryllium	SM 3120 B	mg/l			
7.5	Cadmium	SM 3120 B	mg/l			
7.6	Lead	SM 3111 B	mg/l			
7.7	Nickel	SM 3120 B	mg/l			
7.8	Copper	SM 3111 B	mg/l			
7.9	Manganese	SM 3111 B	mg/l			
7.1	Zinc	SM 2320 B	mg/l			
7.11	Chromium	SM 3120 B	mg/l			
7.12	Aluminum	SM 3120 B	mg/l			
7.13	Strontium	SM 3120 B	mg/l			
7.14	Cobalt	SM 3120 B	mg/l			
08. Hydrocarbons						
8.1	TOC	SM 5310 B	mg/l	Semi Annual	Monthly	Quarterly
09. Volatile Organic Compounds						

9. 1	methylene chloride	524.2 EPA	µg/l	Monthly*	Monthly	Monthly
9. 2	1,2- Dichloroethene (cis & trans)	EPA 524.2	µg/l			
9. 3	2 ,2 -dicloropropane	EPA 524.2	µg/l			
9. 4	bromochloromethane	EPA 524.2	µg/l			
9. 5	1, 2- dichloroethane	EPA 524.2	µg/l			
9. 6	1 ,1 ,1 -trichloroethane	EPA 524.2	µg/l			
9. 7	1, 1 -dichloropropene	EPA 524.2	µg/l			
9. 8	carbon tetrachloride	EPA 524.2	µg/l			
9. 9	benzene	EPA 524.2	µg/l			
9.10	Trichloroethene	EPA 524.2	µg/l			
9.11	1, 2- dichloropropane	EPA 524.2	µg/l			
9.12	1 ,3- dichloropropene (cis & trans)	EPA 524.2	µg/l			
9.13	toluene	EPA 524.2	µg/l			
9.14	Tetrachloroethene	EPA 524.2	µg/l			
9.15	1 ,3- dichloropropane	EPA 524.2	µg/l			
9.16	1,2-dibromoethane	EPA 524.2	µg/l			
9.17	ethyl benzene	EPA 524.2	µg/l			
9.18	xylenes	EPA 524.2	µg/l			
9.19	styrene	EPA 524.2	µg/l			
9.20	1 ,1, 2,2- tetra chloroethane	EPA 524.2	µg/l			
9.21	Monochlorobenzene	EPA 524.2	µg/l			
9.22	1,2 ,3- trichloropropane	EPA 524.2	µg/l			
9.23	isopropylbenzene	EPA 524.2	µg/l			
9.24	n propylbenzene	EPA 524.2	µg/l			
9.25	2 chlorotoluene	EPA 524.2	µg/l			
9.26	4 chlorotoluene	EPA 524.2	µg/l			
9.27	1 ,3, 5 -trimethylbenzene	EPA 524.2	µg/l			
9.28	1, 2 ,4-trimethylbenzene	EPA 524.2	µg/l			
9.29	1 ,3 -dichlorobenzene	EPA 524.2	µg/l			
9.30	1 ,4-dichlorobenzene	EPA 524.2	µg/l			
9.31	p-Isopropyltoluene	EPA 524.2	µg/l			
9.32	n-Butylbenzene	EPA 524.2	µg/l			
9.33	tert-Butylbenzene	EPA 524.2	µg/l			
9.34	sec- Butylbenzene	EPA 524.2	µg/l			
9.34	1,2-Dibromo-3- chloropropane	EPA 524.2	µg/l			
9.35	Trichlorobenzene (total)	EPA 524.2	µg/l			
9.36	naphthalene	EPA 524.2	µg/l			
9.37	hexachlorobutadiene	524.2 EPA	µg/l			

Table 7. Minimum number of samples for microbial testing required for population served (from WHO, 2011)

Population Served within delivery system zone	Minimum number of samples
Above 100,000	samples (each at different locations) per week, plus 1 additional sample 6 .per month for each additional 10 000 above 100 000
to 100,000 5,000	sample per week, plus 1 additional sample per month for each 5,000 1 .above 5,000
to 5,000 1,000	.Preferably 1 sample per week
Under 5,000	.Preferably 1 sample per week

Table 8. Minimum Number of samples for physico-chemical parameters required for population served (from WHO, 2011)

Population Served within delivery system zone	Minimum number of samples per year
500,000 <	per 100,000 head of population plus an additional 180 samples 12
to 500,000 100,000	per 10,000 head of population plus an additional 120 samples 12
to 100,000 5,000	per 5 000 head of population 12
Under 5,000	12

3.6 Limits of detection

Generally the limit of detection should be less than the standard (and preferably less than 0.2 – 0.3 times the standard); however, it is recognised that there are limitations in the analytical methods available and not all chemicals will be able to be measured at the desired level. Where the limit of detection cannot be achieved, the likelihood of the analyte being present and the body of results should be reviewed to confirm that there is a low likelihood that the substance is present, and there are no detections that would suggest that the substance may be present. However, the actual detection limits may vary from lab to lab and differs from method to method based on analytical conditions and this needs to be practically evaluated. Suggested & recommended limits of detection for the various analytes are tabulated in table 9 &10.

Table 9. Recommended Methods and Detection Limits – Health

Parameter	Limit of Detection / Method
Organotins (dialkyltins, tributyltin oxide)	(Refer to Standard Methods (APHA 2005
*Arsenic	$\mu\text{g/litre}$ by ICP/MS; $2 \mu\text{g/litre}$ by hydride generation AAS or FAAS (WHO 2011) 0.1 0.001 mg/L by hydride generation followed by atomic absorption spectroscopy or 0.005 (mg/L graphite furnace atomic absorption spectroscopy (NHMRC 2004
Benzene	$(\mu\text{g/litre}$ by GC with photoionization detection and confirmation by MS (WHO 2011 0.2 (mg/L by gas chromatography with photoionization detection (NHMRC 2004 0.001
Boron	$(\mu\text{g/litre}$ by ICP/MS; 6–10 $\mu\text{g/litre}$ by ICP/AES (WHO 2011 0.2 (mg/L by inductively coupled plasma emission spectroscopy (NHMRC 2004 0.05
Bromate	$\mu\text{g/litre}$ by ion chromatography with suppressed conductivity detection; 0.2 $\mu\text{g/litre}$ by 1.5 ion chromatography with UV/visible absorbance detection; 0.3 $\mu\text{g/litre}$ by ion chromatog- raphy with detection by ICP/MS (WHO 2011 (mg/L by ion chromatography with conductivity detection (NHMRC 2004 0.005
Bromide	(Refer to Standard Methods (APHA 2005
*Cadmium	$(\mu\text{g/litre}$ by ICP/MS; $2 \mu\text{g/litre}$ by FAAS (WHO 2011 0.01 (mg/L by graphite furnace atomic absorption spectroscopy (NHMRC 2004 0.0002
*Chromium	$(\mu\text{g/litre}$ for total chromium by AAS (WHO 2011 0.2–0.05 mg/L by inductively coupled plasma emission spectroscopy or graphite furnace 0.01 atomic absorption spectroscopy or 0.005 mg/L by colorimetric method using diphenylcar- bizide (NHMRC 2004
Chlorate	$\mu\text{g/litre}$ by ion chromatography with suppressed conductivity detection for chlorate 5
Chlorite	(Refer to Standard Methods (APHA 2005
*Chlorine	$\mu\text{g/litre}$ following pre-column derivatization to 4-bromoacetanilide by HPLC; 10 $\mu\text{g/}$ 0.01 (litre as free chlorine by colorimetry; 0.2 mg/litre by ion chromatography (WHO 2011 (mg/L by DPD ferrous titrimetric method (NHMRC 2004 0.1
*Copper	$\mu\text{g/litre}$ by ICP/MS; 0.3 $\mu\text{g/litre}$ by ICP/optical emission spectroscopy; 0.5 $\mu\text{g/}$ 0.1–0.02 (litre by FAAS (WHO 2011 mg/L by coupled plasma emission spectroscopy, 0.05 mg/L for flame atomic ab- 0.01 sorption spectroscopy or 0.005 mg/L for graphite furnace atomic absorption spectroscop- y (NHMRC 2004
*Fluoride	mg/litre by ion chromatography; 0.1 mg/litre by ion- selective electrodes or the 0.01 SPADNS (sulfo phenyl azo dihydroxy naphthalene disulfonic acid) colorimetric method (WHO 2011
*Lead	$\mu\text{g/litre}$ by AAS (WHO 2011) or 0.005 mg/L graphite furnace atomic absorption 1 (spectroscopy (NHMRC 2004
*Manganese	$\mu\text{g/litre}$ by AAS; 0.05 $\mu\text{g/litre}$ by ICP/MS; 0.5 $\mu\text{g/litre}$ by ICP/optical emission 0.01 (spectroscopy; 1 $\mu\text{g/litre}$ by EAAS; 10 $\mu\text{g/litre}$ by FAAS (WHO 2011 mg/L for inductively coupled plasma emission spectroscopy or 0.001 mg/L for 0.005 (graphite furnace atomic absorption spectroscopy (NHMRC 2004
Mercury	$(\mu\text{g/litre}$ by cold vapour AAS; 0.6 $\mu\text{g/litre}$ by ICP; 5 $\mu\text{g/litre}$ by FAAS (WHO 2011 0.05 (mg/L for cold vapour atomic absorption method (NHMRC 2004 0.00001
*Nickel	$(\mu\text{g/litre}$ by ICP-MS; 0.5 $\mu\text{g/litre}$ by FAAS; 10 $\mu\text{g/litre}$ by ICP-AES (WHO 2011 0.1 mg/L using inductively coupled plasma emission spectroscopy or 0.005 mg/L using 0.02 (graphite furnace atomic absorption spectroscopy (NHMRC 2004

Parameter	Limit of Detection / Method
Nitrate* as NO ₃	mg/litre (nitrate) and 0.05 mg/litre (nitrite) by liquid chromatography; 0.01–1 mg/litre 0.1 (nitrate) by spectrometric techniques; 0.005–0.01 mg/litre (nitrite) by a molecular absorption spectrometric method; 22 µg/litre (nitrate) and 35 µg/litre (nitrite) by ion chromatography (WHO 2011) Molecular absorption spectrophotometric method, Colourimetric method (GSO (379/1994) mg/L using the colorimetric method following reduction of nitrate to nitrite using a 0.01 (cadmium column (NHMRC 2004
Nitrite* as NO ₂	See Nitrate
PAHs	µg/litre by GC/MS and reverse-phase HPLC with a fluorescence detector (WHO 0.01 (2011 ng/L using gas chromatography and mass spectrometry or 50 ng/L using liquid chromatography with spectrofluorometric detection (NHMRC 2004
Petroleum Hydrocarbons	(Refer to Standard Methods (APHA 2005
(THMs (general	µg/litre (method detection limits) by purge-and-trap and liquid–liquid extraction 0.2–0.1 and direct aqueous injection in combination with a chromatographic system; 0.1 µg/litre (by GC with ECD; 2.2 µg/ litre by GC/MS (WHO 2011 (ng/L using gas chromatography with electron capture detection (NHMRC 2004 20
TOC	(Refer to Standard Methods (APHA 2005
Xylene	(µg/litre by GC/MS; 1 µg/litre by GC with FID (WHO 2011 0.1 (mg/L using gas chromatography with photoionization detection (NHMRC 2004 0.001
**E. coli	(Refer to Standard Methods (APHA 2005
** Total Coliforms	(Refer to Standard Methods (APHA 2005
Radionuclides: (Total activity of alpha and (beta rays	Coprecipitation (suitable for higher TDS water). Refer to Standard Methods (APHA (2005) and NHMRC (2004: Section 10.4

indicates that KAHRAMAA already test for these parameters. # Note that KAHRAMAA currently use IDEXX * .Colilert™ for these analyses

NB: AAS – Atomic Absorption Spectrometry, AES – Atomic Emission Spectrometry, EAAS – Electrothermal Atomic Absorption Spectrometry, ECD – Electron Capture Detector, FAAS – Flame Atomic Absorption Spectrometry, GC – Gas Chromatography, HPLC – High Performance Liquid Chromatography, ICP – Inductively Coupled .(Plasma, MS – Mass Spectrometry. For other parameters, refer to Standard Methods (APHA 2005

Table 10. Methods and Detection Limits – Aesthetics and other factor

Parameter	Limit of Detection / Method
*Turbidity	(NTU (NHMRC 2004) Visual Method, Nephelometric method (GSO 112/1989 0.1
*Hardness	(Refer to Standard Methods (APHA 2005
*Colour	Determination of colour with visual comparison method or using platinum-cobalt ((GSO 112/1989
TDS/Electrical *Conductivity	(Refer to Standard Methods (APHA 2005
*pH	(Refer to Standard Methods (APHA 2005
*Temperature	(Refer to Standard Methods (APHA 2005
*Taste and Odour	(Refer to Standard Methods (APHA 2005
Copper	$\mu\text{g/litre}$ by ICP/MS; 0.3 $\mu\text{g/litre}$ by ICP/optical emission spectroscopy; 0.1–0.02 (0.5 $\mu\text{g/litre}$ by FAAS (WHO 2011 mg/L by inductively coupled plasma emission spectroscopy, 0.05 mg/L by 0.01 flame atomic absorption spectroscopy or 0.005 mg/L by graphite furnace atomic (absorption spectroscopy (NHMRC 2004
Hydrogen Sulphide	(Electric conductivity measurement method, Methyl Blue Method (GSO 379/1994 mg/L determined using the methylene blue colrimetric method (NHMRC 0.02 (2004
*Iron	mg/L by inductively coupled plasma emission spectroscopy, 0.005 mg/L by 0.01 (graphite absorption spectroscopy (NHMRC 2004
*Manganese	$\mu\text{g/litre}$ by AAS; 0.05 $\mu\text{g/litre}$ by ICP/MS; 0.5 $\mu\text{g/litre}$ by ICP/optical emission 0.01 (spectroscopy; 1 $\mu\text{g/litre}$ by EAAS; 10 $\mu\text{g/litre}$ by FAAS (WHO 2011 mg/L for graphite furnace atomic absorption spectroscopy or 0.005 mg/L 0.001 (for coupled plasma emission spectroscopy (NHMRC 2004
*Zinc	mg/L by flame atomic absorption spectroscopy or inductively coupled plas- 0.02 (ma emission spectroscopy (NHMRC 2004
*Ammonia	mg/L by phenate colorimetric method (APHA 4500-NH ₃ Parts D and H,1992) 0.02 ((NHMRC 2004
*Chloride	mg/L by ion chromatography or 1 mg/L by titrimetric techniques (NHMRC 0.1 (2004
*Chlorine	$\mu\text{g/litre}$ following pre-column derivatization to 4-bromoacetanilide by HPLC; 0.01 10 $\mu\text{g/litre}$ as free chlorine by colorimetry; 0.2 mg/litre by ion chromatography ((WHO 2011 (mg/L using DPD ferrous titrimetric method (NHMRC 2004 0.1
*Sodium	Less than 0.1 mg/L by FAAS, inductively coupled emission spectroscopy or flame (emission spectroscopy (NHMRC 2004
*Sulphate	(mg/L by methythymol blue or 1 mg/L by ion chromatography (NHMRC 2004 0.1
KAHRAMAA already test for these parameters. NB: AAS – Atomic Absorption Spectrometry, AES – * Atomic Emission Spectrometry, EAAS – Electrothermal Atomic Absorption Spectrometry, ECD – Electron Capture Detector, FAAS – Flame Atomic Absorption Spectrometry, GC – Gas Chromatography, HPLC – High Performance Liquid Chromatography, ICP – Inductively Coupled Plasma, MS – Mass (Spectrometry. For other parameters, refer to Standard Methods (APHA 2005	

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Abbreviation used

APHA: American Public Health Association

USEPA: United States Environmental Protection Agency

WHO: World Health Organization

NHMRC : National Health & Medical Research Council (Australia).

GSO: Gulf Standardization Organization.

THM's: Trihalomethanes.

GHD: Australian Consultancy Company.

IARC: International Atomic Research Center





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Qatar General Electricity & Water Corporation

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