QUALITY CONTROL OF POTABLE WATER SUPPLIES FROM SWCC'S MULTISTAGE FLASH EVAPORATION PLANTS IN THE EASTERN PROVINCE AND RIYADH AREA.[1]

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ABSTRACT

A study was conducted to determine the water quality parameters in the desalination derived drinking water supplied by Saline Water Conversion Corporation of Saudi Arabia in the Eastern Province and Riyadh areas. Ten important cities and communities were selected for evaluation of parameters of health significance: cyanide, fluoride, nitrate, arsenic, cadmium, chromium, lead, mercury, selenium, total organic carbon, trihalomethanes, chloroform, total coliform bacteria and faecal coliform bacteria and aesthetic significance: temperature, colour, turbidity, conductivity, pH, TDS, total hardness, chloride residual chlorine, sulfate, calcium, magnesium, sodium, aluminium, copper, iron, manganese and zinc. The blended water samples were collected and analysed for above mentioned parameters over a period of six months.

It appears from the results of these studies that the concentrations of all inorganic parameters except fluoride are well within the limits of WHO and SASO specified guidelines. The fluoride ion remain deficient in all the samples. None of the samples tested positive for coliform or faceal coliform bacteria. Total organics, chloroform and trichloromethanes were either absent or if present in negligible amounts.

Al-Khafji was the only city which is not served with the blended water due to absence of good quality ground water. A method has been suggested to upgrade the mineral contents of the Khafji's drinking water quality at par with the other cities.

INTRODUCTION

Regular monitoring of water quality parameters has been proposed by international organizations like WHO. It is important to assess these parameters in order to maintain the quality of drinking water. Many standards, both international and national, are available now. These standards recommend maximum permissible limits on several water quality parameters in order to avoid any adverse effect on the health of the population consuming the water.

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It is by now an established fact that the tremendous industrial growth witnessed during the past decades has caused serious environmental pollution throughout the world. Air and water get contaminated with several harmful materials continuously discharged from the industries. Majority of these contaminants end up with drinking water sources seriously affecting human health. Consequently regular monitoring of the drinking water quality has become essential more than ever before.

depending on sea water desalination as the main source of drinking water. The most widely used sea water desalination processes are the multistage flash distillation (MSF) and the reverse osmosis (RO). Both these methods are known to produce good quality product water during the process eliminating the harmful materials present in sea water. The product water obtained from the desalination plants are generally subjected to some post treatment processes such as:

a) Adjustment of pH by controlled CO_2 and lime dosing etc. in order to make the water non-corrosive to the storage tanks and water carrying pipings,

b) disinfection to destroy micro-organisms so as to make water safe and hygienic for human consumption, and

c) in the case of the distillates from the MSF plants, blending with good quality brackish well water to upgrade the mineral contents.

Various post - treatment processes could cause contamination of the finished water from undesirable constituents. For instance, it has been established that disinfection of drinking water by chlorination produces compounds such as chloroform and other trihalomethanes, which are suspected to be carcinogenics in small concentrations. Similarly, mixing of brackish water with the distillates also might bring in the contaminants originally present in the former to the finished potable water. Such possibilities make it essential to monitor all parameters of importance to human health on a regular basis.

Several parameters such as pH, total dissolved solids, electrical conductivity, hardness, alkalinity, chloride, residual chlorine, coliform bacteria and especially faecal coliform bacteria are determined on a routine basis, once per day or per shift, in the process control laboratories attached to the potable water blending stations. All these are relatively easy to monitor. However, most chemical parameters such as heavy metals, total organic carbon, various halogenated hydrocarbons etc. can not be regularly measured in such process control laboratories. In addition to physical, chemical and biological parameters, organoleptic parameters like colour, taste, and odour etc. also must be monitored. These are also important, since, in assessing the quality of drinking water, the ordinary consumer relies up on his senses and evaluate the quality and acceptability on these criteria.

In 1984 World Health Organization (WHO) revived its 1971 recommendations on the maximum permissible levels of various water quality parameters and, instead, specified guideline values for several constituents of health and aesthetic importance. According to WHO the primary aim of setting such guidelines is the "protection of public health and thus the elimination, or reduction to a minimum, of constituents of water that are known to be hazardous to the health and well being of the community"(l).

The Kingdom of Saudi Arabia has realized the potential of desalination as a source of drinking water ever since the first desalination plant was set up in 1928 based on MSF technology. The Kingdom's desalination capability has increased several folds during the last decade. The cities like Riyadh, Jeddah, Dammam, Khobar, Makkah, Taif and Madinah and other smaller cities and communities throughout the kingdom, are now thriving on desalinated water to meet the drinking water requirements. The Kingdom presently has an installed capacity of 550 million gallons of desalinated water per day from the all operating plants at three locations along the Arabian Gulf and more than twenty along Red Sea coasts. With such wide spread consumption of desalination-derived water through out the Kingdom, it becomes essential and more important to measure the water quality parameters to ensure that the water consumed by the population is healthy and safe. However, it is beyond the capability of the individual laboratories attached to each desalination facility to undertake such a tedious job on a routine basis. It is due to this reason that the SWCC's Research and Development Center decided, in 1989, to undertake a study on the various water quality parameters of health and aesthetic importance. However, this study was confined to the Eastern Province and Riyadh areas. Several samples, collected from the distribution points of desalinated water which are served by the 3 MSF desalination plants (Al-Khobar, Al-Jubail and Al-Khafji) located along the Arabian Gulf coast were evaluated.

The areas in the Western Province of the Kingdom were not included in the present studies due to the difficulties involved in the collection and transportation of the samples to the Research Center laboratories located at Al-Jubail without violating the sampling and preservation techniques required by US Environmental Protection Agency, American Water Works Association and Water Pollution Control Federation.

The present study covers 10 important cities and communities stretched from Al-Khobar to Al-Khafji and the city of Riyadh which is situated at 450 kms. to the south - west of Al- Jubail. Replicate samples from pre-selected sampling points were collected over a period of five months (April-Aug. 1989) with regular intervals. All parameters were determined according to well established procedures. The parameters determined were divided into two categories, i.e. (1) constituents of health significance and (2) constituents of aesthetic significance. These parameters cover the most important of those listed under WHO guidelines, except the organic constituents of health significance. The latter group of compounds includes 18 priority pollutants whose guideline values were recommended by WHO in 1984. These compounds were not determined during the present studies since they were monitored in several desalinated water samples from Eastern Province plants in a previous study carried out in our laboratories (2). Since none of these compounds except

trihalomethanes were found in detectable levels in any of the samples tested, and repetitions of theanalysis involve considerable work load, it was decided to exclude them from the present studies. However, chloroform and other trihalomethanes were determined in all samples due to their occurrence in chlorinated water and ease of determination.

EXPERIMENTAL

Chemicals and Glasswares

All chemicals used were either Analytical Grade "AR" or patents of Hach chemical company.

Nalgene brand Polyethylene bottles of 1L capacity were used to collect the samples for general analysis. The bottles were cleaned by soaking in 0.5% nitric acid overnight followed by washing with tap water and rinsing with deionised water. Separate 250 ml amber colored bottles were used to collect samples for microbiological and trihalomethanes analysis. Sodium thiosulphate was added into the bottles to quench the chlorine residual.

On reaching the laboratory small portions of the samples from the 1L bottles were separated and acidified to 0.5% in nitric acid for the analysis of metals by Atomic Absorption Spectrophotometry.

If the analysis were delayed the samples were preserved at $4^{o}C$. The stored samples were thermally equilibrated to room temperature before analysis.

Sampling and sample locations:

The sampling points were selected carefully so that the collected samples broadly represent the quality of the water reaching the consumer. Mostly the samples were collected from the discharge side of the pumps feeding the city distribution net works. Replicate samples from a total of 12 sampling points were collected from 10 locations. The locations and the sampling points are as detailed below:

(1) Al-Jubail Blending Station #I serving SWCC Housing Compound (Jubail BS #I), (2) Al-Jubail Blending Station #2, serving Al-Jubail Naval Base (Jubail BS #2), (3) Al-Jubail Blending Station #3, serving Al-Jubail city areas (Jubail BS #3), (4) Dammam city feeder (Dammam) (5) Al-Khobar city feeder (Khobar), (6) Rastanura city feeder (Rastanura), (7) Qatif city feeder (Qatif) (8) Al-Khafji feeder serving SWCC housing compound (Khafji SWCC compound), (9) Al-Khafji feeder serving the city areas (Khafji city tank) and (10) three storage tanks at Riyadh high point serving the city areas of Riyadh (Riyadh HPT Tank #I, Tank #2, Tank #3).

Analytical Procedures:

The parameters analysed and the methods are briefly described below:

1) Temperature: Sample temperatures were measured in the field using a mercury thermometer after flushing the line for 10 minutes.

2) Colour: The samples were filtered using a whatman No.1 filter paper and the absorption intensity of the filtrates were measured spectrophotometrically at 450 nm. (3) Blanks were measured with deionised water of less than 0.2 us/cm conductivity.

3) Turbidity: Turbidity was measured spectrophotometricaly at a wave length of 450 nm using formazine standards and expressed in formazine turbidity units (FTU) (4).

4) pH: A portable pH meter with temperature compensation capability was used to measure pH in the field while collecting the samples.

5) Total dissolved solids: Determined by dry-weight method (5).

6) Total hardness: Analysed by titrimetric method using EDTA and eriochrome black-T as indicator (6).

7) Chloride: Determined by titrimetric method using standard silver nitrate solution (7).

8) Chlorine residual: Chlorine residuals were analysed as soon as the samples were brought to the laboratory by DPD-Spectrophotometric method (8) at an absorption wave length of 525 nm.

9) Fluoride: Determined by fluoride ion-selective electrode (9) using standards in the range of 0.1 - 1.5 mg/L.

10) Nitrate: Nitrate was analysed spectrophotometricaly by Hach method using NitraVer-5 pillows (10)

11) Sulfate: Hach sulfaVer-4 sulfate reagent pillows were used to determine sulfate turbidimetrically at 450 nm (11).

12) Metal ions: Calcium (12), magnesium (13) and Sodium (14) ions were analysed by flame atomic absorption spectrophotometry. Trace concentrations of aluminium (15) cadmium (16) chromium (17), copper (18), iron (19), lead (20), manganese (21) and zinc (22) were determined by atomic absorption spectrophotometer using graphite tube atomizer (GTA). Mercury was analysed by cold vapor technique (23), while arsenic and selenium were determined by hydride generation method (24) by atomic absorption spectrophotometer.

Varian model AA 975 spectrophotometer, GTA-95 graphite tube atomizer and VGA-76 vapor generator assembly were used to make atomic absorption measurements.

13) Total Organic Carbon (TOC): TOC was analysed using a Beckman Industrial Model 915B TOC analyzer after removing the inorganic carbon compounds from the samples by acidification and helium sparging (25).

14) Chloroform and Total trihalomethanes (THMs): These species were determined by purge and trap technique as per USEPA method #624 (26). 5 ml water samples were purged with helium gas for 10 minutes using Tekmar model LSC-2 liquid sample concentrator. The trapped organics from the tenax column of the concentrator were desorbed and analysed gas chromatographically using Hewlett Packard GC-5880 installed with 63 Ni EC detector and DB-5 capillary column.

15) Total coliform and faecal coliform bacteria: Multiple tube method was used with McConkey broth to determine the most probable number (MPN) of coliform bacteria (27) EC broth was used for the confirmatory tests for coliform bacteria. Since none of the samples tested positive for faecal bacteria, the reliability of the method was occasionally tested with water samples collected from sewage treatment plant.

RESULTS AND DISCUSSION

In 1984 WHO has published the guideline values for several water quality parameters (1). These guidelines were intended to supersede both the "European standards for drinking water"(28) and "The International standards for drinking water (29) which had been in existence for more than a decade. The new guideline values are not to be considered as recommended standards but were intended for use by countries as a basis for the development of standards, which, if properly implemented, will ensure the safety of drinking water supplies (1). By doing so WHO appreciates the fact that it may not be possible for all countries to provide potable water that attains a recommended or standard set of water quality parameters. Nevertheless each country is expected to try to develop water quality standards as close as possible to the guideline values in an endeavour to protect public health.

The results of the present work on the monitoring of water quality parameters of the desalination - derived drinking water from the three MSF desalination plant in the Eastern Coast of Saudi Arabia are given in Tables 1 and 2. Parameters which are considered to have significant effect on the health of the population are grouped in Table 1, while the constituents of aesthetic importance are given in Table 2. This categorization has been done according to that of WHO guide lines. The last column of each table contains the guideline values set by WHO for the purpose of easy reference and comparison with the results of the present study.

Before reviewing the results a brief description of the quality of the product distillate generally obtained from MSF plants, and the post - treatment methods employed at each plant before distribution of the water for public consumption may be helpful. All three plants under this study are based on multistage flash evaporation process. The distillates obtained from these plants were specified not to have more than 25 ppm of total dissolved solids (TDS). During the past several years of the operational experience TDS of the distillates

from Al-Jubail and Al-Khafji plants seldom exceeded this limit though lately, there have been several instances of high TDS in the distillates of Al-Khobar plant. In Al-Jubail plant the combined distillates are disinfected with chlorine gas and then treated with CO_2/lime dosing. Both at Al-Khafji and Al-khobar plants chlorination is done by the addition of sodium hypochlorite from sea water electrolysers. pH is adjusted by CO_2/lime dosing in Al-Khobar. The pretreated distillates from Al-Jubail and Al-Khobar plants are blended with good quality brackish well water to upgrade the mineral contents in several blending station facilities located near the respective distribution centers. Al-Khafji does not have blending facility due to the absence of good quality ground water nearby. The potable water available from all these facilities are constantly monitored for residual chlorine, which is controlled between 0.2 - 0.5 ppm, and pH in order to make it safe for human consumption and non-corrosive to equipments and pipings.

Various constituents present in desalination derived potable water thus may originate from several sources such as carry over in the product dististillates from the plant, treatment chemicals such as CO_2, lime, chlorine/hypochlorite constituents from the brackish water used for blending, contamination from or reaction products of water carrying equipments or treatment chemicals etc. A periodic assessment of the quality of the potable water thus becomes essential to ensure its safety for human consumption.

The parameters which are considered to be toxic or have some adverse effects on human health are listed in Table 1. This table contains nine health related inorganic constituents besides organic and microbiological parameters monitored during this study. In general it can be seen that none of the samples tested during the period of this study exceeded the guideline values recommended for any of the parameters set by WHO. Cyanide, mercury and selenium were totally absent in all samples tested. Lead, cadmium and arsenic appeared in few samples, occasionally. However, their concentrations were found to be negligible than the WHO guideline values by an order of magnitude or more. Presence of chromium was more significant than other constituents. This is not surprising since traces of chromium may leach into water from the stainless steel parts extensively used in the plant. The concentrations detected are much lower than the guideline values. Though chromium is well known for its toxicity, traces of chromium intake is considered necessary according to some researches due to its beneficial effects on glucose metabolism. Nitrate varied from 0 - 2.04 and is considerably less than the guide line value of 10 ppm.

Among the other inorganic constituents the concentrations of fluoride (F-) in drinking water samples require special mentioning. There is no conclusive evidence to indicate that fluoride is an essential ion for human nutrition. Extensive studies conducted in U.S., Europe and several other countries indicate that there is some correlation between dental health and fluoride content in drinking water. In general the data indicate that water containing fluoride upto an optimal concentration of 1.5 ppm reduces dental caries especially among children while higher concentrations result in mottling of teeth and dental fluorosis (30). The concentration of fluoride found in various samples analysed during the present study varied from Nil in Al-Khafji to 0.13 mg/L in Qatif

(Table 1). The literature data indicate that such low concentrations in drinking water may cause higher incidences of dental caries among children. Artificial fluoridation of the desalinated water might be a solution if abnormal incidences of dental caries is detected among population consuming this water. But before taking a decision on this matter base line data on dental health, food habits etc. should be collected on some selected communities and the effects of fluoridation should be tested for a considerable period of time. Various aspects related to the fluoridation of desalinated drinking water in Saudi Arabia have already been discussed (30).

Total organic carbon (TOC) has not been considered to be of health significance by WHO. Since high level of TOC is generally considered to be indicative of organic pollutants this, parameter was determined in all samples and was found to be negligibly small.

Among the various organic pollutant whose guideline values have been recommended by WHO only chloroform and total trihatomethanes (THMs) were covered during the present study for reasons explained before. The guideline value for chloroform is 30 ug/L while the concentrations found in all samples except at Al-Khafji were considerably less than 0.1 ug/L. At Al-Khafji the chloroform level was slightly higher (0.91 ug/L). Though WHO did not propose a guideline value for THMs many other organizations such as US Environmental Protection Agency, GCC countries etc. have set maximum permissible levels for this class of compounds (US EPA = 100 ug/L, GCC = 200 ug/L). Compared to these high set values the concentrations between 3 - 12 ug/L found in the samples tested during this study are quite negligible. A detailed evaluation of the problem of THMs in desalinated water is reported elsewhere (31).

All samples tested for microbiological quality indicated the absence of coliform organisms. This may be due to the strict adherence to the disinfection procedures at various stages of the water production by the concerned agencies. In all the localities selected for this study disinfection is done by chlorination by dosing sodium hypochlorite or chlorine gas. The residual chlorine in the finished water is normally controlled between 0.2 - 0.5 mg/L.

Water quality parameters related to aesthetic and organoleptic aspects are presented in Table 2 WHO did not recommend any guideline values for some of the parameters in this table, however, they are included here since some of them are routinely monitored in the chemical control laboratories attached to each desalination or blending station facilities and may be helpful for future reference.

Many substances which affect the taste and colour are commonly found in water although they are scantly found at toxic levels. The guideline values of the parameters listed in this table as recommended by WHO are based more on their possible impact on the aesthetic quality of the water than their health effects. It is quite obvious from the results that parameters monitored in several samples from various sampling points were within the WHO guideline values except pH of the water samples in Al-Khafji plant where it is not properly adjusted by lime/CO_2 dosing. One of the main objectives in controlling pH is to minimize corrosion damage to the distribution system. At Al-Khafji most of the water carrying systems from the SWCC plant up to the main storage tank

in the city are either organic coated or made of fiberglass. Near absence of metallic impurities such as iron, copper, chromium or lead in Al-Khafji samples also indicate this. pH levels of less than 7 is known to cause severe corrosion and leach these ions into water provided the distribution system is made of metals or alloys. According to WHO (1) the acceptable range of pH may be broader than the recommended guideline value of 6.5 - 8.5 if the corrosion aspect is excluded.

The temperature of all samples are comparatively high since they were collected during summer months. No guideline value is recommended for the temperature since it is impracticable to control it in the distribution system. Other physical factors such as colour and turbidity are well within the guidelines.

Since total dissolved solids (TDS) and hardness are two of the most important parameters they need to be elaborated in detail. In most of the desalination plants based on evaporation process blending with good quality brackish water is normally practised in order to upgrade the mineral contents, increase the palatability of the potable water and render it less aggressive to the distribution system. Water from all locations, except from Al-Khafji, contains significant levels of TDS and hardness.

Extensive studies were carried out in the past to correlate high incidences of cardiovascular (CV) diseases with the hardness of drinking water (32). Though the results of these studies indicated a negative correlation between CV diseases and water hardness, an expert group on the health aspects of long term use of desalinated water, suggested in 1985 (33) that the evidence so far available does not justify introducing at the present time specific water treatment such as hardening aimed at reducing the risk of CV disease. However, it is well known that certain parameters like TDS, alkalinity, pH and hardness etc. play important role in influencing the CO_2 carbonate - bicarbonate equilibrium in water. This equilibria has direct bearing on the corrosive nature of water.. It is necessary to have certain optimum concentrations of hardness and alkalinity in order to keep the saturation index (Langelier's Index) positive to avoid corrosion of the water carrying equipments. Considering all these aspects some Australian (34) and Russian (35) researchers have proposed optimal levels for some parameters (Table 3). It is interesting to note that all blended water samples tested in the present study fall within the suggested range. The only exception is the samples from Al-Khafji area. Blending is not practised in this plant due to non-availability of good quality ground water. As an alternative, SWCC may consider to blend the distillates with filtered and sterilized seawater which is a cheap remineralisation procedure that can produce water similar to that produced by a traditional reverse osmosis plant (33).

Water from a beach-well could be even a better choice for this purpose. The distillate can be pre-treated with lime/CO_2 dosing to increase the calcium and alkalinity levels to the minimum concentrations as per Table 3. These treatments would improve the water quality of Al-Khafji like those of other SWCC plants.

CONCLUSIONS

The present study indicates that the desalination - derived drinking water originating from the three sea water MSF plants in the Eastern Coast of Saudi Arabia meet all specifications with respect to various health related and aesthetically important water quality parameters with reference to 1984 WHO guideline values. It is particularly important to note that none of the samples collected during this period from various locations tested positive to pathogenic bacteria (faecal or general coliform) or any other parameters known to be toxic for human consumption. All inorganic parameters were well within the WHO guidelines values and among the organics tested chloroform and trihalo- methanes concentrations were either zero or extremely low.

The absence of good quality ground water has compelled water authorities to distribute treated distillate without blending in Al-Khafji area. A method has been suggested to upgrade the mineral contents of this water in order to improve its quality at par with the water from other SWCC plants.

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TABLE -1

WATER CONSTITUENTS OF HEALTH SIGNIFICANCE

Samp.Loc. Const	1	2	3	4	5	6	7	8	9	10	11	12	WHO G.V
INORGANIC													
CN^-,mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.1
F^-,mg/L	0.1	0.1	0.1	0.1	0.1	0.0	0.1	ND	ND	0.1	0.1	0.1	1.5
NO_2^-,mg/L (N)	0.4	1.1	0.4	0.8	ND	0.1	2.0	ND	ND	0.3	0.4	1.1	10
AS,ug/L	ND	0.1	0.08	ND	0.08	0.03	ND	NA	ND	ND	ND	ND	50
Cd,ug/L	0.01	0.42	ND	0.04	ND	ND	0.04	ND	ND	ND	ND	ND	5
Cr,ug/L	5.7	12.8	4.7	4.3	9.1	6.5	8	16	16	4.4	4.1	3	50
Pb,ug/L	1.0	ND	ND	ND	ND	ND	ND	ND	ND	0.1	ND	ND	50
Hg,ug/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	1.0
Sc,=ug/L	ND	ND	ND	ND	ND	0.1	ND	ND	ND	ND	ND	ND	10
ORGANIC													
TOC,ug/L	30	10	15	70	ND	250	80	ND	NA	ND	25	ND	NG
THMs,ug/L	4.1	3.0	4.0	11	8.5	12	9.9	4.4	NA	4	4.3	4.5	NG
CF,ug/L	0.0	ND	0.0	0.0	0.01	0.0	0.9	0.9	NA	ND	ND	ND	30
M.BIOLOG.													
T.Cliform No./100ml	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0
F.ColiformNo./ 100ml	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0

CF= Chloroform, NA= Not analysed, ND= Not detected, NG= No guidelines value set
GV= Guidelines Values.

1= Jubail BS#1, 2= Jubail BS#2, 3= Jubail BS#3, 4= Dammam, 5= Khobar,
6= Rastanura, 7= Qatif, 8= Khafji(SWCC), 9= Khafji (City),10= Riyadh HPT Tank#1
11= Riyadh HPT Tank#2, 12= Riyadh HPT Tank#3

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TABLE - 2

WATER CONSTITUENTS OF AESTHETIC SIGNIFICANCE

Samp.Loc. Const	1	2	3	4	5	6	7	8	9	10	11	12	WHO G.V
Color,TCU	0.3	ND	5	ND	ND	5	5	ND	ND	ND	ND	6.7	15
Turb.,FTU	0.5	ND	3.3	ND	1	ND	1.3	ND	ND	ND	ND	ND	5
Conductivi-ty us/cm	553	512	529		561	283	696	3	32	357	373	396	NG
pH	7.9	8.3	8.0	8.5	8.5	9.0	8.1	5.7	6.3	8.3	8.3	8.2	6.5 8.5
TDS,mg/L	298	350	318	201	308	140	410	ND	<10	221	229	245	1000
T.H,mg/L ($CaCO_3$	151	127	127	74	108	56	158	ND	ND	123	130	133	500
Cl^-,mg/L	100	99	117	100	131	68	149	ND	ND	43	44	44	250
Cl_2 R, mg/L	0.23	0.24	0.26	0.7	0.4	0.38	0.7	0.5	0.5	0.7	0.7	0.7	NG
S04,mg/L	60	58	47	21	35	11	70	ND	5	69	75	72	400
Ca,mg/L	40	32	35	20	27	13	40	ND	2	37	37	38	NG
Mg,mg/L	12	13	10	7	10	6	14	ND	ND	7	10	10	NG
Na,mg/L	46	41	52	47	63	34	75	ND	ND	22	24	25	200
Al,ug/L	4	ND	1.47	0.06	0.4	1.3	0.09	ND	1.76	ND	1.4	11.4	200
Cu,ug/L	11	6.7	9.9	12	27	11	13.4	40.1	17.3	7.9	8.1	10	1000
Fe,ug/L	43	69	31	24	22	7.6	14.5	11.1	59	19.04	20	33	300
Mn,ug/L	1.7	1.5	2.3	1.4	0.56	0.43	0.82	0.74	1	0.5	0.32	3.77	100
Zn,ug/L	1.75	ND	0.7	0.5	0.8	17	ND	2	1.5	ND	ND	ND	5000

R=Residual, N.G= No guideline Value Set, TH= Total Hardness,
ND= Not detected, GV= Guidelines Value

1= Jubail BS#1, 2= Jubail BS#2, 3= Jubail BS#3, 4= Dammam, 5= Khobar,
6= Rastanura, 7= Qatif, 8= Khafji(SWCC), 9= Khafji (City),10= Riyadh HPT Tank#1
11= Riyadh HPT Tank#2, 12= Riyadh HPT Tank#3

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TABLE 3

DESALINATED DRINKING WATER QUALITY
[SUGGESTED RANGES FOR SOME PARAMETERS]

Parameter	Suggested Cont.* (Australian)	Russian Proposal*
TDS	200-400 mg/L	TDS 200-400 mg/L
Cl^-	150 mg/L	Alkalinity 30-400 mg/L as HCO_3
Na	100 mg/L	Na 200 mg/L
Ca	50-75 mg/L	Min.Ca 30 mg/L
Hardness	8-20 French Degree	Min. Hardness 75 mg/L
Mg	10 mg/L	
Fe	0.25 mg/L	
	*Ref. 34	** Ref.35

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