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Greece, 4-6 April 2017

Agenda item 4: Review of Proposed Updated Guidelines on Desalination

Assessment report on Desalination Activities in the Mediterranean

First Draft

UNEP/MAP
Athens, 2017

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List of Abbreviations / Acronyms

BAT	Best Available Technologies
BEP	Best Environmental Practices
COP	Conference of the Parties
Cr	Chromium
Cu	Copper
EIA	Environmental Impact Assessment
Fe	Iron
GES	Good Environmental Status
GHG	Greenhouse Gas
MAP	Mediterranean Action Plan
MED	Multiple Effect Distillation
MED POL	Programme for the Assessment and Control of Marine Pollution in the Mediterranean Sea
Mo	Molybdenum
MSF	Multi Stage Flash Distillation
Ni	Nickel
PoW	Programme of Work
RO	Reverse Osmosis
SWIM	Sustainable Water Integrated Management
Ti	Titanium
UN	United Nations
UNEP	United Nations Environment Programme

1. Introduction

1. The MED POL Programme of UN Environment/Mediterranean Action Plan (hereinafter referred to as MAP), following their approval by the MED POL Focal Point meeting, published in 2003 the MAP Technical Report No. 139: Sea Water Desalination in the Mediterranean. Assessment and Guidelines. At the time, the guidelines, largely used by the Contracting Parties, were up to date and described the need for seawater desalination, the basic technologies, the state and trends of seawater desalination in the Mediterranean region and touched on the environmental impacts and legal aspects of brine disposal.

2. Since 2003, the global desalination effort has grown exponentially due to increase in freshwater demand and improvement of technologies and economic viability. The Mediterranean region followed the global trend and the installed desalination capacity increased from ca. 4 million m3/day (Mm3/day) in 2003 to 12 Mm3/day in 2013. Technologies changed as well, together with increased awareness of the possible environmental impacts, in particular on the marine environment. Moreover, the legal framework for the regulation of waste disposal into the Mediterranean evolved and a series of Decisions were adopted by the Contracting Parties to implement the ecosystem approach in the Mediterranean region and integrate it into the different MAP policies including those relating to pollution prevention and reduction, in order to achieve and maintain Good Environmental Status (GES).

2. Objectives and methodology

3. In line with the MAP Programme of Work (PoW) 2016-2017, adopted by the COP19 (Athens, Greece, 2016), the Secretariat (MED POL), with technical support from a regional expert, prepared updated Guidelines on Desalination for submission to the MED POL Focal Points Meeting. In this context MED POL also undertook an assessment of desalination activities in the region, in order to enhance the knowledge on this sector and support the implementation of the updated Guidelines, in view of achieving/maintaining GES.

4. The objectives of this assessment were to quantify the current desalination status in the Mediterranean, to assess the possible impacts on the coastal and marine environments and to recommend policy and mitigation measures for the protection of the environment. The assessment relied on the information collected from the scientific literature, monitoring results and data from previous reports, including, among others, the MAP Technical report 139 (UNEP/MAP/MEDPOL 2003), SWIM report (Khordagui 2013), UNEP and NRC publications (NRC 2008, UNEP 2008). In addition, questionnaires were sent by MED POL to the Contracting Parties, asking for up to date information on installed desalination capacity, actual production, and operational details.

5. The present report is composed of four parts. The first part is a brief assessment and description of the status of desalination activities in the Mediterranean and the changes that have occurred between 1999 and 2013. The second part identifies the main gaps and needs related to information and data. The third part lists the main contaminants derived from the desalination activities, while the last part consists of a list of concrete policy and technical recommendations to prevent and reduce potential impacts on marine and coastal environment from desalination activities.

3. State of play of desalination in the Mediterranean

6. The total desalination capacity around the Mediterranean in 1970 was 0.025 Mm^3/day. By the end of 1999, it had increased by almost 2 orders of magnitude to a total capacity of close to 2 Mm^3/day, with

41% produced by Reverse Osmosis (RO) (UNEP/MAP/MEDPOL 2003) (Fig.1). Spain was the bigger producer of desalinated water with 33% of the total capacity, mainly from RO process. Libya was the second producer, with 30% or the total capacity, mainly from Multi Stage Flash Distillation (MSF) process. Italy, Malta, Algeria and Cyprus accounted for 18, 6, 5 and 2% of the total capacity, respectively (UNEP/MAP/MEDPOL 2003) (Fig.2).

7. In 2007, the total desalination capacity in the Mediterranean was 4.0 Mm^3/day (14% of the total global capacity). Spain was the main producer, with 35% of the total capacity in the Mediterranean followed by Libya, with 20%. Algeria, Israel, Italy, Malta and Cyprus accounted for 19, 10, 7, 5 and 4% of the total capacity, respectively (Lattemann et al. 2010a, Lattemann et al. 2010b). The main process utilized was RO.

8. In 2011, the capacity was increased to 11.6 Mm^3/day in the Mediterranean countries, however this estimate may include desalination in the Atlantic and Red Sea. Spain was the main producer (41% or the total capacity in the Mediterranean) followed by Algeria and Israel with 15 and 10%, respectively. Libya accounted for 7% of the total production and Italy and Egypt, 6% each (Cuenca 2013).

9. In 2013, the total cumulative installed desalination capacity was about 12 Mm^3/day (Khordagui 2013). Spain was the main producer (31% of the total capacity) followed by Algeria, Israel and Libya with 20, 18 and 11%, respectively. RO was the most common desalination technology in the area (ca. 82%) followed by MSF (11%) and Multiple Effect Distillation MED (6.5%). From 2000 to 2013 the installed capacity increased by 560%, with the sharpest increase between 2005 and 2010 (Fig. 1).

Figure 1. Progression of the desalination's installed capacity around the Mediterranean Sea

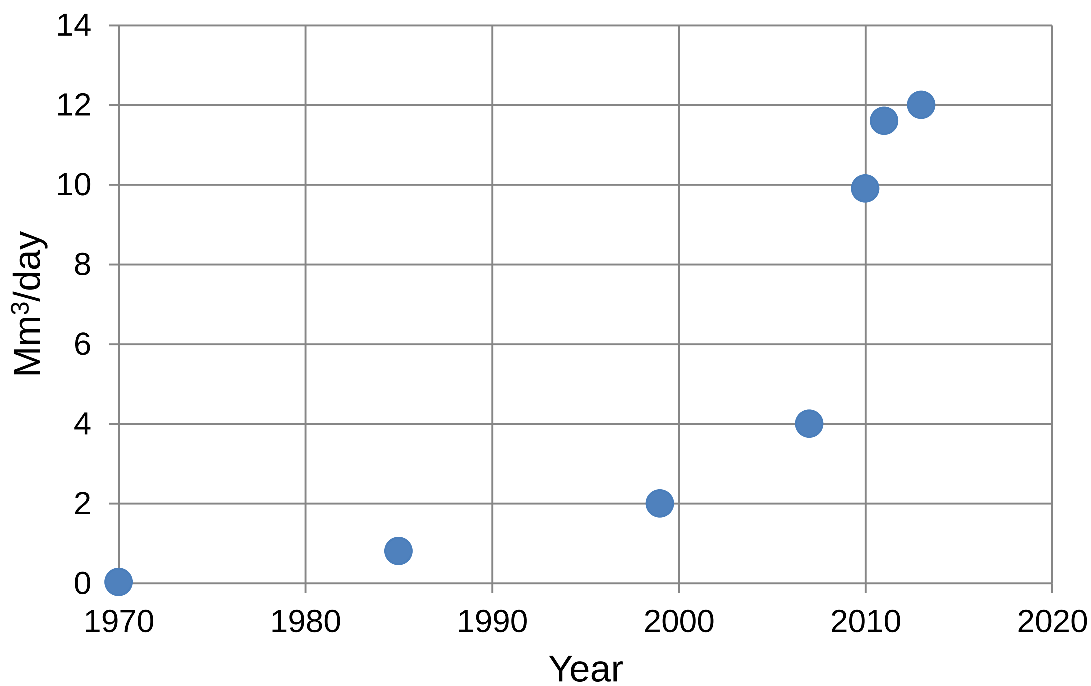
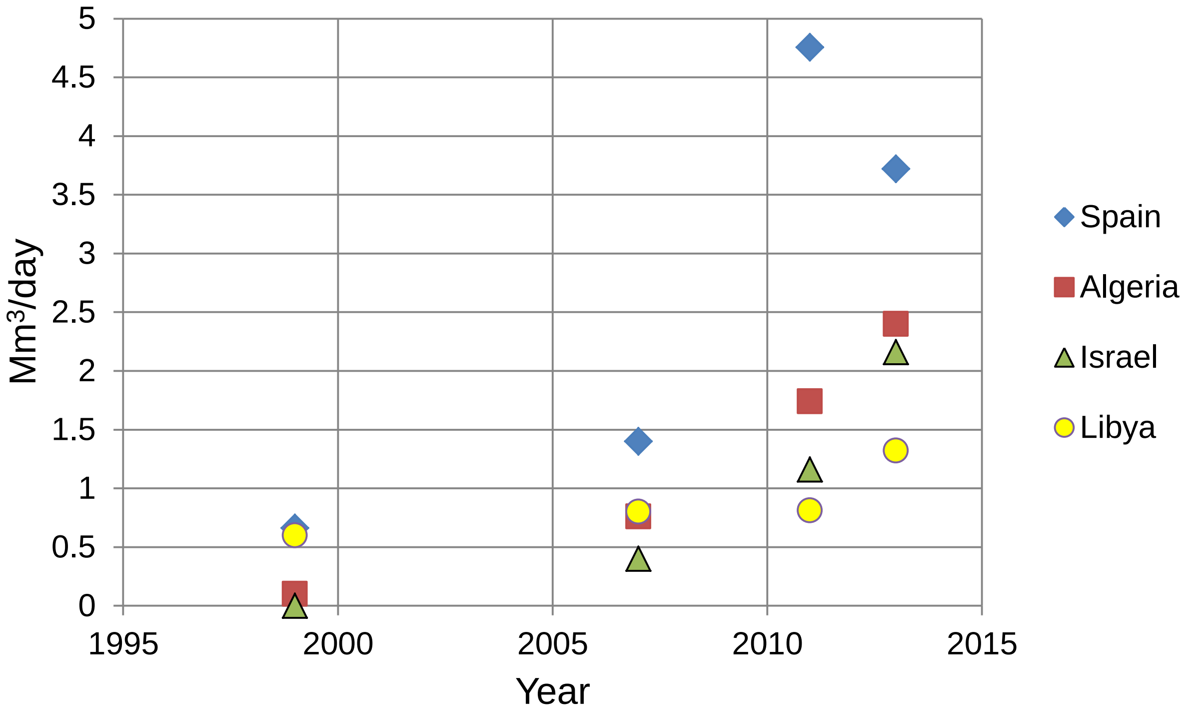


Figure 2. Progression of the desalination installed capacity four Mediterranean countries that together constitute more than 65% of the total capacity.



4. Data and information gaps and needs

10. The main information gap while trying to quantify desalination in the Mediterranean is the actual desalination effort taking place. Most of the data presented in reports originate from GWI-DesalData (www.desaldata.com) that compiles installed capacity and presumed installed desalination capacity. The desalination capacity is usually higher than the actual desalination effort. For example, desalination capacity in Israel in 2013 was reported as 2.16Mm^3/day, when the actual desalination effort (including brackish water) in 2014 was 1.2 Mm^3/day (Israel's Water Authority, 2015 Report).

11. An additional gap is the lack of details for each desalination plant that would help to assess the possible effects of desalination on the environment. In order to bridge this gap, partially filled questionnaires were sent by MED POL to the Contracting Parties, asking for their collaboration to supply the following general information (installed desalination capacity, actual production, the contribution of seawater desalination to the actual production and future plans) and specific data (number of plants that desalinate more than 10,000 m^3/day, their location, mode of intake and discharge, process used, details on chemical usage and discharges' loads to the environment). A sample questionnaire is presented in Annex 1. To date, not all the Contracting Parties have sent completed questionnaires, and therefore the present assessment may be updated when all the responses are received by the Secretariat, based on new information provided.

12. Moreover, not enough data exist globally on the possible effects of desalination on the environment. Of special importance is the lack of long term, in situ, studies to follow the possible long term effects of desalination and brine discharge on the environment.

5. Emerging contaminants

13. The Secretariat (MED POL) has been mandated by the Contracting Parties to identify a list of priority contaminants affecting the marine and coastal environment in the Mediterranean. In this respect the present assessment was considered as an opportunity to identify main contaminants originating from desalination activities.

14. The main impacts of seawater desalination on the marine environment are associated with two components: intake of seawater (feed water) into the desalination plant that can entrain and impinge biota, and brine discharge that can introduce contaminants into the marine environment and affect water and sediment quality and impact biota.

15. The desalination industry is very dynamic, striving to improve yield, to reduce the amount of chemicals used in the process and discharged with the brine, and to use less hazardous substances (green chemistry). Therefore, it is hard to keep up with the changes and the environmental scientist should work in close cooperation with the desalination plants operators to be advised on the changes made in the process.

16. An additional hindrance is that many of the chemicals (mainly coagulants and anti-scalants) are protected by patents; therefore the exact composition is usually proprietary and cannot be divulged. In this case, the active compound should be identified and compiled together with its toxicological properties. It should be mentioned that known pollutants are also used in the process: such as acids, bases, cleaning solutions, metal salts as well as known corrosion products (metals).

17. Based on a review of existing technologies and state of play, the following contaminants emerge from desalination technologies:

Contaminants	Used/produced in desalination process	
	Membrane	Thermal
Fe salts, Al salts, organic polymers	Coagulant	Not used
Heavy metals Fe, Ni, Cr, Mo	Stainless steel Corrosion	Stainless steel Corrosion
Heavy metals Cu, Ni, Ti	Not relevant	Corrosion from heat
Chlorine, other oxidants	Biocide, Used but neutralized with bisulfite prior to disposal	Biocide Residual chlorine
Bisulfite	Biocide neutralizer	Not used
Polyglycol, detergents	Not Used	Antifoaming agent
Detergent, oxidants, complexing agents	Membrane cleaning	Not used
Polyphosphate, Polyphosphonate, organic polymers (polymaleic and polyacrylic acids)	Antiscalant	Antiscalant
Alkaline solutions	Cleaning (neutralized prior to disposal)	Not used
Acidic solutions	Cleaning (neutralized prior to disposal)	Cleaning

Contaminants	Used/produced in desalination process	
	Membrane	Thermal
	Not used	Corrosion inhibitors
Limestone ($CaCO_3$)	pH and hardness adjustor of produced water	pH and hardness adjustor of produced water
Salt	Brine	Brine
Temperature	Not applicable	Temperature

6. Proposed recommendations

18. Recognizing the individual character of each location and desalination plant, it is still possible to outline general policy and technical recommendations to reduce and abate possible environmental impacts of seawater desalination. In order to achieve and/or maintain good environmental status at the desalination sites it is extremely important to implement an ecosystem approach, which has been also reaffirmed as one of the overarching principles of MAP Barcelona Convention and it is therefore integrated into all MAP policies.

19. During the planning and design of a desalination plant, the following steps are recommended:

(a) Desalination is expensive. The utilization of alternative water sources and measures (water conservation, water treatment and re-use, prevention of water waste due to faulty infrastructure, among others) should be considered before the desalination option.
(b) A sustainability study should be conducted to evaluating the economic, environmental and social impacts of seawater desalination
(c) The decision to build a desalination plant should be accompanied by an Environmental Impact Assessment (EIA) to identify, at the design and planning stages, the possible effects on the environment. If identified, the design should be changed to reduce or avoid the effects. Locating the desalination plant at environmental sensitive areas or near areas with archeological and cultural value should be avoided.
(d) The EIA should be prepared by specialists in a multidisciplinary manner, and performed within the country regulatory framework.
(e) The EIA should include the following components: A general description of the purpose and need of the project, proposed location, existing and future facilities and uses in the area, details of the desalination technology, expected energy usage and source, description of the area and method of source water input, all the steps in the desalination process, including the identity and quantity of chemicals to be used and mode of disposal, the types and quantities of expected discharges and emissions (marine, terrestrial and atmospheric), modeling of the expected brine dispersion.
(f) The use of desalination technologies that minimize energy use, utilize renewable energy, reduce GHG emissions, brine discharge and chemicals, and that utilize green materials should be encouraged and directed to at the planning stages.
(g) The EIA should be complemented with laboratory studies on the toxicity of the brine and chemicals expected to be disposed of at sea or inland. The studies should target species relevant to the site, encompass different taxa and different life stages.
(h) The EIA should address the use of best available technologies (BAT) and the best environmental practices (BEP) to protect the environment during construction and operation of the desalination plant.

(i) The plant facilities should be designed to minimize the permanent alteration of the coastal environment, to aesthetically integrate with the landscape, to be insulated acoustically, to have minimal external lighting to minimize light pollution and to have pipelines laid underground. The buildings should not impede public access to the coastal area.
(j) The possible impacts during the construction stage originate from the land and marine works and may alter the natural terrain, affect fauna and flora, pollute soil, water and air, impose noise disturbance, seawater turbidity, among others. These impacts should be mitigated using environmental friendly construction methods such as pipe-jacking instead of open trenches, pollution prevention measures such as containment basins, surface wetting, recycling of construction waste, area rehabilitation.

20. During the operation of a desalination plant the main impacts on the marine environment are associated with two components of the process: intake of seawater into the plant that entrain and impinge biota, and brine discharge that affect hydrography, seawater quality and biota. The following measures are recommended to mitigate the possible impacts:

(a) Entrainment can be reduced by locating the seawater intakes away from biologically productive areas, such as in deeper water farther offshore, or by using underground beach wells (subsurface) to pump source water.
(b) Impingement can be reduced through a combination of intake screen size and lower intake velocity.
(c) Brine should be discharged through marine outfalls equipped with diffusers to increase initial dilution. In in open discharge systems, dilution can be achieved by co-discharging the brine with other discharges, such as cooling waters from power stations.
(d) If possible, zero liquid discharge technology should be implemented.
(e) The amount of chemicals used in the desalination process and disposed of should be minimal, and reduced when possible.
(f) A long term environmental monitoring program should be conducted through the lifetime of the desalination plant. The monitoring data should be analyzed critically and monitoring design changed accordingly. The results should be used to enforce the permitting license's guidelines conditions.
(g) The monitoring data should be published and disseminated to the community.
(h) The monitoring program should be kept updated by open communications with plant operators. Although the general process at a specific plant is well defined, changes that can influence the monitoring program do occur, such as: changes in chemicals' identities and quantities used in the process, in pre-treatment methodology, plant capacity, in intake and outfall position, specific production.

21. Cooperation among the Mediterranean countries, the desalination industry at both the operational and development level, researchers in the appropriate disciplines and regulators is imperative for a comprehensive and sustainable desalination practice. A feed-back mechanism should be encouraged among the players:

(a) Criteria and standards for intake and brine discharge should be developed and adopted by the Mediterranean countries and enforced by the national regulating authorities. The cumulative effects of desalination around the Mediterranean Sea should be assessed using the ecosystem approach and modeling tools.

(b) A Mediterranean network for data and knowledge exchange and dissemination should be established. The network should be easily accessible, open to all, and include individuals from diverse, complementary fields. The database should include information on the chemicals (or for proprietorial chemicals, their active compounds) used in the desalination process and their toxicological properties; environmental effects observed; technical problems encountered in the process and with feed water quality and their solution; improvement of the processes, etc.
(c) Findings of the monitoring studies should be relayed to all players: to the desalination industry, emphasizing environmental problems that need technological solutions; to the regulator that should analyze the guidelines and permits and when necessary request changes or further treatment at the plant; to researchers to fine tune laboratory experiments.
(d) Desalination is an ever changing industry in an era of climate change and other extensive uses of the marine environment. Its impact should not be addressed alone but in conjunction with other specific uses in the area.

7. References

Cuenca, J. C. 2013. Report on water desalination status in the Mediterranean countries. IMIDA, Spain.

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Annex I
Questionnaire
Seawater desalination status in the Mediterranean Region

Questionnaire

Seawater desalination status in the Mediterranean Region

1. Introduction

Seawater desalination has for a long time been a major source of water in parts of the Mediterranean to meet water demands, supplying ca. 12 Mm^3/day desalinated water in 2013. The desalination effort is expected to continue to increase. The MED POL Programme of UNEP/MAP is assessing now the implementation of its desalination guidelines published in 2004 and evaluating the state of play of the desalination section in the Mediterranean. The purpose is to produce an updated guideline and provide the Contracting Parties with adequate technical guidance to reduce to a minimum all environmental impacts. For this we would appreciate your collaboration in completing this short questionnaire.

2. General Questions– Only for plants along or near the Mediterranean Coast

2.1. Country:

2.2. How many desalination plants are in operation in your country along or near the Mediterranean Coast? ________

2.2.1. How many plants desalinate <u>seawater</u>? ________

2.2.2. How many plants desalinate <u>brackish</u> water? ________

2.2.3. How many plants have a production capacity >50,000 m^3/day? ________

2.3. What is the total annual production of desalinated water? ___________

2.3.1. What is the total annual <u>production</u> of desalinated water? ___________

2.3.2. What is the actual total annual production originating from <u>seawater desalination</u>?

2.4. Are there more desalination plants at the planning/construction stage along the Mediterranean coast? ___________

2.4.1. How many? ___________

2.4.2. Total planned desalination production ___________

2.4.3. Expected year for start of production ___________

3. Detailed information for large size plants (>10,000 m^3/day, 3.65 Mm^3/year production) only along the Mediterranean Coast . (Please copy table for additional columns).

	Plant Name	**Plant Name**	**Plant Name**	**Plant Name**	**Plant Name**	**Plant Name**
Name						
Year starting to operate						
Location[1]						
Desalination Technology[2]						
Production, m^3/day						
Method of brine discharge[3]						
Co- discharge with brine[4]						
Chemicals used in the desalination process[5]						
Coagulants						
Anti-Scalant						
Biocides						
Water Hardener						
Other						
Chemicals co-discharged with brine[6]						
Is there a marine monitoring program in place?						

[1]Location: city, area

[2]Desalination technology: **RO**-Reverse Osmosis, **MSF-** Multi Stage Flash , **MED -** Multi Effect Distillation, **Other** – please add technology

[3]Method of Brine discharge: **OD-**Open discharge, **MO-** Marine outfall, **Other** – please add details

[4]Co-discharge with brine: Other discharges, for example, cooling waters from Electric power stations

[5]Please name the chemicals: i.e Coagulants – iron salts **(FE)**; anti-scalant**-** polyphosphonates (Ppho), **If the identity of the chemical is unknown, please add yes or no**

[6]Please name the chemicals discharged with the brine

4. References and historical data

1. http://www.fao.org/nr/water/aquastat/water_res/index.stm#cp

2. FAO, Aquastat

3. Khordagui, H.: Assessment of potential cumulative environmental impacts of desalination plants around the Mediterranean Sea, SWIM Final report, Activity 1.3.2.1, 2013.

4. Report on water desalination status in the Mediterranean countries. Dr. J.C.Cuenca, IMIDA, Spain, 2013

5. Lattemann, S., Kennedy, M. D., Schippers, J. C., and Amy, G.: Chapter 2 Global Desalination Situation. In: Sustainability Science and Engineering, Isabel, C. E. and Andrea, I. S. (Eds.), Elsevier, 2010

6. UNEP/MAP/MEDPOL: Sea Water Desalination in the Mediterranean: Assessment and Guidelines, MAP Technical Reports Series No. 139, UNEP/MAP, Athens, 2003.

7. Other