Desalination and Water Treatment
www.deswater.com
doi: 10.1080/19443994.2014.1002990

55 (2015) 3519–3526
September

Taylor & Francis
Taylor & Francis Group

Quality considerations from integrating desalinated water into existing water infrastructure

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Received 16 April 2014; Accepted 4 December 2014

ABSTRACT

This paper presents Cyprus Water Development Departments '(WDD)' experience in relation to quality issues from the integration of desalinated water into existing water infrastructure. Desalination has been a part of a series of measures taken by Cyprus Government in an attempt to mitigate the shortage of the islands' intensely stressed water resources. Since the late 90s, desalinated water of various qualities has been introduced into existing water distribution systems as both finished and blend water. The desalinated waters' quality acceptance criteria were predetermined in accordance to the end use, national and local water quality standards and regulations, possible effects on distribution systems and the disinfection process being applied. Once full-scale operations were implemented, WDD's quality monitoring programs were revised to better monitor the probable effects on drinking water quality and distribution systems. The quality parameters were monitored before and after integration as well as in selected endpoints of the distribution system. Most adverse effects related to the effectiveness of the disinfection process and the waters' palatability. They were designated during the integration of the blend in the distribution system or during alternation between desalinated and treated surface water. In conclusion there is need for more quality parameters to be added in the quality monitoring program in order to enhance its effectiveness.

Keywords: Desalination; Cyprus; Water quality; Integration; Water infrastructure

1. Background

Cyprus is an island of the Eastern Mediterranean sea; as such, it has an intense Mediterranean climate, characterized by hot dry summers from mid-May to mid-September and rainy winters from November to mid-May. In the past centuries, the islands water resources depended heavily on rainfall. During the last three decades, the semi-arid conditions of the island deteriorated, due to an increase of the annual cumulative frequency of occurrence of low precipitation and drought, thus, limiting the availability of surface and ground water [1]. In addition, the uncontrolled and unsupervised subtraction of ground water until the early 60s caused a quantitative and qualitative deterioration of the islands' main water aquifers [2].

Presented at the Conference on Desalination for the Environment: Clean Water and Energy 11–15 May 2014, Limassol, Cyprus

The initial measures taken by Cyprus Government in an attempt to elevate some of the stress faced by the aquifers included the construction of numerous dams, part of Pafos Irrigation Project, Vasilikos—Pentaschoinos Project, Chrysochou Irrigation Project, Pitsilia Integrated Rural Development Project and the Southern Conveyor Project [3]. All these, inadvertently further increased the islands' dependency on precipitation. Unfortunately, after 15 years of operation it was calculated that the actual yields of the reservoir dams were approximately 30–35% lower than expected and groundwater yields approximately 10–15% less, thus proving inadequate to meet the steadily increasing water demand [2]. A measure of the stressed faced by the islands water resources is given by the water exploitation index, which according to the European Environment Agency, since 1993, exceeds 45% and is the highest among the European countries [4].

In the late 90s the Cyprus Government, in order to reduce the islands water recourses' dependency on precipitation, turned to desalination. The first desalination plant constructed was the Dekelia Desalination Plantin 1997, with an initial nominal capacity of 40,000 m^3/d, followed closely by Larnaca Desalination Plant with an initial nominal capacity of 52,000 m^3/d. Today, Cyprus has four desalination plants with a total capacity ranging from approximately 200,000–230,000 m^3/d is expected to increase to 250,000 m^3/d once Larnaca Desalination Plants' upgrade is completed (Table 1).

The task of overseeing the introduction of desalinated technology in Cyprus water balance was assigned to Cyprus Water Development Department (WDD) as the primary authority in water issues. Desalinated water had to be integrated into the existing water infrastructure, which, at the time, included three surface water treatment plants, a considerable number of boreholes and a complex system of potable water transportation pipelines. In addition the pipelines were of various age, condition and materials such as black and blue color medium density polyethylene, galvanized iron, asbestos cement, unplasticized polyvinylchloride, black low density polyethylene and ductile iron [5]. As such, the matter of desalinated waters' quality was of primary importance.

2. Methodology

Desalinated waters' required quality plays an essential role in the choice of the applied technology for the desalination process [8,9]. Moreover, according to World Health Organization (WHO) (2006), desalinated water due to its inherently low mineral content is considered to be aggressive towards existing infrastructure and consumption suitability can only be achieved after appropriate post-treatment [10]. In addition, when desalinated water is integrated into an existing pipeline, either directly or as a blend, it can potentially disrupt the already established biofilms' equilibrium in the inner walls of the pipelines [11], negatively affecting the waters' palatability and possibly causing the release of harmful bacteria [12], metals (i.e. iron, copper, aluminum) [13] and organic matter [14]. Therefore, the waters' quality parameters should be predefined to safeguard the public's health, minimize its effects in the existing infrastructure and environment, and provide plants' engineers with the necessary information for optimum design at a mutual beneficial cost.

Cyprus WDD assigned the task of setting the desalinated waters' quality criteria to an internal team of experts. They contacted an extensive literature review of the then available knowledge, giving emphasis on peer reviewed scholarly articles and books as well as reports, directives, rules and regulations and legislation from national and international organizations like WHO, US Environmental Protection Agency and the

Table 1
Cyprus past and present desalination plants [6,7]

A/A	Desalination plants location	Type	Construction/upgrade date	Nominal capacity (m^3/d)
1	Dekelia	Permanent	04/1997/07/2008	40,000–60,000
2	Larnaca	Permanent (undergoing upgrade)	07/2001/2014 (expected completion year)	52,000–62,000
3	Moni	Mobile	12/2008 (operated for 5 years)	200,000
4	Garylli	Mobile	01/2009 (operated for 5 years)	10,000
5	Pafos (Kouklia)	Mobile	11/2010 (operated for 3 years)	30,000
6	Limassol (Episcopi)	Permanent	07/2013	40–60,000
7	Vasilikou (AEC)	Permanent	07/2013	60,000

European Council (EEC). The review focused on potable water quality, desalination technology, disinfection process and its byproducts and the potential effects on drinking water infrastructure. The team also consulted experts on the above issues both within and outside the Department. In the end, a set of water quality acceptance criteria were proposed based on the following:

(1) Intended use.
(2) National and local water quality standards and regulations.
(3) Applied disinfection process.
(4) Possible effects on distribution systems.

Desalinated waters' acceptance criteria are reevaluated and revised following a similar procedure, in every upcoming desalination plant or existing desalination plants' impending upgrade in order to reflect current needs, available knowledge and technology. In every case, the water quality acceptance criteria are made available to any interesting Party through the contract documents. Table 2 displays a comparative table of Larnaca Desalination Plants water quality acceptance criteria in the first contract of 2001 and the new contract of 2010.

After setting the desalinated waters' quality acceptance criteria, a proper water quality-monitoring program needs to be established for each plant. Water quality monitoring comprises a key component of water management [17,18]. Ward et al. defined it as "any effort by government or private enterprise to obtain an understanding of the physical, chemical and biological characteristics of water via statistical sampling" [17]. WDDs' desalinated water-monitoring program comprises two discernible components with distinct purposes:

(1) Verifying that the produced water meets the quality acceptance criteria.
(2) Documenting desalinated waters' behavior once it permeates the distribution system.

For the first part of the monitoring program, desalinated water samples are collected from the predefined delivery point, every 2 h on a daily basis. At the initial stages, a systematic re-sampling technique is applied to the collected samples begging with the first sample ever collected, followed by every other sample. The purpose of this intense sampling schedule is to determine which quality parameters display the greatest variation throughout time. Once full-scale operation is established, the re-sampling technique converts to stratified sampling. The samples are divided into seven subgroups, one per each day, and then a sample is randomly selected from each subgroup and analyzed according to the results of the initial stage.

The second part of the monitoring program begins along with the revised first part, once full-scale operation is established. Besides the initial point of delivery, it includes samples from selected endpoints in the existing water infrastructure such as pipelines endpoints, pumping stations and delivery points at the surface water treatment plants. The samples are collected on a monthly basis, and analyzed to determine the effect of desalinated water on the disinfection process, existing water infrastructures' metal corrosion and palatability. An indicative monitoring program is prostrated in Table 3.

3. Results and discussion

In the past two decades, desalinated water of various qualities has been integrated into Cyprus existing water infrastructure as a blend and as finished water directly supplying consumers. Both the quality of the water and the manner of integration depends on the applied desalinated technology, the plants location and water demand.

3.1. Integrating desalinated water as a blend

One of the most common ways WDD employs to augment existing drinking water supplies is by blending desalinated water with surface water from the water treatment plants. It is usually done in the surface water treatment plants outlet reservoir, before entering the potable water transportation pipelines. Besides the obvious advantage of meeting the ever-increasing water demand, blend water offers the opportunity for higher-quality finished water that meets the increased regulatory requirements [19].

For instance, as indicated in Fig. 1, blend water better suits boron's regulatory requirement of less than 1.0 mg/L [20]. The method of reverse osmosis, which is employed by most of Cyprus desalination plants, under traditional conditions can only retain boron compounds up to 30–70% [21]. Seasonal variation of the feed-water, water system demand and membrane age further impede boron removal [19,21]. Although surface water treatment does not remove boron compounds, boron concentration in most of Cyprus's surface water is well below 1.0 mg/L, thus a blend typically results in lower boron concentration. Although boron human toxicity in the past few years has been greatly debated [22,23], maintaining boron concentration below this level is still important for human consumption, environment and agriculture [24–26].

Table 2
Larnaca desalination plants water quality acceptance criteria in the initial contract of 2001 and subsequent contract of 2010 [15,16]

		Limit	
A/A	Parameter	Initial contract (2001)	Subsequent contract (2010)
1. Physicochemical parameters			
1.1	Temperature	≤25˚C	NA
1.2	Total dissolved solids (TDS)	≤500 mg/L	≤500 mg/L
1.3	pH	7.0–8.0	7.0–8.5
1.4	Total alkalinity	≥ 30 mg/L as HCO_3^-	≥ 80 mg/L as $CaCO_3$
1.5	Calcium (Ca^{2+})	NA	30–50 mg/L
1.6	Total hardness as $CaCO_3$	100–150 mg/L	80–130 mg/L
1.7	Dissolved oxygen	≥60% of saturation	≥60% of saturation
1.8	Free chlorine	≥0.2 mg/L	0.2–0.5 mg/L
1.9	Boron (B)	≤1.0 mg/L	≤0.5 mg/L
1.10	Nitrate (NO^{3-})	≤50 mg/L	Law 87(I)/2001 (EEC Council Directive No. 98/83)
1.11	Nitrite (NO^{2-})	≤0.1 mg/L	Law 87(I)/2001 (EEC Council Directive No. 98/83)
1.12	Ammonia (NH^{4+})	≤0.5 mg/L	Law 87(I)/2001 (EEC Council Directive No. 98/83)
1.13	Oxidisability	≤5 mg/L	Law 87(I)/2001 (EEC Council Directive No. 98/83)
1.14	Total organic carbon (C)	≤3 mg/L	Law 87(I)/2001 (EEC Council Directive No. 98/83)
1.15	Hydrocarbons	≤10 μg/L	Law 87(I)/2001 (EEC Council Directive No. 98/83)
1.16	Phenols	≤0.5 μg/L	≤0.5 μg/L
1.17	Oils, grease	≤10 μg/L	≤10 μg/L
1.18	Surface active substances	≤0.2 mg/L	≤0.2 mg/L
2. Water stability indices			
2.1	Calcium carbonate precipitation potential (CCPP)	NA	3–10 mg/L $CaCO_3$
2.2	Langelier saturation index (LSI)	Positive	≥0.2
3. Organoleptic parameters			
3.1	Turbidity	0.2 NTU before the addition of lime, if any	≤1 NTU
3.2	Colour	≤5 Hazen (Pt/Co)	≤5 Hazen (Pt/Co)
3.3	Odour and taste	NIL	NIL

Another important factor of drinking water quality that can potentially benefit from prober blending is chemical stability. It is generally acknowledged that drinking water stability mostly depends on a series of parameters such as the waters' buffering capacity, its propensity to precipitate $CaCO_3$, total hardness or soluble Ca^{2+} concentration and the dependant parameter of pH [27].

The buffering capacity of water refers to its ability to resist changes in pH when either an acid or base is added to it. This is attributed to the dual presence of the week carbonic acid and its conjugate base bicarbonate ion, which readily form in water following equations:

$$CO_2(aq) + H_2O(l) \rightleftharpoons H_2CO_3 \rightleftharpoons H^+(aq) + HCO_3^-(aq) \quad (1)$$

$$CO_3^{2-}(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + OH^-(aq) \quad (2)$$

where CO_2: carbon dioxide, H_2O: water, H_2CO_3: carbonic acid, H^+: hydrogen ion, HCO_3^-: bicarbonate ion, CO_3^{2-}: carbonate ion, OH^-: hydroxide ion.

Alkalinity is the total sum of the concentration of carbonates, bicarbonates, carbonic acid, hydroxide and hydrogen (Eq. (3)), thus it provides a measure for the waters' buffering capacity.

Table 3
An indicative quality monitoring program

A/A	Parameter	Monitoring program	
		First component	Second component
1. Physicochemical parameters			
1.1	Conductivity	Daily	Once a month
1.2	Total dissolved solids (TDS)	Daily	Once a month
1.3	pH	Daily	Once a month
1.4	Temperature	Daily	Once a month
1.5	Total Alkalinity	Daily	Once a month
1.6	Calcium (Ca^{2+})	Daily	Once a month
1.7	Potassium (K^{+})	Once a week	Once a month
1.8	Sodium (Na^{+})	Once a week	Once a month
1.9	Magnesium (Mg^{2+})	Once a week	Once a month
1.10	Total hardness as $CaCO_3$	Once a week	Once a month
1.11	Nitrate (NO^{3-})	Once a week	Once a month
1.12	Fluorides (F^{-})	Once a week	Once a month
1.13	Sulphates (SO_4^{2-})	Once a week	Once a month
1.14	Chlorides (Cl^{-})	Twice a week	Once a month
1.15	Iron (Fe)	Once a month	Once a month
1.16	Copper (Cu)	Once a month	Once a month
1.17	Aluminium (Al)	Once a month	Once a month
1.18	Free chlorine	Daily	Once a month
1.19	Total chlorine	Daily	Once a month
2. Water stability indices			
2.1	Calcium carbonate precipitation potential (CCPP)	Daily	Once a month
2.2	Langelier saturation index (LSI)	Daily	Once a month
3. Organoleptic parameters			
3.1	Turbidity	Once a week	Once a month
3.2	Colour	Once a week	Once a month
3.3	Odour and taste	Daily	Once a month
4. Microbiological parameters			
4.1	Coliform bacteria	Once a month	Once a month
4.2	*Escherichia coli (E. coli)*	Once a month	Once a month
4.3	Enterococci	Once a month	Once a month
4.4	Colony count 22°C	Once a month	Once a month

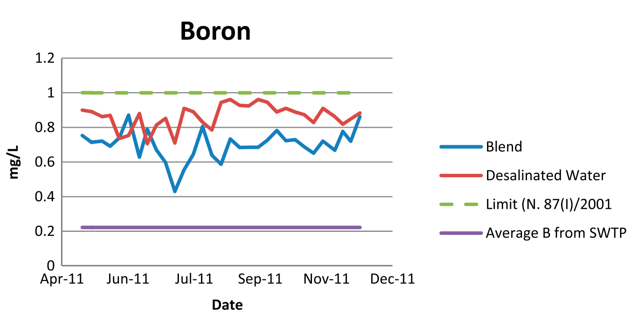

Fig. 1. Boron concentration levels in desalinated, treated and blend water between May and November 2011.

$$Alkalinity = 2^{*}[CO_3^{2-}] + [HCO_3^{-}] + [OH^{-}] - [H^{+}] \quad (3)$$

An increase in alkalinity, as indicated in Fig. 2, improves waters' buffering capacity enabling it to assimilate large pH changes and lower corrosion rates [19,27]. In conjunction with higher pH levels, it prevents iron corrosion [13,28]. Caution should be taken to maintain the blends' pH value above 8 because increasing alkalinity with decreasing pH can lead to copper release of pipe distribution systems [13,26].

The waters propensity to precipitate calcium carbonate ($CaCO_3$), which as is commonly acknowledged, provides a protective coating in the interior of the pipe surfaces, directly relates to corrosion control [29]. Alkalinity, calcium concentration, pH, temperature and Total dissolve solids (TDS) are some of the parameters that influence $CaCO_3$ precipitation. To address corrosion effects WDD, like other organizations uses corrosion indices such as Langelier saturation index (LSI) and Calcium carbonate precipitation potential. Although indices do not address all the

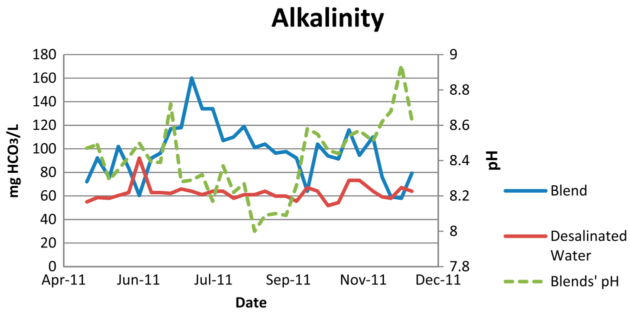

Fig. 2. Alkalinity concentration levels of desalinated and blend water between May and November 2011. Blends' pH value is also indicated.

water quality issues concerning in decretation of blend water into the distribution system, they provide valuable information on pipeline material behavior when water of different quality is introduced [30]. For example, blend water with LSI value greater than 0.5 indicates a tendency to precipitate $CaCO_3$, whereas LSI values between −0.5 and 0.5 indicate a passive blend (Fig. 3).

The effectiveness of the chosen index greatly depends on the age and material of the pipeline [26,28,30]. To address this issue WDD also monitors a number of other parameters such as iron and copper concentrations, chlorides and sulfates ions. It also monitors the effectiveness of the applied disinfection process through measurements of free and total chloride, coliforms, *E. coli*, total bacteria count at 22˚C and *enterococci*.

3.2. Integrating desalinated water directly

As already mentioned the manner of integrating desalinated water into the existing water infrastructure depends on the plants location and water demand. Whenever blending at a surface water treatment plant is not practically possible, desalinated water is directly

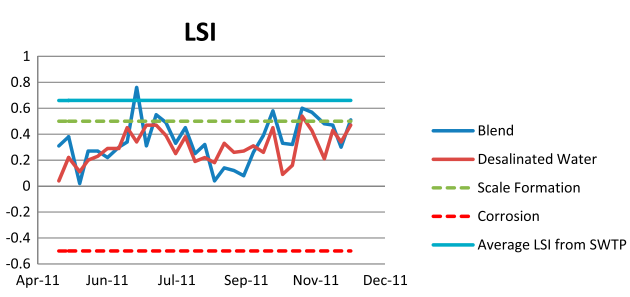

Fig. 3. LSI levels in desalinated, treated surface and blend water between May and November 2011.

fed into the existing drinking water pipelines. Provided that desalinated water meets the quality acceptance criteria, monitoring the parameters already stated above, provides adequate quality control.

In the past couple of years WDD, taking advantage of the unusual high rainfall that was noted [31], switched most of the desalination plants into stand-by mode, and shifted the production of drinking water to Surface water treatment plants. In the summer time though, due to an increase on water demand and a lowering of the available surface water, desalinated water is re-integrated directly into existing drinking water pipelines. The process designated a number of adverse effects, mostly centered in the first few days of operation. They related to the waters palatability, the effectiveness of the disinfection process and most recently aluminium release from pipeline distribution systems.

The waters' palatability refers to the consumers' perception of water odor, taste or mouth-feel sensation. In the first few days of alternating from desalinated water to surface treated water there is a noted increase in the number of consumers' complains. This can be attributed to the change of the source water [32]. Recent studies also revealed that the consumers' assessment of flavor is mostly based on the waters' salinity, with waters of lower TDS content like desalinated water, being preferable to those of higher TDS content, like Cyprus surface treated water [33]. After a while, the public becomes accustomed to the water and complains discontinue.

In regards to the disinfection process, chlorination is WDDs' disinfection method of choice. Drinking water regardless of origin is chlorinated at the production point weather that is the desalination plant or Surface water treatment plant as well as in selected points of the pipeline distribution system. Re-integrating desalinated water into existing water pipeline system after a period of supplying surface treated water results in the disruption of the established biofilms' equilibrium in the inner walls of the pipelines and causes the randomly release of harmful bacteria such as coliform bacteria and enterococcoi [12]. This phenomenon is further supported by the lowering levels of free chlorine compared to other periods of measurement. An increase in chlorination of the affected sites usually proves an effective remediate measure.

The shift towards Surface Water Treatment plants in the past years led to the introduction of aluminium (Al) in WDD's intensive pipeline distribution system monitoring program. Aluminium sulphate, which is used as a coagulant in the surface waters' treatment process, usually raises Al concentrations in treated water, which in consequence leads to hydrous Al

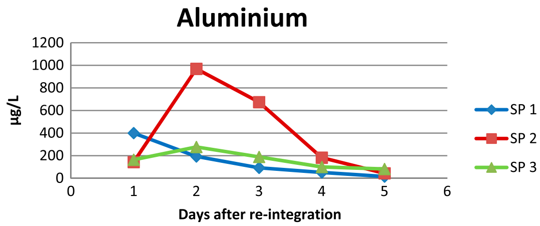

Fig. 4. Al levels in selected points of the distribution system after desalinated water was re-integrated. Sampling point SP1 is located closes to the plant whereas sampling point SP2 represents the end-point closes to the plant. Sampling point SP3 is located furthest from the plant at an opposite end.

precipitate and Al hydrolysis products in the pipeline walls [34]. Water with low alkalinity or calcium content, like desalinated, can cause Al leaching from cement-mortar linings [35]. As Fig. 4 shows, this phenomenon occurred recently when desalinated water was re-integrated into the distribution system.

4. Conclusion

Cyprus experience has proven that desalination can be a useful tool for augmenting the available recourses of water stressed regions.

Predefining desalinated waters' quality acceptance criteria is of primary importance in order to safeguard public's health, minimize its effects in the existing infrastructure and environment, and provide plants' engineers with the necessary information for optimum design at a beneficial cost for both the constructors and the purveyors.

Effective water management requests the implementation of a proper monitoring program that verifies the produced water quality and also document sits behavior once it permeates the distribution system. Such a program will provide purveyors with needed information to promptly apply preventive or corrective measures. It is also imperative to periodically re-evaluate and revise the set quality acceptance criteria and the water quality monitoring program, so that they reflect the ever changing needs, knowledge and technology.

Blending desalinated water with treated surface water, if properly applied, can prove advantageous for meeting the ever-increasing water demand and the need for higher-quality finished water. On the other hand, caution should be taken when alternating between desalinated water and blend or treated surface water due to the increase probability for adverse effects being noted, especially in regards to palatability, disinfection process effectiveness and metal-release.

References

[1] Republic of Cyprus, Ministry of Agriculture, Department of Meteorology. Department of Meteorology. 2006–2014. Available from: http://www.moa.gov.cy/moa/ms/ms.nsf/DMLcyclimate_en/DMLcyclimate_en?OpenDocument (accessed March 27, 2014).

[2] N.X. Tsiourtis, Seawater desalination projects. The Cyprus experience, Desalination 139 (2001) 139–147.

[3] Republic of Cyprus, Water Development Department. Water Development Department. 2003–2014. Available from: http://www.moa.gov.cy/moa/wdd/Wdd.nsf/All/D9DD3467701044CDC2256E44003D7207?OpenDocument (accessed March 27, 2014).

[4] C. Marcuello, C. Lalana, European Environment Agency, Water Exploitation Index, 06 2003. Available from: http://www.eea.europa.eu/data-and-maps/indicators/water-exploitation-index/water-exploitation-index (accessed March 27, 2014).

[5] S. Christodoulou, A. Agathokleous, A study on the effects of intermittent water supply on the vulnerability of urban water distribution networks, Water Sci. Technol.: Water Supply 12(4) (2012) 523–530.

[6] R. Hochstrat, T. Wintgens, C. Kazner, T. Melin, Options for water scarcity and drought management—The role of desalination, Desalin. Water Treat. 18 (2010) 96–102.

[7] Republic of Cyprus, Water Development Department, 2003–2014. Available from: http://www.moa.gov.cy/moa/wdd/Wdd.nsf/all/BED8F791F8232344C22570EC0029DB96/$file/Cyp_Irrig_grk.pdf?openelement (accessed March 27, 2014).

[8] R. Penn, L. Birnhack, A. Adin, O. Lahav, New desalinated drinking water regulations are met by an innovative post-treatment process for improved public health, Water Sci. Technol.: Water Supply—WSTWS 9 (3) (2009) 225–231.

[9] T. Uemura, K. Kotera, M. Henmi, H. Tomioka, Membrane technology in seawater desalination: History, recent developments and future prospects, Desalin. Water Treat. 33 (2011) 283–288.

[10] World Health Organization, Guidelines for Drinking-water Quality, Incorporating First Addendum, vol. 1: Recommendations, third ed., World Health Organization, Geneva, 2006.

[11] J. Zhang, J. Liang, J. Hu, R. Xie, M. Gomez, A. Deng, C. Nam, Impact of blended tap water and desalinated seawater on biofilm stability, Desalin. Water Treat. (2013) 1–6.

[12] Z.G. Tsvetanova, D.N. Dimitrov, Biofilms and bacteriological water quality in a domestic installation model simulating daily drinking water consumption, Water Sci. Technol.: Water Supply 12(6) (2012) 720–726.

[13] J. Taylor, J. Dietz, A. Randall, S. Hong, Impact of RO-desalted water on distribution water qualities, Water Sci. Technol. (Q IWA Publishing) 51(6–7) (2005) 285–291.

[14] F. Echeverría, J.G. Castaño, C. Arroyave, G. Peñuela, A. Ramírez, J. Morató, Characterization of deposits formed in a water distribution system, Ingeniare. Revista chilena de ingeniería 17(2) (2009) 275–281.

[15] Republic of Cyprus, Water Development Department. Larnaca Desalination Plant Tender Documents for Supply, Installation, Operation and Sale of Water No. 39/96/69. Contract, Water Development Department, Nicosia, 1999.

[16] Republic of Cyprus, Water Development Department. Renovation and Operation of the Larnaca Desalination Plant TAY57/2010. Contract, Republic of Cyprus, Water Development Department, Nicosia, 2010.
[17] R.C. Ward, J.C. Loftis, G.B. McBride, The "data-rich but information-poor" in water quality monitoring, Environ. Manage. 10(3) (1986) 291–297.
[18] The Council of the European Union, Council Directive 98/83/EC on the Quality of Water Intended for Human Consumption, Directive, Official Journal of the European Communities, Brussels, 1998.
[19] S.J. Duranceau, R.J. Wilder, S.S. Douglas, Guidance and recommendations for posttreatment of desalinated water, J. Am. Water Works Assoc. E (2012) E510–E520, doi: 10.5942/jawwa.2012.104.0119.
[20] Y.V. Babak, V.V. Goncharuk, L.A. Mel'nik, V.P. Badekha, Removal of boron compounds in pressure-driven desalination of the Black Sea water, J. Water Chem. Technol. 34(6) (2012) 288–293.
[21] J. Xu, X. Gao, G. Chen, L. Zou, C. Gao, High performance boron removal from seawater by two-pass SWRO system with different membranes, Water Sci. Technol.: Water Supply—WSTWS 10(3) (2010) 327–336.
[22] C. Yazbeck, W. Kloppmann, R. Cottier, J. Sahuquillo, G. Debotte, G. Huel, Health impact evaluation of boron in drinking water: A geographical risk assessment in Northern France, Environ. Geochem. Health 27 (2005) 419–427.
[23] M.V. Pahl, B.D. Culver, P.L. Strong, F.J. Murray, N.D. Vaziri, The effect of pregnancy on renal clearance of boron in humans: A study based on normal dietary intake of boron, Toxicol. Sci. 60 (2001) 252–256.
[24] N. Kabay, S. Sarp, M. Yuksel, Ö. Arar, M. Bryjak, Removal of boron from seawater by selective ion exchange resins, React. Funct. Polym. 67 (2007) 1643–1650.
[25] J.L. Parks, M. Edwards, Boron in the environment, Crit. Rev. Environ. Sci. Technol. 35(2) (2007) 81–114.
[26] S.A. Imran, J.D. Dietz, G. Mutoti, W. Xiao, J.S. Taylor, V. Desai, Optimizing source water blends for corrosion and residual control in distribution systems, Am. Water Works Assoc. J. 98(5) (2006) 107–115.
[27] O. Lahav, L. Birnhack, Quality criteria for desalinated water following post-treatment, Desalination 207 (2007) 286–303.
[28] Z. Tang, S. Hong, W. Xiao, J. Taylor, Characteristics of iron corrosion scales established under blending of ground, surface, and saline waters and their impacts on iron release in the pipe distribution system, Corros. Sci. 48 (2006) 322–342.
[29] L.A. Maddison, G.A. Gagnon, J.D. Eisnor, Corrosion control strategies for the Halifax regional distribution system, Can. J. Civ. Eng. 28 (2001) 305–313.
[30] R.C. Cheng, C. Andrews-Tate, T.J. Tseng, K.L. Wattier, Distribution of desalinated seawaters: Are corrosion indicators sufficient? IDA J. First Quarter (2010) 24–31.
[31] R.C. Cheng, C. Andrews-Tate, T.J. Tseng, K.L. Wattier, Water Development Department. Cyprus Annual Precipitation (Area under Goverment control) (2003–2014). Available from: http://www.moa.gov.cy/moa/wdd/wdd.nsf/0/87daebacfbc286f8c225755300333307/$FILE/RAINFALL_from_1901_ENG_Meter.pdf (accessed April 11, 2014).
[32] M.J. McGuire, R. Hund, G. Burlingame, A practical decision tree tool that water utilities can use, J. Water Supply: Res. Technol. —AQUA 54(5) (2005) 321–327.
[33] V. García, A. Fernández, M.E. Medina, O. Ferrer, J.L. Cortina, F. Valero, R. Devesa, Flavour assessment of blends between desalinated and conventionally treated sources, Desalin. Water Treat. (2014) 1–9. doi:10.1080/19443994.2013.875943.
[34] P.T. Srinivasan, T. Viraraghavan, K.S. Subramanian, Aluminium in drinking water: An overview, Water SA 25(1) (1999) 47–55.
[35] V.L. Snoeyink, M.R. Schock, P. Sarin, L. Wang, A.S.-C. Chen, S.M. Harmon, Aluminium-containing scales in water distribution, J. Water Supply: Res. Technol.—AQUA 52(7) (2003) 455–474.