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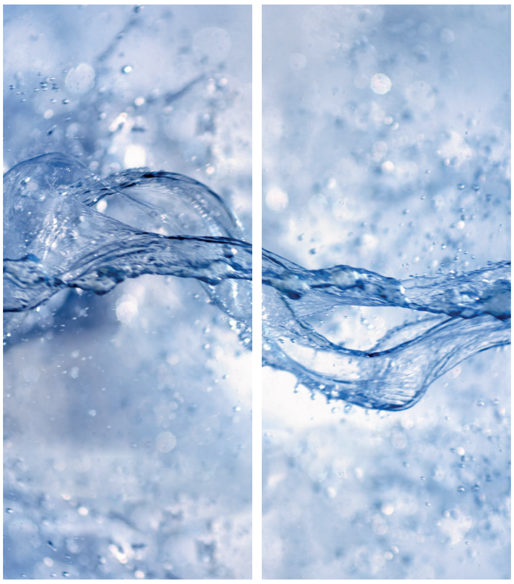

Water Report 120

Safe, Sufficient and Good Potable Water Offshore

A guideline to design and operation of offshore potable water systems

3rd edition

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Norwegian Institute of Public Health

Published by the Norwegian Institute of Public Health
Division of Environmental medicine
January 2013

Title:
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Ordering:
The report can be downloaded as pdf
on the NIPH web pages: www.fhi.no

Cover design:
Per Kristian Svendsen og Grete Søimer

Layout cover:
Unni Harsten

Photo front page:
Colourbox (left)/Eyvind Andersen (right)

ISBN 978-82-8082-538-4

Preface

This is the 3rd edition of the guideline to offshore potable water supply. The 1st and 2nd editions were published in 2005 and 2009 respectively.

The objective with the guideline is:

- To inform about basic considerations to be taken in planning and construction of potable water systems offshore, without covering all technical details.
- To guide personnel in operation, control and maintenance of potable water systems offshore to ensure a safe potable water.

The guideline gathers NIPH's information to industry, state authorities and specialists in relevant fields. The guideline is published on the NIPH offshore webpages: www.fhi.no/offshore, and will be updated regularly. Comments to the guideline can be sent to folkehelseinstituttet@fhi.no

Working with potable water brings you in contact with many special fields, such as environmental health protection, technical disciplines, law and medicine, just to mention a few. The different aspects are not equally and thoroughly explored in this guideline. Chapters 1 to 4 contain general information on regulations, system control requirements and water quality. The remaining chapters cover design, operation, and maintenance of various components of the potable water system.

This guideline has been revised by Eyvind Andersen. We emphasise the following changes:

- References to regulations have been revised and chapter 2 has been changed after input from the Norwegian Food Safety Authority.
- The recommended testing programme in appendix 4 is revised. Boron is to be analysed yearly where reverse osmosis is used for water production, whilst 1,2-dichloroethane, ammonia, trichloroethene and tetrachloroethene has been removed form the analysis programme.
- Section 4.4 on sample points has been made and appendices 7 and 8 changed after input from the Norwegian Food Safety Authority
- Sections 3.7 on internal control, 4.2.5 on water temperatures and 8.3.2 on UV-units have been revised.
- Section 9.1.4 on application of protective coatings is new.
- Section 9.2 on water distribution systems has been changed substantially.

The NIPH wants to express thanks for input to the guideline to: Torbjørn Andersen, John Øyvind Auestad, Odd-Anders Beckmann, Russel Caldwell, Hans Donker, Tjarda den Dunnen, Anne Nilsen Figenschou, Mads Kristian Fjelldal, Joar Gangenes, Karl Olav Gjerstad, Guy Heijnen, Kjersti Høgestøl, Eivind Iden, Synne Kleiven, Truls Krogh, Johnny Kvernstuen, Olav Langhelle, Kyrre Loen, Anne Linn Lundeland, Martin Mjøs-Haugland, Morten Nicholls, Ståle Nordlien, Ola Nøst, Bjørn Pedersen, Einar J. Pettersen, Yvonne Putzig, Jan Risberg, Håkon Songedal, Bjørn Steen, Jeroen Stelling-Freyee and Kjetil Todnem. We offer special thanks to Catrine Ahlén and Yvonne Putzig who made the draft of the chapter on potable water systems on diving vessels; and to Sam Sutherland for valuable input to the English version

The guideline was translated by Rigmor Paulsen (NIPH), with 2nd and 3rd edition changes by Eyvind Andersen. If discrepancies occur, the Norwegian version takes precedence.

Oslo, 7th January 2013

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Contents

1 Introduction

1.1 Sufficient, safe and good potable water

The purpose of the Potable Water Regulations is to ensure delivery of sufficient, safe and good potable water. The general philosophy is that, when good water sources are chosen, the water works treatment plant is optimal, and the routines for operation, control and maintenance are the very best, the result is good potable water. If one level fails, the safety is reduced.

The quality requirements apply to all Norwegian potable water supplies: ”Potable water shall be hygienically safe, clear and without any specific smell, taste or colour. It shall not contain physical, chemical nor biological components that can lead to any health hazard in common use”. The Regulations require at least two hygienic barriers against all physical, chemical and microbiological pollution that could possibly affect the potable water supply. Two different safety barriers ensure that the potable water remains safe, even if one barrier fails, due to human or technical errors.

Different skilled groups co-operate to run potable water systems offshore. To avoid problems and misunderstandings, it is important that these groups “talk the same language” and have access to relevant information. Failure in an offshore potable water system is normally caused by human errors or inadequate operation systems. Only rarely is technical failure the cause of serious problems. Even the best systems can deliver bad water quality if operation systems are inferior, while a technically weaker system can deliver safe and good potable water when it is run by dedicated personnel. Internal control, including sufficient routines for training personnel and for operation of the system, is crucial to secure that the system functions adequately in the long run.

1.2 How to use the guideline

The guideline can be used as a complete reference book, or to just get help to solve one single problem.

1.2.1 Guideline status

Authorities are detailed in section 2.1. The Potable Water Regulations, see 2.2, define the requirements that must be followed during design and operation of potable water systems offshore. This guideline is prepared by the NIPH, and contains our best advice, based on the regulation requirements and on our experience from offshore inspections, research and reports from the offshore industry etc.

The guidelines to the Norwegian offshore Health, Safety and Environmental Regulations (on the Petroleum Safety Authority Norway web-page www.ptil.no) refer to our guideline when it comes to building and operating potable water systems offshore. Our advice will therefore be a key element in defining necessary safety requirements, based on regulation requirements in the HSE-Regulations and the Potable Water Regulations.

In the guideline we have tried to only state the Regulations requirements. In addition we give advice on good practise, where the Regulations allow for use of various solutions. If the guideline states requirements that appear not to be defined in the Regulations, we would appreciate being informed of this. Therefore, examples on solutions and attached check lists must not be interpreted as absolute requirements. The companies must use their own judgement in deciding the need for equipment, operation routines and supervision in their specific activity.

1.2.2 Guideline application

The guideline, including appendices, can be used in different manners, depending on the various needs the user might have:

- Before planning water supply systems on new offshore units, those responsible should read the guideline, as this is necessary in order to secure the very best solutions. In the long run this will give the best results with regard to quality, operation and costs. Use of the design check list in appendix 1, and the check list for control systems in appendix 2, can not compensate for a thorough study of the guideline, but is meant to be used after

the planning process, to ensure that solutions chosen are adequate.
- The guideline may be used as a reference book, to be consulted in the every day operations, when relevant information is not available in the unit's management system.
- The guideline may also be used in potable water courses for offshore personnel.

1.3 Definitions

Acknowledgement of Compliance (AoC): A statement from the Petroleum Safety Authority Norway that a mobile offshore unit both technically and with regard to organisation and the management system is deemed to be in accordance with relevant Norwegian offshore regulations.

Hygienic barriers: Natural or man made physical or chemical hindrance, such as means of removing, render harmless or killing bacteria, viruses, parasites and the like, and/or dilute, break down, destroy or remove chemical and physical components to a level where the substances no longer represent any health hazard, see Potable Water Regulations § 3.

Hygienically safe potable water: Potable water that neither contains physical, chemical nor microbiological components posing neither short nor long term health hazards.

Letter of Compliance (LOC): A document issued by the Norwegian Maritime Directorate, con-firming that a foreign registered offshore unit complies with all technical requirements specified by the Norwegian Maritime Directorate and its affiliated supervisory authorities.

Microbes: Microorganisms such as amoebas, bacteria, parasites, fungus and virus.

Offshore unit: Installations and equipment for the petroleum activity, but not supply- and auxiliary vessels, nor petroleum bulk carriers, see Framework regulations § 6.

Operation analyses of potable water: Analyses taken of the potable water as an in-house control measure, and in adjusting the operation of the potable water system, including analyses per-formed when bunkering potable water.

Potable water: All types of water, treated or untreated, designated for drinking, cooking or other household purposes, regardless of the origin of the water, and regardless of whether it is delivered through a distribution system, from supply vessels, from bottles or other packaging, see the Potable Water Regulations §3.

Potable water systems offshore (figure 1.1): The system normally consists of the following elements: water sources, sea water inlet, water producing systems, bunkering stations, treatment units, water tanks, piping, taps, calorifiers and operation routines. The potable water system also includes the water.

Simple and extended routine control: Routine control analyses of potable water should be sent to an accredited laboratory ashore, and used to document that the operation of the potable water system has proven adequate, and also as an inst-rument for making operational improvements.

Figure 1.1: Potable water system with evapora-tor, scale inhibitor tank, chlorine tank, alkalizing filter and UV-units (Photo: Eyvind Andersen)

2. Regulations and authorities

(Revised as per 1st January 2013)

Regulations and authorities for potable water supply in the petroleum activities are governed through the Health, Safety and the Environment (HSE) Regulations and the Norwegian Potable Water Regulations.

2.1 Authorities

The Petroleum Safety Authority Norway (PSA), The Climate and Pollution Agency (CPA), The Norwegian Board of Health Supervision (BHS) and the Norwegian Food Safety Authority (FSA), or person/institution given supervisory authority by these organizations, assess whether offshore industry adhere to the requirements for health, safety and the environment. The PSA co-ordinates the supervisory activities on the off-shore units. The County Governor of Rogaland (CGR) is responsible for the supervision of health and hygiene matters on behalf of the BHS. The FSA is authority after the Law on Food, but has delegated the offshore supervision work to the CGR. In addition some mobile offshore units have maritime certificates from the NMD.

The NIPH has no formal authority regarding pot-able water offshore, but advice the CGR and the NMD on matters related to potable water. Formal reactions and recommendations are issued by the authorities based on observations and findings.

2.2 Regulations

For potable water issues, the HSE-regulations refer to the potable water regulations. Regulati-ons concerning potable water systems and potable water supply on mobile offshore units, apply to units that hold maritime certificates from The NMD, but must also adhere to the HSE-regulations when operating on the Norwegian continental shelf. Table 2.1 is a summary of existing Regulations and suggested standards.

2.2.1 The Potable Water Regulations

The Potable Water Regulations are in accordance with the European Union Regulations for potable water. The Regulations apply to units operating on the Norwegian continental shelf. The NIPH has made an analyses programme for potable water on offshore units, see 4.3. The programme has been designed to accommodate the requirements of the Potable Water Regulations.

2.2.2 Health, Safety and the Environment Regulations

For offshore units on the Norwegian continental shelf, the HSE regulations apply. Practical water supply offshore differs somewhat from onshore systems, and the HSE regulations are used to de-tail the Potable water regulations requirements.

The HSE Regulations give general requirements as to function, and thus contain no details for design and operation. But, in the comments to the Regulations, standards are specified. Accord-ing to the Framework Regulations § 24 these standards are to be followed, or the alternative solutions chosen must be proven to be at least as reliable. The complete HSE Regulations cover potable water, but not all of it is equally relevant. The most important points are:

- The Framework Regulations are the basis for the health, safety and environment work. The object clause requires health, safety and environment levels to be the very best and maintained by systematic work and constant improvement. Chapter II gives the basic prin-ciples to be as follows: All health, safety and environment matters should be adequately taken care of and hazards reduced to a mini-mum. Organization and level of competence should be satisfactory and according to requirements.
- The Management Regulations pose important requirements to the design process such as hazard reduction, barriers, planning and analyses.
- The Facilities Regulations pose general re-quirements to design and equipment, such as top level security, ergonomics and uncompli-cated and sturdy design. § 61 establish that the design should be in accordance with re-quirements in the Activities Regulations and the Potable Water Regulations. Specific de-sign requirements are not defined. Comments to this paragraph refer to design solutions in the guideline issued by the NIPH.

- The Activities Regulations cover performance of activities on the unit. § 13 states that sufficient supply of good quality potable water is required, and reference is made to the Potable Water Regulation. Reference is also made to the guideline prepared by the NIPH.

2.2.3 Regulations concerning potable water system and potable water supply on mobile offshore units

The Norwegian Maritime Directorate issues certificates for Norwegian mobile units. The Regulations concerning potable water systems and potable water supply on mobile offshore units have detailed requirements that must be met in design and operation of potable water systems. For water quality, these Regulations also refer to the Potable Water Regulations requirements.

It is the license owner's responsibility to document that mobile offshore units on the Norwegian Continental Shelf comply with the requirements of the HSE Regulations. A certificate from the Norwegian Maritime Directorate may be a practical way to assure this with respect to potable water, although this is not a formal solution.

2.2.4 The Law on Food

The law on food production and food safety applies to potable water systems and potable water supply on land, ships and offshore units, see 2.1.

2.3 Norwegian Institute of Public Health - functions

The NIPH advice the CGR and the NMD on matters related to potable water and potable water systems on offshore units. NIPH also provides general advice within this special field. In addition to general guidance to the offshore industry, the institute is engaged in the following:

2.3.1 Evaluation of new offshore units

NIPH advice the authorities when evaluating the potable water system on new builds (figure 2.1). To avoid unnecessary and costly mistakes in the construction process, The NIPH recommends that the project manager uses the check list in appendix 1, to be more certain that the project is according to standard. Survey by or on behalf of the potable water authority, may also occur at the stage of planning.

When the project is near completion, a final survey is made of the unit at the yard. If standards have been followed, the NIPH normally has had few objections, and the supervisory control authorities can be notified that the NIPH see no water related objections to the start-up of the unit. Generally a new inspection is made after one year of operation, to ascertain the system is functioning properly.

Table 2.1: Regulations and suggested standards for offshore units on the Norwegian continental shelf

	Permanent units	**Mobile units** registered in the Norwegian ship register and foreign units with LOC*	**Mobile units** registered in foreign ship registers. Bound to conformity explanation. (CE)*
The Law on Food	Legally binding		
Potable Water Regulations	Legally binding		
Health, Safety and the Environment Regulations	Legally binding		
Regulations concerning potable water system and potable water supply on mobile offshore units		Legally binding	Voluntary standard, see the HSE Framework Regulations § 3
The NIPH – Guideline	Guideline solutions are recommended standard, see the HSE Framework Regulations § 24		
NORSOK P-100 system 53	Recommended standard, see the HSE Framework Regulations § 24		

* see 1.3

2.3.2 Audits

Audits are carried out based on risk and vulnerability analyses. Relevant system documentation is compared with the Regulations requirements. It is emphasized that internal control systems find and solve problems, and that similar problems are prevented in the future.

2.3.3 Evaluation of yearly potable water reports

According to Framework Regulations § 23 and Potable Water Regulation § 7, the license owner is asked to submit potable water reports to the authorities, represented by NIPH. This enables the institute to catch problems with-out actual on-site surveys. Potable water reports include results of analyses made by accredited laboratories. In case of deviations from requirements, information should be given as to corrective measures taken. If events important to the safety and quality of the portable water systems occur, this should also be reported.

2.3.4 Product approval

The following requirements apply to products for potable water use:

Paints, protective coatings and other materials

The potable water regulations state that such products shall not pollute the potable water, and the regulations for mobile offshore units have an additional requirement for certification of paints and protective coatings.The NIPH evaluate such products toxicologically for potable water use in Norway, and this evaluation is accepted as "certified" according to the NMD-regulations. Norwegian approval is not necessary for water pipes in metal alloys or hard plastic, or for gaskets and hoses etc., as long as these products have been produced for use in potable water systems by an acknowledged manufacturer, see 9.2.6.

Potable water treatment chemicals

The NIPH evaluate water treatment products and other products that may pollute the potable water through leakages or after system maintenance. According to the Potable Water Regulations, water treatment products must be approved by the FSA, and in the guideline for these regulations it is stated that offshore it is also acceptable to use the products that are on the NIPH lists. Certified products for potable water treatment include alkaline filter material, corrosion- and scale inhibitor in heating circuits, cleaning products, disinfection products, anti freeze products, etc. No approval is necessary for stabilising sand in alkalising filters or active carbon filter material, as these products are not dissolved by water.

Such products are only to be used in accordance with dosing requirements. It is the producer that usually applies for NIPH certification. Products that have HSE-datasheets are not necessarily also certified for potable water use. If certifieded products are used according to the premises for the approval, they are considered safe

UV-units

Evaluation of UV-units is done by the NIPH to ensure that the unit carries sufficient radiation capacity. The units are evaluated for maximum water supply, worst case water quality and necessary maintenance. If these requirements are not followed, the result is a sense of false security. UV-unit requirements are described under 8.3.2.

Product lists

A product may only be used if both product name and producer/supplier is found on the lists. The work to establish common lists for products to be used both on- and offshore is ongoing. Until such common lists have been established, lists of products that can be used offshore are available on the NIPH web pages: www.fhi.no/offshore

Figure 2.1: Picture taken at the shipyard of the Skarv unit (Photo: Eyvind Andersen)

3. Management systems

The Framework Regulations section 17 states that "The responsible party shall establish, follow up and further develop a management system designed to ensure compliance with requirements in the health, safety and environment legislation". The Potable Water Regulations section 5 states that internal control is a requirement, and must be designed according to the needs of each water works. Possible hazards for health must be identified, and management of critical control points and processes must be a part of the internal control, see principles for Hazard analysis and critical control points (HACCP).

The established level of management of health, safety and environment should be under frequent assessment. The management system should be continuously improved as a natural consequence of operation experiences, changes in the Regulations, system revisions etc. This will improve the quality of potable water supply. The management system is based on internal control, with emergency preparedness considerations being an integrated part of the system. The following main points must be included:

3.1 Potable water documentation

The Framework Regulations § 23 establish that "The responsible party shall prepare and retain material and information necessary to ensure and document that the activities are planned and carried out in a prudent manner". For potable water systems it is common to prepare a manual that covers the main documentation requirements mentioned here, but such manuals must be suplemented by drawings, periodical maintenance systems etc.

Potable water manuals are often voluminous documents containing most of the information needed to run the system, but there are smaller manuals which referer to other documents, procedures and systems with more detailed information. The current trend is that more and more of the potable water documentation is integrated in company data systems and/or unit documentation systems.

Both methods can function well. The important point is that the information is actually used and is easy to up-date whenever the need arises, and that it is easy to find relevant information both in the daily operation and when problems arise.

But, even if the format of the documentation is not of the greatest importance, there are numerous conditions that require documentation. Appendix 2 lists the type of information that ought to be included in the potable water document as a minimum. This documentation must be organized in a manner that makes is easy to find and compile.

3.2 Competence

The Framework Regulations § 12 establish that "the responsible party shall ensure that everyone who carries out work on its behalf … has the competence necessary to carry out such work in a prudent manner".

The party responsible decides the degree of training needed for personnel within the different disciplines with regard to both technical systems and potable water hygiene. Training should be carried out before personnel are assigned to their tasks. The party responsible must have routines to ensure and document that the necessary training has been given, including refresher routines. This documentation could be a job description and specifications for the various tasks, including potable water education program. There are several institutions offering courses in offshore potable water treatment. The party responsible may also choose to take responsibility for the training, but is then required to document that this training is on a satisfactory professional level.

3.3 Maintenance system

Many components in an offshore potable water system require regular maintenance in order to function properly at all times. Frequency and the extent of the maintenance are in part based on requirements made by the authorities, for example the yearly cleaning and disinfection of tanks and pipe systems (figure 3.1). Other requirements follow the general requirements in the Activity Regulations chapter IX and the Potable Water Regulations § 11.

A planned maintenance programme must be prepared, describing the extent and frequency of the maintenance work on the potable water system, including evaporator, reverse osmosis unit, alkalization filter, bunkering station, chlorination plant, potable water tanks, UV-unit, measuring instruments, non-return valves, active carbon filter, pressure setting systems and pipe system. The supplier of the equipment should document the necessary maintenance.

A job description has to be provided for each element in the maintenance system. Such a description should present all necessary safety measures and description of how the work is to be done and by whom.

3.4 Collection, processing and use of data

The Management Regulations § 19 require that the party responsible collects and processes data information for:

- Surveillance and control of the state of technical, operational and organizational conditions
- Providing statistics and design data bases
- Implementing corrective and preventive measures

In connection with potable water systems, focus is mostly on the water analyses. This is obviously important, but even more important is the collection of data on critical operational parameters, see specifications for hygienic barriers under 5.2.4, and work carried out on the potable water system. Exchange of such information is necessary at the time of shift handovers, and acts as an important source for detecting faults at the earliest opportunity, whereas water analyses will show the situation later.

The party responsible chooses type of data collection and routines for data use, provided that this also covers sufficient reporting to the authorities. Suggestions for logging the daily potable water analyses are illustrated in appendix 3, and such logging must be supplemented by logging of bunkering, maintenance and other operations.

3.5 Handling of deviations

The Potable Water regulations demand that deviations are handled as soon as possible, se action type A to C in the regulations, referred to in appendix 4 (including possibilities for exemptions). The Management Regulations § 22 establishes that "the responsible party shall register and follow up nonconformities". Included are also non-conformities to internal requirements that are of significance in fulfilling the requirements contained in the HSE Regulations. "Nonconformities shall be corrected, the causes shall be identified, and remedial measures shall be implemented to prevent the nonconformity from recurring".

Poor water quality and deficiency in water production must be treated formally through channels for "incident reporting". It is also necessary to establish criteria for when formal treatment of deviations are needed.

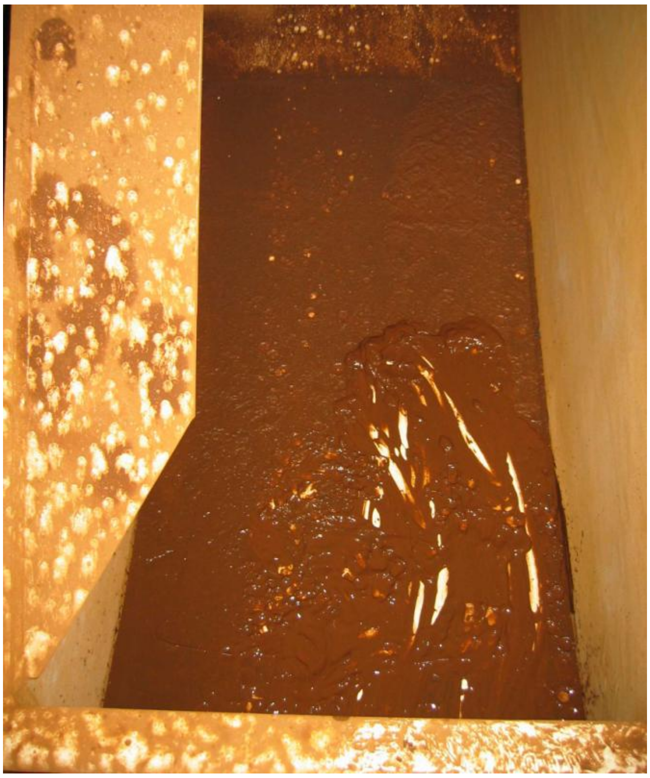


Figure 3.1: Demand for cleaning of tanks at least once a year is set to avoid situations illustrated in the picture above, where there is a layer of mud at the bottom of the tank. Such occurrences have to be handled as a non-conformity case. (Photo: Bjørn Løfsgaard)

3.6 Emergency preparedness

Failure within a basic function such as the potable water system is very serious. Both the Potable Water Regulations and the Management and Activities Regulations state that a risk- and vulnerability analyses must be done as the foundation for emergency planning. The analysis should at least include the following scenarios:

- Outbreaks of water borne epidemics
- Chemical pollution of the potable water causing it to be unsuitable for use, for example as a consequence of bad bunkered water, leakage or faulty connections to various systems.
- Lack of water due to leakage, technical failure, bad weather or other causes.
- Malfunction in the disinfection process or other circumstances causing hazards to the quality of the potable water.

Based on the emergency preparedness analyses being done, measures are taken to reduce the probability of failure, and an emergency preparedness plan should be established for each unit to plan for the remaining risks. The emergency preparedness strategy is meant to prevent hazardous situations from arising, and to establish routines for actions to be taken.

3.7 Internal audits

The Framework Regulations § 12 state that “The operator shall have an organization in Norway, which, on an independent basis, is capable of ensuring that petroleum activities are carried out according to rules and regulations”. The organization must be competent to verify that the following is satisfactory:

- Are critical contol points identified and plans for management of these satisfactory?
- Is the risk- and vulnerabilty analysis revised?
- Is the management documentation revised?
- Are the water quality trends satisfactory?
- Are the maintenance trends satisfactory?
- Are the technical systems still satisfactory?
- Are the drawings correct?

Internal audits, including by personnel from the onshore organization, are important tools in this work. The necessary procedures, check lists etc. should be established to manage critical control points in the water supply. The competence can be inhouse or external, but the overall responsibility for the work must be held by the operator/owner.

3.8 Reporting to the authorities

The Potable Water Regulations require reports to the supervisory authorities. The County Governor of Rogaland and the Food safety Authority of Norway may change this, but until then reporting shall be done as follows:

The results from monthly and yearly water sampling are normally included in the yearly report, sent to the NIPH, who assesses the report on behalf of the County Governor and the NMD. For most of the parameters the duty to report is complied with when correcting measures of minor nonconformities are documented in such reports. The reports should describe deviations, presumed causes and corrective measures taken. Findings of *E. coli* and intestinal enterococci must be reported immediately, at the latest the first working day after discovery, see also figure 4.5. The same applies to major non-conformities to the Potable Water Regulations, jeopardizing the water supply on the unit.

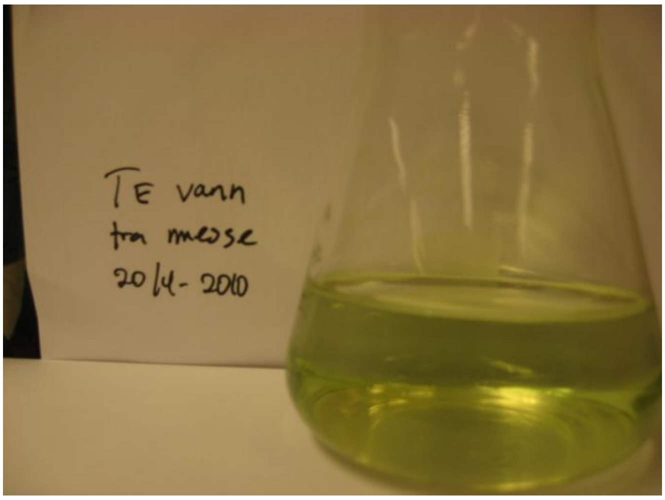


Figure 3.2: Green water caused hectic activity on an offshore unit. Was this an emergency situation or was the pollution less serious?This colour was due to high copper content following leakage of citric acid when washing an UV-unit, causing instant corrotion. The non-conformity was reported immediately. (Photo: Used anonymously in agreement with the company)

4. Water quality

Potable water is our most important nutrient, and is used for both drinking and cooking. The water being used for personal hygiene and all types of cleaning requires the same high quality (figure 4.1). It is therefore important to have enough water of satisfactory quality to cover all types of usage. Water treatment is described in chapter 8. It is important to establish sufficient hygienic barriers in order to secure high quality potable water, see 5.2.4.

4.1 Potable water and health

Safe potable water secures good health, but water can also contain hazardous elements that can be divided into two groups:

1. Microbes that cause infectious disease or food poisoning, such as bacteria, virus, amoebas and parasites.
2. Organic and non organic substances that may cause health hazards, such as acutely poisonous substances, substances that by accumulation in the human organism causing health hazards, carcinogenic and/or allergenic substances.

Indirect health hazards have to be considered as well. It can, for example, be difficult to obtain a satisfactory disinfection by chlorine or UV-radiation if the water is discoloured or holds a large quantity of particles, see 4.2.2.

Figure 4.1: Potable water is our most important nutrient, and must be treated effectively in order to secure safe delivery (Photo: Lasse Farstad)

4.1.1 Microbes

Potable water shall not contain microbes that can lead to disease. When suspecting an outbreak of a contagious disease, it is important to locate the source and eliminate it quickly, thereby preventing spreading. To be able to do this, it is necessary to have an emergency preparedness plan, see 3.6. Sufficient preventive safety measures are achieved only by building good potable water systems and having sufficient internal control.

All potable water for consumption offshore has to be disinfected, but even then, microbes can cause problems. This can be due to failure in the disinfection process, or contamination after the disinfection process. Humans and animals have several means of defence against infectious disease. Whether infection will occur or not, depends on the power of the infectant and how much infected water that was consumed.

Infectious diseases are the most serious threats to the health, related to potable water supply. Faecal contamination from humans and animals is normally the cause of such infections, and human faeces are particularly dangerous. The most common water related infectious diseases are cholera, bacterial dysentery, salmonellosis, typhoid fever and hepatitis A. Lately, focus has been on bacteria like *Yersinia enterocolitica* and *Campylobacter jejuni*, viruses such as *Norovirus* (earlier called Norwalk virus), and protozoa like *Giardia intestinalis* and *Cryptosporidium parvum*. Infections by these bacteria and parasites cause diarrhoea with strong abdominal pain. Recently attention has been drawn to the dangers caused by *Legionella pneumophila*, see 9.2.7. It is established that the different types of epidemics described in Norway are most often set off by several unfortunate circumstances. The offshore units are as susceptible to human and technical malfunctions as is the case onshore, and there are reasons to be on guard.

Since the potable water is used for cooking, microbes in the water can cause food borne infections as well. Some disease producing bacteria can grow in food products, and just a few bacteria can, within a short time, grow to huge concentrations and make consumers ill. Some of the bacteria in food produce toxic substances that can cause poisoning even if the food is properly cooked and the bacteria killed in the cooking process.

To analyse potable water for every type of infectious substances that might transmit a disease is very demanding, and is not done. Instead, analyses are done on various types of indicator organisms such as microbes prevalent in large amounts in faeces from humans and animals, and having at least the same life span as the true infectious substances (figure 4.2). The group ”coliform bacteria” is being used as an indicator for faecal contamination, and the bacteria *E. coli* indicates fresh faeces. When an indicator organism is found in the water, it is a sign that there might be disease producing organisms in that same water.

The parameter ”Colony count 22^{o} C” is used to assess the level of biofilm in the pipe system. Consequently the “Colony count” may also indicate growth in the pipe system of organisms hazardous to the health, but not detected by other indicator parameters. With a colony count below 100 per ml there is little risk of harmful exposure to such organisms. In a well maintained and operated system it is often possible to achieve colony counts below 10/ml.

Figure 4.2: Birds regularly rest on offshore platforms, and some even nest there. They can spread pathogens for example through insufficiently secured air vents and bunkering pipes. (Photo: Bjørn Løfsgaard)

4.1.2 Chemical substances posing health hazards

Potable water shall not contain chemical substances that may pose a threat to health. Exposure to potentially hazardous substances should be as low as possible. Offshore, such exposure may be a result of contaminated seawater supply or unfortunate occurrences in the operation of the units system, for example back-suction through hose connections. It is important to minimize the risk of pollution related to materials and additives that come in contact with the potable water during transportation, storage, treatment, leakage etc. See certification requirements in 2.3.4.

Chemically caused health problems are seldom connected to acute poisoning by hazardous substances, but more often a result of prolonged exposure to small amounts of those substances, finally resulting in health problems. Most significant are substances accumulating in the organism, causing cancer or triggering allergic reactions. When the human body is exposed to, for instance, heavy metals over a period of time, the accumulation may reach a critical level, resulting in illness. Limit values for such substances are set to a maximum acceptable daily intake, with sufficient safety limits to avoid levels hazardous to the health in the course of a lifetime.

Some chemical substances are classified as carcinogenic, and many of these are genotoxic. For such substances there is no threshold value for when damage may occur, and these substances are not supposed to exist in potable water. Since it is impossible to avoid traces of such substances in the water, Norway has set the upper limit value, based on acceptable life time risk, to be lower than 10^{-6}. This means that fewer than one out of a million people drinking two litres of water containing maximum acceptable amount of this substance every day for 70 years, develop cancer. Even so, the chance of developing cancer will be signifycantly lower, since limits are set with a high safety margin, and detected concentrations of the substances only rarely are close to the limit values. The danger is further reduced by the fact that a person seldom drinks water from the same source during his or her entire lifetime.

Disinfection is crucial in safeguarding the potable water, but some disinfection methods may cause hazardous by-products. The chlorine doses used in Norway do not cause any direct health hazards, but there may be a possibility that the process can form *chlorination by-products* like trihalomethanes, causing health hazards. For this process to take place, it is a prerequisite that the water contains organic substances such as natural organic material, see 4.2.2. Potable water produced offshore seldom contains such material. Some units that evaporate water, where electro chlorination is used as marine growth prevention in the sea chests, have found chlorination by-products in the produced water. If the potable water is bunkered onshore and has a low colour value (under 20 mg Pt/l), and is chlorinated with the low chlorine levels used in Norway, it is generally safe to assume that the chlorination by-products will be insignificant. But the level of by-products may increase if the supply vessel chlorinates excessively or if the offshore unit bunkers water by topping up tanks that already contains a large volume of chlorinated water.

4.2 Other general requirements

According to the Potable Water Regulations the potable water shall be clear, without smell, taste and colour, and non-corrosive.

4.2.1 Smell and taste

Potable water shall have no specific smell or taste. Unpleasant smell and/or taste can be a sign of other types of water pollutants. Investigation is then required in order to find the cause and initiate corrective measures. Potable water with a bad smell and/or taste may also lead to the crew drinking beverages less favourable to their health.

Unpleasant smell and taste can originate both on the unit and outside. Such problems increase when the water temperature is high. If tanks and pipes contain organic material resulting in growth of micro-organisms, decomposing processes may give “rotten” smell and taste. A high content of humic particles can give a “marshy taste”. Chemical reactions between chlorine and nitric components may form new chemical combinations with strong smell and taste.

Different microorganisms can be found in large amounts in sea water, and can release smell and taste components that may pass an evaporator. Algae can also produce organic substances that do not smell, but form unpleasant smelling substances in contact with chlorine or UV-radiation. The same might happen when the water contains other types of organic substances.

Traces of chemicals like phenols, diesel and mineral oils can cause unacceptable smell and taste. A common reason for this in offshore potable water systems is the use of protective coatings that are applied too thickly or are not adequately hardened, see 9.1.4. High concentrations of for instance chloride and sulphate from sea water pollution can give potable water a salty taste. Corrosion particles, like iron, zinc and copper, can also cause an unpleasant taste to the potable water. How to remove the unpleasant smell and taste in potable water is covered in chapter 8.

4.2.2 Discoloured and turbid water

Particles in water (turbidity) can contain microbes that consequently will not be killed by UV or chlorination. Such particles and certain dissolved substances (for example humic particles), can absorb UV-light and reduce the effect of the UV-treatment, see 8.3. A high content of organic material will also lead to high chlorine consumption that is not desirable, as it will cause unpleasant taste, see 4.2.1. Specific micro- organisms living in the pipe system (biofilm) feed on organic substances. Some of these may pose a health hazard, for example *Legionella pneumophila* which can cause Legionnaire’s disease, see 9.2.7.

Potable water produced offshore normally contains few particles. The turbidity limit of < 1.0 FNU is generally easy to maintain. In corroded pipes, rust particles may loosen from the inside of the pipes and be transferred through the pipe lines to the consumer (figure 4.3). Particles may also occur if there is bacterial growth in the system that loosens due to pH-changes or turbulent weather. Bunkered water may have a rather high content of particles or high colour number, depending on the quality of the onshore water source. Such contents will often have seasonal variations. Water delivered by supply vessels or water works onshore with visible colour or turbidity should be refused, see 4.3.2. Problems with turbidity can be prevented by using particle filters, see 8.3.1.

Figure 4.3: Discoloured water due to corrosion (Photo: Eyvind Andersen)

4.2.3 Corrosive water

Corrosive water means water that corrodes the pipe line system, fittings and other installations connected to the pipe line system. Untreated offshore produced water corrodes most metal surfaces that are not stainless steel or titan. Some corrosion will always occur in a potable water system, but it is important that the level is kept as low as possible, thereby avoiding inferior water quality, or that the entire system has to be replaced sooner than its normal life span would require. Corrosion may also lead to heavy metals, such as lead and cadmium, being released from the pipe line system and fittings, with undesirable consequences to health. By letting the water run for a short time before use, the heavy metal residue is lowered. Corrosion also necessitates more frequent cleaning and flushing of pipe systems, causing increase in operation costs.

Corrosion is due to a complex relation between pH-value, carbon dioxide content, oxygen content, hardness, (standard mainly set by calcium and magnesium), alkalinity (acid neutralizing ability, most of the time as a result of *hydrogen carbonate* content) and temperature. High content of ions such as chloride and sulphate can also increase corrosion. When the pH-value is below 7, the water is considered acid and will corrode most metals. High pH-values (> 9.5) will also corrode certain metals. A pH of approximately 8 is recommended. High levels of iron or copper are water quality parameters indicating corrosion problems.

Water from Norwegian water works is usually surface water and is commonly acid, with low levels of calcium and alkalinity. Such water will corrode most materials. Potable water produced offshore is even more acid, has lower levels of calcium, alkalinity and, if produced by the reverse osmosis method, can have a relatively high salt level. Such potable water needs treatment, see 8.1.

Pipe systems with speckled deposits on the metal surface may experience pitting corrosion. Under this residue the oxygen level will be lower due to the micro-organisms' oxygen consumption. The difference will make electrons move from areas with residue to areas without such build -ups. This process releases metal ions to the potable water under the speckled residue, creating a pit in the metal. It is mainly a problem in iron and copper pipes, and offshore units based on bunkered water that are more susceptible to pitting.

Corrosion by-products may reduce the water flow and make the water turbid, see 4.2.2. In potable water pipes of iron and steel, corrosion clusters may be formed especially in older pipe systems. The clusters are formed by bacteria converting dissolved iron to solid corrosion clusters. The corrosion clusters are hollow and can be crushed when the force of the water flow and flow direction is changed, see figure 4.4.

Figure 4.3: Corrosion clusters can result in poor water quality and clogging of pipes (Photo: Eyvind Andersen)

Iron and copper can cause other problems too:
- High iron content can give turbid and red to brown water. Fittings, sinks, bathtubs and toilets become rust coloured. Stagnant water may get an unwanted taste, and washing white clothing may result in brownish-red spots due to iron deposits.
- High copper content can cause bad taste. Consumers may experience stomach problems if concentrations are very high. High copper concentration can also cause greenish discolouring of sanitary equipment and hair.

When metal piping of good quality is used, see 9.2.6, and the potable water treated to be as non-corrosive as possible, the main installation components in the system will last the life span of the unit. Unfortunately, there have been cases where parts of or entire distribution systems have had to be replaced due to corrosion. This is costly.

Potable water pipes can leak due to corrosion, and as they often are concealed in the walls, the damage by the water can become extensive before being discovered. Corrosion control is covered in chapter 8.1.

4.2.4 Itching and skin irritation

Some people working offshore are bothered by itching and other skin irritation. This is often seen in relation to showering, especially if there is scepticism to the treatment methods of the potable water (chlorination, alkalizing, reverse osmosis, etc). It is often difficult to find the cause for such symptoms. These problems may vary from one person to another and from one place to another. Many components, water related or not (like dry air etc.), may cause the problems to occur. If the problems can be related to showering and nothing else, we have made a list of possible causes and remedies:

- One important explanation to the problems is frequent showering, using soap that removes the natural fatty protection of the skin. It is also possibile that people shower more often offshore than at home. To solve such problems it is advisable to showers less frequently or do without soap every time. Use of body lotion after showering may also help.
- Some people have symptoms wintertime even if they do not shower often. This is probably a cold weather eczema caused by the skin's protective layer being washed off. Use of body lotion often reduces such problems.
- It has proven helpful for people experiencing itching and irritation of the skin to use a milder type of soap or shower oil. Some may also react on the soap used in the washery.
- Even if the potable water in itself is not the cause of these skin problems, there are some micro-organisms existing in pipe systems that may set free substances sensitive persons react to. Disinfection of the cold and the hot water systems once a year can prevent growth of these micro-organisms.
- Hard water will also have an influence on how the skin might feel after showering. Taking showers in soft water makes the skin feel less dry but soapy, while showering in hard water makes the skin feel dry and coarse. Persons used to hard water will react to the soft water and the other way around. In Norway most waters are originally soft, but alkalizing/hardening makes the potable water harder, see 4.2.3.
- Treatment methods used offshore are not known to be the cause of itching or other skin reactions under normal circumstances.

4.2.5 Water temperatures

Cold water temperature above 20 ^{o}C and hot water temperature below 60 ^{o}C increase the risk for microbial growth in the system, including *Legionella*, see 9.2.7. To document sufficient temperatures everywhere in the system, a test programme, based on an analysis of where the risk of unwanted temperatures is high, must be established. After sufficient temperatures have been documented throughout the system, monthly testing (randomised locations) may be sufficient.

Cold water tastes better than lukewarm water, and the water should therefore be kept as cool as possible, see 4.2.1. By keeping fresh and cool water available, for example in water fountains connected to the potable water system, chances are that the platform crew will prefer water to the more expensive and less healthy alternatives.

The hot water temperature must be kept high enough to avoid growth of unwanted microbes such as *Legionella pneumophila*, see 9.2.7.

4.3 Quality requirements

It is a common misunderstanding that the water analyses assure good quality potable water. Only high quality technical systems and adequate internal control can assure this. Water analyses will only afterwards document whether the water was of good quality or not. Still water analyses are important to discover problems and errors as early as possible.

The Potable Water Regulations list several parameters to be analysed, thus documenting that the water quality meets the requirements. Some limit values are established because exceeding those values can cause short or long term health hazards, or because exceeding the limit value may make the potable water quality unfit for consumption. Exceeding other limit values do not pose any immediate health hazard, but may indicate that the potable water contains other components hazardous to health. Exceeding limit values may reveal that the water works is operated incorrectly and consequently may not produce safe potable water.

The potable water Regulations applies offshore and contains a total of 58 parameters to be measured. Apart from parameters applying to bottled water only, all the parameters should be measured at least once a year and many once every month or more often. The authorities can deviate from this programme provided that the water works owner can document that limit values are unlikely to be exceeded.

In many aspects offshore water works differ from water works onshore, for example by producing potable water from sea water. Bunkered water comes from onshore water works with approved control routines. Some pollutants are thereby avoided in the offshore systems, but special conditions offshore make units susceptible to other types of pollution. The NIPH, in agreement with the RCMO and the Norwegian Food Authority, has suggested an analysis program for offshore potable water that covers the requirements in the Potable Water Regulations, see appendix 4. The RCMO suggests that the program is followed until 2018, when an evaluation of the number of parameters to be analysed will be made. Often one will need to do more tests to have sufficient control with the water, and the program must be supplemented with other parameters when contamination is suspected.

Analysis frequency, limit values and the consequences of exceeding such parameters are commented on below, whilst recommendations for sample points is detailed in 4.4. When the limits are exceeded, steps to find the causes have to be taken, and normal water quality restored, see 3.5. The authorities must be informed, and for problems that will last for some time, the company must apply for exemptions, see appendix 4. In addition to the analys programme required in the potable water regulations, water temperatures must be analysed, see 4.2.5.

4.3.1 Daily analyses

The potable water quality on board must be measured and logged daily, see appendix 3. Results are used to evaluate the need for adjustments of the potable water operations. The following parameters are included in the daily control:

Smell: Should not be noticeable. Smell may be a sign of contamination by, for instance chlorine/ chlorination by-products, volatile substances produced by algae, miscellaneous chemicals, oil, hydrogen sulphide gases (rotten smell), metals, salts, humic substances, marsh etc. A slight smell of chlorine is normal following the chlorination procedure, see 4.2.1.

Taste: Should not be noticeable. Unpleasant taste may indicate several types of contamination. See the above information regarding smell.

Clearness: The water should be clear. This must be evaluated by using strong light and a white ore black background, depending on particle colour. Unclear water may indicate contamination and may even reduce the effects of disinfection, see 4.2.2.

pH-value: Should be between 6.5 and 9.5. To avoid corrosion, the pH-level should be kept stablen between 8 and 8.5. Chlorination functions best at a pH-level below 8, requiring chlorination before alkalization. Small deviations from the limit values for pH does not cause any health hazard, but pH-value above 11 can cause cauterization damage especially to eyes and skin, see 4.2.3. pH fluctuations increase copper corrosion and may lead to loosening of biofilm, with high colony counts as a consequence.

Conductivity, see 6.4: Abnormal conductivity levels should not be accepted on an offshore unit. Conductivity varies with type of water, depending on how the potable water is produced and where in the system the water is tested.

In water production units, the conductivity at the sample point of the production unit will indicate its functionality. The sample point from an evaporator shall not show conductivity higher than 6 mS/m (= 60 µS/cm). Modern evaporators often produce water with conductivity less than 1 mS/m. At the sample point from a reverse osmosis unit, a conductivity level up to 75 mS/m is acceptable, but modern osmosis units will produce water with much lower levels. Water with unusually high conductivity should be dumped.

When water passes through an alkaline filter, the conductivity level will increase. How much depends on the type of alkalization unit being used, and it is important that conductivity levels have no abnormal variations. The cause of the abnormal fluctuations must be found. High levels of conductivity offshore imply high sodium chloride content.

Free chlorine: Chlorination is no longer recommended as the only disinfection method in the potable water system. If the potable water is treated with UV-radiation, free chlorine is not required, and consequently daily chlorine analyses are not necessary.

Free chlorine values should be between 0.05 and 0.5 milligram per litre (equals ppm, parts per million). The NIPH recommends that the value is kept above 0.1 mg/l, as lower levels may be difficult to measure safely with normal offshore equipment. If free chlorine is not found, the disinfection has failed. It is then important to immediately take measures to avoid infections and prevent such situations to develop in the future.

The higher limit value of 0.5 mg/l, is set to prevent the water from smelling and tasting of chlorine. It is not hazardous to the health to use water with a higher chlorine level. Some countries recommend higher levels of chlorine, and the World Health Organization permits up to 5 mg/l, but in such cases it is recommended that the crew be informed that the potable water regulatin requirements are not fulfilled, see appendix 12.

Total chlorine: Should be kept below 5 mg/l. Water with high total levels will smell and taste strongly of chlorine. Adding as much as 5 mg/l should therefore be used only while disinfecting the pipe lines, see 9.2.9, as the Potable Water Regulations requirements for smell and taste are not fulfilled. During normal operations of the potable water system the total chlorine amount should not exceed 1.0 mg/l, unless it is necessary in order to reach adequate levels of free chlorine.

4.3.2 Analyses when bunkering

Water samples for quality testing should be taken from each one of the tanks the bunkering vessel delivers water from. Appendix 5 contains a suggested bunkering log. Before the water is accepted, the following parameters have to be measured and found acceptable:

Smell, taste, clearness and pH: See 4.3.1. Smell and taste are to be evaluated indoor, and clearness to be evaluated in good lighting.

Conductivity: Water delivered offshore should have approximately the same conductivity as it had when it was in the onshore pipes. In the past Norwegian water works onshore had conductivity levels below 10 mS/m (=100 µS/cm). Several onshore water works now treat the water with alkaline filters to obtain conductivity between 10 and 15 mS/m. This water can be accepted offshore. The most important issue here is that there is no significant increase in conductivity during transport from the water works to the offshore unit. When entering into an agreement on water delivery to an offshore unit, the normal conductivity level for the onshore water works should be established, see appendix 6.

Colour value: Should be below 20 mg Pt/l. Higher colour value is normally caused by a high content of natural organic material (humic particles) in the water delivered by the water works onshore, see figure 4.5. High colour value reduces the effect of the disinfection, and may also cause formation of disinfection by-products.

Figure 4.5: Norwegian surface water often has a high content of natural organic material, requiring increased dose of chlorine when bunkering (Photo: Bjørn Løfsgaard)

Free chlorine: Must be verified 30 minutes after ended bunkering/circulation, see 4.3.1.

4.3.3 Monthly routine control

Monthly samples of water should be sent to an accredited laboratory. Recommendations for test programme are detailed in 4.4, and procedures for this are described in appendices 7 and 8. A form for use in fault-finding, covering common deviations in potable water quality is shown in appendix 9. The NIPH suggests a monthly water test programme with the following parameters:

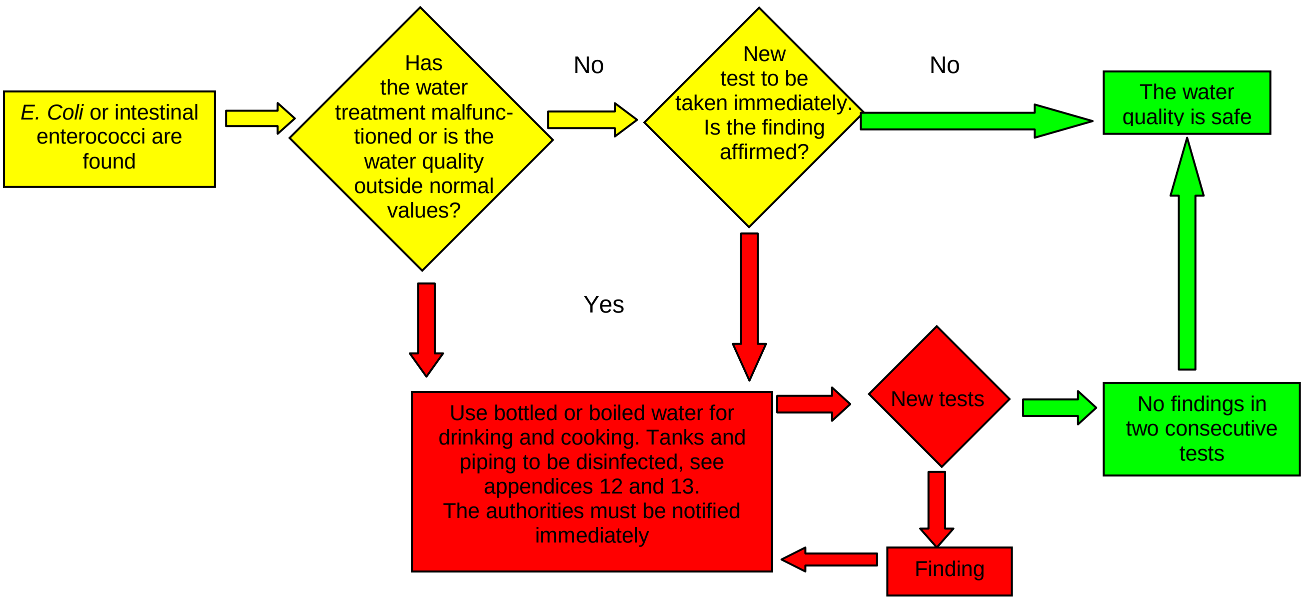
Colour: See 4.3.2.

Smell and taste: See 4.3.1.
Turbidity: Shall be below 1 FNU. High turbidity makes the water unclear, normally due to a high content of small particles. The effects of disinfection is reduced, see 4.2.2, and the water appears less appetising.

***Clostridium perfringens*:** Shall not be present in 100 ml water. If the limit value is exceeded, the entire water system must be investigated to ensure that it is not contaminated by other disease-spreading substances with long survival abilities such as *Cryptosporidium* or norovirus. *Clostridium perfringens* can also cause food poisoning.

***E. coli*:** Shall not be present in 100 ml water and if discovered, must be reported immediately to the authorities. *E. coli* has about the same life span in water as other common disease-producing intestinal bacteria, and is used as an indicator of such bacteria. Human faeces with high levels of *E. coli*, is the most dangerous microbiological contamination of potable water.

If *E. coli* is found, immediate measures must be taken to avoid disease, see figure 4.6, and to prevent similar incidents in the future. Immediate measures will normally be a systematic check of the entire water system to ensure that it functions properly. Special attention should be given to disinfection. Are the chlorine level sufficient and is the UV-radiation unit functioning?



Figur 4.6: How to act when E. coli *or intestinal enterococci have been found in potable water samples (Illustration: Karin Melsom)*

When it has been established that all systems are functioning properly, new water samples should be analysed by an onshore laboratory. If malfunction in the system are found, immediate actions have to be taken to prevent disease outbreaks. Such actions usually include announcement via the PA-system, boiling of water, use of bottled water etc. The detection of *E. coli* must be followed by disinfection of contaminated tanks and pipe system.

Intestinal enterococci: Shall not be present in 100 ml of water. Finding intestinal enterococci indicate faecal contamination, and should be reported immediately to the authorities. Intestinal enterococci have even better means of survival in salt water than *E.coli*, and are used as an indicator of disease causing intestinal bacteria. The same preventive measures as described for *E.coli* should be taken.

Colony count 22^{o} C/72 hour: Colony count in tanks and pipe system should be below 100/ml of water. Sample from the UV-outlet should be below 10/ml of water. In the colony count analysis, a wide range of micro-organisms, being naturally present in water, are found. Colony count above 100 reveals a problem with microbial growth (biofilm) in the system, and must lead to investigations to disclose the cause of the problems and to find necessary corrective measures. Extensive biofilm can lead to bad smell and taste and reduce the effect of the disinfection. High colony counts are also a sign that the system may harbour microbes like *Legionella*, see 4.2.5.

Coliform bacteria: Shall not be present in 100 ml of water. Finding coliform bacteria without finding *E.coli* normally indicates an older contamination without a great disease-producing potential. Even so, the same preventive measures as described for *E.coli* should be taken.

Iron: Limit value is 0.2 mg/l (milligram/ litre). If the limit value is exceeded, it is an indication of corrosion in the potable water system. Generally this is not a health problem, but may indicate potential for other types of corrosion, like heavy metals. The iron value should also be kept as low as possible because deposits of iron may reduce the disinfection effect. High iron content will discolour the water itself as well as clothes and sanitary installations, and give the water an unpleasant taste. High iron content may indicate the possibility of other types of corrosion, i.e. of toxic heavy metals such as lead and cadmium.

Conductivity: See 4.3.1.

Copper: Limit value is 1.0 mg/l, measured at the end of the pipeing. The copper values in hot water can be much higher than in cold water. Consequently the copper value should be much lower when measured in the cold water fixture, after a short flushing. Copper values above 0.3 mg/l indicate that the alkalizing system is not working properly. The copper level in the cold water system should be maximum 0.3 mg/l (except when copper is used to combat biofilm, see 9.2.7). If water has been stagnant in the pipe system for some time, it is not unusual to have levels above 3 mg/l, which can give acute gastrointestinal disorders. High copper content will give the water a bitter taste and cause discolouring of sanitary equipment and sometimes give blond persons a greenish hair colour, see figure 4.7. Dissolved copper ions will also accelerate corrosion on other metals. High copper content may indicate the possibility of other types of corrosion, i.e. of toxic heavy metals such as lead and cadmium.

pH (acid value): See 4.3.1.

Figure 4.7: Corrosive water in copper pipes can result in too high copper content in the potable water (Photo: Bjørn Løfsgaard)

Supplementary analyses:
Calcium: If an alkalizing filter, see 8.1, is used in the water treatment process, calcium should be analysed monthly. The calcium value should be between 15 and 25 mg Ca/l. Such analyses indicate whether the operation of the system is optimal or not. High calcium content can lead to deposits in the UV-operation system.

4.3.4 Extended yearly routine control

An increased number of physical/chemical potable water parameters should be analysed yearly in an accredited laboratory. Appendix 8 describes how the samples should be collected, but the laboratory should specify what type of bottles to use. The yearly programme should be carried out simultaneously with the monthly analyses and taken at the same locations on the distribution system (living quarter). The programme should include the following parameters:

Benzene: Shall be below 1 μg/l. Benzene has been found offshore and is believed to be caused by contamination from protective coatings. Carcinogenic and also harmful in other respects.

Benzo(a)pyrene: Shall be below 0,010 μg/l. The environment may be contaminated by such polycyclic aromatic hydrocarbons and higher content than the above stated proves that the contamination has reached the potable water. It is most likely carcinogenic.

Bromate: Shall be below 5 μg/l. By-product that may be formed when electro chlorinated sea water has passed an evaporator. Also found offshore as pollutant after using hypochlorite that is not approved for potable water use, see 2.3.4. It may possibly be carcinogenic.

Cadmium: Shall be below 5 μg/l. Higher content of Cadmium is normally a sign of corrosion on the pipe lines and fixtures. Cadmium is toxic and accumulates in the human body and affects many organs. It is suspected to be carcinogenic.

Chemical oxygen demand (COD) (alternatively total organic carbon (TOC) may be measured): Shall be below 5.0 mg/l O (or 5.0 mg/l C for TOC). Shows how much organic material the water contains. It can cause microbiological growth and/or foul taste.

Hydrocarbons, mineral oils: Shall be below 10 μg/l. Found offshore after leaks and after contamination by coatings (paints) or solvents, often accompanied by an unpleasant smell and taste.

Lead: Shall be below 10 μg/l. High content of lead is normally caused by corrosion in pipe lines and fittings. Lead is toxic and accumulates in the body and affects many human organs.

Polycyclic aromatic hydrocarbons (PAH): Shall be below 0.10 μg/l (includes the sum of benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(ghi)perylene and indeno(1,2,3-cd)pyrene). Found offshore, most likely as a result of exhaust pollution via air vents for tanks. It is believed to be carcinogenic.

Trihalomethanes: Shall be below 50 μg/l (includes the sum of chloroform, bromoform, dibromochlormethane and bromodichlormethane). These substances have been found on offshore units following electro chlorination of the sea water inlets. The substances are volatile and concentrations can increase in the evaporation process. Increased levels have also been found as a result of platform chlorination, when the water from the onshore water works already contains high levels of trihalomethanes, especially when the water is chlorinated several times (bunkering to tanks that contain much water). Chloroform and bromodichlormethane are most likely carcinogenic. More research has to be done before the other substances can be classified.

UV-transmission: Values for UV-intensity and UV-transmission should give parallel results, high levels for one, should show high levels for the other. Comparing results to previous years may reveal if the UV-intensity meter functions, provided the water is of the same origin.

Supplementary analyses:
Boron: Shall be below 1,0 mg/l. Need only to be measured for reverse osmosis produced water. Boron is a sea water component, and boron may pass reverse osmosis membranes. May cause adverse reproductive and developmental effects.

Glycols: Shall be below 10 μg/l. Need only to be measured if there is a risk of such pollution through leakages from evaporators etc.

4.3.5 Parameters without yearly analysis recommendation

Some Potable Water Regulations parameters will, for various reasons, not be exceeded in offshore systems. The CGR has decided that offshore platforms, for the time being, do not need to analyse the following, see 4.3:

1.2-dichlorethane: Not detected offshore.

Acryl amide: Not applicable for Norwegian water.

Aluminium: Not used in offshore water treatment and will consequently not be present in potable water produced offshore. The analysis requirements are fulfilled by analyses done by the onshore water works.

Ammonia: Not detected offshore.

Antimony: Not applicable for Norwegian water.

Arsenic: Not applicable for Norwegian water.

Chloride: Shall be below 200 mg/l. Only to be measured if the conductivity is high. High content leads to corrosive water, unpleasant taste, and indicates sea water contamination. Conductivity measured after evaporation or reverse osmosis is mainly due to traces of sodium chloride (NaCl), and a conductivity of 1 mS/m implies a chloride content somewhat less than 3 mg/l Cl.

Chrome: Not applicable for Norwegian water.

Cyanide: Not applicable for Norwegian water.

Epichlor hydrine: Not applicable for Norwegian water.

Fluoride: Only a problem in connection with ground water sources. No water works with fluoride problems deliver water to offshore units. The analysis requirements are fulfilled by analyses done by the onshore water works.

Manganese: Only a problem with ground water sources, and no water works containing manganese deliver potable water to offshore units. The analysis requirements are fulfilled by analyses done by the onshore water works.

Mercury: Not applicable for Norwegian water.

Nickel: Not applicable for Norwegian water.

Nitrate and Nitrite: Not used offshore. The analysis requirements are fulfilled by analyses done by the onshore water works.

Pesticides: Not used offshore. The analysis requirements are fulfilled by analyses done by the onshore water works.

Radon: Only a problem in connection with ground water sources. Even if ground water from onshore sources may perhaps contain radon, the amounts will be insignificant since the water is aired during transport.

Selenium: Not applicable for Norwegian water.

Sodium: Shall be below 200 mg/l, and should ideally be far below this level. Only to be measured if the values for conductivity are unnormal. High levels can be caused by failure in the production unit or the potable water being contaminated by sea water. An elevated sodium level is detected by high conductivity. The sodium content offshore is no problem to people with good health, but raised levels can be problematic for people on a low salt diet. High sodium content increases blood pressure that may cause cardiovascular disease. Conductivity measured after evaporation or reverse osmosis is mainly due to traces of sodium chloride (NaCl), and a conductivity of 1 mS/m implies a sodium content somewhat less than 2 mg/l Na.

Sulphate: Analysis is not necessary offshore as sea water contamination is revealed when measuring conductivity. Offshore water treatment does not carry risks for sulphate contamination.

Tetrachloroethene and trichloroethene: Not detected offshore.

Total indicative dose: Not applicable for Norwegian water.

Tritium: Not applicable for Norwegian water.

Vinyl chloride: Not applicable for Norwegian water.

4.4 Sample points

The potable water regulations state that the water shall have potable water quality where it is supplied to the consumer. Normally this will be the tap, and applies to all taps on the unit. For testing purposes one needs to do a risk analysis to find the most important taps and other testing points. If there are many such points, it is normal to test them according to a rotating test regime.

Examples of important testing points:

- Seawater prior to water production
- Water treatment units
- Water tank outlet
- Kitchen taps
- Other potable water taps; especially taps near the end of distribytion branches

One of the sample points in the distribution system should be a fixed reference point. Recommended analysis parameters and analysis frequency is detailed in 4.3.

4.5 Drinking water in bottles or other packaging

Drinking water in bottles etc. may supplement the water supply, but is not a reason to compromise on quality. As a thirst quencher, in addition to normal intake of juice, milk, tea and coffee, water is recommended and un-rivalled. Drinking water coolers placed where people gather make it more tempting to drink water. Whether the water comes from a potable water system or is delivered in a water barrel has no significant health consequence. For those being cost- and environment conscious it is important to note that bottled water is extremely expensive compared to tap water. In addition packaging and transport of the bottled water makes it an environmentally bad choice.

Some bottled water is labelled natural mineral water, and is covered by other rules and regulations. These products may have very high levels of sodium (figure 4.8). Bottled water used for daily consumption should have a low sodium level (labelled Na+ or Sodium). It does not make any difference to the health whether the bottled water contains carbonic acid or not.

4.6 Essential analysis equipment

Offshore units must have equipment measuring:

Chlorine: See 4.3.1. Free and total chlorine is measured in milligram per litre (mg/l). Normal chlorine values during operation offshore are 0.05 to 1 mg/l, but during disinfection of the system, values as high as 10 mg/l should be measurable. Certain measuring equipment is claimed to measure free chlorine values as low as 0.01 mg/l. Such low measured values may not be dependable. The measuring requirement for free chlorine is thus set to a minimum of 0.05 mg/l, and the minimum requirement value must be above the limit the equipment is able to measure. Using a colour comparator makes it difficult to prove the exact value of free chlorine below 0.1 mg/l, therefore 0.1 should be used as the minimum value for free chlorine level. The chlorine measuring equipment on the unit should be able to measure chlorine levels of 0.05-10 mg/l, with precision requirements as follows:
+/- 0.05 mg Cl_2/l covering 0.1-1 mg Cl_2/l
+/- 0.2 mg Cl_2/l covering 1-10 mg Cl_2/l

Colour: See 4.3.2. Measured in milligram per litre platinum (mg/l Pt) by using photometer or spectrophotometer, and the measuring equipment must measure colour values within 2-50 mg Pt/l.

Conductivity: See 4.3.1. Is measured as milli-Siemens per meter (mS/m) or microSiemens per centimetres (µS/cm). 1 mS/m equals 10 µS/cm. The measuring equipment must measure conductivity within 0-100 mS/m at 25^{o}C, with a precision requirement of +/- 5 %.

PH-value: See 4.3.1. The measuring equipment must measure pH-values within 4-10, with a precision requirement of +/- 0.1 pH-unit.

Figure 4.8: Some natural mineral water has very high sodium content, as the conductivity meter shows (Photo: Eyvind Andersen)

5. General design requirements

Potable water systems shall be designed to give the crew sufficient quantities of high quality water at all times. Offshore potable water system differs from onshore systems in several ways, and requires special considerations.

Failure in the offshore potable water system can have serious consequences since it is difficult to find other means of water supply. A water borne epidemic can infect so many persons within a short time, that it will become difficult to maintain operation on the unit.

The HSE-regulations emphasise that potable water systems must be designed to minimize risks of failure as much as possible, by for example doubling crucial elements in the process, and choosing systems that are easy to operate, with minimal risks of technical malfunction

When deciding if an offshore unit will have water production equipment, it is important to know that produced water normally is of very high quality, and often also is the cheapest solution in the long run, as bunkered water is costly. Bunkering of water involves a long chain of operations, each of which may fail, see chapter 7.

Design suggestions for offshore potable water systems can be found in chapter 5.1. A number of general requirements to design are given in chapter 5.2. Special advice regarding details is given in chapters 6 to 10 in the guideline.

5.1 Design example

Figure 5.1 shows schematic how to design a potable water system. The numbers given on the drawing refer to the following text:

1. Two sea water inlets supply the unit with water. This makes it possible to use sea water from different locations and different depths, thereby avoiding local contamination.

2. Two water production units, each with 100 % production capacity (alternatively 3*50 %), safeguard the water production even if one production unit is out of order. Produced water is dumped automatically if the conductivity is too high, and in addition the water production units have a common conductivity meter and dump valve as extra safety

3. The alkaline filter makes the water less aggressive. CO_2 added prior to the filter speeds up the process and stabilizes pH within the best values, see 4.2.3.

4. Bunkering hoses can be flushed and samples taken before filling the tanks. Two bunkering stations increase the possibility for bunkering in bad weather etc. Flushing of hose and pipe is to be done with the same water speed as when bunkering (often around 250 m^3/t). The flush water pipe size should match the capacity of the bunkering pipe. The piping needs a low point drain to facilitate complete draining of the pipes after bunkering.

5. Flowmeter controlled chlorination equipment assures correct chlorination.

6. A minimum of two separate storage tanks, see table 9.1, assure available water even if one tank must be drained due to pollution, maintenance etc. The tanks have drain valves, but tank suction is placed higher to avoid tank sediment from entering the pipe system. Storage tanks and manholes are designed to make it easy for the maintenance crew to inspect and clean the tanks while the unit is in operation, see 5.2.1. Storage tanks, including air vents, are protected against penetration of sea water and other contamination, see 9.1.2. The pipes supplying water to the tank is located in a position that enhances water circulation in the tank. Automatic valves makes impossible to bunker water to a tank that at the same time is supplying the distribution network.

7. The system has two frequency controlled water pumps, each with 100% supply capacity. Pumping will normally be a better solution than using hydrophore tanks due to cleaning requirements and microbial growth potential.

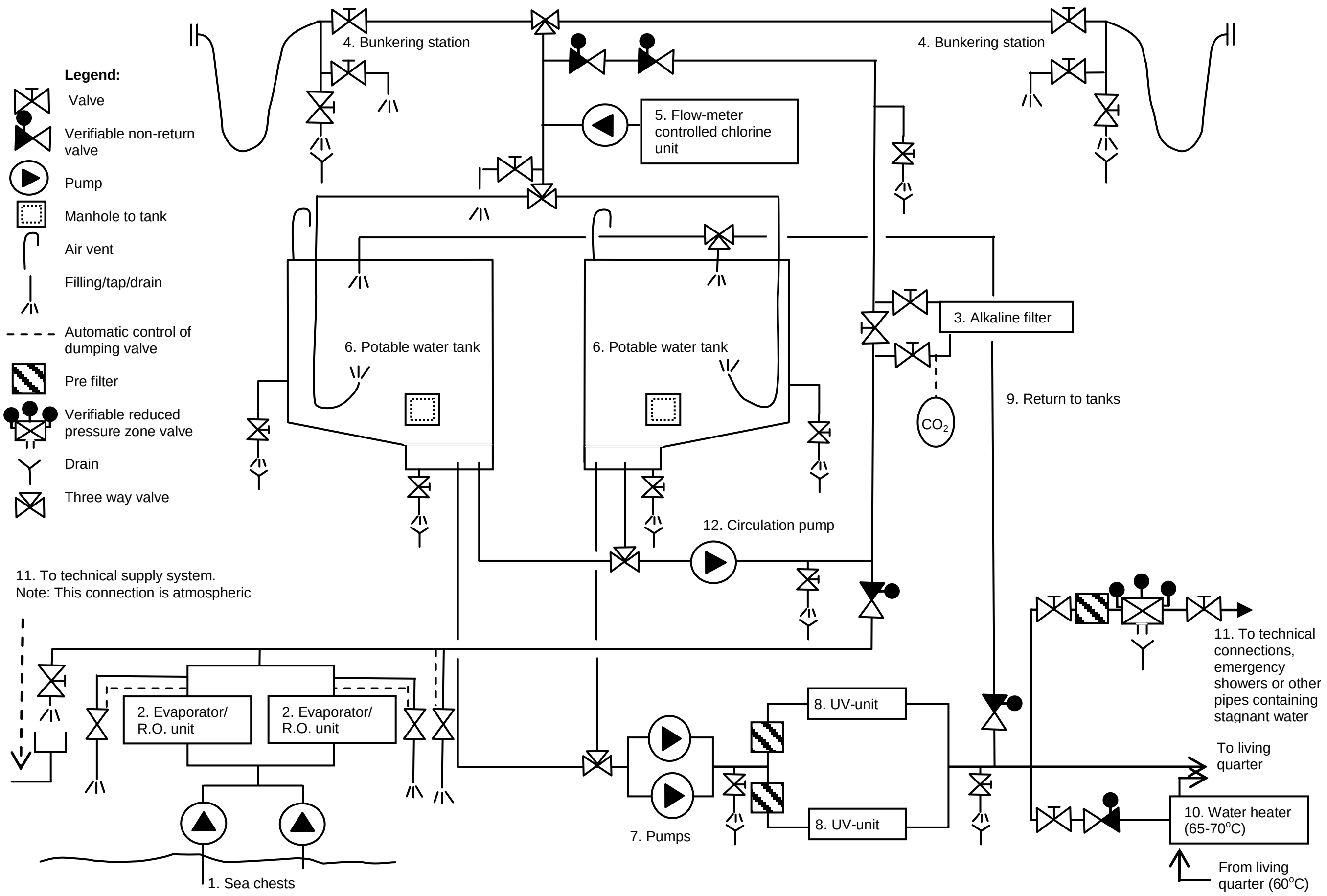


Figure 5.1: Outline of an offshore potable water system (Illustration: Karin Melsom)

8. Two or more UV-units which, even with one unit out of use due to maintenance or technical failure, still have sufficient capacity to disinfect the maximum water supply at the lowest relevant UV-transmission, see 8.3.2. The UV-units are equipped with solenoid valves that shut off the water flow if technical failure occurs. To avoid stops in the water supply, the units should be connected to emergency power supply. Particle filters are positioned in front of the UV-units to prevent microbes from passing the UV-unit in periods of turbid water.

9. Tank return line (alternatively a hydrophore tank) provides stable water pressure in the pipes. The return line is connected after the UV-units to prevent overheating of UV-chambers through sufficient minimum flow. This solution may also improve the general water quality by letting the water pass through particle filters and UV-units several times. The tank return inlet is located to enhance tank circulation. The water is automatically routed to the same tank that supplies the network.

10. Hot water circulates through a water heater with sufficient temperature (normally 65-70^o C) to ensure both that the water in the bottom of the heater frequently holds 60^o C and that the temperature in the entire hot water system stays above 60^o C, see 4.2.5. Insulation of piping is necessary to achieve this, see 9.2.8. A verifiable non-return valve prevents hot water from leaking into the cold water. Other connections to equipment where hot and cold water is mixed must be safeguarded as well.

11. Technical and other connections are separate from the potable water system. Such connections are atmospheric or in other ways separated to prevent back suction of dirty water, see 9.2.5. Stagnant water is to be avoided, and safety measures are to be located as close to the potable water branch-off as possible.

12. The system has a dedicated pump with a large enough capacity to quickly circulate and chlorinate water in one of the tanks (often 4-6 hours), whilst water is being supplied to con-

sumption from the other tank. The water is automatically pumped back to the tank of origin.

5.2 Directions for design and construction of a potable water system

The majority of necessary considerations when designing offshore potable water systems are obvious. Nevertheless, it is easy to make mistakes, either because not all aspects have been sufficiently considered, or because the potable water system is in conflict with other technical, economical or practical aspects. The NIPH suggests that persons in charge of the project use our check list in appendix 1, to evaluate if the project is in accordance with regulatory requirements.

Below we have listed the most important aspects to be considered in design of a potable water system. It is important to study closely all the different aspects throughout the planning and construction process (figure 5.2). By involving personnel with experience in operation of offshore potable water systems, many mistakes can be avoided.

Figure 5.2: During the construction process it is important that pipe systems are not contaminated. The picture shows how pipe ends are secured by being compressed (Photo: Bjørn Løfsgaard)

5.2.1 Ergonomic design

According to the Facilities Regulations § 20.1 ”work areas and work equipment shall be designed and placed in such way that the employees are not subjected to adverse physical or mental strain as a result of manual handling, work position, repetitive movements or work intensity etc. that may cause injury or illness”.

The requirement to ergonomics applies to the entire potable water system, operations as well as maintenance. Insufficient ergonomics measures can result in necessary work operations not being undertaken in a proper manner. The NIPH often has experienced inferior ergonomic design in the following situations:

Figure 5.3: This potable water tank is high and lacks internal platforms for easy cleaning. This has resulted in insufficient cleaning. The walls are pretty clean up to 2 meters height and very dirty above 4 meters height (Photo: Eyvind Andersen)

- The flush valve on the bunkering station is often placed in such a position that the crew on the unit or the supply vessel crew is subject to heavy splashes of water.
- Potable water tanks are often built with very high or low walls, this obstructing cleaning and maintenance (figure 5.3). With high walls, ladders and platforms can be built inside the tank, but such equipment must also be constructed to facilitate cleaning and maintenance.
- Existing potable water tanks often have compartments and braces on the inside, making cleaning and maintenance difficult. Such obstructions should be avoided if possible, or be designed to make access easy, and to make flush water drain away properly (figure 5.4).
- Potable water tanks lacking an effective low point drain.

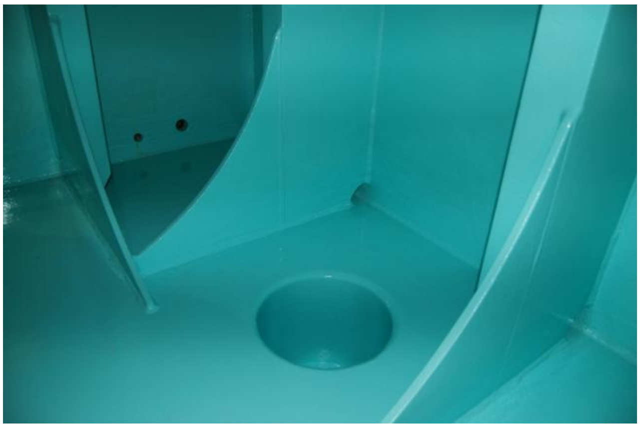


Figure 5.4: This tank has a drain well, and the stiffeners are placed vertically, with drain cavities against tank floor. Consequently the tank is easy to drain (Photo: Eyvind Andersen)

Figure 5.5: Alkalising filters, hydrophore tanks and calorifiers are often supplied with access openings of such a small size that the tanks are impossible to clean (Photo: Eyvind Andersen)

- The design of alkalizing filters often makes it awkward to fill or empty the filter as this frequently involves climbing and heavy lifting. Access to the filter for inside maintenance may also be difficult.
- Water heaters and hydrophore tanks often have limited access for internal maintenance.
- Valves, that are opened or closed manually, are placed in awkward positions.
- Manholes for potable water tanks and hydrophore tanks are difficult to reach, especially when heavy equipment is needed for repairs inside the tanks.
- Sections of the potable water system requiring regular attendance are often placed in areas with disturbing noise levels.

5.2.2 Safeguarding against mistakes

According to the Facilities Regulations § 20.2 " Work sites and equipment shall also be designed and placed in such a way that the risk of mistakes that can have an impact on safety, is reduced". Supply of sufficient, safe and good potable water is a prerequisite for the unit to be operated safely, and the unit must be designed to minimize probability of mistakes that could jeopardise the water supply.

The potable water system should be based on the use of simple and robust technical solutions, see the Facilities Regulations § 5. Technical solutions with many different and complicated details that may fail should be avoided and simple solutions chosen, thereby eliminating risks for failure, and also minimizing the risk for human errors. Listed below are solutions that should be avoided:

- Technical solutions where one mistake can cause important systems to malfunction, such as bypassing the disinfection units.
- Technical solutions requiring intensive supervision to function properly.
- Technical solutions not functioning due to unstable water quality, volume changes etc.
- Technical solutions where failure is difficult to uncover, or where it is difficult to limit the damages and do repairs.
- Technical solutions where it is stated: "We know this might easily fail, but we have a procedure that will prevent failure".

5.2.3 Storage capacity requirements

Offshore units must always have enough water aboard, and offshore experience shows that the daily consumption is often quite high. The minimum daily supply is 200 litres potable water per person for drinking, cooking, personal hygiene, cleaning etc. Storage *capacity* should be large enough to supply these needs even if water delivery is interrupted. The storage tanks should be of equal size, and requirements for total storage capacity depend on number of tanks and water production capacity, see 9.1.1.

If the water is stored too long, bad taste and smell may develop. The storage tanks should be operated to prevent this, and the water should not be stored more than 20 days. Under normal operation the tanks can not be emptied at the same time, and the minimum storage *reserve* is two days of maximum water consumption. If the reserve under operation comes under 2 days of consumption, non-conformity action must be taken, see 3.5.

5.2.4 Hygienic barriers – preventing contamination

A fundamental principle in Norwegian water supply, is the requirement for at least two independent hygienic barriers against the various contaminants that could occur in a potable water system, see the Potable Water Regulations § 14. The barriers ensure, even if one barrier fails, that the water quality will still be satisfactory, since the second barrier should not fail for the same reasons as the first one. The following are examples of hygienic barriers in a potable water system:

Figure 5.6: The remains of a bird colected from offshore potable water tanks. The bird entered via the bunkering hose, got stuck in a valve, and was spread to all the water tanks as it gradually decomposed (Photo: Anonymous in agreement with the company)

- Something preventing contamination of sea water used in potable water supply, see 6.1.1.
- Something diluting sea water contamination to a harmless concentration before the water reaches the sea water inlets, see 6.1.2.
- A treatment process removes or makes microbes harmless, braking down, removing or thinning chemical and physical substances. See 6.2 and 6.3 regarding evaporation and reverse osmosis, and chapter 8, about water treatment in general.
- Precautions taken in the distribution system to prevent already treated water from again being contaminated, see chapter 9.

Numerous types of pollution can influence the potable water quality from the sea water inlets through the treatment units to the distribution system (figure 5.6). To secure two hygienic barriers against all types of pollution throughout the entire process is a demanding task. Important actions could be:

- Sufficient safety measures for sea water inlets require restrictions in the discharge of polluted water from the offshore unit. Polluted waste water should be diluted and the sea water inlet located in the most suitable place considering water depth, polluted discharge water and common current directions, see 6.1. These safety measures equal at least one barrier against most types of pollution.
- Water production through evaporation or reverse osmosis is considered as a barrier against most types of pollution, see chapter 6.
- The hose connections and routines for bunkering water from the onshore supply source represent a weak element in the delivery chain, but transport safety routines, and flushing and taking water samples at the bunkering station, can provide two barriers against physical and chemical substances, see chapter 7.
- Transport and bunkering routines are important, but are not considered a reliable hygienic microbial barrier. Chlorinating the water when bunkering is therefore necessary in order to secure one barrier against microbes, see 7.2.
- The other microbe barrier is normally UV-radiation of the water passing from storage tanks to the distribution system, see 8.3.
- It is vital to prevent the potable water from contamination on its way to the consumers. Atmospheric connections or equivalent solutions, see 9.2.5, prevent contamination from a variety of technical devices using potable water. Contamination via leakage or pollution through chemical dosing tanks or air vents must be avoided by placing tanks in areas separated from other contamination sources.

The potable water system should be designed to minimize the risk of contamination. Examples on solutions to be avoided are given in chapter 5.2.2.

5.2.5 Placing, marking and protecting the equipment

Detailed descriptions are given in chapters 6-10. According to the HSE-regulations, the following general design requirements apply:

- Important operation equipment, valves, tanks etc. shall be marked and easily accessible.
- Design of technical equipment and work areas shall make maintenance operations easy.
- The equipment shall be protected against pollution from other process equipment.
- Potable water pipes shall be physically secured and clearly marked and colour coded to make following easy in case of an emergency, and to prevent link up with other fluid systems by misunderstandings etc.

- Tanks for additives are secured by using screw cap or equivalent and marked to avoid pollution by accidents etc. (figure 5.7).
- Sections of the potable water system placed outdoors should be of non-corrosive material.
- The entire potable water system must be of a non-corrosive material adjusted to the corrosivity of the potable water, see 9.2.6.

5.2.6 Location of sample points

In case problems in the potable water system occur, it is important to be able to locate the exact position of the problem and how far it extends. A sufficient number of strategically placed sample points along the entire system are necessary. These sample points should be placed on bunkering stations, storage tanks, and subsequent to each main component in the system, such as production unit, disinfection unit, alkalizing filter and other treatment units.

Placing, marking and protection of equipment are described in 5.2.5, but the following should be observed: Piping from main pipeline to sample valve should be as short as possible to avoid stagnant water. Piping after sample valve should be self draining, as short as possible and shaped to enable easy disinfection by means of chlorine, alcohol or heat. End cap on pipe is recommended.

5.2.7 Paints and protective coatings

Paints and coatings being used in storage tanks have often contaminated the potable water by improper use, shortened hardening processes or illegal use of thinners, see 9.1.4. Paints and other protective coatings shall be evaluated, see 2.3.4, and the owner must be able to document that such products have been applied according to certification requirements and the manufacturer's instructions.

5.3 Alterations of the potable water system

When parts of a potable water system is altered, reconstructed or taken out of operation, it is necessary to assess whether the entire system still fulfils the requirements to offshore potable water systems. Significant changes must be reported to the authorities, see Management Regulations § 25.

Figure 5.7: A marked and protected chlorine tank with easy access (Photo: Eyvind Andersen)

6. Potable water production

Potable water on an offshore unit is produced either by reverse osmosis or evaporation. Such water must be treated to become non-corrosive to the pipes and fittings, see 8.1. It is important to make sure that the sea water used in the production is not polluted. If polluted sea water is suspected, the water production must stop.

6.1 Sea water inlets

A sea water system normally has two sea water inlets. The water is pumped through sea water pipes for the various types of use, for instance fire fighting water, production unit for potable water and a variety of technical needs. The sea water must be protected against pollution.

6.1.1 Possible pollution threats

Sea water used in the potable water production might be polluted. The reasons could be discharge from own or adjacent offshore units, or discharge from ships. Water production should not take place when the water is polluted or when the unit is near harbours etc. The following pollutants are the most common:

Sanitary waste: Sewage and waste water from living quarters contain nutrients and various microbes. If such elements get into the potable water system they can lead to growth of biofilm in storage tanks and pipes, problems with smell and taste, and in worst case, disease.

Figure 6.1: Normally there is turbulence in the water around the platform legs. Sea water inlets should be placed where the danger of pollution is at a minimum (Photo: Eyvind Andersen)

Wastes containing oil: Production water discharge, deck flushing water, oil wastes from own or adjacent units, are potential sources for oil pollution. Such pollution can give an unpleasant smell and taste to the water even in very small quantities, and may also damage production units.

Chemical discharge: This might come from the same sources as the oil wastes and create the same type of problems. Volatile chemicals can pass an evaporator and the concentration might increase.

Growth of micro-organisms: Periodically some organisms have an intense growth in sea water. Some will emit volatile components into the sea water, causing problems with smell and taste in the produced water. This occurs mostly from spring to autumn.

Electro chlorination of sea chests: This method of marine growth prevention increases the risk of exceeding the limits for bromate, trihalomethanes etc. when water is produced through evaporation. To minimise such problems, the company must make sure that the electro chlorination is being done without overdosing of chlorine in periods with low seawater consumption. The company must also establish a sufficient analysis programme to document that the electro chlorination is conducted without posing any health risks.

6.1.2 Placing sea water inlets

Placing sea water inlets require documentation that the discharges from the unit will not cause unacceptable levels of pollution. For existing units shell analyses may be used to assess influence. In order to assess the pollution threat, it is necessary to analyse the dispersal area using a recognized model, see Management Regulations § 16. If several of the factors listed below are uncertain, the safety limits should be high. The following measures will prevent or reduce pollution:

Sea water inlets to be located as far away from the discharge points as technically feasible. When waves hit the platform legs the result is a strong shift in the water masses (figure 6.1). Discharge beneath the platform ends in turbulent water masses that can cause spreading and thinning of pollution both horizontally and vertically. Sea water inlet and discharge points should be located on separate platform legs/pontoons, preferably the sea water inlet on the outside of the leg and the discharge on the inside. By placing sea water inlets deep down, the influence from the surface is slight, temperatures are low and fewer micro-organisms exist.

Placing sea water inlets favourable to currents The sea water inlets should be placed upstream of the discharge point, considering the most common current direction (figure 6.2).

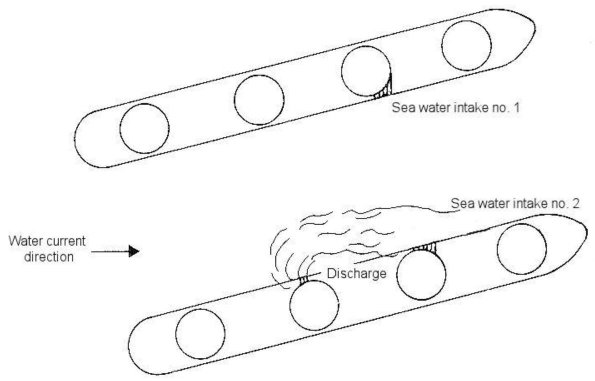


Figure 6.2: Sea water inlets must not be placed downstream from the discharge points, taking into account the prevailing current direction. Inlets should not be placed on the same side of the unit as the discharge. The inlets, as illustrated above, should be moved to the outside of the pontoons. (Illustration from B3/NIVA's engineering office)

Discharges with equal physical characteristics should be gathered together. A discharge with a different density than the surroundings it is discharged to, can move significantly in vertical direction before being diluted. A high density discharge is therefore expected to sink, and should consequently be placed below the sea water inlets. On the other hand, a low density discharge should be placed higher up. Vertical separation of sea water inlets and discharge is easier to achieve on offshore units placed on the sea floor.

Design and size of discharge pipes are key elements in the way discharge water is spread and diluted. A pipe ending in many small holes, like a diffuser, will greatly increase dilution compared to an open pipe with the same diameter. The concentration of pollutants will be lower with an efficient dilution.

Several sea water inlets operating separately should be installed. The unit should have at least two sea water inlets spaced well apart. When local currents change so that polluted discharge water is directed towards the sea water inlets in use, the other sea water inlet should be used.

Other sea water connections must be placed in a way that does not lead to contamination of the sea water pipe system by back-flow or back-suction. The sea water inlet can be secured by being the first connection on the sea water system and securing other branch-offs with non-return valves.

The best solution is to have separate closable sea water inlets for production of potable water, as common inlets for sea water supply tend to be used also in ports etc, and thus pose a risk of contaminating the water supply for potable water production. Such separation is particularly important for units that have diving systems, as these are more vulnerable to the effects of contamination.

6.2 Evaporation

Evaporation is the most common method used in potable water production on the Norwegian Continental Shelf. The evaporation process means that sea water is heated until it evaporates and is thereafter cooled off, resulting in fresh water. There are different types of evaporation units, but only vacuum distillation will be described here, see figure 6.3, this being about the only type of evaporation unit in use on the Norwegian Continental Shelf.

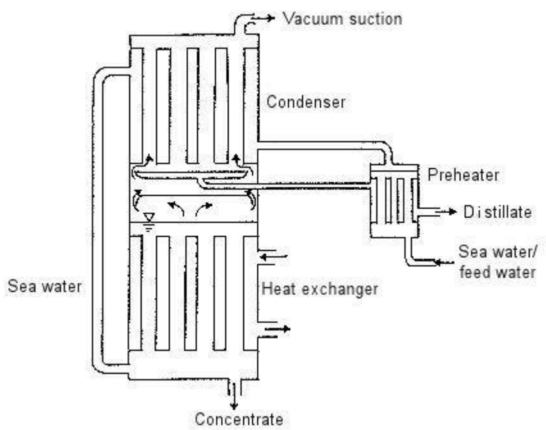


Figure 6.3: Design principals for a vacuum distillation unit (Illustration from B3/NIVA's engineering office)

Figure 6.4: Shows the inside of an evaporator. The net prevents sea water drops from passing on to the distillate (Photo: Bjørn Løfsgaard)

When pressure is reduced, the evaporation temperature is lowered to between 30 and 60° C. Sea water is pre-heated in a heat exchanger with hot distillate. The feed water is then led into the condenser where the water accumulates condensation energy from the steam. Heated feed water is led into an evaporator and heated with an external source, starting the vaporization process (figure 6.4). Hot water, steam or electricity is used as a heating source. For units with plenty of hot cooling water, for example from diesel engines, this could be used in heating the water, and in such cases evaporation will be a less expensive production process than reverse osmosis. The low evaporation temperature reduces problems with boiler scale and reduces the need for chemicals.

If the sea water is polluted, substances more volatile than water may pass the evaporator while other substances and microbes only pass in case of uneven boiling, operation failure etc. As only some of the feed water evaporates, while it is assumed that all volatile substances will evaporate, this can result in concentration of such components in the produced water. When the sea water is electro chlorinated prior to evaporation, see 6.1.1, problems with chlorine and bromine compounds like bromate and trihalomethanes may occur see 4.3.4. Such problems may be minimised through better operation of the electro chlorination, and through reducing the effect of the evaporator, thus producing cleaner water. Volatile substances can be removed, see 8.4.

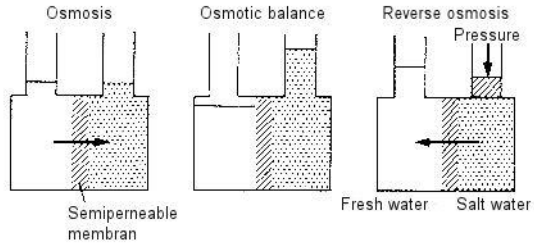


Figure 6.5: The drawing shows process principles for osmosis and reverse osmosis (Illustration from B3/NIVA's engineering office)

6.3 Reverse osmosis

Reverse osmosis is a process where sea water is forced under high pressure against a membrane with microscopic openings. The water molecules are very small and will pass the membrane, but most of the salt and other contaminants will be held back. Potable water produced by reverse osmosis will have a higher salt concentration than water produced by evaporation. Production costs for an evaporation process are normally higher than for reverse osmosis, except for units that can utilize cooling water for heating. The higher the salt concentration is, the more corrosive water, and it is therefore important to use high quality pipe material in the system, see 8.1.

The principles for osmosis and reverse osmosis are shown in figure 6.5. When two solutions with different salt concentrations are separated by a semi permeable membrane, the water with the lower salt concentration will flow towards the water with the stronger salt concentration. This process is called osmosis. The water level remains higher on the side with the high concentration of salt. The difference between water levels is called an osmotic pressure. In reverse osmosis the pressure applied on the salt concentration is higher than the osmotic pressure. Fresh water will consequently flow from the high salt concentration into the lower salt concentration. Because the sea water salt content increases during the process, the concentrate must be drained into the waste water system and new sea water supplied.

Except for Boron, see supplementary analyses in 4.3.3, reverse osmosis is safer than evaporation in eliminating contamination, but if the membranes are damaged, micro-organisms and other substances can slip through. Membranes vary in design, see figure 6.6. To avoid damage to the membranes by pollutants in the sea water, the water requires treatment. Chlorine is often added in the sea water inlets to reduce algae/bacterial growth in the system. Chlorine residues can damage the membranes, but this can be avoided with an active carbon filter ob by using sodium bisulphite. The feed water might contain particles too small to be stopped in the sea water inlet filter, but large enough to clog the fibre membranes. Particles down to 5 micrometers must be removed. This can be done by using different filter types. To reduce the manual maintenance work, the flushing and cleaning process should be automatic. Some membranes will break if pressurised in the wrong direction, and must be protected against this.

Figure 6.6: Reverse osmosis unit with the membrane placed in the roll on top of the unit (Photo: Bjørn Løfsgaard)

6.4 Conductivity control

To ensure that water produced by evaporation or reverse osmosis is safe enough, conductivity is measured at the production unit outlet. Sea water has a high conductivity level, and a possible malfunction in the production process can be detected by a rise in the conductivity (figure 6.7).

The conductivity meter, also called salinometer, is placed at the production unit outlet. Conductivity determines the quantity of salt in the water. The limits are set in advance at maximum 6 mS/m for the evaporator process and 75 mS/m for reverse osmosis. If the limits are exceeded, the water distribution to the tanks should be stopped and the alarm activated, as this indicate that the system is not operating as it should be. Conductivity is described under chapter 4.3.1.

There have been several incidents where malfunctions in conductivity meters or dump valves have resulted in salt water contamination of the potable water. This is a hygienic problem, and also results in much work to re-establish good potable water quality. It is recommended that water production units are equipped with two stages of conductivity metering and dumping, see figure 5.1.

The conductivity meter shows the conductivity in mS/m, µS/cm or as ppm sea salt (1 mS/m = 10 µS/cm = 4,6 mg/l NaCl). The conductivity meter should be a type where the setting can be adjusted and controlled. A tap should be placed on the outlet to make it possible to cross check the conductivity meter with another conductivity meter.

6.5 Use of chemicals

All substances used in the potable water process shall be certified, see 2.3.4. Filling pipes used for adding chemicals shall have close-fitting caps to avoid contamination.

Evaporator operation requires the use of chemicals. The chemical can either be added continuously, for example scale inhibitor added to the feed water to prevent boiler scale on hot surfaces, or intermittently, such as in the cleaning process. Chemicals are also used indirectly as the heating medium for the evaporator often contains hot water or steam, to which the chemicals are added to prevent boiler scale, corrosion and possible freezing. Chemicals are seldom continuously added in an osmosis process. Periodically chemicals are used to clean the membranes, and for preservation, as membranes can easily be damaged when not in use.

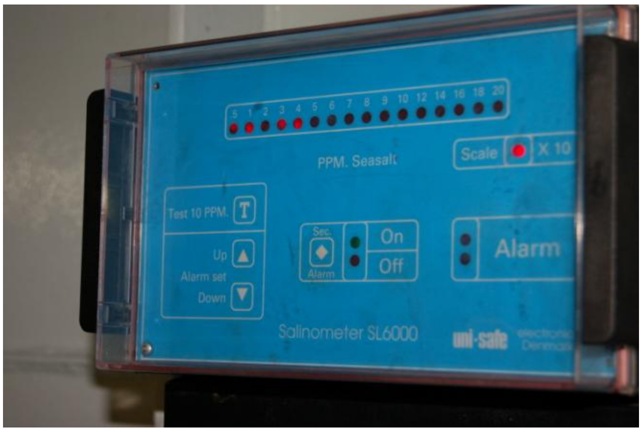


Figure 6.7: A conductivity meter automatically measures salt content in produced water and dumps it if the 6 mS/m limit is exceeded (Photo: Eyvind Andersen)

7 Bunkering potable water

When bunkering water from supply vessels, it is difficult to have full control of the water quality. The water may be contaminated when delivered to the supply vessel (figure 7.1), or contaminated during transport to the offshore unit. Contamination can happen both onboard the supply vessel and in the bunkering process through for example dirty hoses. Tests at the bunkering station have occasionally revealed pollution by sea water, diesel etc.

All water delivered by supply vessels is of uncertain quality regardless of precautions taken by the supplier and recipient. The biggest uncertainty is connected to microbiological contamination, as it is not possible to take such samples when bunkering. Consequently it is important that all potable water is disinfected during bunkering.

Frequently the colony count increases in the entire potable water system after bunkering. It is significant to check the disinfection units and control routines, as each disinfection unit should separately be able to deactivate the majority of microbes in the water. Even though the unit is responsible for poor water quality after bunkering, the danger of bunkering inferior quality water is reduced if the owner requires that supply bases (figure 7.2) and supply vessels have good routines in drawing and transporting the potable water, in addition to satisfactory cleaning and maintenance of the storage tanks, see appendix 6.

Figure 7.1: Bunkring station on onshore supply base. Water may be polluted prior to entering the supply base, and if supply base routines are weak, both hose connections and hoses may be contaminated (Photo: Eyvind Andersen)

Figure 7.2: This supply base has a water tank that fills up slowly, whilst still providing rapid filling for supply vessels. This way a flushing effect for the water mains is avoided, resulting in cleaner water (Photo: Eyvind Andersen)

7.1 Design of bunkering system, including water circulation

Figure 7.3 shows a bunkering system with the possibility for circulating water from one storage tank, through to the chlorination unit, back to the same storage tank, without feeding the water into the distribution system. The numbers in the text below refer to details in the figure. Interlocks or other measures ensure that water is bunkered and circulated into other tanks than the one that is supplying accommodation, see 5.1.

An offshore unit should have two bunkering stations to facilitate maintenance, preferably placed on each side of the unit, to increase the possibility to bunker during bad weather conditions. The bunkering pipe system should be designed to ensure that the pipes are drained completely after bunkering is completed. Both bunkering stations and hoses have to be marked to avoid confusion with hoses for other liquids, and the bunkering stations for potable water should be separate from bunkering stations for other types of fresh water.

Bunkering hoses (1) are either coiled up on a drum, or hanging down the sides of the unit. The couplings are susceptible to pollution from sea water, various processes onboard and pollution from birds. Dead birds have been found in potable water pipes. It is therefore important to cover the hose ends. It is also important that the hoses are equipped with a floating device to prevent them from contact with the supply vessel propellers. Hose connections for potable water should be of a distinct design to prevent contamination by connecting the wrong hoses.

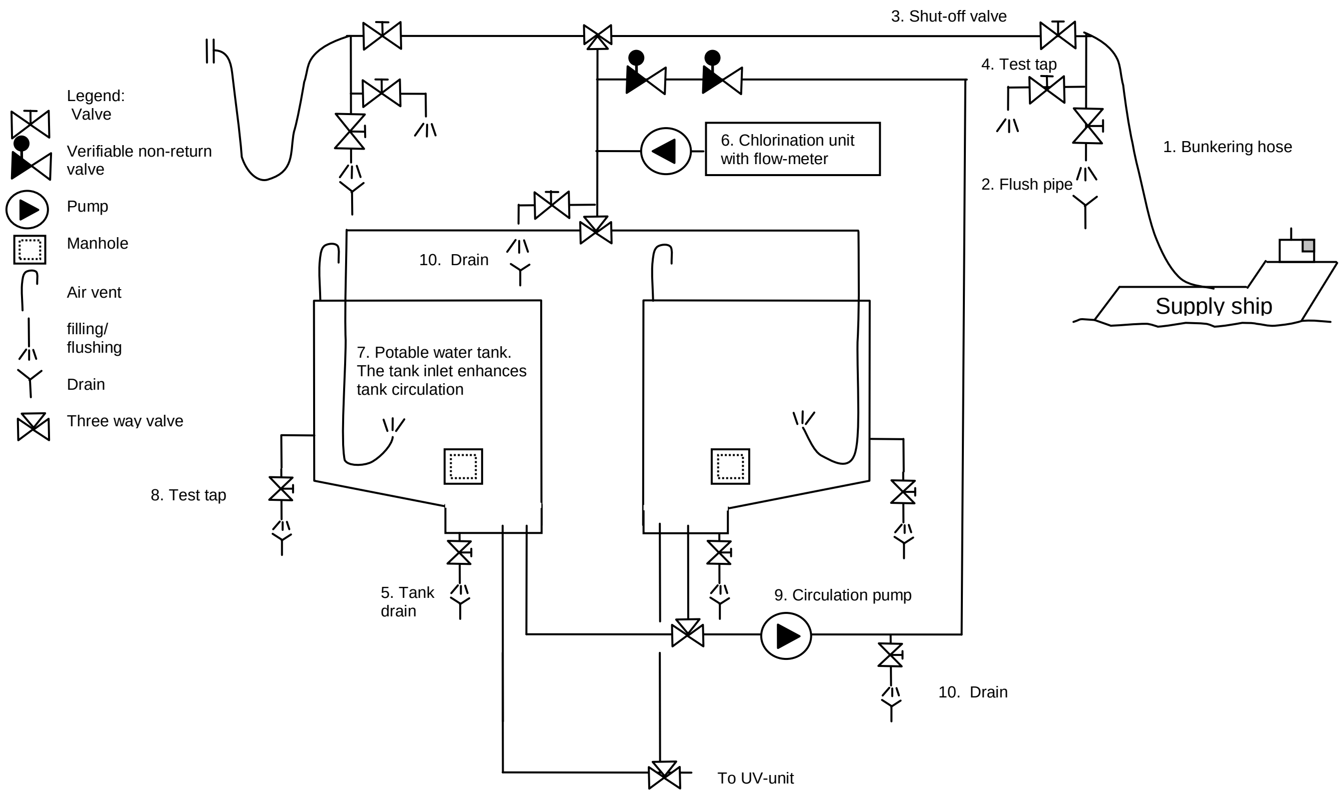


Figure 7.3: Drawing of a bunkering system with recirculation pipe (Illustration: Karin Melsom)

Bunkering hoses are normally made of rubber, and may serve as ”food” for microbes. Dark coloured hoses with moisture inside warm up fast in the sunlight, resulting in excellent growing conditions for microbes. Hoses should be flushed thoroughly before each bunkering, and after bunkering they should be drained before they are hanged and stored (figure 7.4). Hoses are difficult to clean and should therefore regularly be exchanged. At the connection point for the bunkering hose a flush water pipe (2) should be installed as well as a shut-off valve down stream on the feed pipe (3). Sudden increase in water flow results in contaminants being dislodged from the walls of pipes and hoses. To prevent increase in water flow after flushing, the flush water pipe dimension must be at least as large as the feeding pipe. Bunkering stations should be designed to prevent operating personnel on the unit or the supply vessel crew from being sprayed with water in the flushing process. The test tap (4) is placed in front of the shut-off valve on the flush water pipe. It may be located on the feed pipe and should be easily accessible for sampling. Discharge of old potable water from storage tanks (5) is advisable before bunkering. This will wash out the sediment and make chlorination more effective, see 7.2, and will also reduce the amount of chlorination by-products, as all water is chlorinated only once, see 4.1.2.

A chlorine dosing pump (6) is connected to the bunkering pipe system, see 8.2.4. The best mixing ratios are achieved if the chlorine pump is controlled by a flow-meter. Bunkering pipes should be designed in a way that enhances water circulation in the tank (7), for example by separating the inlet and outlet, and by pointing the inlet in a direction that enhance circulation of the total tank volume. This will result in more efficient chlorination of the water as the chlorine also reaches any “old” water in the storage tank, and will also make tank recirculation easier to achieve.

Figure 7.4: Bunkering hose for potable water. The hose has light colour in order to reduce warming. Both hoses in the picture have floating devices to prevent entangling in the supply vessel propellers (Photo: Eyvind Andersen)

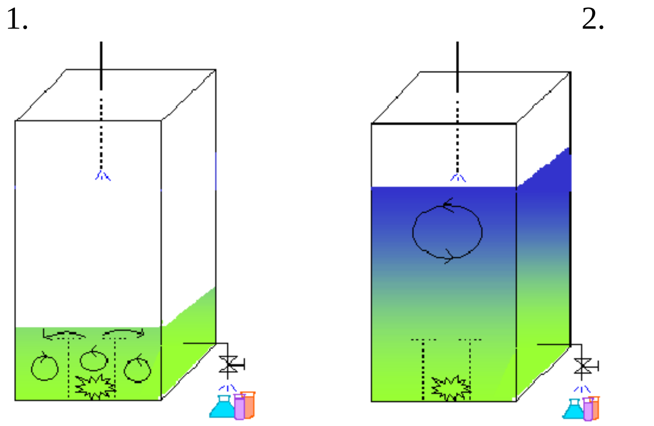


Figure 7.5: Pouring chlorine directly into storage tanks may result in lack of chlorination in parts of the tank and overdosing in other parts (Illustration: Bjørn Løfsgaard).

Test taps (8) makes it possible to sample the chlorinated water in the tanks, without simultaneously feeding this water to the consumers. Test taps should be easily accessible. Operation, maintenance, design and other requirements for storage tanks are described in detail in chapter 9.

A large capacity circulation pump (9) provides the possibility for a fast circulation of water from one storage tank, via the chlorination unit and back to the same tank, without having to distribute it. Simultaneously, water will have to be distributed to the network from another tank. This makes it easy to dose extra chlorine to bunkered water that have received too little chlorine during bunkering. Without this option, bunkered water with no residual chlorine will have to be dumped and tanks refilled, and this increases the risk of running out of water. Circulation is enhanced by separating the tank inlet and outlet. It is preferable to design this distribution system to let the water pass the alkalizing filter as well, see 8.1. Low point drains on the bunkering and circulation pipes (10) make it possible to avoid stagnant water after bunkering.

Figure 7.6: The flow meter display is visible to the right, and the chlorine hose and dosing point to the left (Photo: Eyvind Andersen)

7.2 Disinfection requirements

Disinfection of potable water is done by adding chlorine. Chlorination is described in detail in chapter 8.2. To achieve sufficient disinfection, the chlorine must be well mixed with the water. It should be evenly distributed into the water flow during the entire bunkering process. Often the shape of offshore potable water tanks result in inadequately disinfected water, because of insufficient mixing when chlorine is poured directly into storage tanks before bunkering (figure 7.5). To achieve the best possible chlorine-water mixture in the entire tank, it is best to start the filling process with tanks being as empty as possible. This will also contribute to reducing the levels of chlorination by-products, see 4.1.2.

7.2.1 Flowmeter regulated dosing

A flow meter on the bunkering pipe adjusts the chlorine pump speed (figure 7.6). The pump doses a calculated amount of chlorine per cubic meter water. To chlorinate bunkered water adequately, the concentration of the solution must be adjusted. If bunkering always is into an empty tank, generally the same chlorine concentration can be used each time. When bunkering to a tank with residual water (to be avoided if possible), the chlorine concentration should either be increased to chlorinate the residual water as well, or the volume of chlorine that the flowmeter is set to give must be adjusted.

7.2.2 Manually regulated pump dosing

This method offers greater flexibility in choosing the concentration of chlorine. If the chlorine solution is concentrated, the pump speed is slow, and if the chlorine solution is diluted the speed is increased. It is recommended that a diluted chlorine solution is used, since this will result in a better mixing of the chlorine in the bunkering water stream, due to higher speed and volume of the injected chlorine water. When using a manually regulated pump it is necessary to know how long the bunkering will take, and adjust the chlorination pump speed to deliver the necessary chlorine dose for the entire time span. If bunkering to a tank with residual water (to be avoided if possible), enough chlorine should be added to chlorinate the residual water as well. This can be achieved by increasing the chlorine pump speed or by increasing the concentration of chlorine solution.

7.3 Bunkering procedures

Appendix 10 gives advice for bunkering. These issues are further discussed below.

7.3.1 Prior to bunkering

Before bunkering starts, an adequate amount of chlorine solution with the correct concentration should be prepared, see calculation examples in appendix 11. The dosing should be adjusted according to experience from previous bunkering, achieving a sufficient chlorine residue relevant to the water quality being bunkered, see 7.4. The chlorine amount is adjusted by changing chlorine concentration or through modification of the volume of chlorine solution being added. If the pump is not flowmeter regulated, the dosing speed must be calculated, see appendix 11, as the dosing shall be uniform during all the bunkering time.

It is important to make sure that all valves are in correct positions, see 3-6 in appendix 10. Bunkering should always be done to tanks as empty as possible (figure 7.7). This is particularly important when bunkered water has a high content of organic material. If it is possible to dump the residual water in the tanks prior to bunkering, it will make the chlorination procedure easier and reduce troubles with colony counts, chlorination by-products and other pollution of tanks and pipe system.

Figure 7.7: Dumping of potable water from tank. It is recommended to dump "old" water prior to bunkering. This applies to both supply vessels and offshore units (Photo: Eyvind Andersen)

Figure 7.8: When flush valve and the bunkering hose have corresponding diameters the system can be flushed with maximum pressure. (Photo: Eyvind Andersen)

7.3.2 Bunkering

Bunkering starts by flushing the hose and piping a few minutes under maximum pressure (figure 7.8). After flushing, a sample is taken to determine colour, smell, taste, clearness, conductivity and pH of the water, see requirements in chapter 4.3.2. As smell, taste and clearness is a subjective judgement, it is sensible to let two persons share this responsibility. Water that does not fulfil the requirements shall be rejected (figure 7.9). If a supply vessel delivers water from more than one tank, samples must be taken from each tank. If the water is acceptable, the bunkering can start.

7.3.3 After bunkering

The storage tanks are to be isolated for 30 minutes after bunkering, then a sample should be analysed for the free chlorine. The results should be between 0.1 and 0.5 mg/l, see 4.3.1. The free chlorine evaporates after some time. It is important that the sampling is done within a reasonably short time, otherwise it might be impossible to document that the water is disinfected.

If no free chlorine is found after 30 minutes, the water must either be dumped or more chlorine added by circulating the tank content via the chlorination system, if the unit design permits this, see 7.1. The water should circulate until the chlorine is mixed properly, and another sample taken 30 minutes later. This is repeated until free residual chlorine can be measured. This practice is not ideal, since it might be difficult to mix the chlorine satisfactorily in the water. It is recommended that the chlorine dosage is set higher than the minimum requirements to avoid such unfortunate situations. It is reasonable to aim for a free chlorine level of 0.3 mg/l after 30 minutes.

If the concentration of free chlorine is too high, the water can be diluted with water from other storage tanks. The water can also be stored before being consumed. The chlorine concentration will then decrease. There is no health hazard involved by using water with a chlorine concentration up to 5.0 mg/l, but the water will not be according to the potable water regulations as it will smell and taste chlorine, and this should be avoided if possible. In case the water has to be used, the crew should be informed of the situation beforehand, see appendix 12 about disinfection of pipe systems.

There have been several incidents where supply vessels deliberately or incidentally have delivered water of good quality water for testing before switching to a tank with sub-standard water without informing the offshore unit. Some quick and simple tests after bunkering may detect this and prevent further piping contamination. The vater is evaluated visually (clear, without noticeable colour) and tested for smell, taste and conductivity.

7.4 Logging

It is important to keep a log of the various details in the bunkering procedure. This permits adjustments ahead of the next bunkering. Experience shows that many water quality problems are connected to bunkering, either due to poor water quality from the water source, or because the bunkering process is inadequate. The bunkering log is an important tool in solving such problems. Appendix 5 shows an example of such a log.

Figure 7.9: Determination of smell, taste and clearness must take place indoors and under strong light to have any value (Photo: Eyvind Andersen)

8. Water treatment

Both bunkered water and water produced from sea water have to be treated to make sure that the quality requirements in the Regulations are met. A range of methods can be used to accomplish this. In this chapter the most frequently used methods are described. All additives to the potable water, such as chlorine, filter material, cleaning agents etc. have to be certified, see 2.3.4.

Potable water produced from sea water must be treated to make it less corrosive, see 8.1. All offshore potable water has to be disinfected. The disinfection process makes contagious microbes harmless. Disinfection offshore is done through chlorination and UV-radiation, see 8.2 and 8.3. Bunkered potable water is disinfected by adding chlorine during bunkering. In addition, both bunkered and produced water shall be disinfected as it is being distributed to the consumers. The NIPH no longer recommend disinfection only by use of chlorine, as UV-treatment has been proved more effective against some microbes, se 8.3. Chlorine has advantages, both when disinfecting pipes and tanks, and by that the effect can be easily verified through measuring chlorine residue.

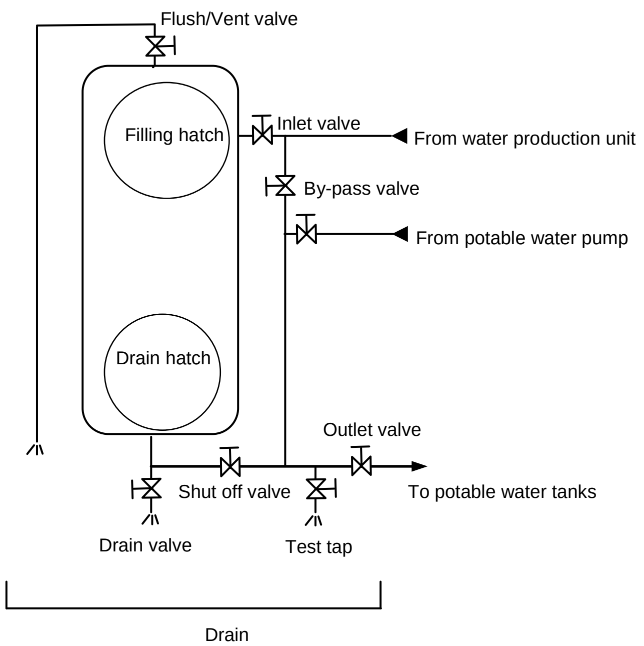


Figure 8.1: The filter has to be designed with easy accessibility for cleaning, changing of filter mass and maintenance (Illustration: Karin Melsom)

8.1 Corrosion control

Corrosion in a potable water system means that the water attacks metal in the piping system, treatment units and fittings, much in the same way as a car becomes corroded by climatic factors. Corrosion causes, chemistry and health consequences are described in chapter 4.2.3. Corrosion reducing water treatments are described below.

The most common method in offshore corrosion control, is to let the water pass through a dolomite mass or limestone filter. Sodium silicate has also been used with good results, and does not require any filter.

8.1.1 Alkaline filter

Alkaline filters are recognized under different names, for example palatability filter, limestone filter, marble filter and re-hardening filter. The filters may be designed in a variety of ways and using a range of filter materials.

Units with CO_2-dosing ahead of the alkaline filter will increase the calcium/hydrogen carbonate content (HCO_3^-), and stabilize the pH within the most favourable limits. Units without CO_2-dosing will have more fluctuation in the pH level both in production and in the pipe system, and such fluctuations may also increase corrosion.

Design

Figure 8.1 shows a filter with the inlet at the top and the outlet at the bottom. This type of filter must always be designed for return flushing. The flush water is led from the distribution net in to the bottom filter, lifting the masses, and is then discharged via the flush drain. High pressure is necessary when flushing. Using the same pump that feeds the water through the filter during normal operation does not always result in adequate pressure. The flush water has to be of potable water quality. The filter must be designed with a filling hatch and a drain hatch, and these must have large enough openings to give easy access for filling and emptying the filter and for internal maintenance. Protective coating inside the filter has to be certified for use in potable water systems.

Dolomite filter (half burnt dolomite)
Filters with half burnt dolomite are the most compact and therefore often used offshore. The water passes through the half burnt dolomite, $Ca(CO_3)MgO$, and part of the mass dissolves in the water. By dosing CO_2-gas to the water prior to the filter, a higher hardness and alkalization is achieved, simultaneously stabilizing the pH level around 8. Without the CO_2-gas, this filter mass can result in extremely high pH levels (pH 11-12), and is therefore not advisable. The effects of the filter mass decrease after a while. To begin with, a rapid release of MgO results in high pH values, while aged masses mainly contain $CaCO_3$, which is less soluble in water and thereby less effective. New filter mass must be added continuously and the entire filter mass changed regularly.

Limestone filter/marble filter
Crushed lime stone ($CaCO_3$, marble) is used in the same way as dolomite, but being less soluble and due to its chemical composition, the pH level will not reach as high levels as the dolomite. New filter mass will bring the pH value up to around 8.5 without adding CO_2, and with CO_2 pH it stabilizes around 8. To obtain a sufficient solution of limestone, it is important to have a large contact surface. A particle size of 1-3 mm and a filter depth of at least 1 m are common. It is also important that the strain on the filter is not too intense, resulting in an insufficient contact period. Marble filters are easy to operate, and have the advantage, compared to other methods, of keeping the pH below the maximum limit. Marble has to be replenished regularly to keep up an even mass grading.

Operation and maintenance
The filter mass is constantly compressed, and consequently clogging the filter. The filter must be cleaned regularly by return flushing, and must be re-filled to ensure that it always is at least 75% full. Some substances in the mass do not dissolve, and are consequently accumulating in the filter tank. Some of these substances will be flushed out during the return flush operation, but after a while the tanks have to be emptied of these substances before refilling with new filter mass. Due to poor maintenance, micro-organisms might settle in the filter mass, causing high colony counts in the potable water tanks. The filter should be emptied before it is cleaned and disinfected at least once a year, like other parts of the potable water system.

8.1.2 Sodium Silicate
Adding sodium silicate reduces corrosion. Experience with sodium silicate is a bit mixed, but it can give just about the same corrosion protection as alkalization. The effect depends on the water quality and material in the pipe system. Using sodium silicate is especially useful in a pipe system of acid-proof stainless steel, where the feeding pipes to drain taps are made of copper. If sodium silicate is used in systems with galvanized iron, the corrosion compounds are washed away into the water before the water quality stabilizes.

Sodium silicate functions best in acid and soft water. Necessary sodium silicate dosage escalates with increased concentration of salts and increasing hardness and temperature in the water being treated. The precise mechanism in this process is not well known. Silicate ions can prevent metal ion deposits like trivalent iron, thereby reducing rust bulbs in iron and steel pipes. Sodium silicate can also grow a film of precipitated silicic acid and metal silicates on the pipe surfaces, and eventually prevent corrosion.

Sodium silicate is supplied dissolved in water, and must be certified, see 2.3.4. Dosing is normally done with a flowmeter regulated pump. This system is easier to use than alkalizing filters, and the risk of microbiological growth is avoided. The dosing point should be placed after UV-units.

8.2 Disinfection by chlorination
Chlorine is still the most commonly used product in disinfection of potable water world wide, and chlorination of potable water offshore does not pose any health hazard, see 4.1.2. Offshore, calcium hypochlorite ($Ca(OCl)_2$) and sodium hypochlorite (NaOCl) are used. The two form the same active chlorine combinations in water, hypochlorous acid (HOCI) and hypochlorite ion (OCI). These two active chlorine compounds in water are called ”free chlorine”. Free chlorine is unstable, and reacts with organic material or is reduced to chloride. The amount of organic material is normally higher in bunkered water, consequently requiring more chlorine in order to disinfect the water. Chlorine may also react with ammonia forming chloramines, so called “combined chlorine”, which has a slow disinfecting effect and may cause “swimming pool odour”.

Figure 8.2: Water discoloured by humic material needs more chlorine than clear water to achieve a proper disinfection (Photo: Bjørn Løfsgaard)

Chlorine inactivates bacteria by attacking the cell wall, penetrating the cell and destroying the enzyme systems. Virus is inactivated both by attacking the protein mantle, disrupting its ability to attack, and destroying the genetic material. As chlorine needs a certain time for these processes, the Potable Water Regulations requires a free chlorine level of at least 0.05 mg/l after 30 minutes of contact.

Experience shows that it may be difficult to verify concentrations below 0.1 mg/l with normal offshore equipment. To achieve a best possible effect of the chlorine, it should be added as early as possible in the bunkering process. If free chlorine content above 0.05 mg/l after 30 minutes can not be confirmed, the water is not satisfactorily disinfected. The water must be rejected, unless the potable water system is equipped to *mix in* extra chlorine, see 7.3.3. How to calculate chlorine amounts, mixing of chlorine solutions etc., are described in appendix 11.

8.2.1 The significance of the water quality

The colour of the water reveals a lot about the content of chlorine consuming organic materials (humic substances), though iron may also cause colour (figure 8.2). The chlorine dose needed to kill microbes must be increased in water with high content of organic material, in order to maintain the required chlorine level after 30 minutes of contact time. Generally it is sufficient to add 1 gram chlorine per ton (= 1 m^3), equivalent to 1 mg chlorine per litre.

To predict the amount of chlorine needed is often a greater problem for water works onshore than offshore, as water quality onshore fluctuates more than it does offshore. Offshore produced water needs less chlorine treatment, because the colour is checked already at the bunkering point and the water refused if the colour is unacceptable.

In contrast to many other countries, Norway has a tradition of not accepting water tasting chlorine. The free residual chlorine in the water shall not exceed 0.5 mg/l after treatment, with the exception of disinfection of the pipe system, see 9.2.9. Generally, the unpleasant smell of chlorine will intensify with increased amount of organic material in the water, as some organic/nitric chlorine compounds have a pungent smell and taste. Tests have shown that chlorine is 50 times more effective fighting bacteria in acid than in alkaline water. With a pH<7, the main part of the chlorine content is chlorous acid (HOCl), while the not so active hypochlorite ion (OCl^-) dominates at a level of pH>8. Consequently, disinfection should be done before the water is alkalized.

8.2.2 Sodium hypochlorite

Sodium hypochlorite (NaOCl) is sold in fluid form and therefore easy to use. Sodium hypochlorite has a limited shelf life, especially if exposed to light and/or heat, causing the active chlorine compound to break down and weaken its effect. If free chlorine is not found in the water after 30 minutes of treatment, the cause is often that the sodium hypochlorite solution is too old.

In a newly mixed solution the concentration is usually 160-170 gram/litre, and is called 15 % solution. Because it breaks down during storage, it is safer to assume it is 10 % instead of 15 %. 15% sodium hypochlorite should not be stored more than 3 months after production date, but refrigerated it is good enough for 6 months. Some vendors supply chlorine of lower consentration that may be stored longer.

The chlorine solution can be added to the water without premixing, but if the chlorine pump capacity is good, it is preferable to dilute the solution, achieving a better control of the process. Sodium hypochlorite is a strong alkaline solution (pH 10-11), and precautions have to be taken. It is particularly important to protect eyes and skin. Bottles with eye rinsing water should be kept within reach. Clothes are also easily ruined by chlorine. Instructions should be carefully read and followed, such as wearing face protection, rubber apron, rubber gloves and other protective items suggested in the instruction data sheet. Accidents in operation of swimming pools have been reported, where sodium hypochlorite has been mixed with acid, forming chlorine gas, which is extremely poisonous. Such accidents are not known to have happened in connection with potable water, but it is advisable to be aware of the potential danger when storing and using such chemicals.

Sodium hypochlorite can be produced by sodium chloride electrolysis (NaCl), so called electro chlorination. Several offshore units use electro chlorination on the sea water inlet to stop shell, plants and other marine growth. It is important to be aware of the fact that chlorous acid evaporates at a lower temperature than water, and will result in higher concentration in water produced in an evaporator. This can cause problems with taste, smell and unwanted by-products, see 6.2.

8.2.3 Calcium hypochlorite

Dry calcium hypochlorite ($Ca(OCl)_2$) has an almost unlimited shelf life. Dissolved in water, the chlorine will break down in about the same manner as sodium hypochlorite. For work environment, the same precautions as for sodium hypochlorite should be taken, see 8.2.2. Normally the chemical contains 60-65 % chlorine, but is often labelled with a content of 70 %. It contains 2-10 % insoluble components, and causes sedimentation in the storage tanks. Such components, and should be separated before dosing, to prevent clogging of nozzles. Alternatively the suction hoses to the chlorine dosing pump could be lifted high enough to prevent suction of the bottom deposits.

8.2.4 Design

The biggest challenge in chlorination is to ensure uniform mixing of chlorine in all the water. The regulations concerning mobile offshore units require that the chlorine dosing unit is permanently connected to the bunkering system, and it is favourable to have the dosing point located as near the beginning of the bunkering system as possible, in order to achieve best possible mixing.

If chlorine is used for disinfecting produced potable water as well, the chlorine should be added before the water reaches the alkaline filter, since chlorine is most effective in acid water. It must be possible to add mix in more chlorine after finishing bunkering, and this is normally done through a circulation system.

The unit should have short pipelines and hoses with small dimension from chlorine tank to bunkering pipeline. Chlorine pumps and tanks must have a capacity that corresponds with the chlorine solution volume to be used, and the dosing unit must correspond with the water quantities delivered by the supply vessel with the maximum pump capacity. The chlorine tank must be marked and leak proof, its water supplied from the potable water system, and have an easy to reach drain valve with a closed drainage system. If calcium hypochlorite is used, the tanks should be equipped with a stirring device to dissolve the powder.

The best chlorine mixing is achieved if the speed of the chlorination pump is controlled by a flow meter, recording the speed of the water transferred to the storage tanks (figure 8.3). Experience with such controlled dosing is good, because it is easy to dose the correct chlorine amount into the entire water mass being bunkered. Chances for mistakes are reduced, as the chlorine dosing stops if the bunkering is interrupted. With a manually controlled pump there is no such control of the chlorine dosing following the water bunkering flow. New units, and rehabilitation of existing units, should be designed with flow meter controlled dosing, see the Facilities Regulations § 10.

Figure 8.3: Flow meter controlled chlorination unit, safely placed in a cabinet (Photo: Bjørn Løfsgaard)

8.2.5 Operation and maintenance

One advantage of chlorine disinfection is the simplicity of the equipment. But even simple equipment may fail. This may be due to the corrosive effects of chlorine, or due to squeezing or blocking of the hoses feeding the chlorine. The entire chlorination unit should be checked and cleaned regularly. The NIPH recommends that this is done at least every three months. If calcium hypochlorite is being used, sediment will form in the tank, requiring more frequent inspection and cleaning.

It is important to make sure that the pump suction is satisfactory, and that the chlorine does actually reach the water. It may happen that a pump only sucks in air only and not the chlorine. Necessary spare parts should always be available. Chlorine pumps are cheap compared to the consequences inferior chlorination might have, and an extra chlorine pump should always in stock.

The following describes common causes when free residual chlorine is not present 30 minutes after bunkering is completed:

- Defect pump/chlorine hose squeezed/air in dosing pipe
- Too little chlorine added, see chlorine calculations in appendix 11
- The sodium hypochlorite is too old
- Insufficient chlorine mixing
- Organic material content in the water too high

Some offshore potable water tests have shown free chlorine concentration way above the level of total chlorine. Such test results are not correct.

8.3 Disinfection by UV-radiation

Ultraviolet rays are part of the sun light spectre and are divided into UV-A, UV-B and UV-C radiation. UV-light is harmful to skin and eyes. Humans are exposed to UV from the sun and from man-made UV-sources like welding flames, solariums or UV-units. UV-C is the most harmful type of radiation. Fortunately, the atmosphere filters away UV-C and the greater part of the UV-B radiation. To inactivate microbes, a high dose UV-C radiation is needed. The UV-dose is a function of radiation intensity and time of exposure.

Figure 8.4: During bunkering or in unstable weather particles and sediments in the potable water tanks can be whirled up and sucked into the distribution system, reducing the effect of the UV-radiation. (Photo: Bjørn Løfsgaard)

Most offshore units use both chlorine and UV in their water treatment. One advantage of UV-disinfection, compared to chlorination, is that UV is more effective against some microbes like *Giardia* and *Cryptosporidium* parasites.

8.3.1 The importance of water quality

Coloured and particle containing water can cause problems in the UV-disinfection, see 4.2.2, because the intensity in the chamber drops, thereby reducing the UV-dose. But coloured water can be disinfected by extending the radiation time. Particles in the water may "conceal" microbes. This is particularly problematic in offshore units if tank sediments are sucked into the potable water inlet (figure 8.4). During bunkering or unstable weather conditions tank sediments may be whirled up. Exceeding the particle limit (turbidity above 1 FNU) must be avoided, and normally this is accomplished by installing particle filters prior to UV-units.

Chemical parameters such as iron and manganese may cause deposits on the quartz glasses reducing the UV-radiation intensity. The same may happen with calcium from the alkalizing filter. Regular cleaning is therefore important.

8.3.2 Design, dimensioning and NIPH-evaluation

The UV-unit (figure 8.5) is the last treatment before the water is distributed, and must be sufficiently designed and dimensioned for maximum water supply and for the worst possible water quality regarding colour and turbidity. The NIPH evaluates UV-units, see 2.3.4.

Only use biodosimetrically tested UV-units
When building new offshore units, and when replacing old UV-units, only biodosimetrically tested UV-units that give an UV-dose of 40 mWs/cm^2 should be installed. Offshore the best available technology shall be used, and these UV-units have better systems for operation and control than units approved according to old method. They also give a barrier against bacterial spores (alternatevely a spore barrier may be achieved by filtration through membranes with nominal pore openings less than 100 nanometres). The units approved with an effect of 30 mWs/cm^2 should gradually be phased out on old offshore units. Lists of approved UV-units are available on www.fhi.no/offshore.

Redundancy is necessary
To ensure the availability of disinfected water, the UV-unit must have at least two radiation chambers in parallel, each able to disinfect 100% of the supplied water. With three chambers, each must cover at least 50% of the water. This allows for safe disinfection, even when one chamber is out of use due to technical errors or maintenance. If a chamber has less than 100% capacity, the flow must be physically limited to the maximum capacity, and this must be documented through flow-metering; having two 50% chambers in parallel operation is not safe unless the water is divided evenly.

Figure 8.5: This UV-unit has two radiation chambers, each chamber has a control panel (white) and an UV-sensor (on the front). The black valve closes if the radiation falls below the alarm level. (Photo: Eyvind Andersen)

Design for peak daily consumption
Maximum supply is normally much higher than the average water consumption, as the consumption varies. If pumps and piping systems can supply more water than the disinfection capacity of the UV-unit, flow restricting devices should be fitted.

Prevent turbid water
The turbidity of water that is to be treated with UV must be less than 1 FNU. If higher turbidity values may occur, a particle filter must be installed. Turbidity problems may occur due to bunkering, change of tanks or corrosion. Most offshore units will need a particle filter in the potable water system (maximum pore size 50 micrometers).

Design for coloured bunkered water
All offshore units may have to bunker water. Acceptable water from Norwegian water works may have colour up to 20 mg Pt/l. The UV-transmission (remaining UV-radiation after having passed through the water) of this water may be below 30 %/5 cm, see figure 8.6. When installing an UV-unit, it is important to make sure that is has sufficient capacity even when the UV-transmission is 30%/5 cm. In the list of approved biodosimetrically tested UV-units, column 2 contains information of which capacity each unit has at the lowest UV-transmission it is tested for. Unfortunately, only a few of the UV-units on this list have been tested at the low transmission values that may occur when bunkering Norwegian water.

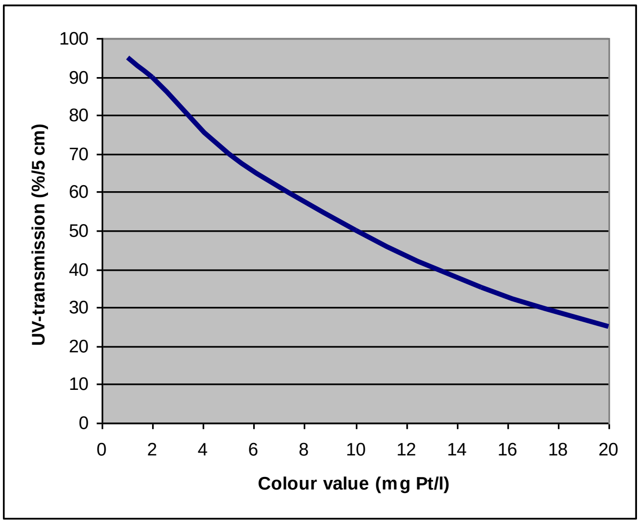


Figure 8.6: The figure shows how average values for UV-transmission decrease as the colour number increases. The figure is based on water quality data from a large number of Norwegian water sources (Illustration: Karin Melsom)

Figure 8.7: UV-unit with test taps before and after disinfection (Photo: Eyvind Andersen)

Figure 8.6 shows average values for Norwegian water. The real UV-transmission of bunkered water of acceptable colour may be lower. To compensate for this, it is possible to use all chambers in parallel or change to new UV-lamps when measurements of bunkered water show values near the colour limit.

Prevent over heating

By dimensioning the UV-unit for the poorest quality of bunkered water, one will need much bigger UV-units than what would be required only for produced water. This may also result in an unwanted increase in water temperature, but can be avoided through several measures, for example by having a 3*50% capacity UV-unit, where only one is used for produced water, if this gives sufficient effect and the alarm is correctly set.

To avoid overheating and shutting of UV-units, the suppliers recommended minimum water flow must be met at all times. One recommended solution to achieve this is to design the potable water system with continuous pumping of water, with a return line to the tanks connected after the UV-units. If consumption is low, a pressure valve opens, and the water is automatically returned to the same tank it was supplied from, see figure 5.1.

Necessary equipment for control and operation

Each UV-chamber must have a sensor for intensity monitoring and an alarm in case of low intensity or radiation tube or power supply failure. Each radiation tube shall have an alarm light showing that it is functioning. A timer shows how long time the radiation tubes have been in operation. The alarm should go to a manned control room.

Each UV-unit shall have a solenoid valve closing the water distribution in case of electrical malfunction, failure in one of the radiation tubes or, if the sensor indicates radiation intensity being too low. To ensure that enough disinfected is available at all times, the UV-unit should be connected to stable emergency power supply.

Air inside the UV-chambers will reduce the effect. Gas traps must be avoided through having high-point vent possibility for each chamber, and the chamber outlet should be placed on a high point if possible. Test taps fitted just before and after the UV-unit may be used to verify that the disinfection is functioning (figure 8.7).

8.3.3 Operation and maintenance

UV-units should be supervised daily. If the alarm is connected to a manned control room, physical supervision can be reduced. Every control should be logged and information recorded, describing corrective actions taken.

*Never expose eyes and skin to such UV-light without protection. S*ymptoms usually occur a few hours, and such injuries have happened on offshore units. Blurred sight and the feeling of sand in the eyes are minor reactions, but temporary or permanent blindness, may be the consequence.

Written instructions in Norwegian should describe maintenance routines such as sensor calibration, cleaning instructions and changing of UV- tubes. Maintenance procedures given by the supplier should be followed. Minimum maintenance frequency for vital functions should be as follows:

Intensity meter

If the unit is not equipped with an automatic alarm system, the UV-intensity meter must be read daily. The intensity meter and alarm set-point should only be adjusted by the supplier or (in agreement with the supplier) by specially trained calibration personnel. Calibration is normally done once a year. For the biodosimetrically tested UV-units calibration is easy, as the type approval demands that such units use standardised UV-sensors that may be replaced by reference sensors.

If low UV-intensity is detected the cause must be found and corrected without delay or the UV-tubes changed. If it is due to sedimentation on the tubes or sensor eye, the *entire* inside should be cleaned. Other elements in the system should be checked as well. If the intensity of the radiation tubes is too low, the tubes should be replaced. Low intensity can also be caused by inferior water quality. This may happen after bunkering or in connection with switching of storage tanks.

Signal lamps, radiation tubes and hour counter
Hour counter and signal lamps for UV-radiation tubes should be checked weekly. The UV-tubes should be replaced before the radiation effect is reduced by 20-40 %, when maximum operation time has been reached, and according to the supplier's recommendations. Normal operation time for low pressure tubes is 8,000 hours and 3,000 hours for medium pressure tubes. If the UV-unit has several radiation tubes in each chamber, they should all be replaced at the same time, to maintain control of the chamber intensity (figure 8.8). The exemption to this rule is a radiation tube that malfunctions shortly after being replaced. But at the next time of replacement all radiation tubes should be replaced, including the newest one.

NB: The type approval of UV-units is only valid when using radiaton tubes of at least the same effect as the ones that were a part of the type approval application. If type of radiation tube is changed, the effect must be sufficiently documented.

Cleaning
The radiation chamber (such as quartz pipes, sensor eyes, reflectors) must be cleaned regularly, depending on water quality – minimum once every three months. If the system is equipped with automatic mechanisms for cleaning (brushes, rubber rings or equivalent) the effectiveness must be checked and the equipment cleaned at least every six months. If the water contains iron or manganese, this may scorch the quartz glass. The scorching is normally removed by acid washing, but in some cases it is necessary to scrub by hand.

Spare parts
The unit shall have the necessary spare parts for continuous operation, ref. approval document, including radiation tubes (a complete set), quartz tubes, packing material, radiation tube relays, fuses, ignition charge and light bulbs for the indicator lamp. Spare parts for the UV-intensiometer and the alarm system should also be available.

8.4 Active carbon filters

Carbon filters solve certain water quality problems by efficiently removing pollutants in the water. Such substances often cause unpleasant smell and taste, and may be hazardous to the health, see 4.2.1. Filters must be changed or regenerated before they become saturated. As saturation time will depend on type of pollution, extra water tests are necessary to ensure safe operation. Nevertheless, the need for carbon filters point towards substandard operation or unfortunate technical solutions, and therefore ought to be unnecessary. Carbon filters are efficient in treatment of unpleasant taste and other problems caused by for example:

- Chlorine
- Chlorine by-products for instance trihalomethanes
- Waste product from algae
- Soluble products from protective coatings in the potable water storage tanks

Continuous maintenance of the filters is vital for the effect, but also because bacteria might develop in the filter due to good growth conditions. Today, most filters are delivered with filter material in a cartridge. Since the filter binds chlorine, it must be removed during the yearly pipeline disinfection and be replaced according to recommendations made by the supplier. With the probability for bacterial growth, the filter should always be placed prior to the UV-unit. Some carbon filters also function as particle filters, and such filters may replace ordinary particle filters prior to UV-units.

Figure 8.8: Control panel for UV-unit with eight UV-tubes. As both tube 6 and the signal lap for tube 1 is defect, the UV-unit is not safe to use. The UV-intensity is still quite high. This may be due to clear water or long distance between UV-sensor and the defect UV-tube (Photo: Eyvind Andersen)

9. Storage tanks and distribution system

Bunkered or produced potable water will be stored in water tanks and from there passed on to the consumers through a distribution system. Calorifiers, hydrophore tanks and day tanks are also common types of potable water tanks offshore.

9.1 Potable water tanks

Offshore units are required to have a sufficient amount of potable water aboard, and the tanks must be operated separately to avoid simultaneous pollution of all tanks. The necessary number of storage tanks and total storage capacity depends on production capacity and demand. Storage tanks with an unsuitable design may require increased maintenance and maintenance costs, and may also result in inferior water quality.

9.1.1 Storage capacity

The owner shall be able to document that sufficient hygienically safe potable water can be supplied under any circumstances. The minimum requirement is 200 litres per day per person. The amount of potable water to be stored in the tanks depends on how vulnerable the water system is.

A potable water system exclusively depending on bunkered water is vulnerable because bad weather conditions may make bunkering impossible. The quality of bunkered water is often unpredictable and consequently requires a larger storage capacity. Units that, in addition to bunkering, produce water are less vulnerable, and two or more production units will strengthen the safety. Minimum storage capacity is reduced for such units, and may be even further reduced if several storage tanks are used.

Offshore units without potable water production onboard should have a least three storage tanks. A unit with only two storage tanks can not bunker water according to the requirements if one tank is out of operation. It is required that the storage tank being bunkered to should be isolated until free residual chlorine is documented 30 minutes after bunkering is finished. Consequently, with only two tanks aboard, there is no tank from which water can be distributed, when one tank is out of operation.

Problems with insufficient storage capacity usually arise when one tank is being cleaned, and this risk increases if a new coating has to be applied. This means that one storage tank will be out of operation for several days and, at the same time requiring large amounts of water for the maintenance process. Occasionally storage tanks are out of operation for several weeks following maintenance work because the hardening process has resulted in problems with smell and taste. Sudden contamination of a potable water tank may also leave the tank out of operation. In table 9.1 a minimum storage capacity is recommended for the various unit types.

Under normal circumstances the potable water unit should be operated so that water is not stored in the tanks more than 20 days. This will prevent problems with smell or taste caused by the tank coating or decomposing of organic material.

Table 9.1: Guide to minimum total storage capacity specified in number of consumption days. Each tank is presumed to have equal storage capacity.

Recommended total storage capacity for:	Number of storage tanks	
	2	3 or more
Unit based on bunkering only	Not recommended!	20 days capacity
Unit with **one** production unit with 100 % capacity plus bunkering	20 days capacity	15 days capacity
Unit with **two** production units with 50 % capacity each plus bunkering	15 days capacity	10 days capacity
Unit with **three** production units with 50% capacity or **two** units with 100 % capacity each plus bunkering	8 days capacity	5 days capacity

Figure 9.1: Approximately 4 meters high potable water tank in stainless steel with no obstructing internal structures. Such tanks are easy to clean, and problems with applying and maintenance of coating is avoided (Photo: Bjørn Løfsgaard)

9.1.2 Design and location

The Facilities regulations §§ 5, 10 and 20 give general requirements for system design, and the following advice is based on these requirements.

Choice of materials

If the tanks are made of stainless steel or other corrosion proof material see figure 9.1, problems related to use of coatings will be avoided, see 9.1.4.

Internal tank design

The inside of a potable water tank should be as smooth as possible, without nooks and corners that may harbour microbes. Frames and other constructions breaking up the interior should be avoided since this may form ”pockets” of stagnant water not being reached by the disinfectants, creating opportunities for growth of microbes. Large inner surface, compared to volume, have created problems with smell and taste after protective coatings have been applied, see 9.1.4. Tank height should be at least 2 meters to allow for maintenance work to be carried out in an upright position. Tank height should also be less than 4 meters, to avoid having to build permanent access platforms etc. to make maintenance easy, see figure 9.2. Scaffolding for maintenance should be avoided, as this takes much time, increase the risk of pollution and often will lead to damage on tank coating.

Prevent tank contamination

Potable water tanks shall not have joint walls with tanks containing petroleum products, liquid chemicals etc. Pipes transporting other products than potable water are not accepted in a potable water tank, but if this is necessary, these pipes shall be carried through open ducts.

To avoid contamination of all potable water onboard, the storage tanks must be separated from each other to prevent possible contamination of one tank from spreading to the other tanks. 3-way valves, interlocks or other technical solutions should secure that water is not produced, bunkered or circulated into all tanks simultaneously.

Potable water inlet and outlet

The inlets for both bunkered water and return water from the distribution network should be located away from the outlet, to enhance water circulation in the tank. The high pressure of bunkered water should also be utilized by pointing the inlet in angle that increase the circulation of the full tank volume (figure 5.1). This will prevent pockets of stagnant water and improve the mixing of chlorine in the tank. The potable water outlet shall be placed above the bottom level of the tank to prevent sediments from entering in to the water distribution system. Sediments may carry bacteria through the UV-unit and may also cause operation problems with the UV-unit, pipeline system and filters.

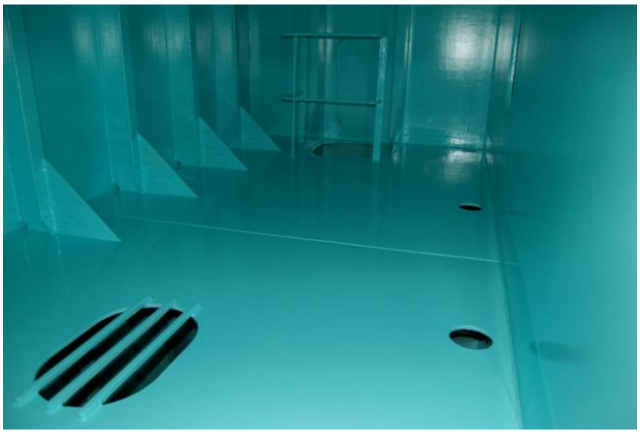


Figure 9.2: A 12 meters high tank has been split into 4 meter compartments to make maintenance easy. Vertical stiffeners are easy to high pressure clean standing on the tank floor. Between compartments the openings are secured (though more openings would have been advisable to avoid stagnant pockets). Circulation is achieved by placing the inlet in the upper compartment and the outlet in the bottom one (Photo: Eyvind Andersen).

Figure 9.3: Air vents for potable water tanks must be sufficiently protected. The picture shows vent safeguarded with floating ball and fine mesh corrosion material. The picture is taken on a newbuild prior to marking (Photo: Eyvind Andersen)

Air vents

Potable water tanks shall be vented to the open air or a non-polluted area. Normally it is sufficient to have one air vent connected to each storage tank but, if the tank has separate, closed sections, each section has to have an air vent. The opening must be protected against sea water, birds and other substances that might contaminate the water (figure 9.3). The opening shall be covered by a fine meshed net of a non-corrosive material.

Drainage

The storage tanks should be equipped with sufficient drainage facilities. Cross braces shall have openings near the tank bottom to enable total drainage. The tank bottom should be sloped or supplied with a pump well leading the water towards the drainage point (figure 5.3). The drain valve should be placed at the lowest point. If the tank bottom construction does not allow "natural" drainage, a permanent pump should be installed. Unfortunately storage tanks are often built with a flat bottom and without a pump well. Draining of storage tanks is therefore frequently done by using the potable water pumps, which is unfortunate if a tank is drained because the water is contaminated.

Access possibilities

A storage tank has to be equipped with a manhole to facilitate inspection, cleaning and maintenance. It is sormally sensible to have two manholses to better access and ventilation possibilities. To avoid contamination of the tanks the manholes should have close-fitting covers.

Figure 9.4: The picture shows a storage tank with easily reached test tap and an accessible manhole (Photo: Eyvind Andersen)

The manhole must have a size and location that provides easy access to the tank for both workers and equipment (figure 9.4). Some storage tanks have tank roofs as part of the deck. Manholes on deck should have a rim minimum 5 cm high, and be located in a "clean" area.

Water temperature

Potable water storage tanks should be placed where they are frost safe and not will be heated from the surroundings, neither sun nor any other source. Water temperature should be kept below 20^{o} C, even during the summer season (may not be possible in warmer climates, see 9.2.11).

Water for flushing

Potable water tanks are often cleaned by use of high pressure water, and this water should be of potable water quality.

Test tap

A test tap should be fitted to facilitate testing of chlorinated water in the tank without having to lead the water into the distribution net. A drain should be installed to handle flush water.

Figure 9.5: Also smaller tanks in the potable water system, like hydrophore tanks, calorifiers and alkalising filters must have sufficient access for inside maintenance. The pictured tank is made of stainless steel and has sufficient manholes (Photo: Eyvind Andersen)

Water gauge

The water gauge system should be automatic. Water quantity in the storage tanks will then be constantly monitored from the control room, activating an alarm if the water level becomes too low. Visual control is still used on some older offshore units, but use of dip stick is not hygienically acceptable (such tank openings should be welded closed).

Design of other water tanks

Small water tanks like calorifiers, hydrophore tanks, small pressure vessels and small day tanks etc. must also have sufficient access for inside cleaning and maintenance (figure 9.5). It must also be possible to take such tanks out of use without having to cut off the water supply on the offshore unit.

9.1.3 Operation and maintenance

During operation, organic material, rust particles etc., will settle on the tank bottom, becoming an ideal growth environment for microbes. A film of organic material will form on the tank walls, in which microbes will settle. The storage tanks have to be cleaned and disinfected at least once a year. Experience with potable water tanks receiving bunkered water only, indicates that cleaning at least twice a year is necessary, while once a year often is sufficient if the potable water is produced onboard. If water storage tanks are not cleaned often enough, it will be difficult to remove the growth. Following any type of maintenance work, tanks must be disinfected. Calorifiers, hydrophore tanks and day tanks all require the same cleaning and disinfection procedures. The procedures are described in appendix 13.

During maintenance it is not unusual that a tank is out of service for several days, even more if a new surface coating is needed. Cleaning and disinfection must be well planned. The full storage capacity of the other tanks must be utilized. Water budget, hardening time, manpower, water production etc. should be considered in planning the work. Maintenance, such as renewing the coating, is best done during the summer months, when the weather is good and hardening time shortened.

During tank inspection the cleaning intervals should be considered. If the bottom sediments are negligible and the colony count steady and low, cleaning intervals are satisfactory. The storage tanks must not have any substantial corrosion damage. The water gauge, air-vent net and float should be inspected. All results shall be logged.

9.1.4 Application of protective coatings

Protective coatings have to be applied correctly to avoid problems. Negligence will often result in the coating having to be removed prior to recoating the tank. The following recommendations should be observed:

Choice of product

Only products certified for potable water tanks are to be used, see 2.3.4. Some certified products can not be applied offshore, as it will be impossible to achieve the necessary curing conditions due to low temperatures, cold steel and short deadlines.

Choose a product for potable water tanks recommended by the supplier. The supplier may have several certified products, and it is important to choose one that is easily applied with good results, both at yard stays and during offshore operations, see Management Regulations § 4.

Documentation of correct appliance
Satisfactory working conditions for the painters must be documented. Both when choosing the product and after application it must be documented that the supplier's recommendations for pre treatment, application, curing and washing have been adhered to.

After coating new tanks, and after full renewal of old tank coating, the work should be approved by a certified paint inspector (FROSIO- or NACE-certified). Before the tank is taken into use, it must be verified that the coating does not pollute the water. After water has been stored for a normal storage period, hydrocarbons should be analysed (limit 10 microgrammes/litre). This analysis must be specified for the different components (including BTEX), to ensure that only paint contamination and not other components are being measured.

Pre treatment
Pre treatment of the surface is necessary to ensure sufficient coating adhesion and to avoid corrosion. Blasting with sand or metal is an effective method for surface treatment that will normally facilitate good adhesion. Rough edges and welding seams must be grinded. All traces of rust, salt (including welding smoke), fat, oil and dirt must be washed away or removed (figure 9.6).

Application
Spray painting is effective and give good results. A round paint brush is applied where spraying is impossible. The use of roller should be avoided, as a roller will give too thick layers and only poorly wets the surface (gives pores). The supplier will state pre treatment requirements, coating thickness and number of layers for the coating system. Thinners may only be used if specifically approved for the product. Spray painting results in thin coating film on edges, corners, welding seams, stiffeners and cavities, and such places should be stripe coated with a brush. A different (also approved) colour is recommended when stripe coating, to keep track of the work progress.

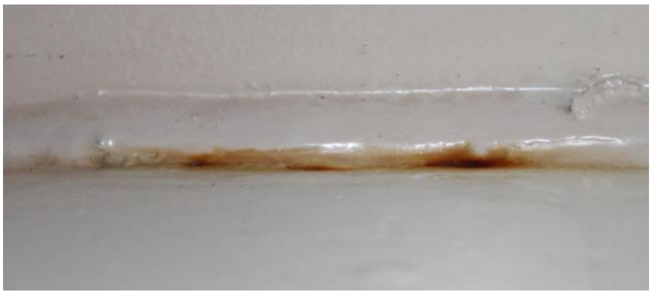


Figure 9.6: Insufficient pre treatment after welding has resulted in corrosion (Photo: Bjørn Løfsgaard)

Curing
Curing problems may occur after illegal use of thinners or when neglecting the supplier's recommendations for curing time, aeration, air humidity and temperature. Tank location may also cause problems. The inner surface of a tank which is exposed to the weather and/or poorly insulated, may be cold even if the temperature inside the tank is high enough for curing, and volatile substances may continue to leak from the coating. When the coating is sufficiently cured, the surface must be washed to remove any traces of pollution.

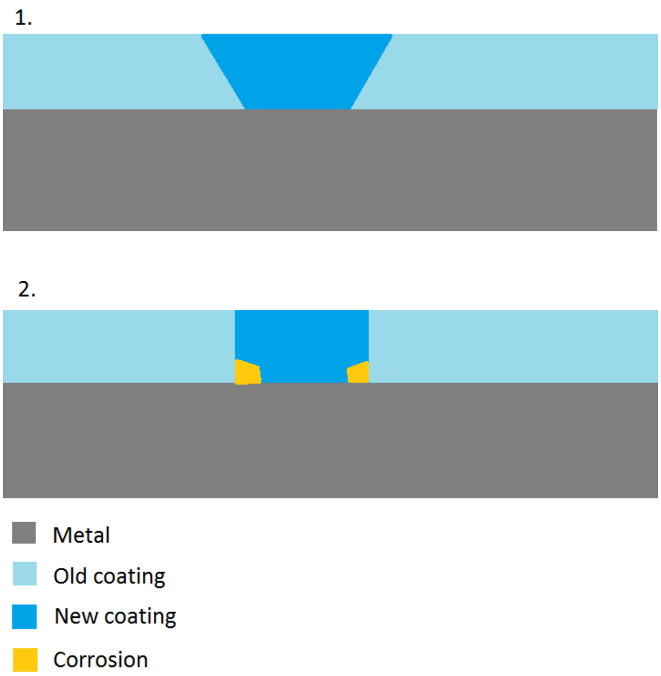


Figure 9.7: Cross section 1 shows correct patch coating, where the edge between old and new coating has been grinded. Cross section 2 illustrates starting corrosion where "sharp edges" makes it impossible to coat the wall sufficiently, even if a brush is used for appliance (Ill. Eyvind Andersen)

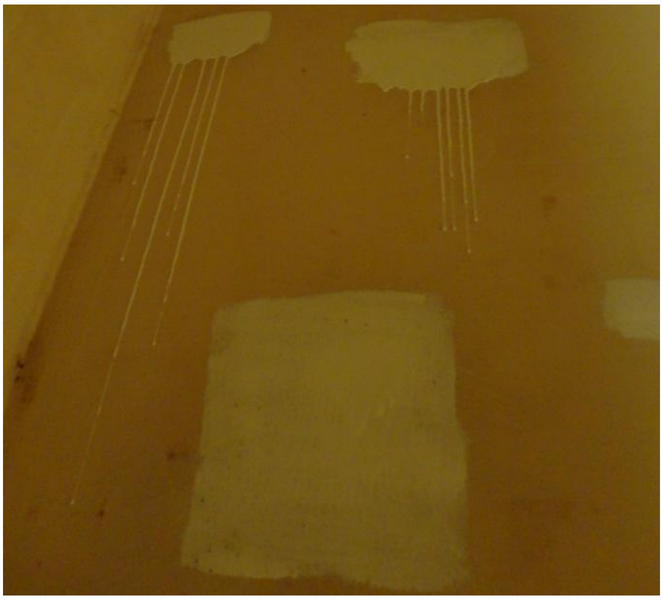


Figure 9.8: Wrongful coation appliance. A roller has been used instead of a round brush, and the coating has been used on too large areas and in a far too thick layer (Photo: Bjørn Løfsgaard)

Patch coating and renewal of tank coating
During the annual tank maintenance, all corroded places should be patch coated. Start by removing all traces of rust, and grind the edges of the remaining coating, before the whole area is cleaned (figure 9.7). The use of a steel brush grinder with a fibre disc will remove rust and give good adhesion.

Patch coating must only cover the affected area (the coating shall not be applied to the surrounding area). A round paint brush should be used to make the coating stick. *Do not use a roller to apply the coating,* as this method of application is not suitable for patch coating (figure 9.8). The coating must be cured and washed according to the supplier's instructions. Where several spots of corrosion are located near eachother, the whole area should be grinded, washed and painted.

If the corrosion is extensive (more than 3% of the tank is corroded, and the corrosion is not confined to a few places in the tank), the whole tank coating should be renewed. Even when the coating is applied correctly, a renewal of the coating should be expected every 15 years. If the coating, after 15 years, is inspected and found to be in good condition, a limited life extension is acceptable.

Figure 9.9: Picture from a tank where wrongful coating application has resulted in corrosion and need for touch ups. Coating applied to thickly on cold steel and by wrong application methods, increase the risk for growth of micro-organisms, as well as problems with unpleasant smell and taste from tank coating (Photo: Eyvind Andersen)

Problems with smell and taste after coating application
Unpleasant smell and taste, following protective coating inside a storage tank, is unfortunately a common problem on offshore installations (figure 9.9). Some substances that give the water smell and taste may, in high concentrations, be hazardous to the health. Water with smell and taste should not be used for human consumption, see 4.2.1 and 4.3. These problems are often caused by wrongful coating application, curing and washing or illegal use of thinners. Poor tank design, see 9.1.2, will increase the risk of such problems occurring. The use of active carbon filter has proved effective in removing these substances, see 8.4.

9.2 Water distribution system

The water distribution system supplies water to living quarters, galley etc., and may consist of pressurizing systems, hot water system, valves, pipes and other equipment. Inferior potable water quality may be a consequence of wrong system design, poor material quality, cross contamination or insufficient operation procedures.

9.2.1 General design advice

To maintain good hygienic water quality throughout the distribution system, the following items should be considered:

Choose good quality materials
When planning or rebuilding a unit, the quality of materials should be carefully assessed, see 9.2.6.

Keep the cold water cold and the warm water warm
To avoid growth of microbes like *Legionella* and *Pseudomonas*, cold water should always be below 20° C and hot water above 60° C. If it is not possible to keep the cold water below 20° C, additional water treatment and flushing will be required, see 9.2.11. As cold water tastes better, it is recommended that the temperature is kept even lower. To achieve sufficient temperatures, both hot and cold water pipes must be insulated, see 9.2.8.

Avoid installing warm water pipes under cold water pipes. Due the radiation from the heat of the warm water pipes, the cold water temperature will increase. Where possible, avoid installing cold water pipes in the same trunk as hot water pipes and other heating sources.

Avoid stagnation
Keep the water flowing through the mains by having frequently used connections as the last consumers on each branch. All end taps must be frequently used or documented flushed. The need for flushing can be eliminated through system design that maintains water circulation until mixers, toilets etc., leaving only a miniscule amount of stagnant water. A flow distributor that harnesses the venturi effect is one technical solution for maintaining circulation in all pipes (figure 9.10).

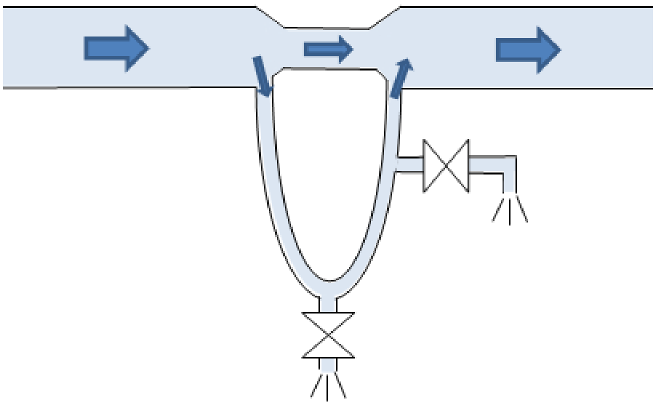


Figure 9.10: Due to the narrower passage, some of the water in the main pipe will circulate via all connections to the smaller pipe, before returning to the main pipe. This provides constant flow also to connections with infrequent use (Ill. Karin Melsom).

Figure 9.11: This shower is not in use, and is used for storage. Water in such pipes will be at room temperature, and there is a growth potential for Legionella *and other microbes. This water may then contaminate the rest of the piping. Piping that is not in use should be eliminated, alternatively flushed weekly (Photo: Eyvind Andersen)*

Blind pipes and pipes with stagnant water should be avoided since that water will maintain room temperature (figure 9.11). Bacteria growing in blind pipes will not be reached by disinfectants during the yearly disinfection, resulting in microbes re-spreading throughout the distribution system. Pipe ends that are longer than 10 times the pipe diameter are considered "blind", and should be removed. Long pipes supplying small units like coffee makers and water coolers etc., should be avoided due to possible corrosion contamination.

Avoid cross contamination
The best solution is to totally separate the potable water system from all other systems like technical water, drill water, fire water etc. All remaining connections, including hoses etc., that may contaminate the water during episodes of back flow/back suction, must be protected according to NS-EN 1717, see 9.2.5.

Use as small piping as possible
If the pipe size is too big, water will mostly flow in the middle of the pipe (laminar flow), and this will increase the potential for biofilm formation

on the pipe walls. Pipes of smaller size will have higher water speed and turbulent water flow, greatly reducing the potential for biofilm.

Prevent biofilm problems
Biofilm formation can be minimised through the following measures:

- Maintaining sufficient water flow until all taps.
- Continuous dosing of chemicals
- Frequent disinfection of distribution system (yearly as a minimum even in systems with low colony counts and good quality piping).

Tagging, marking and colour coding
Tagging and marking equipment and valves, and marking and colour coding of piping, will help to prevent mistakes and contamination. Having a properly marked water distribution system also makes it easier to follow the pipe lines in critical situations, when it is important to be able to quickly locate a malfunction.

Provide sufficient access for maintenance
All water treatment units must have access for maintenance. Sufficient size manholes must be provided for tanks like calorifiers, hydrophore tanks and rehardening filters. All valves that are being frequently used or which will need to be verified on a regular basis must be easily accessible.

9.2.2 Pressurising systems

The pressure is normally kept through continuous pumping or through the use of hydrophore tanks. As there will always be pressure changes in the system, a small membrane pressure vessel may be useful.

Pressurizing with pumps
Often a system will have two pumps, one being in operation and the other stand-by. Pumps should be switched weekly, and preferently be operated from a control room. A recirculation pipe line going back to the distribution tank should always be installed. This pipe line feeds a small return stream in order to prevent the pump from overheating during periods of low consumption. This line should be connected after the UV-unit, as this will provide sufficient minimum flow through the UV-units and extra water disinfection. The pumps should not have too large capacity since excess heat can increase the potable water temperature, see 4.2.5. Pump energy consumption can be minimised through automatically reducing the water output when the consumption is low, and this will also reduce heating effect from pumps.

Pressurizing with hydrophore units or day tanks
A hydrophore unit consists of a pressure pump and an air pressured hydrophore tank. The pump is controlled by the water pressure. For new offshore units pumping is considered a better solution than hydrofore systems, as hydrophore tanks are often difficult to clean and are known to have caused problems with microbial growth. The pressurized air can also contain oil traces, and must be filtered if there is any risk of such substances. A membrane tank can alternatively be a solution.

Some systems have small elevated day tanks to make distribution by gravity possible. The same design and operation requirements apply as for other types of storage tanks. With only one day tank, it has to be designed with a by-pass possibility to allow for regular cleaning and maintenance without stopping water distribution. Hydrophore tanks and day tanks save energy as pumps run only when tanks are being filled. These tanks are constantly being filled with water containing new nutrients, and as they have a rather small volume compared to bigger tanks, they may need more frequent cleaning compared to larger tanks.

9.2.3 Cold water

We recommend that the system is designed to maximise the flow through all pipes by having (see also 9.2.1):

- As small piping dimensions as possible (e.g. the shower, sink and toilet in a cabin will not be used at the same time). The necessary pipe size for each branch must be calculated.
- Frequently used taps as end points for each branch (galley, washery, sky lobby toilet etc.). Alternatively an automatic flushing valve may be installed.
- Minimising branch lengths from supply line (with flow) to tap points (stagnant when not in use)

For offshore units operating in cold climates (sea water below 20^{o} C), it will normally be possible to achieve cold water temperatures below 20^o C (after one minute flushing) without installing a circulation system with chilling. Tap points that contain stagnant water should be flushed on a weekly basis (manually or automatically). For pipes where the cold water temperature is above 25^o C, daily flushing is recommended by Dutch authorities. Outdoor piping should be insulated against frost and heat and should not be exposed to direct sunlight.

Specific advice for vessels operating in warm climates is given in chapter 9.2.11.

9.2.4 Hot water

The hot water must also be of potable water quality, and must be connected downstream of the disinfection unit. The connection has to be secured against back-flow of hot water to the cold water system, see 9.2.5. It is important that the hot water pipes are insulated and placed in a way that prevents warming of the cold water during transport through the pipe system. Choosing correct piping size throughout the system (see 9.2.3) is economically sensible and will give the best water quality.

Water is normally heated by electricity, but some units use surplus heat from cooling water or steam in a heat exchanger. Chemicals being added to such water or steam have to be certified/approved, see 2.3.4.

Metals will always corrode quicker in a hot water system, and consequently hot water should not be used for making food or hot beverages. The hot water distribution system must also be protected against pollution, see 9.2.5.

Certain patogenic bacteria may grow in hot water systems maintained at low a temperature. The *Legionella* bacteria in particular can cause problems if the water is not kept hot enough. If the hot water in the distribution system is at least 60^o C (following one minute of flushing), the risk for infection is minimized, see 9.2.7. With sufficient insulation, this should be possible to achieve with an outgoing temperature below 65^o C, resulting in less energy consumption, scalding risk and precipitation of minerals due to hardness.

Table 9.2: Relevant technical barriers to protect potable water systems against pollution (EN1717)

Protection module*	**Protection against**
AA – Complete air gap	Harmful microbes and all other types of contamination
BA – Verifiable backflow protection device	Toxic, radioactive, muta-genic or carcinogenic substances
EA – Verifiable non-return valve	Water that does not pose any health risks, but may have different taste, smell, colour or temperature. On certain conditions also acceptable for hose stations and washing machines etc.

* The table contains modules that are particularly relevant fore offshore use. EN1717 also contains other protection modules that may be applied. Ordinary non return valves may only be used in private homes.

9.2.5 Protection against pollution

The potable water must be safeguarded against pollution. Alternative methods are described in Standard ”EN 1717”. The distribution network must be evaluated with regard to risk and vulnera-bility for different sources of contamination, and protective technical measures must be applied, see table 9.2. Movement caused by the sea increases the risk for back flow on offshore units.

Figure 9.12: Full air gap of type «AA» is the best way of eliminating contamination from other systems supplied with potable water (Photo: Eyvind Andersen)

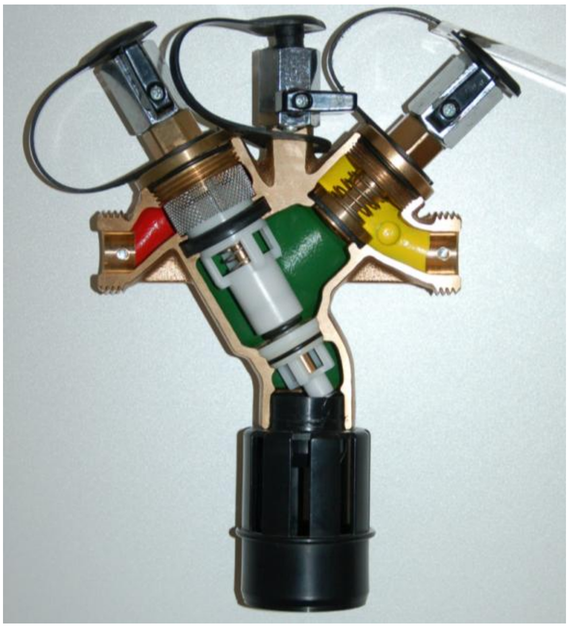


Figure 9.13: Other liquid carrying systems should not be connected to the potable water. If this can not be avoided a type BA backflow prevention device give the best level of protection. Note the 3 test points on top of valve. This valve needs to be fitted with a strainer and stop valves before and after for testing (Photo: Eyvind Andersen)

The best way to protect the potable water system is to keep it separated from potential sources of contamination. This is achieved by using a separate system for process water, or by separating connections through a complete air-gap, a so called “broken connection” (figure 9.12) . The air-gap must be at least 20 millimetres and at least 2 times the pipe diameter (measured between the bottom of the water tap and the highest possible water level in the connected equipment). Such a connection is according to level “AA” in the standard, and is acceptable for all types of contamination, including microbes.

Some times it is difficult to achieve “broken connections” between the potable water system and all technical systems supplied with potable water. In such cases other technical solutions may be evaluated to prevent back-flow. When such barriers are applied, the equipment must be opened and cleaned before the effect is verified, recommended intervals are yearly (EA) or two yearly (BA). Which barrier is chosen depend on the risk each connection poses, and the greater the probability and/or consequences are, the greater the safety requirements are.

Figure 9.14: Verifiable non return valve with integrated stop valve. The test port is between the white non return valve and the screw down stop valve (Photo: Eyvind Andersen)

The second best level of technical safety is achieved by fitting a verifiable backflow prevention device (level “BA” in the standard, also known as reduced pressure zone valve). A backflow preventer consists of two non-return valves separated by drain module (figure 9.13). This device will suck air during back suction conditions and the drain will open if back pressure from technical connections occurs. Stop valves must be fitted before and after the BA-valve, to facilitate testing, and a strainer before this valve is also necessary.

Verifiable non-return valves (level “EA” in the standard) represent the lowest level of safety that should be applied offshore (figure 9.14).

Level “EA” gives sufficient protection against water that does not contain harmful substances, but where the water quality may have changed with regard to taste, smell, colour or temperature. A stop valve must be fitted before the EA-valve, to facilitate testing. After a thorough evaluation such valves may also be fitted on hose connections (depending on where the hose may be used) and pipes supplying washing machines etc. (such connections must also be protected by locating the connection above the fluid level). Showers are recommended safeguarded in the same way if the hose can reach the toilet. In galleys and other places where a hose is connected to a mixing battery, both the hot and cold water supply must have an EA-valve, as the cold and hot water will be directly connected when the mixing battery is in open position and the hose is closed (figure 9.15).

Figure 9.15: A hose station where water is leaking between the hot and the cold water when the mixer is left in open position and the hose is not in use. A sign to close the mixer is ***not*** *a barrier against such leaks (Photo: Eyvind Andersen)*

9.2.6 Materials

Both for newbuilds and repairs it is important that the pipeline material chosen withstands the particular type of water quality (figure 9.16). This may seem obvious, but on some offshore units choosing the wrong type of pipe material have caused instant corrosion problems and large extra costs to replace big parts of the potable water system.

Materials that come into contact with potable water shall not corrode or give off substances to the water in such quantities as to make it hazardous to health or unsuitable as drinking water. It is the owner who is responsible to ensure that the materials have sufficient quality, but materials with Norwegian or European potable water approval like DVGW, KIWA, WRAS, etc. will normally have sufficient quality.

Figure 9.16: Pipes and valves in potable water systems vary in size and material. It is important that corrosion resistant materials and materials that do not encourage bacterial growth are chosen (Photo: Eyvind Andersen)

Figure 9.17: Legionella *can be prevented by keeping the cold water cold and the warm water warm (Photo: Eyvind Andersen)*

The most common pipe materials used in water distribution systems offshore are copper in the living quarters and stainless steel in the rest of the unit, but different types of plastic piping are also becoming more common. Metal pipes may be susceptible to corrosion, but are generally easy to work with and resistant to pressure damage. Titan and acid resistant stainless steel are eminent corrosion resistant pipe materials, and are therefore used in pipes that are particularly exposed to corrosion such as sea water pipes and pipes between water production unit and alkalizing filter. Plastic does not corrode, and but questions of leakage of unwanted substances, mechanical strength, need for expansion loops and bacterial growth in the distribution system should be assessed.

9.2.7 Legionella prevention

Legionella growth normally occurs in potable water systems with temperatures between 20 and 50° C, where routines for operation and disinfection are lacking, see 9.2.9. Breathing in aerosols (micro sized water drops) emitted from for example air-condition units or showers can, under certain unfortunate circumstances, result in two types of sickness. Legionnaire's disease is a very serious type of pneumonia with high mortality whilst Pontiac fever is normally quite like influenza.

Figure 9.18: Shower hoses and heads are problem spots for Legionella *growth due to low temperatures after mixers combined with stagnant water when not in use. Here growth is prevented through drying of the equipment (Photo: Arild Tolo)*

The following measures will reduce the risk of *Legionella* growth in the potable water system:

- The cold water temperature should be below 20^o C, the hot water system should be kept above 60^o C, measured at the coldest point in the pipe system after one minute of flushing (figure 9.17). Water temperatures in the distribution network are documented through a monthly test programme.
- Blind pipes are removed from the potable water system, see 9.2.1.
- Tap points that are rarely used should be equipped with back flow protection type "BA", see 9.2.5. Alternatively they must be flushed at full speed for stagnant water on a weekly basis. When flushing safety showers and other devices that will lead to much aerosol formation, it is recommended to prevent the spreading or inhaling of aerosols.
- The potable water distribution system is cleaned and disinfected regularly, see 9.2.9.
- Shower hoses and heads are difficult to keep clean and will always contain tepid water. Every 3 months these fixtures should be disassembled, cleaned if necessary with soap or mild acid and disinfected by heat, drying or use of disinfectant, see appendix 12. After a period without use of the showers, such disinfection is even more important (figure 9.18).

In addition to these measures, growth of *Legionella* in the system has also been prevented by silver and copper ionisation, with a maximum dose of 0.1 mg silver and 1.0 mg copper. Offshore this method may contribute to reducing the risks connected with stagnant water and elevated temperatures. For the method to be effective, the minimum concentration for silver in the distribution system has to be above 20 microgrammes per litre. One advantage of using silver and copper (compared to yearly chlorine disinfection), is that this will work better in older, corroded systems, but the method is not accepted as an alternative to normal maintenance and cleaning of piping. By 2012 EU is still evaluating if this process will still be allowed. Other additives may also be used, provided that they are accepted for such use by the Norwegian Food Safety Authority.

For more information on *Legionella*, including the latest about *Legionella* prevention, please see the NIPH guideline on *Legionella* prevention (only in Norwegian language). Legionella advice from Dutch authorities (in English) can be found on the following web page: www.ivw.nl (content may differ somewhat from Norwegian advice).

9.2.8 Insulation

Cold water should be insulated with foam, and should be applied (glued) with no gaps. Besides keeping the water cooler it prevents condensation. We also recommend that hot water piping is isolated with mineral wool of 0,035 W/mK. For both hot and cold water isolation thickness of 100% of outer pipe diameter is recommended.

9.2.9 Operation and maintenance

The main problem with biofilm (bacteria and other microbes) in the potable water distribution system is that it can suddenly give the water an unpleasant smell and taste, see 4.2.1. Some of the bacteria may also be pathogenic, and underneath a biofilm pitting may begin, see 4.2.3.

Frequent and good quality maintenance is a prerequisite to prevent water quality changes in the distribution network. Chemicals may be needed for this work. One possible procedure for this work is detailed in appendix 12. It is more difficult to succeed with disinfection if a biofilm is already present, and the disinfection process might have to be repeated to remove bacteria.

The Potable water regulation requires internal control routines. In addition, section 12 in the Regulations concerning potable water system and potable water supply on mobile offshore units states that "tanks, pipes and pipe systems for potable water shall at all times be kept clean on the inside all the way to the tapping points. Cleaning and disinfection of the entire potable water system shall be carried out before the unit leaves the yard, after repairs, and then at least once a year". It is important to notice that the Regulations say at least once a year, and that it has to be cleaned and disinfected more often if necessary. Cleaning of the distribution system may be done in connection with disinfection of one or more storage tanks, see 9.1.3).

Increased colony counts indicate a need for cleaning and disinfection regardless of planned maintenance intervals. Colony counts above 100 (at 22^{o} C/72 hours) in two consecutive tests indicate the presence of biofilm in the distribution system (a single test may not be representative, and should be followed up by a second test quickly). Flushing the system should be the first remedy to be tried. If the colony count does not decrease or soon increases again ("dead" biofilm after disinfection may be the perfect breeding ground for the new or surviving bacteria), the entire distribution system should be flushed once more and disinfected. To ensure that the entire distribution system is sufficiently chlorinated is a major undertaking and is often delegated to external consultants. If high colony counts are re-occurring frequently, the source must be identified, see 9.2.1. Shower heads and shower hoses often contain a great deal of biofilm, and should be dismantled, cleaned and disinfected regularly, see 9.2.7.

High water temperature may lead to quicker decomposition of chlorine when disinfecting the hot water system with chlorine. Alternatively the hot water system can be disinfected by increasing the temperature in the distribution system to 70^{o} C for at least 5 minutes. It is also possible to use hot water to disinfect the cold water system. This is acceptable on condition that the piping is designed with this in mind, and that the risk of scalding is minimised. If silver and copper ionisation is used to prevent *Legionella*, see 9.2.7, this method may also prevent the formation of biofilm.

If the potable water distribution system is connected to other systems, back-flow protection devices must be tested, see 9.2.5. Pumps and other equipment should also be maintained in accordance with recommendations made by the producer, and in addition, disinfected along with the rest of the potable water system.

9.2.10 Pressure testing

For pressure tests follow the next steps:

1. Fill pipes with clean potable water.
2. Flush the system with potable water to get rid of contamination from construction. The outlets (taps) need to be fully opened and unobstructed (strainer etc. removed).
3. Do the pressure test.
4. If normal operation of the system is not to be started yet, drain the system by gravity and use compressed, oil free air to dry the pipes. Alternatively compressed oil free air may be used instead of water for the pressure testing, whilst postponing the flushing .

9.2.11 Special considerations for units operating in warm waters

Offshore units operating in warm climates (sea water above 20^{o} C), will not achieve cold water temperatures below 20^{o} C (after one minute flushing) without installing a circulation system with chilling. The chiller must as a minimum keep the cold potable water average temperature below 25 degrees. On peak moments (when a lot of people take a shower etc.) the temperature is allowed to increase, but after this period, the chiller has to reduce the temperature. The UV unit has to be in this circulation loop.

Tap points that are not in use must be flushed on a weekly basis (manually or automatically). If the coldwater temperature is above 25^{o} C, flushing should be done daily. When it's not possible to keep the average temperature below 25^{o} C, it is recommended to use chemicals, see 9.2.7.

10. Water supply on diving vessels – special requirements

Diving vessels are vessels equipped with units for deep diving operations. These vessels are often in operation close to other units where divers perform construction and maintenance work. The work periods will last up to 3 weeks and include compression, actual operation time and decompression. During this time the divers live in compression chambers onboard the diving vessel when they are not working from diving bells in deep water. The compression chambers are closed systems where contamination may accumulate and where traditional medical treatment cannot be easily executed, making it particularly important to ensure safe operations (figure 10.1). The NORSOK U100 guide describes the special requirements for potable water distribution systems on diving vessels.

This chapter covers challenges that are special for diving vessels. The general requirements for potable water described in chapters 1-9 will in some instances not be pertinent because diving vessels have different requirements than other offshore units. For instance will the requirements for training of personnel have to include the special considerations that are necessary on diving vessels.

Divers also need hot water to keep the diving suits warm in the cold sea water. For this purpose heated sea water is used, but this is not discussed in this guide.

Living quarters and work environment for divers was studied in a medical research program carried out by Statoil, Norsk Hydro, Saga Petroleum, Norske Esso and the Norwegian Petroleum Directorate. Divers often have skin infections, and *Pseudomonas aeruginosa* is almost always the cause. The bacteria are common in both salt water and fresh water. The main reservoir for such bacteria in the diving system is the potable water, where infection may spread through showers and other use of the water. A few genotypes of *P. aeruginosa* are predominant in the infections, and those genotypes repeatedly appear in disease outbreaks. Regardless of which type of *P. aeruginosa* being present, curative actions should be taken. SINTEF Health keeps a database of North Sea genotypes.

10.1 Water analyses

The Potable Water Regulations apply to ships as well. The recommended analyses in chapter 4, made by the NIPH, apply to diving vessels as well. Additional operation analyses for *P. aeruginosa* should be taken of the diving system on the vessel, before operation starts and then at least monthly during operation periods. In both the ordinary potable water system and the diving system 500 ml tests of the cold water (cw) plus the hot water (hw) should be taken at the following test points:

- Mess: cw (only when the diving system and the rest of the vessel share the water distribution system)
- Diver's kitchen: cw and hw
- Room for rinsing diving suits: cw and hw
- Showers in the diving system chambers: cw and hw from each chamber
- Cold water/ and hot water tanks supplying the diving system

Even though monthly analyses normally will be sufficient, according to the experience of the diving companies, the frequency will have to be increased when for instance *P. aeruginosa* is found. For units that repeatedly experience infections among divers, increased analysis frequency should always be considered.

10.2 Water production

It is recommended that the water supply in the diving unit is based primarily on production aboard and not by bunkering water delivered from ashore. This is preferable because:

- *P. aeruginosa* cannot pass through either an evaporator or a reverse osmosis unit, as long as these are operated correctly. Bunkered water may contain *P. aeruginosa*.
- *P. aeruginosa* grows faster when pH is around 8. Produced water that is not alkalized holds a pH below 6. Feeding the diving system with this type of water will also limit growth of *P. aeruginosa*. Bunkered water and alkalized water normally hold a pH between 7 and 9.

10.3 Design

The following criteria should be considered in the design and construction of a diving system:

Separate closable sea water inlets, see 6.1.2.

Suitable pipe material

Non- alkalized water produced aboard is very corrosive, and a suitable quality material must therefore be used. Titan is the best material and highly recommended. Hard plastic material is sometimes suggested because of its resistance to corrosion, but should often be avoided because *P. aeruginosa* is a bacteria that easily forms biofilm on several types of plastic materials and may "feed" on PVC.

Dedicated tanks

Recommendations for non-alkalized water being produced onboard require separate potable water storage tanks for the diving system. The water is lead directly from the production unit to these tanks, and consequently, does not pass through the ordinary potable water tanks. This solution has the advantage that water from the regular potable water tanks, potentially contaminated by *P. aeruginosa* from bunkered water, is not fed into the diving water system.

Diving vessels often operate close to other units, making it difficult to produce water. To avoid using bunkered water in the diving systems, it is preferable to have storage tanks with enough capacity to ensure an adequate water supply.

Disinfection units

The diving system should have a system for chlorination of the storage tanks, and possibility to increase the chlorine concentration by circulation. Two parallel UV-units with particle filter in front should be installed, as close as possible to the pressure chamber.

10.4 Maintenance

When the diving system is not in use, the water storage tanks and the pipe system should be drained. Before the storage tanks are filled up again, they should be cleaned and disinfected, see appendix 13. If the diving system is in use often, it may be sufficient to disinfect the storage tanks twice a year. Before the pipelines from the tanks are ready for use, they should be disinfected with chlorine dioxide. This method is effective and inexpensive, and does not influence the rest of the potable water system on the unit.

If the water analyses show growth of *P. aeruginosa*, the infected parts of the system must be cleaned and disinfected. If the growth is located within the diving system, the same procedures as described above should be used. If the growth includes the entire potable water system, procedures described in appendices 12 and 13 apply.

Suggested procedures for water production onboard the units to dedicated storage tanks, and routines for disinfection of the storage tanks and pipelines, are given to prevent growth of *P. aeruginosa*, but are safeguarding against *Legionella pneumophila* as well.

Figure 10.1: Pressure chamber designed for diving operations (Photo: Eyvind Andersen)

Appendix 1 – Check list for design of potable water systems on offshore units

Name of unit:	
Type of unit:	
Delivery date:	
Bed capacity:	
Maximum number of people aboard:	
Official contact person(s):	
Owner(s)/operator(s):	

1. Preface

This check list is meant as a tool for the planning and construction of potable water systems on offshore units, and should be included in the documentation submitted to the authorities when potable water systems are being built. The check list should also be used in the planning of major changes of existing potable water systems.

The check list is general, and there will always be items not covered by this list, but nonetheless should be considered during the planning and construction. The owner/operator is responsible for building and operating the potable water system and delivering sufficient and satisfactory potable water according to the Regulations.

2. Rules and guidelines

The persons responsible for planning and construction of the potable water system should be familiar with the contents in the following Regulations and guidelines:

- ☐ Regulations of 31 August 2001, relating to health, environment and safety in the petroleum activities (consisting of the HSE Framework Regulations with subordinate regulations)
- ☐ Regulations of 4 September 1987, no. 860 concerning potable water system and potable water supply on mobile offshore units
- ☐ Regulations of 4 December 2001, concerning potable water
- ☐ The NIPH guideline ”Sufficient, safe and good potable water offshore”

3. Important decisions during early conceptual phase

When building a potable water system, many important decisions are taken in the early planning stages. Our experience is that the best offshore water systems consist of the following units:

- ☐ Two sea water inlets located at a safe distance from the unit’s discharge points, ref. item 5
- ☐ A sea water system where the first tapping point after the inlet is the outlet to the production unit for potable water. Subsequent connections to the sea water system must be equipped with back-flow/back-suction valves to prevent contamination, ref. item 5
- ☐ At least two water production units (evaporators or reverse osmosis units), ref. item 8
- ☐ Alkalizing filter, ref. item 7
- ☐ Two bunkering stations placed on opposite sides of the offshore unit, ref. item 8
- ☐ Permanently installed chlorination unit (s), connected to the filling and recirculation pipes for the potable water tanks, ref. item 9
- ☐ A sufficient number of potable water storage tanks with enough capacity, designed to facilitate maintenance and placed to avoid warming of the stored water, ref. item 10
- ☐ At least two UV-units, ref. item 11

In addition to choosing type of units to be installed, the following must be clarified during the early design stage:

- ☐ Maximum amount of potable water required (at least 200 litres/person/day) m^3/day:____________

- ☐ Maximum need for water supplied from the potable water system for purposes other than domestic (i.e. technical connections to the potable water system):________________
- ☐ A potable water system completely separated from the technical water supply system
- ☐ Experienced personnel have used 3D-verification of drawings to ensure that all components in the potable water system requiring regular maintenance or service, are easily accessible and ergonomically designed, including:
  - ☐ Bunkering station
  - ☐ Chlorination unit
  - ☐ Potable water tanks
  - ☐ UV-units
  - ☐ Water maker
  - ☐ Alkalizing filter
  - ☐ CO_2-unit
  - ☐ Other water treatment units
  - ☐ Manually operated valves

4. The potable water system in general

- ☐ The potable water system has been evaluated and measures taken to safeguard against human errors
- ☐ An analysis of the risk/vulnerability has been conducted for the potable water system
- ☐ All chemicals added to the potable water, or chemicals that may contaminate the system through leakage, maintenance work, back-suction etc., are certified, see 2.3.4
- ☐ All drawings are easy to understand and include the entire potable water system, as well as other systems connected to the potable water system
- ☐ An internal control system is established, certifying that the potable water system is built according to drawings and specifications

5. Sea water inlet and sea water system

- ☐ There are two separate sea water inlets that may be operated separately
- ☐ The sea water inlets are placed separated from each other both horizontally and vertically to ensure that one inlet can operate should the other be polluted
- ☐ The spreading pattern of discharges from the unit has been calculated in relation to positioning the sea water inlets to secure a minimum of risks of pollution via the sea water inlets
- ☐ If electro chlorination is used to prevent marine growth from blocking the sea water inlet, this system will at all times be operated without any risk of unacceptable levels of chlorine and bromine compounds after an evaporator

6. Water production system

- ☐ The water production system has at least 2 production units, <u>each</u> producing at least 100 % of the water needed, or 3 units, <u>each</u> producing at least 50 % of the water needed
- ☐ Each production unit has a conductivity meter activating an alarm in the control room when the salt content of the produced water is too high, and the produced water is automatically dumped
- ☐ As extra safety, there is an extra stage of conductivity measuring and dumping before the water is conducted to the potable water tanks
- ☐ For evaporators: The heating medium does not contain any harmful components that may pollute the potable water system if a leakage occurs.
- ☐ All additives are approved

7. Alkalizing filter

- ☐ Alkalizing filter is placed ahead of the potable water tanks, preferably connected to the recirculation pipe
- ☐ It is possible to add CO_2-gas to the water ahead of the filter
- ☐ There is sufficient water pressure to enable back flushing of the filter with potable water

☐ The filter is easy to fill, empty and clean internally

8. Bunkering station

☐ There are at least two bunkering stations, placed on either side of the unit
☐ The bunkering hoses are protected with a cap/plug
☐ The bunkering hoses can be flushed without any flush water entering the potable water tanks
☐ The flush water pipes and valves have the same (or larger) dimension and capacity as the feeding pipes to the storage tanks
☐ The flush pipe is constructed to prevent flush water from causing inconvenience to the bunkering station attendants, the supply vessel crew and other personnel
☐ Each bunkering station has a test tap placed up-stream the shut-off valve
☐ The bunkering pipes have a low point drain to facilitate complete draining of the pipes after bunkering
☐ The bunkering station is clearly marked ”Drikkevann / Potable water” in blue colour

9. Chlorine dosing unit(s)

☐ A chlorine dosing unit is permanently installed and connected to the filling pipes for the storage tanks
☐ A chlorine dosing unit is permanently installed and connected to the recirculation pipes for the storage tanks
☐ The chlorine dosing unit(s) have sufficient capacity to disinfect all water at maximum supply speed. If a common chlorination unit is used for bunkering and re-circulation, it must be suitable for both
☐ The chlorine dosing is regulated by a flow meter
☐ The water from the bunkering station can not be fed to the storage tanks without passing the chlorine dosing unit
☐ The chlorine dosing unit is placed as close as possible to the dosing point, minimizing the length of the hose between the chlorine dosing unit and the bunkering/recirculation pipe
☐ The chlorine dosing unit is clearly marked and is safeguarded against pollution
☐ The chlorine dosing unit, including the flow meter regulation, has been verified to function

10. Storage tanks for potable water

☐ The potable water tanks are designed to make cleaning and maintenance easy: without inside frames, horizontal stiffeners etc, and with 2 to 4 meters height, scaffolding for maintenance should be avoided
☐ The unit has a sufficient number of storage tanks with adequate storage capacity, ref. table below. The table shows minimum total storage capacity for the different types of potable water systems. The values given state total number of days all the tanks combined can supply water when the unit is fully manned. The tanks must be approximately the same size:

Recommended total storage capacity for:	Number of storage tanks	
	2	3 or more
Unit based on bunkering only	Not recommended!	20 days capacity
Unit with **one** production unit with 100 % capacity, plus bunkering	20 days capacity	15 days capacity
Unit with **two** production units with 50 % capacity each, plus bunkering	15 days capacity	10 days capacity
Unit with **three** units with 50 % capacity or **two** units with 100 % capacity each, plus bunkering	8 days capacity	5 days capacity

☐ The tank inlet and outlet are placed far away form each other to facilitate circulation of all water in the tank during bunkering and normal operation, this to enhance mixing of chlorine and to prevent pockets of stagnant water. Bunkered and re-circulated is pumped into the tank in an angle that enhances circulation of the full water volume in the tank, and return inlet, if any, from the distribution network is located as far apart from the tank outlet as possible

☐ Automatic valves or other physical measures ensure that water can not be produced, bunkered or re-circulated into a tank that at the same time is supplying the distribution network, and that return inlet from distribution network, if any, is routed into the same tank this water was supplied from
☐ The tanks are placed well protected against heat from the surroundings. Water temperatures above 20° C should be avoided
☐ The storage tanks are equipped with test taps to enable water tests to be taken directly from the tanks without feeding the water through to the distribution system
☐ The tanks have a circulation system feeding the water from one tank via a chlorine dosing unit and back to the same tank, without going through the distribution system. The pump and piping that is used for this recirculation have sufficient capacity to circulate the tank quickly (often 4-6 hours). The distribution system can simultaneously be supplied from another storage tank
☐ The tanks are accessible for necessary maintenance during operation. If manholes are located on deck, they must be in a "clean" area and be equipped with a rim at least 5 cm above deck level
☐ Other small water tanks, like calorifiers, hydrophore tanks and day tanks etc., are designed with sufficient access for inside cleaning and maintenance, and equipped with by-pass possibility if this is needed for un-interrupted water supply.
☐ The tanks are equipped with sufficient ventilation in a clean and exhaust free area
☐ The ventilation system is protected against pollution and the openings are covered with a fine net of corrosion proof material
☐ The potable water tanks have drain valves which provide complete and easy drainage (no remaining "pockets" with water) without having to use the potable water pumps
☐ Potable water is supplied for high pressure cleaning of tanks
☐ The potable water tanks are equipped with an automatic level meter connected to a manned control room
☐ The potable water tanks have no joint walls with other tanks carrying petroleum products, liquid chemicals etc
☐ The tank roof should not be part of a deck in a "dirty area"
☐ Pipes carrying other products than potable water are not carried through the potable water tanks. If this has not been possible, these pipes are carried through in open ducts
☐ Internal coating products used for potable water tanks are approved.
☐ The coating has been applied in accordance with routines described in section 9.1.4.
☐ It is documented that the coating has been applied according to vendor's specifications with regard to method of application, thickness, washing and hardening of such coating. After filling the tank, smell, taste and hydrocarbon content of the water has been verified
☐ When deciding upon protective coating, you have chosen the alternative that is easiest to apply correctly and which is most suitable for potable water use

11. UV-units

☐ UV-units are evaluated by the NIPH, and will be used according to specifications
☐ The UV-units are biodosimetrically tested and give an UV-dose of 40 mWs/cm^2 (for newbuilds and when upgrading old units, approved UV-units that only give a dose of 30 mWs/cm^2 are no longer recommended)
☐ The UV-units have been dimensioned to handle the poorest water quality that meets the potable water regulations (with a colour number of 20, Norwegian water typically has an UV-transmission somewhat below 30 %/5 cm, and offshore units must be able to handle bunkered water)
☐ At least two UV-units have been installed. With just two units, each must be capable of disinfecting all potable water at maximum supply rate (peak values). With three units installed, each of these must be able to disinfect 50 % of the water
☐ When two or more UV-units are used in parallel, it must be ensured that the water is evenly distributed between the units
☐ The UV-treatment is the final stage in the potable water treatment system prior to distribution

☐ Each UV-unit has a sensor, measuring radiation intensity. If the intensity falls below accepted levels, or if the power fails, the water supply is automatically shut down
☐ Each UV-unit has a timer and an alarm lamp for each of the UV-lamps
☐ There is a cartridge filter connected up-stream of each UV-unit (maximum pore size 50 micrometers)
☐ Test sampling of the water is made possible just before and after the UV-unit

12. Water distribution system

☐ It is documented that pipes, fittings and other equipment have sufficient quality, both with regard to corrosion and health, see 9.2.6
☐ Potable water pipes outside living quarter areas are marked ”Drikkevann” and/or ”Potable water” in blue colour
☐ Potable water pipes are not carried through tanks carrying other products than potable water. If this is not possible, those pipes are carried through in open ducts.
☐ External pipes are protected against frost and heat
☐ Pipes with stagnant water have been avoided
☐ In case of contamination it is possible to drain the entire potable water system
☐ Connections to other liquid carrying systems are sufficiently safeguarded and broken/atmospheric connections chosen where this has been feasible. All other connections are safeguarded by verifiable technical barriers according to EN 1717, see 9.2.5
☐ Normal hoses connected to the potable water system are equipped with at least one verifiable non-return valve. This also applies to showers where the hose may fall in the toilet.
☐ If galleys etc. are equipped with hoses connected to mixing batterys (that may be in open position when the hose switch is closed), both cold and hot water supply to mixing battery must be equipped with at least one verifiable non-return valve.
☐ The water consumption in the different branches of the distribution system has been analysed, and the piping diameter is reduced to a minimum
☐ A sufficient amount of test taps gives the possibility to trace potable water quality changes throughout the system
☐ Hot water tanks deliver enough hot water to maintain a temperature of at least 60° C at the coldest point in the system (measured after flushing for one minute), and hot enough to ensure that also the water in the bottom of the hot water tank will frequently reach 60° C

Appendix 2 – Check list for operational documentation of a potable water system (Potable water manual)

The requirements are described in chapter 3. The operational documentation can be organized in various manners. Traditionally, offshore units have had voluminous potable water manuals, but it has become more common to integrate the main part of the documentation in the general operational system for the unit. By this integration, the manual simply becomes a key document, describing how the actual operational documentation is organized.

This check list is based on the normal content of traditional potable water manuals, but may also be used to check if it is easy to find similar documentation when these documents are integrated in the general operational system:

General information:

1. Does the manual contain a table of contents (where/page no.)? ____________________________
2. Is revision date for the manual stated (where/page no)? ____________________________
3. Does the manual have a general description of the entire potable water system (where/page no.)? ____________________________
4. Does the manual have a schematic drawing of the entire potable water system (where/page no.)? ____________________________
5. Does the manual have a reference list to all documents referred to (journals, drawings, procedures, maintenance system, manuals, regulations etc. (where/page no)? ____________________________

Potable water management

6. Has a Risk and vulnerability analysis for the potable water supply been made (where/page no.)? ____
7. Does the manual state persons responsible for the various parts of the potable water operational system (platform manager, medical and technical personnel, onshore organization etc.) (where/page no.)? ____________________________
8. Does the manual describe the potable water education programmes needed for the medical and technical personnel before being assigned their specific tasks within the potable water system, see 3.2 (where/page no.)? ____________________________
9. Does the manual describe how this level of knowledge is maintained, see 3.2 (where/page no.)? _____
10. Does the manual describe the documentation medical and technical personnel have to be familiar with before taking responsibilities for their specific tasks, see 3.2 (where/page no.)? __________________
11. Are maintenance requirements of the system described, see 3.3 (where/page no.)? ________________
12. Is it stated that all chemicals that directly or indirectly (through leakages, cleaning etc.) come into contact with potable water must be evaluated or certified, see 2.3.4 (where/page no.)? _____________
13. Are routines for handling non-conformities according to chapter 3.5(where/page no.)? _____________
14. Are routines for applying for excemptions according to chapter 3.8 (where/page no.)? _____________
15. Are potable water problems included in the emergency preparedness plans for the unit, see 3.6 (where/page no.)? ____________________________
16. Does the company have routines for internal audits to verify that technical systems and management systems are functioning and are revised when necessary, see 3.7 (where/page no.)? _____________
17. Are there routines safeguarding that the authorities are always informed of any significant system changes, that may be made in the future (where/page no.)? ____________________________

Sea water system:

18. Is there a general drawing of the sea water system (where/page no.)? ____________________________
19. Is there a general drawing showing vertical and horizontal distance between the sea water inlets and the various discharge points (where/page no.)? ____________________________
20. Is it explicitly emphasized that water production has to stop if the sea water is contaminated (where/page no.)? ____________________________

21. Are equipment and chemicals to be used in sea water production described (where/page no.)? ______
22. Can it be guaranteed that methods of anti-fouling that are being used for the sea water system will not pollute the potable water (where/page no.)? ______

Water production units:

23. Is operating routines for the water production units described and illustrated on drawings (where/page no.)? ______
24. Is the use of chemicals in the water production described, (including cleaning chemicals): type of chemicals, product names, producers, maximum doses and dosing adjustments etc. (where/page no.)? ______
25. Is the measuring of conductivity of produced water described, and procedures described in case the conductivity is too high and sets off the alarm (where/page no.)? ______
26. Is the alarm limit for the conductivity meter listed (maximum 6mS/m for evaporation and 75 mS/m for reverse osmosis) (where/page no.)? ______
27. Are routines for calibration of conductivity meters described (where/page no.)? ______

Bunkering potable water:

28. Are the bunkering procedures according to recommendations in appendix 10 (where/page no.)? ______
29. Is the logging procedure for bunkering according to recommendations stated in appendix 5 (where/page no.)? ______

Alkalizing unit:

30. Are the procedures for alkalizing documented and drawings of the system enclosed (where/page no.)? ______
31. Is the filter material described (where/page no.)?______
32. Is the procedure for back-flushing of the filter described (where/page no.)? ______
33. Is the procedure for change of filter material described (where/page no.)? ______
34. Are the procedures for pH-control described (where/page no.)? ______

Chlorination unit:

35. Is type of chlorine, concentration and dosing described (where/page no)? ______
36. If sodium hypochlorite is used: Are routines established to ensure that the chlorine will be exchanged before expiring date (where/page no.)? ______
37. Is it made clear that the free chlorine level shall be between 0.1 and 0.5 mg/l Cl_2 half an hour after chlorination (where/page no.)? ______

UV-unit:

38. Is the maximum disinfection capacity of the UV-units at the poorest water quality (UV-transmission somewhat below 30 %/5 cm) stated (where/page no.)? ______
39. Is the maximum lifetime for the UV-radiation tubess stated (where/page no.)? ______
40. Are routines for calibration of the UV-sensors described (where/page no.)? ______
41. Is the clearly described how the UV-unit, including quarts glass, UV-sensors etc, is to be cleaned if radiation intensity falls (where/page no.)? ______
42. Is it stated at what intensity level the automatic shut-off valve is activated (where/page no.)? ______
43. Are routines for function testing of the UV-alarm described (where/page no.)? ______

Potable water tanks:

44. Are operation routines for storage tanks described (where/page no.)? ______
45. Are procedures for cleaning and disinfection of the storage tanks in accordance with recommendations made by the NIPH, see appendix 13 (where/page no)? ______

46. Will the specific protective coating, that may be used on patches or re-coating of the tanks, harden sufficiently under the existing temperatures (both air- and tank material temperatures) (where/page no.)? ___
47. Will coating be applied in accordance with routines described in section 9.1.4 (where/page no.)? ___
48. Have procedures been established for documenting that requirements for method of application, coating thickness, washing and hardening have been followed when coating have been applied in potable water tanks (where/page no.)? ___
49. Are routines for cleaning and disinfection of calorifiers, hydrophore tanks and other potable water tanks described (where/page no)? ___

Potable water distribution system:

50. Are the procedures for cleaning and disinfection of the distribution system in accordance with recommendations made by the NIPH, see appendix 12 (where/page no.)? ___
51. Are operation and maintenance routines for pressure tanks described (where/page no.)? ___
52. Are routines for function testing of technical barriers against pollution of the potable water distribution system described, see 9.2.5 (where/page no.)? ___
53. Is it emphasized that all hose couplings should be disconnected after use (where/page no.)? ___
54. Is it emphasized that connections to the potable water system must not take place if back-suction/-back-flow can lead to contamination of the potable water (where/page no.)? ___
55. Is it stated that the thermostat of the water heater must be set to ensure that the water on the coldest place in the distribution network holds at least 60^{o}C after one minute of flushing (where/page no.)? ___
56. Is there etablished a routine for temperature measurement ensuring that the cold water temperature evrywhere in the distribution network is kept below 20^{o}C and the hot water above 60^{o}C (where/page no.)? ___
57. Is a system for weekly switching of components in use (tanks, pumps, UV-units, pipes etc.) established, to avoid stagnant conditions (where/page no.)? ___

Measuring, logging and reporting of water quality:

58. Is the daily logging procedure in accordance with the recommendations given by the NIPH, see appendix 3 (where/page no)? ___
59. Are the monthly and yearly potable water analyses in accordance with recommendations given by the NIPH, see appendix 4 (where/page no)? ___
60. Is the water sample programme varied, with several samples each month and differention through the year, giving a good picture of the water quality throughout the system (where/page no)? ___
61. Are procedures for physical/chemical and bacteriological water tests in accordance with recommendations given by the NIPH, see appendices 7 and 8 (where/page no)? ___
62. Is the use of measuring devices described (where/page no)? ___
63. Is a daily, separate log kept for the technical equipment of the water production system (where/page no.)? ___
64. Are routines established for tracking malfunctions in the potable water system (where/page no.)? ___
65. Are routines established for a yearly report on the potable water quality, see 3.8 (where/page no.) ___

*Appendix 3 – Example of a daily potable water logbook**

Month: ______________________ Year:_________

Date	Smell	Taste	Clearness	pH	Free chlorine mg/l**	Total chlorine mg/l**	Conduc-tivity mS/m	Remarks	Signa-ture
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
11									
12									
13									
14									
15									
16									
17									
18									
19									
20									
21									
22									
23									
24									
25									
26									
27									
28									
29									
30									
31									

* In addition water temperatures must be logged, see 4.2.5
** Need only be analysed if the water is chlorinated, or if there is a risk of chlorine contamination due to electrochlorination of seawater prior to evaporation, see section 6.2

Appendix 4 – Recommended analysis programme and quality requirements

Parameter	Frequency*	Unit	Remarks	Limit values	Action type**
Smell	D/B/M	Subjective evaluation	Cf. with taste samples ”	Not obvious	C
Taste	D/B/M	Subjective evaluation	Cf. with smell samples ”	Not obvious	C
Clearness	D/B	Subjective evaluation		Clear	-
pH-value	D/B/M		The water shall not be corrosive	6.5-9.5	C
Conductivity	D/B/M	MilliSiemens/m (mS/m) at 25^{o} C (1 mS/m = 10 μS/cm)	Note: Alarm for the production unit is set at: - 6 mS/m for evaporator - 75 mS/m for reverse osmosis unit, see 4.3.1	*For bunkred water:* Same conductivity as supplying onshore water works. *For produced water:* Shall be stable. All increa-ses must be pos-sible to explain, see 4.3.1 and 4.3.2	C
Free chlorine	D B	Milligram/l	No analysis needed unless the water is chlorinated Measured 30 minutes after ended bunkering.	0.1-0.5, see 4.3.1 See above.	-
Total chlorine	D B	Milligram/l	No analysis needed unless the water is chlorinated Measured 30 minutes after ended bunkering.	1.0, see 4.3.1 See above.	-
Colour	B/M	Milligram Pt/l	Note: Has to be low in produced water	20	B
Turbidity	M	FNU		1	B
Clostridium perfringens	M	Number/100 ml		0	C
E. coli	M	Number/100ml	Findings to be reported immediately to supervisory control authorities	0	A
Intestinal enterococci	M	Number/100ml	Findings to be reported immediately to supervisory control authorities	0	A
Calcium	M	Milligram Ca/l	No analysis needed unless the water is alkalized	Recommended values: between 15 and 25	-
Colony count at 22^{o} C/ 72T	M	Number/ml	Shall be below 10 after the disinfection unit	100	C
Coliform bacteria	M	Number/100ml		0	B
Iron	M	Milligram Fe/l		0.2	C
Copper	M	Milligram Cu/l		0.3 in cold water, see 4.3.3	B

Table cont'd

Parameter	Frequency*	Unit	Remarks	Limit values	Action type**
Benzene	A	Microgram C_6H_6/l		1.0	B
Benzo(a)pyrene	A	Microgram/l		0.010	B
Lead	A	Microgram Pb /l		10	B
Bromate	A	Microgram BrO_3^-/l		5	B
Cadmium	A	Microgram Cd/l		5.0	B
Chemical oxygen use, COD-Mn ($KMnO_4$)	A	Milligram O/l	TOC may alternatively be measured	5.0	B
Hydrocarbons, mineral oils	A	Microgram/l	Also to be analysed after tank coating, see 9.1.4	10	C
Polycyclic aromatic hydro-carbones (PAH)	A	Microgram/l		0.10	B
Trihalomethanes	A	Microgram/l		50	B
UV-transmission	A	Percentage		See 4.3.4.	-
Boron	M	Milligram B/l	Analysis necessary only when reverse osmosis is used for water production	1.0	B
Glycols	A	Microgram/l	Analysis necessary only when glycols are added to systems that may pollute the potable water if leakages occur.	10	B

*** Frequency is divided into daily analyses (D), analyses when bunkering (B), monthly analyses (M) and annual analyses (A). Requirements for sample points are detailed in section 4.4.**

**** Description of Action types, see the drinking water regulations**

- **Action type A:** Immediate action to be taken to bring the parameter within the limit. Exemptions are not allowed. The Authorities must be notified immediately, see figure 4.5.

- **Action type B:** The necessary actions to be taken as soon as possible to bring the parameter within the limit. The Authorities must be notified. The County Govenor of Rogaland may grant exemptions from the limit values, provided that this poses no risk to health and provided that water supply from other sources is not possible. The exemption shal be given for as short time as possible, and shall not exceed 3 years. The central Norwegian Food Safety Authority shall be notified of the excemption and of the arguments that the excemption is based on, and only they can prolong the exemption for more than 3 years.

- **Action type C:** The necessary actions to be taken as soon as possible to bring the parameter within the limit. The Authorities must be notified, and may grant exemptions from the limit values for a period so that correcting actions can be taken, provided that this poses no risk to health.

Appendix 5 – Bunkering log

Bunkering date: __________________ Time when bunkering was finished: __________________

Supply vessel: ____

Does the supply vessel chlorinate the water (Y*/N)? ______________________________________

Delivering water works onshore: ____

Normal conductivity at the onshore water works (mS/m): ________________________________

Water amount to be bunkered: ________________ Amount of chlorine added: ____________________

Water sample results from each tank the supply vessel delivers water from:

Tank no.:	1	2	3	**Quality parameters:**
Colour:				20 mg/l Pt
Smell:**				Not obvious
Taste:**				Not obvious
Clearness:**				Clear***
Conductivity (mS/m):				Equal to delivering water works****
pH-value:				6.5 – 9.5
Is the water acceptable (Y/N)?				

Water sample results from each tank the water is being bunkered to. Samples shall be taken at least 30 minutes after completed bunkering:

Tank no.:	1	2	3	**Quality parameters:**
Chlorine measuring time				
Free chlorine (mg/l)				0.1 – 0.5 mg/l
Total chlorine quantity (mg/l)				Normally below 1.0 mg/l, see 4.3.1
Control test*****				Are smell, taste, appearance and conductivity still satisfactory?
Is the water acceptable (Y/N)?				

Signature by person responsible for the bunkering: ____

* In general supply vessels do not need to chlorinate the water, as disinfection is ensured through the use of both chlorine and UV-light on the offshore unit. Further chlorination increases the risk of exceeding the limit value for trihalomethanes, and should only be done if the supply vessel can document good chlorination systems and routines. But as this is in one extra step of chlorination, the offshore unit should increase the monitoring frequence for chlorination by-products.
** Preferably tested by two persons, as these values are subjective and may be difficult.
*** Strong light and white background is best to detect dark particles, black background for light ones.
**** Previously values higher than 10 mS/m (equals 100 µS/cm, see 4.6) were rare for Norwegian water works. Several Norwegian water works have introduced water treatment that is increasing the conductivity level to be between 10 and 15 mS/m. Such higher values can be accepted, if it is documented that the values are normal at the onshore water works where the supply vessel bunkers the water.
***** To check if the supply vessel deliberately or by mistake has delivered sub-standard water from a tank that was not sampled when bunkering, some simple tests should be done before distribution.

Appendix 6 – Recommended requirements to supply base and vessels

The water quality shall not deteriorate substantially during transport. Both the supply base and the supply vessel must be able to document satisfactory routines for control and handling of the potable water. Below is a list of potential requirements to be met when signing a contract for delivery of potable water. The list is meant as an example on procedures ensuring a safe and well documented potable water quality.

Requirements to supply bases:

1. Only use supply bases receiving potable water from approved water works with good quality water.
2. The supply base shall be able to document the normal water quality from the supplying water works. The water works is required to have updated information on the potable water quality available to the recipient of the water. An annual report on the water quality should be available, and it is especially important to list the intervals within which the conductivity will vary, see item 9. Such normal conductivity values should be reported to the supply vessel crew.
3. The supply base should have an agreement with the water works on the maximum pump speed applied when pumping to the supply vessel, and make sure that this pump speed is not exceeded. A pump speed that is too high can result in back-suction of contaminated water from the pipe system.
4. If the supply base is storing potable water on tanks from which water is bunkered (recommended solution), these tanks have to be cleaned and disinfected frequently, see procedures in appendix 13.
5. The bunkering station must have a suitable design.
6. Before bunkering is taking place, bunkering hoses and pipes must be flushed a few minutes with the same pump speed as when filling the supply vessel tanks.
7. The supply base must have a quality system ensuring safe operation and maintenance, including water sampling for analyses.

Supply vessel requirements:

8. Dump remaining water in tank before bunkering from shore.
9. After hoses and pipes on the supply base have been flushed, the supply vessel crew shall take samples to document the quality of the received water before bunkering starts. The tests should include colour, smell, taste, clearness and conductivity. The water shall be accepted only if the requirements stated in chapter 4.3.2 are fully met, and when conductivity is within the limits stated by the water works, see item 2. The results shall be logged, and may later be used as documentation in case the water is contaminated after the supply vessel received the water from the supply base.
10. Due to increased risk for formation of disinfection by-products, the supply vessel normally should not chlorinate (or ozonate) the water. Chlorination may only be done under strictly controlled conditions.
11. The storage tanks shall be cleaned and disinfected at least every 3 months, see appendix 13. Water tests will show if this frequency is sufficient.
12. The supply vessel crew should regularly test the water quality in the storage tanks, see appendix 4. Tests should be done just before and just after cleaning, see item 11, and under normal operation. This will also confirm that the cleaning frequency is adequate, see also annual procedure in item 15.
13. Protective coating in the storage tanks should be certified, see 2.3.4. To document that a new protective coating has been sufficiently hardened, water samples should be analysed for hydrocarbons (before and after coating application) and for presence of the most volatile coating components.
14. The supply vessel must have a quality system that ensures training, safe operation and maintenance.

Annual quality test of the entire supply chain:

15. The offshore unit should once a year test if and how the potable water quality varies throughout the supply chain. This is achieved by a test sampling from the supply base, the storage tanks on the supply vessel, the bunkering station and finally from the storage tanks after the water has been chlorinated. These samples should be analysed at an accredited laboratory, and should include parameters suggested in 4.3.3. A comparison of how the quality of the same water varies all through the supply chain will indicate improvement possibilities.

Appendix 7 – Instructions for bacteriological testing of potable water

Methods
Methods for analyses shall be according to the potable water regulations, and the laboratory must be accredited for these methods.

Sample bottles
The laboratory gives instructions on what type of sample bottles to use and how to handle the bottles.

Sampling from tap
1. Remove any strainers from the tap.
2. The spout of the tap is sterilized with a spirit flame (a match will do if necessary). If the use of an open flame is not allowed, the sample point can be disinfected in the following manner: make sure the tap spout is emptied of water. Fill a water glass with 70 % alcohol or a concentrated chlorine solution. Submerge the tap spout into the solution for 30 seconds.
3. Let the water flush for at least 3 minute before the sample is drawn.
4. Remove the cap carefully from the sample bottle without touching the rim of the bottle opening.
5. Fill the bottle with water.
6. Close the sample bottle carefully without touching the cap or the bottle opening.
7. After the test sampling, measure the water temperature at the sample point.

Packing and shipment
1. The bottles should be clearly marked with sender, sample point, date, time, and water temperature. The marking should be water proof.
2. The bottles are to be sent as soon as possible in a clean container (for instance a thermo box). The samples should preferably reach the laboratory within 4 hours after sampling. If the transportation time exceeds this, the samples have to be chilled to between 2 and 10^{o} C during transportation and put in a refrigerator (about 4^{o} C) upon arrival at the laboratory if the analysis cannot take place immediately. The time between sampling and analyzing shall not exceed 24 hours.
3. Test samples are to be sent as soon as possible to the relevant laboratory.
4. Test samples that are not packed and sent according to directions may not be analysed.
5. An analysis arrangement should be made with the laboratory before samples are sent.

Appendix 8 – Instructions for physio-chemical sampling, including annual analyses

Monthly physio-chemical sampling
The laboratory gives instructions on type of sample bottles to use and how to handle the bottles. The laboratory must be accredited for the different test methods.

Annual physio-chemical potable water analysis
Several annual analyses require use of special bottles. Special bottles should be requisitioned from the laboratory performing the analyses. The water being in the piping at the testpoint shall be tested. First the bottles for heavy metal analyses should be filled, thereafter special bottles for the different organic parameters, and finally a one litre bottle is filled, all from the same sample point.

If the values of for instance the heavy metals lead or cadmium are exceeded, one may take an extended sample from the very same sample point to establish how much is caused by leakage from materials in the piping. By comparing tests from the start and end points in the piping, changes in water quality will be documented.

Extended sample
Special bottles for heavy metal analyses are requisitioned from the laboratory doing the analyses. These bottles shall not be cleaned before use.

1. The sample point must not have been in use for the past 10 hours before the sampling takes place.
2. A sample is taken of the first cold water being tapped.
3. Following a one minute continuous flushing with the tap fully opened, a new sample is taken.
4. The water samples should be analysed for relevant parameter, if necessary also for lead, cadmium, chrome, mercury and nickel.

Appendix 9 – Troubleshooting guide

PROBLEM	POSSIBLE CAUSE	CORRECTIVE MEASURES
A. Bad smell/taste	1. Contaminated water from the supply vessel	Water with bad smell/taste shall not be accepted for bunkering
	2. Water containing sodium from the production unit	See problem G, item 3
	3. Newly painted storage tanks (including those on the supply vessel). Chemical substances in the coating may have reacted with chlorine	Check that the supplier's instructions regarding hardening temperature, time and humidity have been followed, see 9.1.4. Try reducing the chlorine dose without reducing the microbiological qualities. Active carbon filter may remove some smell- and taste components
	4. Organisms contaminating sea water inlet (e.g. algae)	Change sea water inlet or stop the fresh water production. Active carbon filter may remove some smell and taste components
	5. Oil polluting the sea water inlet	Same as item 4
	6. Microbial growth in storage tanks and/or distribution system	See problem J
	7. High iron content	See problem L
	8. High copper content	See problem L
	9. The water may have been exposed to UV-radiation too long	Reduce number of UV-units in operation, or establish continuous water flow
	10. Overdose of chlorine (sodium- or calcium hypochlorite)	Reduce chlorine dose, but make sure that the concentration is within the required levels of 0.1–0.5 mg Cl_2/1
B. High colour values (yellow/ brown water)	1. Water from the supply vessel contains humic particles	Water containing humic particles shall not be accepted for bunkering (Limit: 20 mg Pt/l)
	2. High iron content	See problem L
C. Turbidity (particles)	1. High iron content (iron corrosion clusters)	See problem L. In addition cleaning or renewal of pipes may be necessary
	2. Stormy weather conditions may have stirred up particles from the bottom of the storage tanks	More frequent cleaning of the potable water tanks
	3. After switching tanks, particles may have been sucked up from the tank bottom	More frequent cleaning of the storage tanks is necessary
	4. Particles in the water from the supply vessel	Water containing particles shall not be accepted
D. Low pH	1. Water delivered from the supply vessel with low pH value	Water with a pH lower than 6.5 shall not be accepted unless the water can be alkalized before distribution
	2. The by-pass valve on the alkalization filter is "too open"	Adjust the by-pass valve to increase amount of water flowing through the filter. This should be followed up with a new pH control sampled after the alkalization filter
	3. The alkalizing filter contains an insufficient amount of filter mass	Refill and back flush the filter. Check the pH level after the alkalizing filter. When about 30 % of the filter mass has been used, or when pH level higher than 7.5 is not obtainable even if the by-pass valve is closed, new filter mass should be added
	4. The filter mass is ineffective	Replace the entire filter mass
	5. If calcium-/CO_2-unit being used: a. CO_2-dosing is too high b. Not enough filter mass in the alkalizing filter	 Use smaller dose of CO_2 See item 3
	6. Error in measuring pH-level	See problem F

PROBLEM	POSSIBLE CAUSE	CORRECTIVE MEASURES
E. pH value exceeding requirements	1. The water from the supply vessel exceeded the required pH level	The water may not be accepted if pH level is above 9.5. (may be caused by cement lined storage tanks on the supply vessel)
	2. The by-pass valve on the alkalization filter is not adequately opened	Adjust the by-pass valve to decrease the amount of water flowing through the filter. This should be followed up with a new pH control taken after the alkalizing filter. High pH is normal after replacing filter mass
	3. If lime-/CO_2-unit is used: a. CO_2-dosing is too low b. Recent refill of filter mass in the alkalizing filter	 Use a higher dose of CO_2 See item 2
	4. Error in measuring pH level	See problem F
F. Error in pH-measuring (deviation of more than one pH-unit between offshore and onshore tests)	1. Old buffer solution	Replace buffer solution and calibrate the pH- gauge. Buffer solutions must be stored capped. Recommended pH-value for the buffer solution being used when calibrating is pH=7.0 and pH=9.0. The buffer solution shall be clear and without sediment or algae growth
	2. Water produced by evaporation/reverse osmosis has low buffer capacity	Employ water treatment that increases the alkalinity Note! Water with low buffer capacity is very sensitive to variations in pH level
	3. Old electrode	Replace electrode
	4. pH-electrode is ”dry” or there is air inside the glass membrane	Add new electrolyte/remove all gas bubbles. The electrode may have to be replaced
	5. Gel filled pH-electrode	The electrode shall have a liquid inner electrolyte
	6. Old battery	Replace battery and re-calibrate
	7. Error in the instrument	Have the instrument repaired/replaced
G. High conductivity (= high salinity	1. Water from the supply vessel is polluted by sea water	With a conductivity above 10 mS/m (100 µS/cm) at 25^o C the water should be refused if it can not be confirmed that it is a normal conductivity for that particular water
	2. Salt water in the bunkering hoses	Bunkering hoses shall be flushed before sampling
	3. Salt water from production unit for potable water because of: a. Error in the conductivity meter on the production unit or in the laboratory b. Leakage in the evaporator condenser c. Damage to the reverse osmosis membrane d. Sedimentation in the reverse osmosis/-evaporator unit	 See problem F, item 6 and 7. Error in the conductivity meter is discovered when there is a difference in conductivity measured offshore and onshore Repair the leakage Replace membrane Clean the production unit regularly
H. Insufficient UV-disinfection	1. ”Dirty” radiation tubes in the UV-unit	Clean the radiation tubes
	2. Malfunction in the UV-tubes, or the maximum operation time allowed has been exceeded	Change UV-tubes. The time recorder should be checked regularly. Radiation tubes shall be replaced at the maximum operation time or earlier if necessary
	3. Particles in the water or discoloured water	See problem B and C, item 1. Note! Muddy/discoloured water (high turbidity/high colour count) may trigger the automatic closing of the valve
	4. High temperature on the UV-tubes	See maintenance instructions
	5. Malfunction in the magnetic valve	Shut down the UV-unit until the valve has been repaired or replaced
	6. The UV-unit is not working properly	Check the effect by testing the colony count before and after the UV-unit

PROBLEM	POSSIBLE CAUSE	CORRECTIVE MEASURES
I. Insufficient chlorination	1. Operation procedures have not been followed	Enforce the operation routines
	2. The chlorine solution is too old. Sodium hypochlorite lasts around 3 months. Calcium hypochlorite lasts nearly indefinitely as granulate or powder	If sodium hypochlorite is used – replace the solution. If calcium hypochlorite is used – make a new solution
	3. The chlorination equipment is defect	Check the equipment for defects
	4. The water requires more chlorine, compare with values for total chlorine	Higher chlorination dose may be necessary
J. High colony count	1. Contaminated water from the supply vessel	Make sure that the disinfection unit is working, see problem H or I. Check bunkering routines. Possible causes may be contaminated bunkering hoses, low flush water pipe capacity or failure in supply vessel routines
	2. Microbial growth in the water because of a high content of organic substances or prolonged presence in the potable water system. This may result in microbial growth on tank walls and the distribution system	Make sure that the disinfection unit is working, see problem H or I. If it is working properly, it is important to locate where in the distribution system the problem is originating. This is done by testing the water quality in the tank, before and after the different treatment units and from some taps in the distribution network. A thorough cleaning and disinfection of the tanks and/or the distribution system may be necessary. The filters in the distribution system are especially susceptible to such growth, and the filter mass should be replaced
	3. The potable water is contaminated through air vents or couplings, or in connection with maintenance work	Make sure that the disinfection unit is working correctly. See problem H or I. Secure possible contamination sources and assess procedures
K. *E.coli*, *Clostridium perfringens*, intestinal enterococci or coliform bacteria	1. Contaminated water from the supply vessel	Make sure that the disinfection unit is working correctly. See problem H or I. Check bunkering routines. Possible cause may be contaminated bunkering hoses, inferior flush water pipe capacity or failure in the supply vessel routine
	2. Contaminated sea water to the potable water production	Make sure that the disinfection unit is working correctly. See problem H or I. Make sure that the best suitable sea water inlet is being used
	3. The potable water is contaminated through air vents or couplings, or in connection with maintenance work	Make sure that the disinfection unit is working correctly. See problem H or I. Secure possible contamination sources and assess procedures
L. High content of iron or copper (corrosion)	1. Low pH	pH must be adjusted to be between 7.5 and 8.5. See problem D
	2. Low alkalinity	Use water treatment that increases alkalinity
	3. High sodium content	See problem G
	4. Stagnant water in copper pipes	Flush the water before using it for drinking/cooking
	5. Tapping water from hot water taps	Use cold water only for drinking and cooking
M. High content of heavy metals such as lead/cadmium	1. Corrosion	See problem L
N. Trihalomethanes	1. These substances may develop when electro chlorinating sea water inlets and since they are volatile may increase in concentration over evaporators	Reduce chlorination in the sea water inlets or install active carbon filter
	2. Limit value offshore may be exceeded if water bunkered from onshore water works contain much trihalomethanes	Adjust the chlorination on the offshore unit, change to supply from another water works or install active carbon filter

PROBLEM	POSSIBLE CAUSE	CORRECTIVE MEASURES
O. Bromate	If electro chlorination is used prior to evaporation, the bromate level in the potable water may be exceeded. The level will depend on pH, and may increase after UV-treatment	Reduce electro chlorination, reduce the effect of the evaporators, thus producing cleaner water, or installing active carbon filter

Appendix 10 – Recommended procedures for bunkering potable water

The procedures should be adjusted to the system on the specific unit.

Before bunkering:

1. Bunkering to empty potable water tanks is recommended. If possible: Dump remaining water in the tank via drain valve..
2. Check that a sufficient amount of hypochlorite with the correct concentration is prepared. The solution must not be too old. The hypochlorite amount should be adjusted according to experience made during previous bunkering. If the pump is not operated by a flow meter, the dosing speed must be calculated.
3. Check that the valves on the chlorine dosing system are opened. Start the pump to ensure that it is operating properly.
4. Check that water is not distributed from the tank being bunkered to.
5. Check that the shut-off valve on the bunkering station is closed.
6. Check that the flush valve is open.
7. Check number of tanks the supply vessel is going to deliver water from.

During bunkering:

8. The bunkering hoses are connected to the supply vessel and flushed by way of the drain valve.
9. After the flushing is completed, a water sample is taken. If water is bunkered from more than one tank on the supply vessel, a water sample shall be taken from each one of the supplying tanks. Colour should be measured and smell, taste and clearness should be logged (preferably by two persons to ensure the quality of these judgements). Water that does not meet the requirements should be rejected as potable water. Conductivity is measured and should not deviate from the values logged from previous bunkerings. This is to ensure that the conductivity measured on the bunkering station is approximately the same as conductivity measured on the supplying water works onshore, and normal values onshore should be obtained from this water works. To avoid long discussions with the supply vessel captain, it is advisable to get a second opinion before rejecting water due to smell, taste and clearness.
10. If the water is accepted, the bunkering can start. The drain valve is closed, the chlorine dosing pump started, and the water is pumped to the storage tanks onboard the offshore unit.
11. The chlorine dosing pump is stopped when the necessary calculated amount of chlorine has been added.

After bunkering

12. The storage tank is kept isolated for 30 minutes.
13. Analyse a water sample from the storage tank for free residual chlorine. The content should be within 0.1-0.5 mg/l. When too little chlorine has been added during bunkering, the water must either be dumped or additional chlorine added to the water by recirculating the tank content through the chlorination unit back to the tank to achieve a sufficient mix of new chlorine in the water. Items 12 and 13 are repeated.
14. A quick visual evaluation combined with control of smell, taste and conductivity may detect if the supply vessel deliberately or by mistake has delivered sub standard water from a tank that has not been tested. This will prevent further contamination of the water distribution system.
15. Measured results should be logged, see appendix 5.The dosing pump should be adjusted to the same level at the next bunkering.

Appendix 11 – Calculations in connection with chlorination

Stored chlorine in dissolved form loses its strength after a while. Content of the various substances in different types of potable water require different chlorine doses to achieve sufficient free residual chlorine after the 30 minutes of contact time. The following calculations must be seen as examples only, and must be adjusted to the particular type of water being treated. When experience builds up regarding dosage, bunkering time and so forth, calculations may not be necessary, as the bunkering log, see appendix 5, will give the necessary information on chlorine volume, necessary pump speed, mixing ratio, etc.

1. What is the required chlorine level?

Regardless of method used, such as Flowmeter regulated chlorination or manually regulated pump, the chlorine amount must be calculated. When calculating the correct grams of chlorine to be used, it is important to remember that calcium hypochlorite holds 65 % free chlorine, while sodium hypochlorite holds only 15 % free chlorine, see 8.2.2 and 8.2.3.

If the storage tank being bunkered to already contains substantial amounts of water, extra chlorine must be added to obtain the correct chlorine solution. If the water quality does not fluctuate, this means that it is always the same amount of chlorine that is required when filling a tank. The chlorine solution strength and/or the pump speed may vary if the tank is partly full. It is preferable to avoid bunkering to storage tanks already containing substantial amounts of water, since this may make it difficult to blend in the chlorine properly.

2. How to make a chlorine solution of a specific concentration?

The amount of disinfectant needed to make 1 litre of solution of a specific concentration is as follows:
For sodium hypochlorite:

$$\frac{\text{Wanted concentration (\%) x 1000 ml}}{\text{Chlorine \% in the chlorine container}}$$

- *The answer gives ml solution to be mixed with the water, and the amount of water plus the amount of solution together is one litre.*

For calcium hypochlorite:

$$\frac{\text{Wanted strength (\%) x 1000 g}}{\text{Chlorine \% as powder or pills}}$$

- *The answer will give number of grams to be dissolved in one litre of water.*

3. Calculation example for a flow regulated pump

Let us say we have a potable water tank holding 130 $m^3$20 mg Pt/l). We are going to fill it up completely, and experience from previous bunkering shows that we need 1.0 gram chlorine per m^3.

Necessary chlorine amount:
Total need is 130 m^3 x 1.0 g/m^3 = 130 grams of chlorine to disinfect the entire amount of water in this tank

Bunkering time:
Dosing speed for chlorine the pump is 20 litres per hour, and 200 m^3 per hour is going to be bunkered

$$\text{Bunkering time (hour)} = \frac{\text{Bunkering amount}\,(\text{m}^3)}{\text{Bunkering speed}\,(\text{m}^3/\text{h}our)}$$

$$\text{Bunkering time} = \frac{130\ \text{m}^3}{200\ \text{m}^3/\text{hour}} = 0.65\,hours$$

(If we, for instance, already had 30 m^3 water in the tank when the bunkering started, the bunkering time for the remaining 100 m^3 would have been 0.5 hour).
Necessary chlorine concentration in the solution:

Number of grams (g) chlorine to be added to the entire bunkering volume
Bunkering speed (l/hour) x bunkering time (hour)

$$\text{Necessary chlorine concentration} = \frac{130\ \text{grams chlorine}}{20\ \text{l/hour x } 0.65\ \text{hour}} = \underline{10\ \text{g/l}}$$

10 g/l equals 1 % chlorine solution. If the tank is emptied before bunkering, the required amount of chlorine concentration is not necessary to calculate every time, provided that the quality of the water being bunkered is fairly stable. Had the tank already contained 30 m^3 of water when the bunkering started, the bunkering time would have been 0.5 hour for the remaining 100 m^3, and we would have had to increase the chlorine concentration in the solution to 1.3 % to obtain a sufficient disinfection of the entire water content.

The calculation example is for mixing 13 litres of 1 % sodium hypochlorite solution. The sodium hypochlorite we have holds 15 % strength, and is approximately 2 months old. It weakens between 1 and 2 % per month, and to be safe we estimate the strength to be 10 %, see 8.2.2:

$$\frac{1\%\ x\ 1000\ \text{ml}}{10\ \%} = \underline{100\ \text{ml}}$$

We need 100 ml 10 % solution to get 1 litre 1 % solution. To make 13 litres of such a solution we need 100 ml x 13 = 1300 ml (= 1.3 litre). The easiest way to make this solution is to add the chlorine to the dosing tank, and then add water to a total volume of 13 litres. Please read the product data sheets and remember to wear protective gear!

4. Calculation example for a manually operated pump

We are going to bunker 130 m^3 to an empty tank bunkering speed is 200 m^3 per hour. We need 1 gram chlorine per m^3 and bunkering time is 0.65 hours, see calculations explained above.

Dosing speed calculation:
We can use a variety of chlorine solution strength since the chlorine dosing speed can be adjusted. In this example we have a 5 % solution, and here too we need 130 gram of chlorine to disinfect the tank (this chlorine amount would be the same even if we had for example 30 m^3 in the tank to start with). As experience has shown, the necessary chlorine dose is 1 g/m^3, (but it would have increased to 1.3 g/m^3 if the tank already held 30 m^3 of water). The dosing time (litre/hour) for the pump speed is calculated as follows:

$$\text{Dosing speed (in l/ hour)} = \frac{\text{Bunkering speed } (m^3/\text{hour}) \text{ x chlorine dose } (g/m^3)\, x100\ \%}{\text{Solution strength } (\%) \text{ x } 1000\ (g/l)}$$

The bunkering speed is 200 m^3/hour, and the chlorine solution strength is 5 %, and we want the potable water to hold a chlorine dose of 1 g/m^3 (equals 1 mg chlorine per litre). The result is:

$$\text{Dosing speed} = \frac{200\ m^3/\text{hour x } 1\ g/m^3\, x100\ \%}{5\ \%\, x1000\ g/l} = \underline{4\ \text{l/hour}}$$

Consequently the chlorine dosing pump should be set at 4 l/hour.

Necessary amount of chlorine solution (l) = dosing speed (l/hour) x bunkering time (hour)
Necessary amount of chlorine solution = 4 (l/hour) x 0.65 (hour) = 2,6 litres

If we had 30 m^3 of water in the tank, the chlorine dosing speed would have to be increased to 5.2 l/hour in order to pump the same 2.6 litres of chlorine solution in half an hour.

Appendix 12 – Cleaning and disinfection of a distribution system

Disinfection may be done in different ways, for example by heat treatment (increasing the water temperature to above 70° C for at least 5 minutes) or by chlorination. Below is a description of a chlorination method where the water may be used as potable water even during the disinfection process. Using lower doses of chlorine than those described below, is not recommended as this often will not result in satisfactory distribution system disinfection. If more concentrated chlorine doses are useded, the water is not acceptable as potable water in this period. The chlorine effect is a function of dose*time.

1. Preparations:

One person is assigned the responsibility for completing the work.
Personnel must be informed of the following:

- The distribution system shall be cleaned and disinfected with chlorine.
- The high chlorine concentration may give the water an unpleasant smell and taste, especially if there is much biofilm in the system. Bottled water should be available for cooking and drinking.
- The water may be used for cleaning and personal hygiene (showering), as the values are according to WHO standards for potable water. Coloured clothes washed in this water may become bleached.

2. Adding chlorinated water

Fill a potable water tank with water holding a concentration of close to 5 mg/l free chlorine (but not above this level if the water is still in normal use). Open all taps on the distribution system and let the water run. It should run for a while after the smell of chlorine is obvious. Let the taps drip slowly, thereby allowing new, chlorinated water to be added during the entire disinfection period. To avoid bacterial growth it is important to properly chlorinate places in the distribution system where there may be stagnant water.

3. Measuring chlorine content

Measure the free chlorine content on a few water taps, choosing different locations, including the tap farthest away on the distribution system. The free chlorine concentration should be between 4 and 5 mg/l. If the chlorine content is significantly lower in some samples, the water has not been flushed long enough. Following further flushing of all taps in the area, new chlorine samples must be taken. The water may be used during the disinfection. After 12 hours, samples from different locations in the distribution system should be taken (including one sample at farthest location), to document enough remaining free chlorine.

4. The need to repeat the procedure

If, after 12 hours, the free chlorine content has decreased more than 1 mg/l in most of the sample spots, repeat the procedure without delay. If unpleasant smell and taste still linger after the procedure is finished, this is a sign that the chlorine disinfection has not been effective enough and should be repeated. Before repeating the procedures, it is important to flush the distribution system. This will remove the substances dissolved by chlorine, and new chlorine rich water can easily remove the remaining biofilm.

5. Emptying tanks and distribution system of chlorine rich water

Empty the chlorinated potable water tank, and flush the distribution system with water from another tank, by opening all taps. Chlorine content should now be below 0.5 mg/l. Flushing will also remove organic matter (dead biofilm etc.), and reduce the risk for rapid growth of new biofilm.

6. Special treatment of shower heads and shower hoses

Plastic shower heads and shower hoses are often difficult to chlorinate, as they may contain much biofilm. Every three months such fixtures should be disassembled, cleaned (mechanically or by using soap, acid may be used to remove scaling) before they are disinfected. Disinfection may be done by soaking them in 50 mg/l free chlorine for an hour, by boiling them in water until they have an internal temperature of 100° C, or by hanging them until they are completely dry internally.

If the procedures described above do not give low colony counts, the reason for this must be found.

Appendix 13 – Cleaning and disinfection of potable water tanks

Below is one possible method for cleaning and disinfection of potable water tanks.

1. Preparation

Only clean equipment and protective gear is to be used for such work. The storage capacity in all other potable water tanks should be fully utilized. If re-coating of the tank is required, it will take up to one week before the tank may be ready for use, provided that the hardening process does not cause any problems. If problems arise, the tank may be out of operation for a long time. The amount of water needed, hardening requirements, manpower, potable water production possibilities etc. should be considered and included in planning the maintenance work, to ensure enough water during the maintenance period.

2. Drainage

The tank should be drained completely. If necessary, a mobile drain pump should be used.

3. Inspection/supervision

The frequency of cleaning/disinfection should be assessed during tank inspection/supervision. With a small amount of slime and sediment in the tank and with low and stable colony counts, the cleaning intervals are satisfactory. The inspection results shall be logged.

4. Cleaning

For cleaning purposes, only use water of potable water quality. The surfaces in the tank should be flushed under high pressure, and better results may be achieved through use of certified cleaning agents, see 2.3.4. If necessary, the surface may have to be scrubbed with stiff brushes. After the scrubbing and flushing, the tanks should be completely drained.

5. Inspection/supervision

After draining the tank should be inspected to evaluate the cleaning. The protective coating shall be assessed and completely or partly renewed if necessary. The air-vent opening, including float ball and corrosion proof net, shall be checked and repaired if necessary. The inspection results shall be logged.

6. Appliance of protective coating

The protective coating has to be certified and it must be documented that it has been correctly applied (also for patch coating), see 9.1.4. Incorrect appliance of coating has caused major problems for several offshore units.

7. Disinfection

Water that in addition to tank disinfection, is intended for disinfection of the distribution system, must hold a chlorine content of approximately 5 mg/l chlorine (5ppm). If the water is not intended for disinfection of the distribution system, a chlorine content of at least 10 mg/l (ppm) is recommended. A suggested calculation method for the chlorine solution can be found in appendix 11. When the storage tank has been completely filled up, the water shall have a free chlorine content of at least 4 mg/l (ppm). The water should not be used for at least 12 hours, but it should preferably be circulated in the tank.

8. Control

After 12 hours a sample should be taken to document that the water still contains enough free chlorine; the chlorine reduction should be less than 1 mg/l. Normally the tank water is dumped, as it does not satisfy the potable water requirements regarding smell and taste. The water may also be used for disinfection of the distribution system, provided that the free chlorine content is approximately 5 mg per litre, see appendix 12.

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January 2013
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