Desalination and Water Treatment
www.deswater.com

51 (2013) 1936–1940
February

Taylor & Francis
Taylor & Francis Group

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doi: 10.1080/19443994.2012.714737

Chemical analysis of distilled water: a case study

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Received 5 March 2012; Accepted 18 July 2012

ABSTRACT

This paper is highly concerned with analytical chemical results which are obtained at Doha West Power Station in Kuwait and summarizes the various chemical techniques that carried out at laboratory to emphasize the quality of distilled water through distillation process of the station such as; pH, specific conductivity, iron, copper, silica, total hardness, and chloride during operation.

Keywords: Chemical analysis; Laboratory; Distillation; Water quality

1. Introduction

Kuwait is considered one of the leading countries in the production of fresh water from seawater with the multistage flash (MSF) technology in the Arabian Gulf. The first commercial MSF unit installed was 55 years ago at Shuwaikh near Kuwait's harbor. The plant consisted of four units, each with a production capacity of 0.5 MIGPD.

These days the total water production in Kuwait is equal to 440.6 MIGPD with seven desalination power plants. Doha West Station is the largest desalination and power generation plant in Kuwait. It includes 16 MSF distillers. The total operating capacity of Doha West units is producing 110.4 MIGPD or 38.5% out of the total desalination capacity in Kuwait. The Doha West units were commissioned in (1983–1984) by Reggiane of Italy (4 units) with a capacity of six MIGPD each and in (1984–1985) by Sasakura of Japan (12 units) with a capacity of 7.2 MIGPD each [1].

Doha West Power Station (DWPS) is located on the Arabian Gulf near Doha's harbor, as shown in Fig. 1. The selected site for the DWPS is located at:

47° 48´ longitude East,
29° 22´ latitude North.

This is at the end of the Ashayrig peninsula, on the west side of the access road to the harbor of Doha.

2. Chemical analysis

One of the most important factors to judge any successful distillation process is the continuous following up of water quality by chemical analysis. This paper presents the routine chemical techniques, which are used at DWPS in Kuwait. These routine techniques are carried out at laboratory of DWPS to specify the quality of distilled water through distillation process of the station. Analysis of iron, copper, silica,

Presented at the International Conference on Desalination for the Environment, Clean Water and Energy, European Desalination Society, 23–26 April 2012, Barcelona, Spain

and chloride in distilled water is carried out using Varian DMS100 Spectrophotometer as follows:

Iron — Is detected by 2, 4, 6—tri(2-pyridyl)-S-triazine (TPTZ) method, where the iron is dissolved by thioglycollic acid (5 min boiling) and ferrous ions react with TPTZ to form violet complex which is measured at wavelength (588 nm) using optical cylindrical cell quartz of path length (5 cm) and low-range calibration graph range (0–0.1 ppm)

Copper — Is detected by zinc dibenzyldithiocarbamate method, where copper is extracted in the acidified sample as its dibenzyldithio carbamate complex into carbon tetra chloride, copper concentration is measured at wavelength (438 nm) using optical rectangular cell quartz of 1 cm path length and low-range calibration graph range (0–0.1 ppm)

Silica — Is detected by metol method, where the yellow silicomolybdate is first formed and oxalic acid is added to eliminate the phosphate interference. Silicomolybdate is reduced by metol to give molybdenum blue, which is measured at (720 nm) using optical cylindrical cell quartz of (5 cm) path length

Chloride — Is detected by mercuric thiocyanate method where the chloride ion reacts with mercuric thiocyanate releasing the thiocyanate ion which combines with ferric ion to form red ferric thiocyanate—the intensity of its color is proportional to the concentration of chloride ion and measured at wavelength (460 nm) using optical cylindrical cell quartz of (5 cm) path length

3. Residual chlorine

Residual chlorine in sea water is monitored daily in the intake area where the sodium hypochlorite is produced from seawater Fig. 2. It is measured by N,N-diethyl-p-phenylene diamine (Lovibond-palin DPD1 tablets) using Lovibond comparator 2,000 fitted with glass cells with a rubber stopper 13.5 mm/10 ml type DB424 and standard disks (3/40A) of range (0.1–1.0 ppm free chlorine) and (3/40B) of range (0.2–4.0 ppm free chlorine) which is considered as simple and a very good method. An example of daily residual chlorine readings of distillation is shown in Tables 1 and 2 and an example of seawater intake area specifications is shown in Table 3.

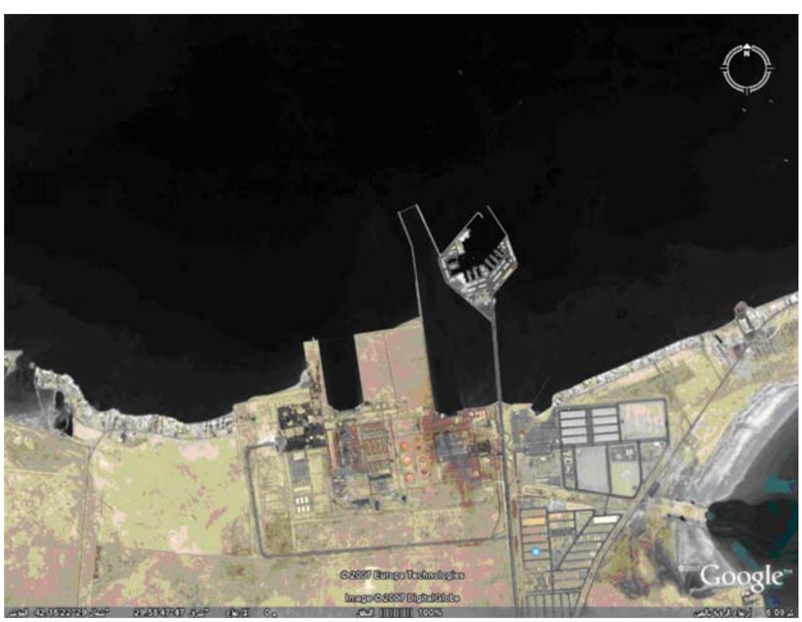

Fig. 1. Satellite view of the DWPS.

Fig. 2. Seawater intake area of DWPS.

4. Ammonia

Ammonia would be present in distillate water if seawater feed to the plant is polluted with organic materials. Also where brine heaters are vented to the first stage, ammonia will be present from decomposition of boiler treatment compound hydrazine. Hydrazine concentration in the feedwater tanks of all operating boilers are restricted to be in the range of (0.1–0.2) ppm to achieve boiler drum water pH in the range of (9.0–9.2) and ammonia concentration in the steam always <1.0 ppm.

Ammonia in seawater is determined in laboratory based on standard methods for the examination of water and wastewater by Leonore S. Clesceri. Ammonia in distillate water will be checked if the pH of the distillate water exceeds pH = 7.0.

Table 1
Seawater intake area

	Bay 1	Bay 2	Bay 3	Bay 4
Bar screen	0.6/1.0	0.7/1.0	1.5/2.0	0.7/1.5
Settling chamber	0.9	0.85	0.9	0.8
Common chamber	0.6/0.85	0.8/0.2	0.7/0.2	0.6/0.7

5. Dissolved oxygen

Dissolved oxygen of seawater at de-aerator in the distiller is determined in the laboratory by Winkler method as follow:

Manganese hydroxide produced by the reaction between manganese sulfate solution and alkaline potassium iodide is oxidized by the dissolved oxygen to manganese hydroxide, when the solution is acidified with sulfuric acid; iodine corresponding to the dissolved oxygen is liberated, which is determined by titration with (1/200)N sodium thio-sulfate using starch as an indicator.

$$2KOH + MnSO_4 \rightarrow Mn(OH)_2 + K_2SO_4 \quad (1)$$

$$2Mn(OH)_2 + \frac{1}{2}O_2 + H_2O \rightarrow 2Mn(OH)_3 \quad (2)$$

$$Mn(OH)_2 + \frac{1}{2}O_2 \rightarrow MnO(OH)_2 \quad (3)$$

$$2Mn(OH)_3 + 2KI + 3H_2SO_4 \rightarrow I_2 + 2MnSO_4 + K_2SO_4 + 6H_2O \quad (4)$$

Table 2
Residual chlorine in heat rejection sections of distillers

D1A	D1B	D2A	D2B	D3A	D3B	D4A	D4B	D5A	D5B	D6A	D6B	D7A	D7B	D8A	D8B
0.7	0.7	0.3	0.3	0.4	0.3	0.3	0.3	S/D	S/D	0.45	0.4	0.4	0.4	S/D	S/D

Table 3
Specifications of Seawater in DWPS intake area

Seawater temperature	17˚C
pH	8.2
Sp.K	63,900 μS/Cm
RCl_2	Nil
P Alkalinity	20 ppm as $CaCO_3$
M Alkalinity	145 ppm as $CaCO_3$
Ca^{2+}	496 ppm
Mg^{2+}	1,574 ppm
Cu	3.5 ppb
Fe	0.018 ppm
SiO_2	1.89 ppm
SO_4^{2-}	3,100 ppm
Cl^-	23,998 ppm
TDS at 180˚C	42,830 ppm

Table 4
An example indicates chloride ion analysis of distiller D3A

Time (h)	09:00	21:00	09:00
Seawater (ppm)	23,700	23,800	23,800
Brine recycle (ppm)	35,700	35,800	35,800
Brine blow-down (ppm)	39,100	39,100	39,200
Chloride ratio	1.506	1.504	1.504

$$MnO(OH)_2 + 2KI + 2H_2SO_4 \rightarrow I_2 + MnSO_4 + K_2SO_4 + 3H_2O \quad (5)$$

$$I_2 + 2NaS_2O_3 \rightarrow 2NaI + Na_2S_4O_6 \quad (6)$$

6. Concentration ratio

The operating condition is 1.5, it is determined in laboratory on the base of chloride concentration in Brine recycle and seawater. The daily results are adjusted when necessary by seawater make up flow rate of any distiller to get the concentration ratio target 1.5. Chloride concentration is determined by Mohr method, Table 4.

7. Distillate specific conductivity

Distillate specific conductivity could be determined by an online specific conductivity indicator in the control room which takes its signal from the local site analyzer and confirmed by a periodic routine checking within 24 h by shift chemist using practical portable specific conductivity meters (Myron L EP range 0.0–5,000 μs/cm) and the daily morning checking by laboratory using bench conductivity meter Orion model 124. Fig. 3, Tables 5 and 6 show specific conductivity readings which should be in a normal condition <10 μs/cm.

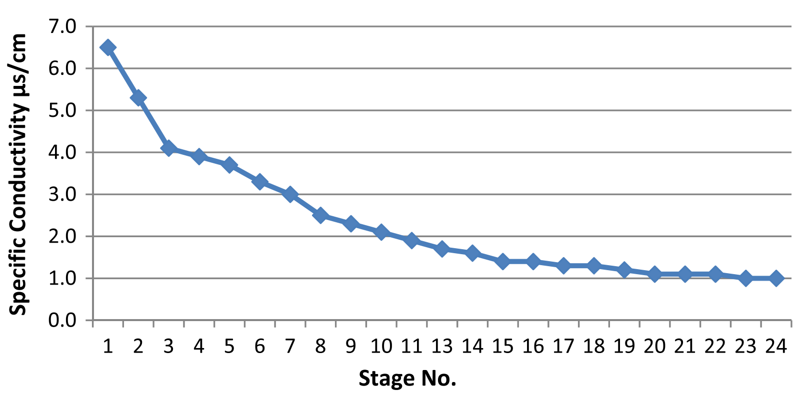

Fig. 3. D3A distiller stage by stage conductivity check using stage conductivity sensor.

Table 5
An example of daily distillate readings

Distiller	D3A	D3B	D4A	D4B	D5A	D5B	D6A	D6B	D7A	D7B	D8A	D8B
Specific conductivity μs/cm	6.2	5.5	1.1	1.1	9.3	6.2	3.8	4.0	1.7	1.5	1.2	1.2
pH	6.6	6.4	6.9	6.8	6.4	6.5	6.7	6.5	6.6	6.7	6.8	6.9

Table 6
An example of D4A distillate readings

pH	6.87
Sp.K μs/cm	1.1
Fe	2.4 ppb
Cu	3.4 ppb
SiO_2	5.6 ppb
Cl^-	0.113 ppm

High specific conductivity reasons were faced due to:

- Presence of ammonia in distilled water.
- Contamination due to some leakage from condensing tube bundles.
- Plant hydraulic instability due to transient phenomena.
- High brine levels inside stages due to miss orifices positioning onto misconception temperature profile.
- Increase in an antifoam dosing.
- Demister damage.

8. pH

The known pH definition is a measure of acidity or basicity of an aqueous solution. The required normal distilled water values of pH are in the range of (6.5–7.0); a low pH value for the distilled water (lower than 6.2) could mean insufficient CO_2 venting and it should be checked.

9. Conclusions

After 30 years of continuous operation, distillers are still working in an excellent condition and a very good quality of distillate water is still produced at DWPS; this is the result of a comprehensive maintenance program and a closely monitored operation.

Reference

[1] Government of Kuwait, Ministry of electricity & Water, Operation and Maintenance Manual for Doha West Distillation Plants, Sasakura Consortium, vol. 1, 1985.