

Report on the

**First meeting of the Technical Committee for
development of WHO Guidance on
Desalination for Safe Water Supply**

Irvine, California, United States of America
22–24 October 2004



World Health Organization
Regional Office for the Eastern Mediterranean
Cairo
2005

© World Health Organization 2005
All rights reserved.

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the World Health Organization concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. Dotted lines on maps represent approximate border lines for which there may not yet be full agreement.

The mention of specific companies or of certain manufacturers' products does not imply that they are endorsed or recommended by the World Health Organization in preference to others of a similar nature that are not mentioned. Errors and omissions excepted, the names of proprietary products are distinguished by initial capital letters.

The World Health Organization does not warrant that the information contained in this publication is complete and correct and shall not be liable for any damages incurred as a result of its use.

Publications of the World Health Organization can be obtained from Distribution and Sales, World Health Organization, Regional Office for the Eastern Mediterranean, PO Box 7608, Nasr City, Cairo 11371, Egypt (tel: +202 670 2535, fax: +202 670 2492; email: DSA@emro.who.int). Requests for permission to reproduce WHO EMRO publications, in part or in whole, or to translate them - whether for sale or for noncommercial distribution - should be addressed to the Regional Adviser, Health and Biomedical Information, at the above address (fax: +202 276 5400; email HBI@emro.who.int).

CONTENTS

1.	BACKGROUND.....	1
2.	INTRODUCTION.....	1
3.	REVIEW OF THE GUIDANCE DEVELOPMENT PROCESS.....	2
3.1	Outline for the guidance document	2
3.2	Technical workgroups	3
4.	WORKGROUP SESSIONS	3
5.	OUTLINES FOR WORKGROUP CONTRIBUTIONS.....	3
5.1	Group I: Technology/engineering/chemistry-technical issues	3
5.2	Group II. Health, toxicology of contaminants and nutritional aspects.....	6
5.3	Group III: Microbiology.....	11
5.4	Group IV: Monitoring, microbiological, analytical chemistry, surveillance, regulatory.....	16
5.5	Group V: Guidance for environmental impact assessment of desalination plants	20
6.	NEXT STEPS.....	24
	Annexes	
1.	PROGRAMME	25
2.	LIST OF PARTICIPANTS	26

1. BACKGROUND

Desalinated seawater or brackish water is a major and rapidly growing source of drinking-water. Advances in the technology and economics of desalination are rapidly making desalination a viable option for providing safe drinking-water in water-scarce regions all over the world, especially in areas where freshwater supplies are inadequate to support the health and welfare needs of the population. Desalination can also provide an engine for enhanced economic growth and improved quality of life.

To facilitate the introduction of desalination benefits on a wider scale, the World Health Organization (WHO) has embarked on a process of developing WHO guidance on health and environmental aspects applicable to the production, distribution and quality of desalinated water. The WHO guidance on desalination for safe water supply will be concerned with health and environmental quality issues that may be unique to desalination projects, and it will supplement and be closely integrated with the main body of WHO Guidelines on Drinking-Water Quality.

The recommendation to embark on a WHO desalination guidance monograph was endorsed unanimously by the WHO Guidelines for Drinking-Water Quality Committee in Berlin, Germany in June 2000. This resulted from an initiative by the WHO Regional Office for the Eastern Mediterranean (WHO/EMRO), and took shape in May 2001, in a Joint Consultation held by WHO, United Nations Environment Programme (UNEP) and the Regional Organization for the Protection of the Marine Environment (ROPME), in Manama, Bahrain. The Consultation emphasized the need to involve broad participation of the numerous interested organizations and individuals from around the world in the guidance development process.

The Steering Committee for the Preparation of the WHO Guidance Document on desalination for safe water supply convened for the first time in Manama, Bahrain, in May 2004, to initiate the process of developing the guidance document. During the meeting, the Committee established a plan of work for the guidance development process and identified members of the five technical workgroups that would comprise the Technical Committee for development of the guidance.

2. INTRODUCTION

The first meeting of the Technical Committee for Development of WHO Guidance on Desalination for Safe Water Supply was held in Irvine, California, United States of America on 22–24 October 2004. The objectives of the meeting were to:

- Familiarize all the experts contributing to the WHO guidance document with the process and steps of preparing the guidance and come to a common understanding of the final product contemplated;
- Discuss, within each of the five workgroups of the Technical Committee, the tasks and plan of the workgroup; and

- Hold discussions among workgroups to clarify what common work has to be done, particularly what information is needed first from Workgroup I, for the other groups to be able to advance their own tasks, while minimizing duplication of efforts.

The meeting was opened by Dr Houssain Abouzaid, Coordinator, Healthy Environments, WHO Regional Office for the Eastern Mediterranean (WHO/EMRO), who conveyed greetings and encouragement from Dr Hussein A. Gezairy, WHO Regional Director for the Eastern Mediterranean. Dr Abouzaid expressed appreciation to the meeting organizers, partner agencies, members of the Steering Committee and to the United States Bureau of Land Reclamation for its joint sponsorship of the first year of the 3-year work plan for the development of the guidance. The development of the guidance would follow the usual WHO process that included development by a worldwide cross-section of technical experts, operating as individuals and not representing organizations, followed by internal and external review to assure quality, and ultimate adoption and release.

Dr Habib El Habr, Deputy Regional Director, UNEP Regional Office for West Asia (UNEP/ROWA), also addressed the participants and reconfirmed the commitment of UNEP to work with WHO and other parties to achieve the goal of producing this valuable and practical guidance for worldwide use.

Dr Abouzaid served as Chair of the meeting. The meeting agenda and list of participants are attached as Annexes 1 and 2. The agenda was modified somewhat at the suggestion of members to add a plenary session on the first day, and the first chairs' meeting was moved to the morning of the second day.

3. REVIEW OF THE GUIDANCE DEVELOPMENT PROCESS

3.1 Outline for the guidance document

The Joint WHO/UNEP/ROPME Consultation for Planning the Preparation of the WHO Water Quality Guidelines for Desalination, convened in Manama, Bahrain in 2001, identified 11 topic sections as its outline for the guidance document, based upon the questions that were identified. A cross reference to the technical workgroups is provided in parentheses.

1. Background: coverage and perspectives; cross-cutting issues
2. Health aspects (I, II, III, IV)
3. Source water (I, III, IV, V)
4. Desalination plants/units (I)
5. Post treatment blending (I, III, IV)
6. Storage and distribution (I, III, IV)
7. Waste management (I, V)
8. Impact assessments for new facilities (V)
9. Water quality control and surveillance (IV)
10. Small facilities and vessels, and household units as an additional application (I)
11. Public perception and acceptability (II, V)

3.2 Technical workgroups

The draft guidance programme development plan distributes the 11 subjects from the topical outline among five technical workgroups to efficiently organize the technical work and to assemble the necessary technical expertise in each group based upon the scope of the group's work.

Group I: Technology–engineering and chemistry: large and small facilities

Group II: Health–toxicology of contaminants and nutritional aspects

Group III: Microbiology–sanitary and marine

Group IV: Monitoring–microbiological, analytical chemistry, surveillance, regulatory

Group V: Environmental effects and impact assessments

The technical workgroups will develop reports examining each of the five topics in the plan taking into account the outline developed for the guidance document by the consultation in Bahrain in 2001. The First Steering Committee Meeting, held in Manama, Bahrain in May 2004, reviewed the recommendations from the 2001 Bahrain consultation and elaborated a number of additional details to be addressed by each workgroup.

4. WORKGROUP SESSIONS

During the meeting, each of the workgroup chairs made a brief presentation and led discussions describing their vision of the content of their part of the guidance development process. They then met in their respective groups to develop plans and tasks. Group-to-group sessions also occurred to develop more detailed understandings of the relationships between the groups. In particular, Groups II, III, IV, V met individually with Group I to reach agreement on the specific questions, issues and deliverables to be provided by Group I and developed by the other groups.

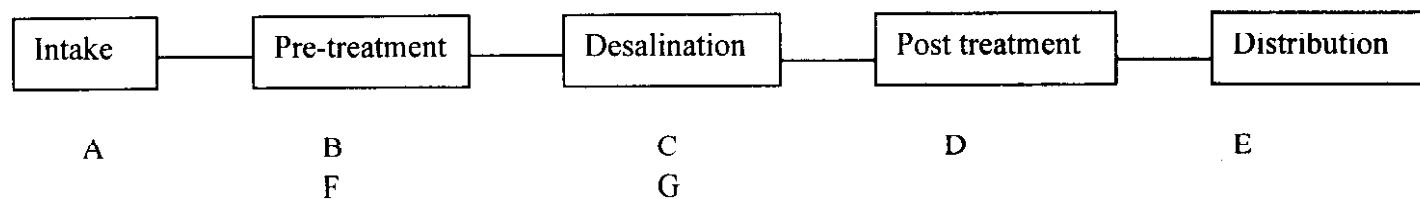
Each group developed a short report and plan that identified the specific topics to be developed for the guidance, assignments for each member and schedules for delivery of draft documents. Some of the reports included some preliminary judgments. The draft workgroup products will be delivered by 1 March 2005 to each chair, who will edit and organize them into a cohesive section. These will be provided to the Secretariat (Abouzaid/Cotruvo) who will prepare a comprehensive draft guidance document that will be the work product tabled in the second and final Technical Committee meeting in mid 2005, where the document will be completed.

5. OUTLINES FOR WORKGROUP CONTRIBUTIONS

5.1 Group I: Technology/engineering/chemistry-technical issues

The group developed a strategy to lay out the areas or processes of potential influence to health and the environment. This will serve as the basis for the report.

Location in the desalination process, to be considered in the guidance development:



Point	Location	Comments	To be covered by	Notes
A	Source/intake <i>Seawater</i> <i>Wastewater</i> <i>Brackish surface</i> <i>Wastewater</i> <i>Seawells</i>	Impingement and entrainment Trace contaminants Emerging compounds Algal toxins Hydrocarbons Natural organic matter Environmental aesthetics	Pankratz	
B	Pre-treatment	Chlorination/biocide Chemical addition Acid Cleaning chemicals	Henthorne and Sommariva	
F	Pre-treatment residuals	Solids/sludge Cleaning solutions Backwash water Concentrate (if cross flow) Spent media Cartridges/membranes Membrane integrity Corrosion byproducts	Henthorne and Sommariva	
C	Desalination process	Corrosion byproducts (include linings and coatings) Process integrity NCGs (other byproducts and steam raising chemicals) Volatile organic compounds Contaminant (and DBP) rejection Temperature of product Membrane disposal pH	Cicccone Awerbuch Jennings Somariva Awerbuch Jennings	Large system Small RO Hybrid EDR Power plants/ cogeneration Nuclear desalination link

G	Concentrate and waste streams	Temperature TDS Cleaning solution Chemicals Concentrated compounds Density Heat Cooling water Disposal method (aquifer) pH		
D	Post treatment	Formation of DBPs/THM/HAA Disinfection (secondary and blended streams) Stabilization/corrosion inhibition Chemical purity (standards) Secondary disinfection Product blending (permeate and distillate) Production blending (feedwater and desalinated water) Production blending (desalinated water with other waters) Fluoridation Aesthetic post treatments (aeration/oxygenation/degassing)	Prévost and Carter	
E	Distribution storage and POE/POU	Residence time Intrusion Leaks Leaching Temperature Commissioning practices Aggressiveness Uncontrolled blending	Carter and Prévost	

The following template will be used for each of the process steps listed above:

Template

Introduction: 1 page

Issues and concerns: 1 page

Flagging: 1 page

Total: approximately 3 pages

Leaching issues will be dealt within each chapter write up.

Draft Chapter 1 write up (each individual) by 1 December 2004

Time schedule

The workgroup chair will collect all deliverables and will edit and compile them. Discussions with other groups have been recorded and will be used in developing the various segments of the chapter.

Issues related to toxicology

Potential issues which have been identified and require further attention.

- Algae
- Toxins
- Disinfection byproducts (DBPs)
- Haloacetic acid disinfection byproducts (HAAs)
- Minimum and maximum (cost and feasibility factors)
 - Magnesium
 - Calcium
 - Others (costing of alternative approaches)
- Typical source and product water analyses for:
 - Thermal desalination. Multi-stage flash distillation (MSF) and multi-effect distillation (MED)
 - Membrane desalination (first pass and second pass) (Tom Pankratz and Corrado Somariva)

Issues related to microbiology and sanitary water quality

Pathogen inactivation against temperature and residence time requires further attention particularly for MED and mechanical vapour compression technologies. Attention should also be given to water quality and treatment issues related to blending.

Issues related to monitoring

Nick Carter will provide a copy of the monitoring pattern adopted in the United Arab Emirates to David Cunliffe, Chair of Group IV.

The issue involved in desalination in an unregulated environment (small systems) requires further attention to ensure that quality issues are properly addressed.

5.2 Group II: Health, toxicology of contaminants and nutritional aspects*Introduction*

Chemicals occur in the desalination process from a series of sources. These include the source water, chemicals that are used in the process to aid its efficient functioning, to ensure microbiological safety or to stabilize the water before it enters the distribution system. Since the process is based on removal of inorganic salts, many will not reach the finished water and

so will not pose a risk to consumers. Others will be significantly reduced in concentration and so will reduce the risk to consumers. However, not all chemicals will be removed and, as indicated above, some will be added post-process and will therefore reach consumers, although some of these may be of nutritional significance and, possibly, beneficial.

The different processes used in desalination will have, to some extent, different requirements for chemical additives and differences in the removal of chemicals from the source water but there will be a considerable overlap.

The stepwise process is as follows:

- Chemicals in source water: natural and anthropogenic
- Chemicals directly or indirectly added during pre-treatment: added chemicals and byproducts of chemical reactions
- Chemicals added to aid the better performance of the process
- Chemicals added post-treatment.

Consideration of the potential risks will depend on a number of factors, not least of which is whether there are vulnerable sub-populations that will be exposed. Groups such as dialysis patients are not considered here as the primary focus is drinking-water and this is a medical intervention where the water will require further treatment to ensure that it meets the very stringent requirements. However, bottle-fed infants are one such group because of their proportionally high intake of water and their developing physiology, which means that they may be less able to handle some constituents such as sodium.

Chemicals in source water

Naturally occurring inorganic chemicals are found in the seawater or brackish water used as the feed for desalination. These include all of the inorganic chemicals that the process is designed to remove, including sodium chloride, but will include naturally occurring chemicals that may impact on the pre-treatment stage, such as bromide and, to a lesser extent, iodide.

Most of the inorganic components will be significantly removed in the desalination process, either distillation or reverse osmosis. In terms of key contaminants for health, the most important is probably boron (as borates), which can be of significance in reverse osmosis plants since the rejection ratio of borates is less than those for other inorganics. The current WHO guideline value for boron (borate) in drinking-water is 0.5 milligrams per litre (mg/l); however, this is due to be reconsidered under the rolling revision of the Guidelines.

There is no formal WHO guideline value for sodium, which is normally present in relatively low concentrations in drinking-water, derived from freshwater sources although the taste threshold is in the region of 250 mg/l depending on the associated anions. Sodium is essential for adequate functioning of human physiology although the requirement of infants for sodium is lower and high sodium may lead to hypernatraemia. This is a problem only for bottle-fed infants and is the reason why sodium levels in infant formulae have been reduced

significantly over time. There have been concerns expressed about the importance of sodium intake for hypertension. The data seem to indicate that this is primarily a problem for a sensitive sub-population, although a number of countries are concerned about overall intake of salt from all sources but particularly food, and are seeking to persuade the populations to decrease salt intake.

Naturally occurring chemicals will also include naturally occurring organic matter such as humic and fulvic acids and the byproducts of algal and seaweed growth, where this occurs to a significant extent. Such chemicals can include substances that can impact on the odour of the final water such as geosmin from cyanobacteria in brackish water and a range of toxins from a variety of different organisms including dinoflagellates which can form significant blooms, although these are usually intermittent in nature and are very rarely present all of the time. The only one of these potential contaminants for which there is a guideline value is the cyanotoxin microcystin-LR, which arises from freshwater cyanobacteria blooms.

The nature of high molecular weight organic molecules is such that they would not be expected to carry over in thermal desalination, although the potential for carryover by steam distillation remains uncertain. The carryover would be expected to be small, but for substances such as geosmin, which has an odour threshold measured in nanograms per litre (ng/l), this could still be of concern for the potential acceptability of the final product. They would be expected to be excluded by membranes, although more data are required concerning the potential for smaller molecular weight or polar compounds to cross the membrane.

There is also a significant potential for anthropogenic contamination of source waters, particularly seawater as a consequence of discharges from sewage treatment and from industry. A number of the potential contaminants such as pharmaceuticals and hormones have a raised profile. Although these molecules would not be expected to be present in the distillate there is a potential issue regarding public perception. There is also a significant potential for contamination by petroleum hydrocarbons, particularly in regions where there is substantial activity in the extraction of oil. There is evidence that more volatile substances can volatilize and be carried over into product water; these include the benzene, toluene, ethyl benzene and xylene (BTEX) compounds and solvents such as carbon tetrachloride and tri- and tetra-chloroethenes. Although there are drinking-water guideline values for all of these substances, the issue regarding the BTEX compounds is the potential for unacceptable odour at concentrations much lower than the health-based guideline value. The assessment of potential hazards and risks from pollutants will require an evaluation of the potential sources and types of pollutant in the local circumstance.

An additional potential concern for which there appear to be no firm data is the use of hydrazine in power plants as an oxygen scavenger. This may be discharged to the source water where plants are sited adjacent to desalination facilities and may be taken into the desalination plant. There is the possibility of some intermixing of steam condensate with finished water.

There have also been suggestions of contamination by metals, particularly mercury, and there is a potential issue for distillation plants with the volatilization potential for mercury.

Pre-treatment

Pre-treatment of the water is normally designed to remove potential contaminants that will interfere with the process. This can include coagulation and filtration which will remove particulate and organic matter, including reducing natural organic matter. Where there is a need to disinfect the usual disinfectant is chlorine.

Humic and fulvic acids and other related substances can react with chlorine to produce a wide range of halogenated byproducts. In the presence of high bromide as found in seawater and many brackish waters, the bromide is oxidized to bromine which will take part in the halogenation reactions. Data from studies on the chlorination of seawater show that the yield of disinfection byproducts in the form of chlorinated trihalomethanes (THMs) is relatively low and they are dominated by the brominated THMs, particularly bromoform and to a lesser extent chlorodibromomethane. The WHO guideline values for these two substances are both 100 micrograms per litre ($\mu\text{g/l}$), while the guideline values for the two other THMs are 200 $\mu\text{g/l}$ for chloroform and 60 $\mu\text{g/l}$ for bromodichloromethane. Small quantities of iodinated THMs may also be present, but there are no guideline values for these substances and there appear to be no data on their occurrence.

Organonitrogen compounds, particularly nitrosodimethyl amine (NDMA) and possibly nitrosodiethyl amine (NDEA) may be formed in chloramination. There are only limited data on the formation of these compounds in drinking-water and there appear to be no data on the formation in seawater. There is evidence of higher levels of formation in chlorinated wastewater, where there will also be ammonia present, and so where chlorinated sewage effluents are likely to impact the raw water there may be potential for these compounds to volatilize and be carried over into the product.

Where hypochlorite is produced by electrolytic generation from seawater/brine with a high bromide level, this can lead to the formation of bromate. Bromate might or might not pass through membranes, and it would not be expected to carry over in thermal systems. Where hypochlorite is allowed to age, there is a potential for the formation and build-up of chlorate.

Theoretically a number of organic contaminants, both raw water contaminants and those resulting from disinfection, could transfer into the product as a consequence of steam distillation. There is a need to determine how important this is and under what circumstances it will take place.

Membranes provide a barrier to most chemical compounds, although not always a complete barrier. The propensity of boron (borate) to pass through membranes raises the question as to what small polar organic molecules are likely to pass through the membranes and as to which non-polar compounds might pass through by dissolving in the membrane polymer.

Post-treatment

There are four primary issues concerning post-treatment water: remineralization; blending; disinfection; and materials used for storage and transport of the water to the tap.

Desalinated water is often blended with other sources that contribute minerals to the final blended water. Seawater as a source for blending has a number of significant disadvantages, particularly in terms of corrosion and taste, and of course without adding any beneficial minerals. It is important that consideration is given to the natural minerals present and whether these would result in water not meeting the Guidelines or causing unacceptable taste. There is also a potential issue regarding potential anthropogenic pollutants from a range of sources but these would need to be considered on a local basis, taking into account potential sources and threats. Should there be an issue over microbiological contamination there may be a requirement for disinfection, and similar considerations regarding the formation of byproducts apply as discussed under pre-treatment processes. Generally the natural organic matter content is very low and the yield of disinfection byproducts would be expected to be low as a consequence.

In a number of cases water is remineralized to reduce its potential for corrosion. Under these circumstances it is appropriate to consider whether the methods used, such as percolation through limestone, can also increase the concentrations of important nutritional minerals, particularly calcium and magnesium. Phosphates may improve the uptake of some minerals. There is a need for WHO to consider the importance of calcium and magnesium for protection against ischaemic heart disease and to determine the optimum levels of calcium and magnesium and the importance of Ca/Mg ratio, in order to provide guidance as to the optimal levels of addition. There are significant considerations with regard to cost benefit in particular circumstances and for public perception.

Fluoride is also a potential consideration with regard to low fluoride, which may lead to loss of fluoride from the bones. The recommendation of a WHO workgroup was for a minimum fluoride concentration of 0.2 mg/l, but this recommendation may require refinement and confirmation. It is also a potential issue with regard to artificial fluoridation to protect against dental caries where this is a significant problem or where there is a significant risk that cannot be addressed through other means.

With regard to sodium levels in the final water, this requires specific consideration with regard to potentially sensitive populations, such as bottle-fed infants.

In addition other corrosion inhibiting chemicals may be added to the water, such as polyphosphate. While these chemicals are not considered to be of direct consequences for health, it is important that they are of a suitable quality for drinking-water addition and that they are verified to be always of an appropriate quality. Approval systems for chemicals that specify the quality and particularly the acceptable levels of contaminants are available and guidance on how such systems can and should operate is needed. Hydrazine as an additive may warrant particular attention if it reaches the finished water.

There is also a requirement to ensure that corrosion does not give rise to levels of metals that exceed the guidelines. These can include metals from primary distribution, particularly iron, and from plumbing and fittings in buildings which may contain leaded brass. In many cases a range of coatings and materials will be used to coat pipes, storage reservoirs or for storage tanks in buildings. It is important that these materials are of a suitable quality for use with potable water and, as indicated above, approval schemes have an important part to play in ensuring their safety and reducing the potential impact on consumer acceptability. There is a particular consideration in the approval of materials since in many of these circumstances they will be used at elevated temperatures, which can exacerbate leaching of components.

Additional issues

There have been suggestions that drinking very low mineral water can lead to a number of adverse effects on humans, particularly on the gastrointestinal tract, even with a diet that provides an adequate level of essential minerals. There is a need to investigate this subject in order to determine if there is a significant issue that needs to be taken into account.

Desalination has been used in some parts of the world for many decades, and this experience potentially provides a basis for epidemiological studies of various health outcomes. Such studies, if properly controlled and with proper consideration of potentially confounding factors, would be of considerable value in determining the long-term safety of desalinated water.

Mixing untreated blending water with finished water provides possible chemical and microbiological contamination issues. It is also important to ensure that disposal of the concentrated brine does not lead to contamination of other water sources and particularly groundwater.

5.3 Group III: Microbiology

Overview

Group III provides technical expertise related to sanitary microbiology of source waters, desalination operations, and distribution systems operations. Four participants were selected on the basis of their previous experience with: catchment characterization and microbiological source water quality (Sunny Jiang, University of California, United States); reverse osmosis membrane technology and biofouling (Harvey Winters, Fairleigh Dickinson University, United States); pathogens in water – epidemiology and treatment (Pierre Payment, University of Québec, Canada); and microbiology/biofilms of drinking-water distribution systems (Jean-Claude Block, University Henri Poincaré, France).

The potential of drinking-water to transport microbial pathogens and algal toxins to large populations causing outbreaks is well documented in countries at all levels of economic development. The problems faced by using specific resources and technology, such as marine and brackish water desalination by membranes/thermal treatments with subsequent transport

through a distribution system, are exactly the same as those encountered in a standard drinking-water distribution system (DWDS).

The group adopted the flow-chart designed for risk-based approach to ensure the safety of drinking-water, which is based on five key components:

- water quality targets based on public health protection and disease prevention
- system assessment to determine whether the water supply chain as a whole can deliver water of quality that meets the defined targets
- monitoring the steps in the supply chain that are of particular importance in securing safe drinking-water
- actions to be undertaken from normal conditions to extreme events
- systematic independent surveillance that verifies that the above are operating properly.

The workgroup first addressed issues to be discussed with special regard to sanitary microbiology:

- What are the contaminants (pathogens, etc) in marine and brackish water?
- Should we monitor for these contaminants or indicators?
- What is the efficiency of desalination processes to remove or inactivate these contaminants?
- Are distribution systems fed with desalinated water different from other drinking-water distribution systems (compare with low total dissolved solids (TDS) natural waters often with higher assimilable organic carbon [AOC])?
- Is there a potential for survival or growth of these contaminants during the treatment processes or in the distribution system?
- Is blending of treated water with other sources a potential risk?
- Are biofouling bacteria of public health significance?
- Is pipe corrosion associated with desalinated water and the subsequent bacterial activity a source of public health concern?
- Is there a public health benefit of maintaining residual disinfectant in DWDS?
- What are indicators of process efficiency?
- Can biotests (e.g. AOC, biodegradable dissolved organic carbon [BDOC]) be applied to desalinated water?
- What are the reported corrosion problems in desalinated water-fed distribution systems when the water is not completely stabilized?
- What are the methods used to control these problems?
- How do they impact the microbial content of distributed water to the consumer?
- Considering the high quality of reverse osmosis water, one may assume after final disinfection that post-chlorination may not be needed in some cases. When is there a public health benefit of maintaining residual disinfectant in DWDS?
- What is the effective concentration of disinfectant in desalinated drinking-water to achieve pathogen inactivation, biofilm control?
- Differences in efficiency of various forms of chlorine disinfectants: in situ electrolytic generation of hypochlorite using seawater.
- Contrasted results for the use of chlorine versus chloramines.

Source water characteristics and microbial quality

Source waters used for desalination are often coastal marine waters that may be subject to faecal contaminants, or brackish ground waters that are more protected from microbial contaminants.

Humans, livestock and wild animals are all sources of coastal water contamination via the wastewater discharges through sewage outfalls; urban or stormwater runoff; and agriculture or aquaculture runoff. Types of pathogen associated with these sources are similar to those found in the freshwater environment including human enteric bacteria and viruses and protozoa. Variations in water quality can be high according to season or peak precipitation events.

In addition to pathogens associated with anthropogenic activities, some indigenous marine bacteria such as *Vibrio* spp. and toxin-producing algae can also be a potential source of human health risk through drinking-water. The abundance of these indigenous bacteria that are of human health risk displays strong seasonal and temporal variability. For example, studies have shown that *Vibrio cholerae* are only isolated from Chesapeake Bay during the warm seasons and the highest concentrations are found at sites with salinity ranging between 10 and 25 parts per thousand in the Newport Bay area. Blooms of toxin-producing algae can be triggered by anthropogenic nutrients input by waste discharge to coastal waters (organic and inorganic).

The following examples highlight some characteristics of saline water:

- Enteric bacteria discharged into the marine environment are not able to multiply and decay more rapidly (or become uncultivable) than those in the freshwater environment, with the exception of *Vibrio* spp. which can multiply in saline water. The decay rate is determined by water temperature and presence of grazers.
- Human viruses and protozoa pathogens may survive for long periods of time and be transported long distances by coastal currents and surface waves.
- Urban and storm runoff can be a source of faecal contamination in areas with combined sewer overflow systems during the storm season.
- Agriculture and aquaculture runoff are direct sources of human pathogens that have an animal reservoir (*Salmonella*, *Escherichia coli* O157, *Cryptosporidium*, *Cyclospora*, *Giardia*).
- Ballast water can also play a role in the transportation of pathogens on a global scale.
- Harmful algal blooms are sources of shellfish poisoning, including paralytic (PSP), neurotoxic (NSP) and amnesic shellfish poisoning (ASP). Toxin-producing algal species include *Gymnodinium breve* (NSP), *Alexandrium* spp. (PSP), *Pfiesteria piscicida*, *Pseudo-nitzschia* spp. (ASP), Brown tide organism (*Aureococcus* and *Aureoumbra*), cyanobacteria
- Human pathogens that are indigenous to marine water include *Vibrio parahaemolyticus*, *Vibrio vulnificus*, *Vibrio minicus*.

Preliminary conclusions (issues, recommendations and actions)

- Routine monitoring (define frequency) of the microbiological quality of the source water can be used to ensure that the treatment processes in place are sufficient to reduce the public health risks to an acceptable level.
- Monitoring of specific microbial pathogens is generally *not* recommended except in disease outbreak investigations.
- The concentrations of enterococci, *E. coli* and coliphage can be used as indicators of the level of faecal contamination. The selection of indicator should be determined by the local authorities, depending on capacity and technology availability.
- The first step in providing safe drinking-water is selection of the best available source water, which includes selection of the location of desalination plants to avoid water of poor microbiological quality (i.e. away from sewage outfall and storm drains), and determination of the plant operating procedures to avoid intake of water containing high concentrations of biotoxins during harmful algal blooms.

Desalination process: efficiency and weaknesses

For membrane filter process, surrogates for pathogen removal are generally accepted. Total aerobic spores or spores of *Clostridium perfringens* are reasonable surrogates for the cysts and oocysts of parasitic protozoa. Coliphages may also be appropriate for human enteric viruses.

The microbiological quality of desalinated water is generally excellent meaning very low or no detectable microorganisms and low organic matter that will limit the growth of heterotrophic bacteria downstream from the process.

The efficiency of the desalination process may be affected by:

- The formation of biofilm on membranes due to attachment and growth of bacteria, and subsequent biofouling (i.e. after dechlorination), depending on the critical flux and crossflow conditions;
- The breaking, by chlorine, of large organic molecules into easily assimilable organic molecules, which becomes an unexpected source of assimilable energy for bacteria.

The microbiological quality of the product water can be compromised by:

- The presence of imperfections (membrane with compromised integrity + cracked o-ring) not producing measurable changes in product flow, which could cause passage of pathogens at undesirable levels;
- The blending of the treated water with 1% to 10% untreated or insufficiently treated resource water (or other available waters), which may result in the introduction of pathogens in finished water.

Preliminary conclusions (issues, recommendations and actions)

- More information is needed about the blending practices in order to evaluate the risks from microbial pathogens.
- With regard to monitoring the process efficiency, in addition to continuous monitoring for physical–chemical parameters, phages can be used as indicators of virus removal and membrane efficiency.
- Quantifying passage is important, e.g. bacterial cells or spores, pathogens, organic carbon, toxins.

Vulnerability of drinking-water distribution systems

There is increasing concern about accidental intrusions of pathogens into distribution systems or deliberate pathogen contamination. Deficiencies in distribution systems (in addition to passage) include cross-connection and back-siphoning, contamination while in storage, contamination during construction/repair, and broken and leaking mains. They have been suggested as the source of pathogens during epidemiological studies of gastrointestinal illness associated with drinking-water transported through distribution systems. Such problems are not specific to the distribution systems of desalinated waters, except perhaps from the blending of source waters with treated waters.

In traditional distribution systems, there is an active microbial community that will limit growth and reduce background pathogen level. This protective effect is less pronounced in nanofiltrated-water fed DWDS due to low biodiversity (especially the low number of protozoa).

Pathogens introduced in DWDS implant biofilm or deposits, which may then be regarded as transitory reservoirs of pathogens. The fate of these pathogens is difficult to predict.

Preliminary conclusions (issues, recommendations and actions)

- Heterotrophic plate count bacteria (HPC) in drinking-water is not public health issue per se.
- HPC is a good indicator of bacteria re-growth in the DWDS.

Pipe corrosion and bacterial activity

The effect of desalinated water on pipe corrosion is well described. Remineralization and pH control are needed to ensure stability and integrity of the distribution system. The microbial colonization of pipe walls is probably promoted when they are highly corroded (better adhesion of negatively charged bacteria on positively charged iron oxide particles). Moreover, biomass production is considerable in highly corroded pipes compared to slightly corroded ones. This leads to rapid loss of chlorine residual and potential survival of embedded pathogens. Iron corrosion products have also been reported to support the growth of the indicator *E. coli*. It is clear that the control of corrosion by decreasing water aggressiveness or

by anti-corrosion treatment is needed to limit the excessive growth of biomass in the network and to alleviate coliform regrowth.

The practice of adding phosphate to control corrosion has raised questions about the possible effects of phosphate on bacterial growth in drinking-water distribution systems. Phosphate is one of the major nutrients required by bacteria, since it is their usual source of phosphorus that is vital to their survival, as it is for any living cell. There is no consensus in the literature about the effect of phosphate on bacterial populations in drinking-water distribution systems. A review of several publications reveals that any addition of phosphate to drinking-water distribution systems can lead either to a very limited change or to a significant increase in biomass.

Disinfection of the desalinated water

Chlorine, chloramine, chlorine dioxide, and chlorine compounds generally, have been used successfully for many years to disinfect drinking-water. Ozone and ultraviolet light are also of interest. Concentration $\times$ time ($C \times T$) values have to be evaluated for saline waters. Sanitary risks of blending untreated waters needs to be evaluated.

Chlorine usefulness in distribution system maintenance

Chlorine is able to limit bacterial regrowth both by injuring bacteria, thereby preventing their growth, and by limiting the production of bacteria in the DWDS, either in the planktonic phase or in the biofilm. However, the chlorine residual resulting from such a treatment, which is usually less than 1 milligram of Cl_2 per litre, is insufficient to kill and remove all the attached biomass. Even large doses and drastic treatments are unable to eradicate biofilms. A large fraction of the bacterial population escapes disinfection. This is because of both the microbial aggregation state, which limits diffusion of the oxidant, and the sophisticated antioxidant strategies developed by many microorganisms. Effects of residual disinfect on pathogens are minimal for viruses and parasites and minimal to partial for bacteria.

In DWDS, chlorine concentration variations can be used to detect changes in water quality. Abnormal changes in HPC number can provide a similar answer in the absence of chlorine (see WHO Guidelines).

5.4 Group IV: Monitoring, microbiological, analytical chemistry, surveillance, regulatory

The task identified for Group IV from the 2004 meeting of the steering committee was to produce a report dealing with monitoring aspects from source to consumer including the following components:

- Source water quality, taking into account fluctuations and potential impacts of contamination sources;
- Process management (membrane based and distillation), including membrane integrity and the impacts of additives and materials used in processes on water quality;

- Water used for blending, control of the blending process and water quality after blending;
- Impacts of storage and distribution, including assessment of corrosion and stability;
- Verification/surveillance of water quality as supplied to consumers; this should include consideration of processes, additives and materials used.

The report was to discuss the use of direct monitoring of chemical and biological parameters as well as the use of surrogates and indicators.

The minutes of the 2004 meeting also indicated that the report should be consistent with the third edition of WHO Guidelines for Drinking-water Quality and the approach described in the Framework for Safe Drinking-water. The Framework discusses several types of monitoring: operational monitoring, verification and surveillance.

a) Operational monitoring

Operational monitoring is used to measure the individual performance of control measures (including treatment processes). The parameters used for operational monitoring need to:

- reflect the effectiveness of each control measure
- provide a timely indication of performance based on compliance with operational limits (used to separate acceptable and non acceptable performance)
- be readily measured
- provide opportunity for corrective responses (where required).

b) Verification

Verification is the final check that water quality provided to users is safe. Verification can be undertaken by the water supplier as part of overall quality control, by a surveillance agency such as a regulator or by a combination of the two. Verification typically involves testing for microbiological and chemical quality. Microbial verification can be undertaken after treatment and in distribution systems. Testing for chemicals of concern may be at the end of treatment/production, in distribution or at the point of consumption (depending on whether the concentrations are likely to change in distribution).

c) Surveillance

Surveillance is generally undertaken by agencies independent of the drinking-water supplier and can include two types of approach. Audit based assessment and direct testing. Where direct testing is undertaken it usually involves the same types of parameters and monitoring undertaken for verification although frequencies may differ.

Developments from the meeting

Prior to the Technical Committee meeting, the 5 abm components were divided among the members of the workgroup as follows:

1. Samia Galal Saad
2. Marie-Marguerite Bourbigot
3. Rick Sakaji
4. Shoichi Kunikane
5. David Cunliffe

Each member of the workgroup prepared a background paper to inform the discussions at the meeting.

At the meeting a table (below) was developed, summarizing monitoring recommendations. This was undertaken in consultation with the other workgroups. The next step is to provide supporting text for the contents of the table. The work will be divided using the same component structure developed before the meeting.

An introductory section will also be prepared by David Cunliffe dealing with general issues including:

- importance of monitoring
- maintenance/calibration/recording/interpretation/documentation
- corrective actions
- training/occupational health and safety
- observational monitoring including integrity of system
- critical limits and target criteria.

Location	Target/issue	Parameters
Source water quality	Cryptosporidium/Giardia/pathogenic bacteria/enteric viruses (likelihood of presence based on sanitary inspection)	Enterococci <i>E. coli</i> Surrogate Turbidity – storms/sewage (used as on-line measurement for process control)
	Microalgae/cyanobacteria	Monitor algal species (toxins–check issue of passage?) Chlorophyll as a surrogate
	Chemical/physical Temperature Total organic carbon (TOC) (if concentrations change investigate sources) boron, silica, iron/manganese (aquifers) alkalinity, pH Oil hydrocarbons/grease, and volatile hydrocarbons (based on an assessment of local conditions) Bromide and iodide, heavy metals (low frequency) radioactivity (based on an assessment of local conditions) Industrial chemicals (based on an assessment of local	

	conditions) Ammonia (impacts on disinfection) Low solubility chemicals e.g. CaCO_3 , CaSO_4 , CaF_2 , BaSO_4 , SiSO_4 (low frequency) Hydrogen sulfide and metal sulfides (precipitation and membrane fouling)	
Pre-treatment	Biofouling/scaling/ precipitation	<i>On-line</i> Flow rates Conductivity (if conductivity/TDS ratio changes can be an indication of biofouling/scaling/ precipitation) Turbidity after pre-treatment Particle counting pH (if acidification or alkalization) <i>Not on line</i> Site density index (SDI)
	Disinfectant dosing	<i>On-line</i> Disinfectant residual Note removal required prior to (membranes) Oxidation reduction potential (ORP)
Process management	Process control	<i>On-line</i> Trans-membrane pressure (membranes) Flow meters on permeate and brine Conductivity on permeate and brine <i>Not on line</i> Recovery ratio (calculated from flow rates) Chemical balance from conductivities and flow rates
	Scaling	Monitor top brine temperature (MSF/MED) – <i>on-line</i>
	Additives e.g. antiscalant (membrane) antifoaming (thermal) Quality control on additives and materials (records + testing) Hydrazine (MIDVC)	Flows Dosing monitoring Dosing + carryover monitoring (frequency based on system design)
	Cryptosporidium/Giardia/pathogenic bacteria/enteric viruses	On-line conductivity (see process control)
Blending	Cryptosporidium/Giardia/pathogenic bacteria/enteric viruses Use pretreated water or protected groundwater Untreated surface water not to be used	<i>E.coli</i> /enterococci in blending water
	Chemical quality	If using alternative source, monitor chemical quality After blending, monitoring on line of pH, and conductivity Lonelier saturation index (LSI) Larson Index where mortar linings used
Remineralization	pH control Chemical addition (e.g. CO_2 , lime or limestone) Quality control on additives and materials (records + testing)	On line measurement of pH, and conductivity LSI Larson Index where mortar linings used
Disinfection	Microbial quality	On line measurement of disinfectant Calculate CxT Monitor heterotrophic plate count (HPC)
	Chemical quality	Disinfection byproducts (note brominated compounds)

Storage distribution	Faecal pathogens	<i>E. coli</i>
	Free living	HPC/disinfectant (disruption from mixing) HPC/disinfectant residual (<i>Legionella</i> / <i>Naegleria</i> potential – could consider persistent residual)
	Corrosion in storage tanks, long pipes, domestic plumbing	Iron and heavy metals where metal piping or fittings Concrete pipes – high pH (due to leaching) monitor magnesium for nutritive value Domestic plumbing could require increased testing for copper, lead, iron, nickel, zinc (aesthetic) Domestic storages if galvanized metal corrosion
	Mixing different sources (desalinated non-desalinated water)	Post mixing increase monitoring for LSI Consider product testing
	Intrusion, microbial and chemical	Hydraulic pressures could indicate leakage/intrusion (increased risk due to corrosion) Turbidity HPC
Consumer	Faecal pathogens	<i>E. coli</i>
	Chemical quality	Usual chemicals. Boron frequency may be higher Consider brominated disinfection byproducts

5.5 Group V: Guidance for environmental impact assessment of desalination plants

Objective

In the process preceding and leading to the establishment of the technical committees, it was decided that the primary objective of Group V would be to provide a guidance document for environmental impact assessment (EIA) studies of desalination plants. Besides environmental impacts, the guidance document should cover socioeconomic implications and aspects of public perception related to desalination.

Progress before the meeting

In order to provide this kind of guidance, the scope and formal requirements of an EIA study – specific to the needs of desalination – were investigated in the time before the first workgroup meeting took place in October 2004. A comprehensive inventory of environmental, socioeconomic and public perception aspects was compiled from the written contributions and comments made by the individual workgroup members via email. These items were then arranged in a logical structure to provide both a checklist, which can be used for actually carrying out EIA studies, and a format for how an EIA report may be organized to

present the results. The draft EIA format provided the basis and starting point for discussions during the meeting.

Progress during the meeting

In the first workgroup session, the scope and objectives of Group V were re-evaluated and discussed to establish a common understanding of the tasks to be completed during the following sessions. It was agreed that the EIA format should be considered as a “recipe” and “checklist” for how to conduct an EIA for desalination plants. It should cover the range of relevant issues as far as possible, but should clearly identify the important aspects, major concerns and problems related to desalination. Gaps in knowledge and uncertainties related to the socioeconomic and environmental impacts of desalination should be addressed in the document.

Furthermore, this WHO guidance document would offer a conceptual approach and recommendations on what to generally include in an EIA for desalination plants. It is the task of the user and regulatory authority to decide what might or should be included to carry out an EIA for a specific project. As the EIA format cannot offer a “template” for all types of plants, processes and environmental settings, and additionally suit the realities of different countries, it will be necessary to make modifications, amendments and deletions of single items and changes to the methodology in most cases. Having this in mind, it was concluded that the EIA format should provide a basis for carrying out specific EIA studies by giving people an idea of what to consider in an EIA (“checklist”) and how to achieve this goal (“recipe”). The guidance document should for this purpose also provide a first overview on these relevant issues, giving references for more background information if necessary.

Topics to be analysed

It was decided that the EIA guidance document should include recommendations on the following areas.

- The actual EIA format.
- The methodology of an EIA, covering:
 - the sequence of succeeding steps in an EIA study
 - approaches to actually assess the severity of predicted effects and how to identify significant impacts (partial link to Group IV).
- Recommendations for the establishment of:
 - baseline data
 - a monitoring programme for the time of construction and beginning of operation of the facility to detect environmental changes relative to the baseline data
 - a monitoring programme for regulatory aspects, with emphasis on the effluent discharges to the marine environment, and also ground water quality in the event of land disposal of concentrates.

A methodological approach was elaborated suggesting 11 successive steps to be followed in an EIA for desalination plants, starting from project screening to concluding the EIA study with recommendations.

- Step 1 – Basic screening process – Is an EIA necessary?
- Step 2 – Scoping – What is needed? (i.e. What are the inputs?)
- Step 3 – Project description (life cycle of project)
- Step 4 – Development of environmental and socioeconomic baseline
- Step 5 – Identification of legislative and regulatory considerations
- Step 6 – Determination of potential impacts
- Step 7 – Identification and evaluation of potential impacts
- Step 8 – Development of a mitigation measures
- Step 9 – Development of monitoring programme for different stages
- Step 10 – Review of EIA
- Step 11 – Preparation of EIA report

The methodological approach was then merged with the draft EIA format that had been elaborated before the meeting. Furthermore, aspects identified by Groups I, II and IV relevant to EIA studies of desalination plants were considered in this process. The result is a first draft of the working product of Group V, which will be an EIA guidance document.

In the draft guidance document, public perception and participation issues will be addressed in a separate chapter to emphasize their importance for the success and acceptability of a desalination project. It was agreed that public participation should start as early as possible in the planning phase of a project and that it should continue during the EIA of the project.

Identified crossover topics with other groups and recommendations

Group I suggested addressing the performance ratio of thermal plants in the EIA guidance document, as an increased performance ratio will reduce thermal discharges and total effluent volumes. Group V asked Group I to:

- provide available information on brine and cooling water concentrations of heavy metals during commissioning, cleaning and operation as well as on the metal speciation during these life cycles (ions, salts, complexes)
- provide available results of studies investigating metal discharges of desalination plants, which were according to Group I carried out in some GCC states
- discusses alternatives to chlorination or dechlorination techniques
- provide available data on biodegradability of polymer antiscalants from material safety data sheets (especially of polymaleic and polyacrylic acid based products and preferably results of ready or inherent biodegradation test conducted according to standardized testing methods)

- about the possibility to treat membrane cleaning solutions in industrial or municipal waste water treatment plants
- about the possibility of sludge disposal from the reverse osmosis backwashing process in landfills.

Group II suggested to:

- include aspects of seawater intake quality in the site selection recommendations
- cover brine and thermal discharge issues
- evaluate the wasted membranes as part of the life cycle assessment.

Group IV suggested to:

- consider worker safety and training requirements (ISO 14000 EMS)
- recommend that the EIA document should be a public, not confidential, document
- cover the requirements for discharge and dispersion of brine for the protection of the near shore environment (including monitoring requirements)
- consider socioeconomic considerations, specifically the status of women
- recommend emergency response preparedness and security (for example protection of intakes)

Lead people responsible for preparing the analysis of each topic

The following list is a condensed preliminary table of contents, outlining the chapters and main subsections of the EIA guidance document as elaborated during the meeting and including assignments to be completed by the nominated individuals by 1 December (preliminary draft) and 1 March (final version).

1. Preamble – *Greg Leslie*
1. Guidelines for the EIA of desalination – *Hosny Khordagui*
2. EIA screening process – *Brad Damitz*
3. Public perception, participation and education issues – *Hosny Mancy, Greg Leslie*
4. Developing the scope of the EIA – *Hosny Khordagui*
5. Description of proposed projects – *Greg Leslie*
6. Baseline factors
 - Environmental factors – *Sabine Lattemann*
 - Socioeconomic factors – *Sabine Lattemann, Brad Damitz*
 - Environmental health factors – *Sabine Lattemann, Hosny Mancy*
7. Determination of potential impacts
 - Techniques to identify magnitude of impact – *Hosny Khordagui*
 - Criteria for the identification of significance of impacts – *Hosny Khordagui*
 - Environmental impacts – *Sabine Lattemann*
 - Socioeconomic impacts – *Sabine Lattemann, Brad Damitz*
 - Environmental health impacts – *Sabine Lattemann, Hosny Mancy*
8. Mitigation and avoidance measures – *Sabine Lattemann*
9. Monitoring programmes – *Greg Leslie (template tables)*

10. Review of EIA – *Hosny Khordagui*
11. EIA report preparation guidelines – *Sabine Lattemann*
12. Conclusion and recommendations – *all*
13. Appendices – *all*

6. NEXT STEPS

In the final session, the entire Technical Committee met in plenary session to review the draft meeting report and to discuss final comments on each of the workgroup plans. Preliminary drafts are to be completed by 1 December 2004 for compilation and circulation among workgroups and Drs Houssain Abouzaid and Joe Cotruvo. Complete draft versions are to be completed by March 2005.

Annex 1

PROGRAMME

Thursday October 21

17:00 Pre-meeting of workgroup Chairs (Abouzaid, Cotruvo)

19:00 Reception for all participants

Friday October 22

8:00 Registration

9:00 Opening plenary session

Welcome from WHO/EMRO (Abouzaid)

Background for meeting

Introductions

Logistics

9:30 Overview of the project (Cotruvo)

10:45 Overview of scope of each workgroup and discussion

I. Technology, Engineering, Chemistry (Sommariva)

II. Health: Toxicology of Contaminants and Nutritional Aspects (Abdulraheem)

III. Microbiology: Sanitary and Marine (Block)

IV. Monitoring: Microbiological, Analytical Chemistry, Surveillance, Regulatory (Cunliffe)

V. Environmental Effects and Impact Assessments (Lattemann)

13:30 Individual workgroups convene

17:30 Reconvene in plenary session

Saturday October 23

8:00 Workgroups reconvene

8:15 Status meeting of workgroup Chairs and Abouzaid, Cotruvo

9:00 Roundrobin interactive meetings between the workgroups

10:15 Workgroups reconvene

16:30 Convene in plenary session: group discussion on progress and issues

21:00 Short status meeting of workgroup Chairs, Abouzaid, Cotruvo

Assemble draft meeting report

Sunday October 24

8:00 Workgroups reconvene and continue guidance development

Draft meeting report review

10:15 Plenary session

12:30 Closure

Annex 2

LIST OF PARTICIPANTS

Members of the workgroups

GROUP I: Technology/engineering/chemistry

Chair: Dr Corrado Somariva

Abu Dhabi

UNITED ARAB EMIRATES

Sc1@mottmac.co.ae

Dr Leon Awerbuch

Leading Edge Technologies

Winchester, Massachusetts

UNITED STATES OF AMERICA

letleon@internetegypt.com

Dr Nick Carter

Director General

Abu Dhabi Regulation and Supervision Bureau

Abu Dhabi

UNITED ARAB EMIRATES

nscarter@rsb.gov.ae

Dr Vince Ciccone

Romem Aqua Systems Co. (RASCO) Inc.

Woodbridge, Virginia

UNITED STATES OF AMERICA

rasco1@aol.com

Dr David Furukawa

Separation Consultants, Inc.

Poway, California

UNITED STATES OF AMERICA

davfuruk@aol.com

Dr Ludwig Heintz*

Fichtner Technology

Stuttgart

GERMANY

* Unable to attend

Dr Lisa Henthorne
CH2M Hill
Global Director of Desalination
Dubai
UNITED ARAB EMIRATES
lisa.henthorne@ch2M.com

Dr Hisham Hettuney*
Kuwait University
Kuwait
KUWAIT
Hishamkuc01@kuniv.edu.kw; hisham@kuniv.edu.kw

Dr Tom Jennings
U.S. Bureau of Reclamation
Denver, Colorado
UNITED STATES OF AMERICA
Tjennings@do.usbr.gov

Dr Frank Leitz*
Water Treatment Engineering and Resource Group
US Bureau of Reclamation
Environmental Research Services
Denver, Colorado
UNITED STATES OF AMERICA

Dr Michèle Prévost
Civil Engineering
Ecole Polytechnique de Montréal
Montreal, Québec
CANADA
Michele.prevast@polymtl.ca

Dr John Tonner
Water Consultants International
Mequon, Wisconsin
UNITED STATES OF AMERICA
john@tonner.com

* Unable to attend

Group II: Health, toxicology, nutrition

Chair: Dr Mahmood Y. Abdulraheem

Kadhema for Environment

Kuwait

KUWAIT

M_abdelraheem@kadhema.com; myaenv@yahoo.com

Dr Fatimah M. Al Awadhi

Kuwait Foundation for the Advancement of Sciences

Safat

KUWAIT

research@kfas.org.kw

Dr John Fawell

Flackwell Health

High Wycombe

Bucks

UNITED KINGDOM

john.fawell@johnfawell.co.uk

Dr Yasumoto Magara

Hokkaido University

Sapporo

JAPAN

magara@eng.hokudai.ac.jp

Dr Choon Nam Ong

National University of Singapore

Department of Community, Occupational and Family Medicine

Singapore

SINGAPORE

cofongen@nus.edu.sg

Dr Edward Ohanian

Director, Health and Ecological Criteria Division

USEPA, Office of Science and Technology/Office of Water

Washington, DC

UNITED STATES OF AMERICA

Ohanian.edward@epa.gov

Dr Tom Pankratz

CH2M Hill

Houston, Texas

UNITED STATES OF AMERICA

tpankrat@ch2m.com

Group III: Marine and sanitary microbiology

Chair: Dr Jean-Claude Block

LCPME-UMR Université CNRS

Vandoeuvre les Nancy

FRANCE

jean-claude.block@pharma.uhp-nancy.fr

Dr Farooq Azab

Scripps Institute of Oceanography

La Jolla, California

UNITED STATES OF AMERICA

Dr Henrik Enevoldsen*

IOC Science and Communication Centre on Harmful Algae

University of Copenhagen

Copenhagen

DENMARK

henrike@bot.ku.dk

Dr Sunny Jiang

University of California, Irvine

Irvine, California

UNITED STATES OF AMERICA

sjiang@uci.edu

Dr Pierre Payment

INRS-Institut Armand-Frappier

Laval, Québec

CANADA

Pierre.payment@inrs-iaf.quebec.ca; Pierre_eau@sympatico.ca

Dr Harvey Winters

Fairleigh Dickenson University

Teaneck, New Jersey

UNITED STATES OF AMERICA

Harvey@fdu.edu

* Unable to attend

Group IV: Monitoring–microbiology/chemistry/surveillance/regulatory

Chair: Dr David Cunliffe

Principal Water Quality Adviser

Environmental Health Service

Department of Health

South Australia

AUSTRALIA

david.cunliffe@dhs.health.gov.au

Dr Marie Bourbigot

Véolia Environment

Paris

FRANCE

[marie-marguerite.bourbigot @groupve.com](mailto:marie-marguerite.bourbigot@groupve.com)

Dr Shoichi Kunikane

Department of Water Supply Engineering

Ministry of Health, Labor and Welfare

Wako

JAPAN

kunikane@niph.go.jp

Dr Richard H. Sakaji

California Department of Health Services

Drinking Water Program

Berkeley, California

UNITED STATES OF AMERICA

rsakaji@dhs.ca.gov

Group V: Environmental impact assessment and public perception

Chair: Dr Sabine Lattemann

Königswinter

GERMANY

sabine.lattemann@paua.de

Dr Bradley Damitz

Monterey, California

UNITED STATES OF AMERICA

brad@centralcalcoast.com

Dr Klaus Genthner

Bremen

GERMANY

genthner@uni-bremen.de

Dr Hosny Khordagui

UN-ESCWA

Beirut

LEBANON

khordagui@un.org

Dr Greg Leslie

School of Chemical Engineering

University of New South Wales

Kennington

AUSTRALIA

g.leslie@unsw.edu.au

Dr Loizos Loizides*

Department of Fisheries and Marine Research

Nicosia

CYPRUS

lloizides@cytanet.com.cy

Dr Kahil. H. Mancy

Emeritus Professor of Environmental Chemistry

University of Michigan

Ann Arbor, Michigan

UNITED STATES OF AMERICA

hmancy@umich.edu

Mr John Ruettan

Resource Trends

Escondido, California

UNITED STATES OF AMERICA

john@resourcetrends.com

Dr Samia Galal Saad

Environment Health Department

High Institute of Public Health

Alexandria

EGYPT

sam_gal@hotmail.com

Observers

Dr Jeff Graham

Scripps Institute of Oceanography

La Jolla, California

UNITED STATES OF AMERICA

* Unable to attend

Dr Scott Jenkins
Scripps Institute of Oceanography
La Jolla, California
UNITED STATES OF AMERICA

Members of the Steering Committee

Dr Houssain Abouzaid
Coordinator, Healthy Environments
WHO Regional Office for the Eastern Mediterranean
Cairo
EGYPT

Mr Amer Al-Rabeh
Saline Water Conversion Corporation
Al-Khobar
SAUDI ARABIA
alrabeh@yahoo.com

Dr Joseph Cotruvo
Joseph Cotruvo and Associates, LLC
Washington DC
UNITED STATES OF AMERICA
joseph.cotruvo@verizon.net

Dr Anthony Fane*
UNESCO Centre for Membranes
School of Chemical Engineering and Industrial Chemistry
University of New South Wales
Sydney
AUSTRALIA

Dr Gelia Frederick van Genderen*
Director, Cayman Water Authority
Grand Cayman
CAYMAN ISLANDS

Dr Totaro Goto*
Managing Director
Water Reuse Promotion Centre
Nihombashi, Ningyo-Cho, Chuo-Ku
Tokyo
JAPAN

* Unable to attend

Dr Kevin Price*
U.S. Bureau of Reclamation
Denver, Colorado
UNITED STATES OF AMERICA

Dr Jose Medina San Juan*
Delegacion Area de Fomento, AEDyR
Las Palmas de Gran Canaria
SPAIN

UNEP Secretariat

Dr Habib El Habr, Deputy Regional Director, United Nations Environment Programme,
Regional Office for West Asia (UNEP/ROWA), Manama, Bahrain
Habib.elhabr@unep.org.bh

WHO Secretariat

Dr Houssain Abouzaid, Coordinator, Healthy Environment, World Health Organization
Regional Office for the Eastern Mediterranean (WHO/EMRO), Cairo, Egypt
azaidh@emro.who.int

Mr Hamed Bakir, Rural Environmental Health Adviser, WHO Centre for Environmental
Health Activities (CEHA), Amman, Jordan
bakirh@ceha.emro.who.int

NWRI Secretariat

Mr Ronald Linsky, Executive Director, National Water Research Institute, Fountain Valley,
California, United States of America
rlinsky@nwri-usa.org

Ms Tammy Russo, NWRI, Fountain Valley, California, United States of America
trusso@nwri-usa.org

Ms Gina Melin, NWRI, Fountain Valley, California, United States of America
gmelin@nwri-usa.org

* Unable to attend