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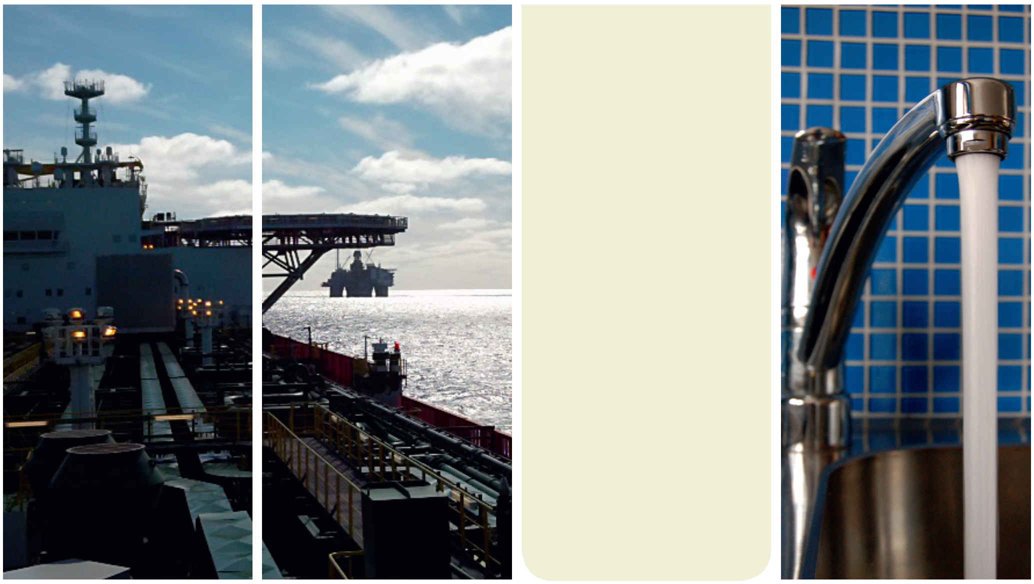

Water Report 129

Safe, Sufficient and Good
Potable Water Offshore

A guideline to design and operation
of offshore potable water systems

5th edition

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Norwegian Institute of Public Health

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Preface

This is the 5th edition of the guideline for supply of offshore potable water, and the last edition to be published by the Norwegian Institute of Public Health (NIPH). The previous editions were published in 2005, 2009, 2013 and 2016. This updated guideline has been published so soon after the last version, is that the NIPH shall cease to do offshore work. The text about NIPH in chapter 2 has been revised accordingly. A new appendix 14 – Procedure for water temperature testing, has also been added, and we thank Tjarda den Dunnen for the draft for this procedure. In addition, some minor changes have been made in section 8.3.2 on UV-disinfection.

Future editions of this guideline will be revised by the NMA, with an expected frequency of one edition every 4 years. Input to guideline changes should be sent to the NMA.

The objectives of the guideline are:

- 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 the operation, control and maintenance of offshore potable water systems to ensure a safe potable water supply.

The guideline gathers information for industry, authorities and specialists in relevant fields from the NIPH. The authorities may, based on relevant regulations, give other requirements than those proposed in this guideline. The guideline is available on the NIPH offshore webpages: www.fhi.no/offshore.

Working with potable water brings you in contact with many specialist fields, such as environmental health protection, technical disciplines, law and medicine. Chapters 1 to 4 contain general information about regulations, system management and water quality. The remaining chapters cover the 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 since the 3rd edition of the guideline:

- The NIPH no longer works for the County Governor of Rogaland. Chapter 2 has been revised accordingly.
- Section 2.4 is revised, as the NMA potable water regulations section 2.3 now refers to the Norwegian Food Safety Authority (FSA) list of approved additives for potable water. Chemicals previously found on the NIPH list of certified products are now included on the FSA list.
- Norwegian approval is no longer required for coatings used in potable water tanks, see sections 2.4, 9.1.4 and 9.2.6. Instead, the NMA potable water regulations section 7.3 and 4 has much stricter requirements for documentation when choosing and applying such products.
- Section 3 emphasises that conducting a Hazard Analysis and defining Critical Control Points is a requirement both according to the NMA potable water regulations section 5 and the Law on Food.
- Section 4.4 contains recommendations to avoid the wrong design of test taps.
- In section 4.5 the consequences of the margin of error for the colour measuring equipment is discussed.
- The alkaline filter in the design example on figures 5.1 has been moved. This to illustrate the need to avoid long distances between water production units and the alkaline filter. Such treatment is rarely needed for bunkered Norwegian water.
- The circulation inlet in the design example in figure 5.1 and 7.3 has been moved. This to illustrate that the best location of the inlet may be different when bunkering to an "empty" tank compared to circulation of a full tank. The same chlorine tank may be used if it is located near to both pipes.
- For units operating in warm climates, and for units that have problems with growth of biofilm, a system for continuous chlorination (or other water treatment) to reduce the risk for biofilm and *Legionella* is described in sections 5.1 and 9.2.11.
- Ref. new requirements in the NMA potable water regulations sections 7.1 and 11.2: For new mobile offshore units it is recommended to have closeable seawater inlets for water production. These inlets should not be connected to the same sea chests that supply

cooling water to machinery and other types of water consumption that may be present close to shore, see sections 5.1 and 6.1.2. In sections 5.1 and 9.1.2 it is also recommended to have void spaces or other rooms that do not pose any threat of pollution around potable water tanks. To ensure easy maintenance inside tanks, access platforms for every 4 metres of height are required, see section 9.1.2.

- Section 9.2.1 is supplemented with design advice to avoid unnecessary maintenance and with more detailed information on piping dimensioning, including reference to NS-EN 806-3, se also NMA potable water regulations section 10.
- Section 9.2.4 contains information about expansion vessels for hot water systems and information about balancing the system flow to ensure sufficient temperatures on all floors.
- Section 9.2.7 on *Legionella* prevention is supplemented with advice about the risk assessment of systems according to the requirements in the environmental health protection regulations. Information on water treatment methods is also revised.
- The recommended testing programme in appendix 4 is revised. Chromium and nickel are recommended to be analysed on new offshore units. Chemical oxygen demand/total organic carbon and UV transmission have been suggested removed from the programme.
- Appendices 12 and 13 have been supplemented with information on alternative methods for cleaning and disinfection.

The NIPH wants to express thanks for input to the guideline to: Frode Andersen, Torbjørn Andersen, John Øyvind Auestad, Odd-Anders Beckmann, Lisbeth Brevik, Russel Caldwell, Hans Donker, Tjarda den Dunnen, Anne Nilsen Figenschou, Mads Kristian Fjelldal, Don van Galen, Joar Gangenes, Karl Olav Gjerstad, Guy Heijnen, Torbjørn Husby, Kjersti Høgestøl, Eivind Iden, Erling Instefjord, Synne Kleiven, Truls Krogh, Johnny Kvernstuen, Olav Langhelle, Kwang Moon Lee, Johan Ljungqvist, 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, Bjørg Stangeland, Bjørn Steen, Jeroen Stelling-Freyee, Morten Sætre, Terje Theien, Sindre Thirud, Kjetil Todnem Åse Waage, Alex Wilson, Lx Yeow and Nina Hanssen Åse. 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, 3rd and 4th edition changes by Eyvind Andersen. 4th and 5th edition has been proofread by Julie Whittle Johansen. If discrepancies occur, the Norwegian version takes precedence.

Oslo, 2nd January 2017

Line Vold
Department Director
Zoonotic, Food- and Waterborne Infections
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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 safe, sufficient and good potable water. When good water sources are chosen, the waterworks treatment plant is working optimally and the routines for operation, control and maintenance are the very best, the result is good potable water. If one level fails, safety is affected.

The quality requirements apply to all Norwegian potable water supplies, included on ships and on offshore units on the Norwegian continental shelf: Potable water is expected to 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 hygienic barriers against all physical, chemical and microbiological pollution that could possibly affect the potable water supply. Multiple safety barriers ensure that the potable water remains safe, even if one barrier fails, due to human or technical error.

Groups with different skills 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 error or inadequate operation systems. Technical failure is rarely the cause of serious problems. Even the best systems can deliver poor water quality if operation systems are inferior, while a technically weaker system can deliver safe and good potable water when run by dedicated personnel. Internal control, including sufficient routines for training personnel and operation of the system, is crucial to ensure that the system functions adequately over time.

1.2 How to use the guideline

The guideline can be used as a complete reference book, or to solve specific problems.

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 the 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.

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 practice, where the regulations allow for use of various solutions. Therefore, examples about solutions and attached checklists must not be interpreted as absolute requirements. Each company must use its own judgement when deciding the need for equipment, operation routines and supervision in their specific activity.

1.2.2 Guideline application

Before planning water supply systems on new offshore units, everyone involvedshould read the guideline to ensure the best solution. In the long term, this will give the best results with regard to quality, operation and cost. Use of the design checklist in appendix 1, and the checklist for control systems in appendix 2, cannot 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 daily operations, when relevant information is not available in the unit’s management system. The guideline may also be used in potable water education 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 manmade hindrance or other measures that reduce risks, remove or inactivate pathogenic microbes or dilute, break down, destroy or remove chemical and physical components to a level where the substances no longer represent any health hazard.

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

Letter of Compliance (LOC): A document issued by the NMA confirming that a foreign-registered offshore unit complies with all technical requirements specified by the NMA and its affiliated supervisory authorities.

Microbes: Microorganisms such as amoebas, bacteria, parasites, fungi and viruses.

NMA: Norwegian Maritime Authority.

Offshore unit: Installations and equipment for petroleum activity, but not supply- and auxiliary vessels, or petroleum bulk carriers.

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

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

Potable water tests: Analyses taken from the potable water as an in-house control measure, and in adjusting the operation of the potable water system, including analyses performed when bunkering potable water.

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

Figure 1.1: Potable water system with evaporator, scale inhibitor tank, chlorine tank, alkalising filter and UV units (Photo: Eyvind Andersen)

2. Regulations and authorities

(Revised as per 1st January 2017)

Potable water offshore is governed by:

- Regulations of 12th February 2010 No. 158 on health, safety and the environment in the petroleum activities and at certain onshore facilities (Framework regulations with specific regulations on management, activities and facilities, referred to as the HSE regulations)
- Regulations of 4th December 2001 No: 1372 on potable water (the potable water regulations, expected to be revised in 2017)
- Regulations of 4th December 2015 No: 1406 on potable water and potable water systems on mobile offshore units (referred to as the NMA potable water regulations).

2.1 Authorities

The Norwegian Petroleum Safety Authority (PSA), Environment Agency, Board of Health Supervision (BHS) and Food Safety Authority (FSA), or person/institution given supervisory authority by these organisations, will assess whether offshore industry adheres to the health, safety and environment requirements. The FSA has authority according to the food legislation but has delegated the offshore supervision work to the CGR. For mobile offshore units with a Norwegian flag, the NMA is authority, according to the maritime regulations.

2.2 Regulations

For potable water issues, the HSE regulations refer to the potable water regulations. Regulations concerning potable water systems and potable water supply on mobile offshore units, apply to units that have a Norwegian flag, but such units must also adhere to the HSE regulations when operating on the Norwegian continental shelf. Foreign offshore units that follow section 3 in the HSE regulations may also follow technical requirements in the NMA potable water regulations, see the guidelines to section 3. Table 2.1 is a summary of existing regulations and suggested standards.

2.2.1 Potable Water Regulations

The potable water regulations are in accordance with the EU regulations for potable water. The regulations apply to units operating on the Norwegian continental shelf. The NIPH has made an analysis 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 HSE 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 detail the potable water regulations requirements.

The HSE regulations give general requirements about function and contain no details about design and operation. However, in the comments to the regulations, standards are specified. According to the Framework Regulations § 24 these standards must be followed, or the alternative solutions chosen must be proven to be at least as safe. 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 principles to be as follows: All health, safety and environment matters should be adequately taken care of and hazards reduced to a minimum. Organisation 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 requirements to design and equipment, such as top-level security, ergonomics and uncomplicated and sturdy design. § 61 states that the design should be in accordance with requirements in the Activities Regulations and the potable water regulations. Specific design 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 wat-

er 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 NMA Potable Water Regulations

The NMA issues certificates for Norwegian mobile offshore units and Letter of Compliance for foreign units. The regulations 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 licence 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 NMA 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 has previously advised the authorities on matters related to potable water and potable water systems on offshore units. The CGR ended the co-operation with the NIPH as of 1st January 2016 and the NIPH ended the co-operation with the NMA as of 1st January 2017. The NIPH no longer has any formal role on this field.

2.4 Product approval

The following requirements apply to products:

Paints, protective coatings and other materials

The potable water regulations state that these products should not pollute the potable water. Norwegian approval is not necessary for such products, see 9.2.6.

Potable water treatment chemicals

According to the potable water regulations and the NMA potable water regulations section 2.3, water treatment products must be approved by the FSA. A product may only be used if both the product name and manufacturer/supplier is on the list. Examples of products that need approval include alkaline filter material, corrosion- and scale inhibitor in heating circuits, disinfection products, antifreeze 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. The list of approved products is available on the FSA web site: www.mattilsynet.no/mat_og_vann/vann/vannverk/vannbehandlingskjemikalier.1875.
If approved products are used as instructed, they are considered safe to use.

UV units

UV units are evaluated 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.

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	**Mobile units** registered in foreign ship registers. Bound to Acknowledgement of Compliance. (AoC)*
The Law on Food	Legally binding		
Potable water regulations	Legally binding		
HSE regulations	Legally binding		
NMA potable water regulations		Legally binding	Voluntary standard, see HSE Framework Regulations § 3
The NIPH – Guideline	Recommended standard, see the HSE Framework Regulations § 24		
NORSOK P-100 system 53	Recommended standard, see the HSE Framework Regulations § 24		

* see section 1.

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". In the potable water regulations, internal control is a requirement, and must be tailored to each waterworks. Furthermore, it is a requirement to perform a risk analysis, and to establish routines to handle risks, both of which must be kept updated.

The NMA has also given requirements for management. Regulations of 5th September 2014 no. 1191 for safety management systems apply for mobile offshore units with a Norwegian flag, and in the NMA potable water regulations section 5 there are requirements for a risk and vulnerability analysis, risk mitigating measures, contingency plans and critical control points (HACCP).

The quality of management of health, safety and environment should be reassessed frequently. The management system should be continuously improved as a natural consequence of experience, changes in the regulations, system revisions etc. This will minimise the risk to the 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 states "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 supplemented 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 refer to other documents, procedures and systems with more detailed information. The current trend is that 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 update when needed, and that it is easy to find relevant information both in the daily operation and when problems arise.

Even though the format of the documentation is not of the greatest importance, numerous conditions require documentation. Appendix 2 lists the type of information that ought to be included as a minimum. This documentation must be organised in a manner that makes is easy to find and compile.

3.2 Competence

The Framework Regulations § 12 states "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". Requirements for competence and training are also stated in the potable water regulations.

The responsible party 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 responsible party 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 programmes. Several institutions offer courses in offshore potable water treatment. The responsible party may also choose to provide the training, but must then 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 to function well. The frequency and extent of the maintenance are in part based on requirements made by the authorities, for example annual 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, alkalisation 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 equipment supplier should document the necessary maintenance but maintenance requirements are also detailed in NS-EN806-5.

A job description must be provided for each element in the maintenance system, describing all necessary safety measures and how the work is to be carried out.

3.4 Collection, processing and use of data

The potable water regulations require that a test programme is established to include regular testing of both untreated and treated water. The Management Regulations § 19 require that the responsible party collects and processes data information for:

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

For potable water systems, focus is often on the water analyses. Collecting data about critical operational parameters (see specifications for hygienic barriers under 5.2.4) and work carried out on the potable water system is also important. Exchange of such information is necessary during shift changes, and helps to detectfaults at the earliest opportunity, whereas water analyses will show the situation later.

The responsible party chooses the 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 described in appendix 3, with additionallogging of bunkering, maintenance and other operations.

3.5 Deviation handling

The potable water regulations demand that deviations are handled as soon as possible. Major deviations must be reported to the authority. The Management Regulations § 22 establishes that “the responsible party shall register and follow up non-conformities”. Non-conformities to internal requirements that significant to fulfilling the requirements contained in the HSE regulations are also included. “Non-conformities shall be corrected, the causes shall be identified, and remedial measures shall be implemented to prevent the non-conformity from recurring”.

Poor water quality and deficiency in water production must be handled formally through channels for “incident reporting”. It is also necessary to establish criteria for when formal deviation handling is needed.

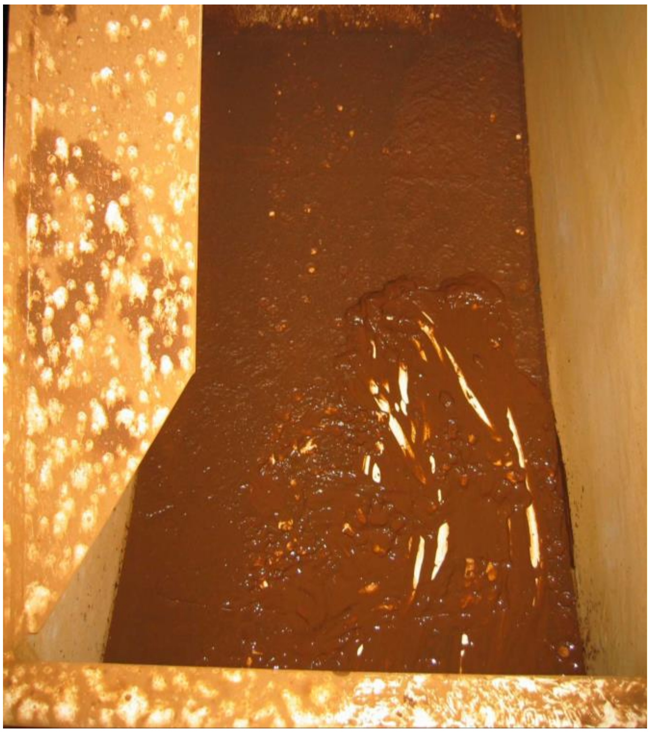

Figure 3.1: The requirement to clean tanks at least once a year is intended to avoid the situation shown above, where there is a layer of mud at the bottom of the tank. This must be handled as a non-conformity case. (Photo: Bjørn Løfsgaard)

3.6 Emergency preparedness

Failure within a basic function such as the potable water system is very serious (figure 3.2). Both the potable water regulations and the Management and Activities Regulations state that a risk and vulnerability assessment must form the basis for emergency planning. The assessment should include the following scenarios:

- Outbreaks of water-borne epidemics
- Chemical pollution of the potable water rendering it to be unsuitable for use, for example as a consequence of poor bunkered water, leakage or faulty connections to various systems
- Lack of water due to leakage, technical failure, bad weather or other causes, see 5.2.3
- Malfunction in the disinfection process or other circumstances causing hazards to the quality of the potable water

Based on the risk and vulnerability assessments, 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 action plans.

3.7 Internal audits

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

- Are critical control points identified and plans for management of these satisfactory?
- Is the risk and vulnerability 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 organisation, are important tools in this work. The necessary procedures, checklists etc. should be established to manage critical control points in the water supply. The competence can be in-house or external, but the overall responsibility for the work must be held by the operator/owner.

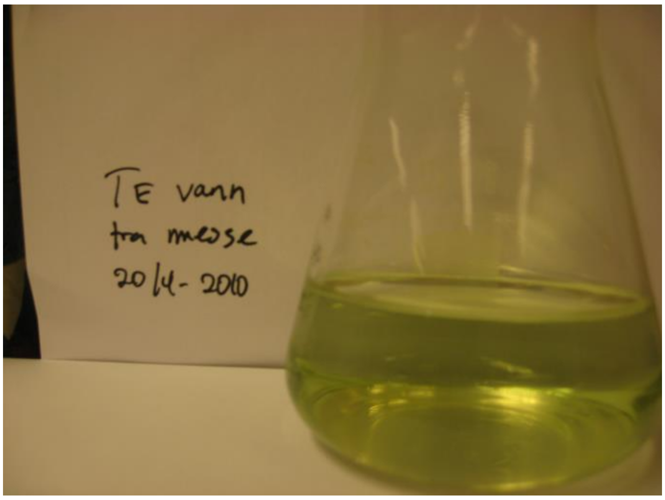

Figure 3.2: Green water caused concern on an offshore unit. Was this an emergency situation or was the pollution less serious?This colour was due to high copper content following leakage of citric acid when washing an UV unit, causing instant corrosion. The non-conformity was reported immediately. (Photo: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

4. Water quality

Access to potable water is necessary for drinking, cooking, personal hygiene and cleaning (figure 4.1). It is therefore important to have sufficient quantities of satisfactory quality for all types of usage. Water treatment is described in chapter 8. Sufficient hygienic barriers should be installed to ensure high quality potable water, see 5.2.4.

4.1 Potable water and health

Water may also contain harmful elements that can be divided into two groups:

1. Microbes, such as bacteria, viruses, amoebas and parasites, can cause infectious disease or food poisoning.
2. Organic and non-organic substances such as acute poisons, carcinogens, allergens or substances that by accumulation in the human organism may cause health hazards.

Indirect health hazards must also be considered. It may be difficult adequately disinfect with chlorine or UVradiation if the water is discoloured or contains many particles, see 4.2.2.

4.1.1 Microbes

Potable water should not contain microbes that can lead to disease. If an outbreak of a contagious or other disease is suspected, locate the source and eliminate it quickly, thereby preventing its spread. An emergency preparedness plan should be introduced, see 3.6. Sufficient preventive safety measures are achieved only by building good potable water systems with sufficient internal control.

Figure 4.1: Potable water must be treated for safe consumption (Photo: Lasse Farstad)

All potable water for offshore consumption must be disinfected, still microbes can cause disease. This may be due to failure in the disinfection, or contamination after disinfection. Humans and animals have several means of defence against infectious diseases. Illness depends on the general health of the individual, the infectivity of the microbe and the number of microbes ingested.

WHO states that infectious diseases are the most serious threats to health from potable water supply. Faecal contamination from humans and animals is often the source, and human faeces are particularly dangerous. Historically, the most common waterborne 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* and *Cryptosporidium*. These microbes can cause illness with vomit, abdominal pain and diarrhoea. Recently, attention has been drawn to the dangers caused by *Legionella*, see 9.2.7. The different types of epidemics described in Norway are usually trigered 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 alert.

Since potable water is used for cooking, microbes in the water can also cause food-borne infections. Some bacteria can grow in food products, and just a few bacteria can rapidly reproduce to high concentrations that make consumers ill. Some of the bacteria in food produce toxins that can cause poisoning even if the food is properly cooked and the bacteria are killed.

Analysing potable water for every type of infectious microbe is too demanding. Instead, analyses are done on indicator organisms, microbes prevalent in large amounts in faeces from humans and animals, and that have similarlife spans to the infectious substances (figure 4.2). The group ”coliform bacteria” is used as an indicator for faecal contamination and the bacteria *E. coli* indicates fresh faeces. When an indicator organism is found in water, it is a sign that there might be disease- producing organisms present.

Figure 4.2: Birds regularly rest on offshore platforms. Their droppings can spread pathogens via unsecured air vents and bunkering pipes (Photo: Eyvind Andersen)

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

4.1.2 Hazardous chemical substances

Potable water should not contain chemical substances that are harmful. Exposure to potentially hazardous substances should be as low as possible. Offshore, such exposure may come from contaminated seawater supply or unwanted occurrences in the operation, for example back-suction through hose connections. It is important to minimise the risk of pollution from materials and additives that come in contact with the potable water during transportation, storage, treatment etc. See approval requirements in 2.4.

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

Some chemical substances are carcinogenic and many of these are genotoxic. There is no threshold value for when damage may occur. Since it is impossible to avoid traces of such substances in the water, Norway has generally set the upper limit value, based on an acceptable lifetime risk, to be lower than 10^{-6}. This means that fewer than one out of a million people drinking two litres of water containing a maximum acceptable amount of this substance every day for 70 years, will develop cancer. The risk of developing cancer will be significantly lower, since limits are set with a high safety margin, and detected concentrations of the substances are rarely close to the limit values. The danger is further reduced by a person seldom drinking water from the same source during his or her entire lifetime.

Disinfection is crucial to safeguard 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 the process may form *chlorination by-products* like trihalomethanes or bromate, causing health hazards. For trihalomethanes to be formed, the water must contain 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 electrochlorination is used to prevent marine growth 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 level of trihalomethanes will be insignificant. However, 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, potable water should be clear, without odour, taste and colour, and non-corrosive.

4.2.1 Odour and taste

Potable water should have no specific odour or taste. An unpleasant odour and/or taste may be a sign of contamination, so an investigation is needed to find and correct the problem. Potable water with an unpleasant odour and/or taste could encourage the crew to drink other beverages than water.

Unpleasant odour and taste can originate both in the unit and outside. Problems increase when the water temperature is high. If tanks and pipes contain organic material resulting in growth of microbes, decomposing processes may give a "rotten" odour 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 a strong odour and taste.

Various microbes can be found in large amounts in seawater, and can release odour 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 UVradiation. 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 incorrect use of protective coatings, see 9.1.4. High concentrations of chloride and sulphate from seawater 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. Removing the unpleasant odour and taste in potable water is covered in chapter 8.

4.2.2 Discoloured and turbid water

Particles (turbidity) can contain microbes that 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 undesirable as it will cause an unpleasant taste. Specific microbes living in the pipe system (biofilm) feed on organic substances. Some of these may pose a health hazard, such as *Legionella pneumophila* that can cause Legionnaire's disease, see 9.2.7.

Potable water produced offshore normally contains few particles, and the turbidity limit of < 1.0 FNU is easy to maintain. In corroded pipes, rust particles may loosen from the inside of the pipes and be flushed through the pipelines 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. There will often be seasonal variation. Water delivered by supply vessels or waterworks onshore with visible colour or turbidity should be rejected, see 4.3.2. Problems with turbidity can be prevented by using particle filters, see 8.3.2.

4.2.3 Corrosive water

Corrosive water means water that corrodes the pipeline system, fittings and other installations connected to the pipeline system. Untreated offshore produced water corrodes most metal surfaces that are not stainless steel or titanium. Some corrosion will always occur in a potable water system, but it is important to keep the level as low as possible, thereby avoiding inferior water quality, or premature replacement of the entire system. Corrosion may also lead to heavy metals such as lead and cadmium being released from the pipeline 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, with an increase in operation costs.

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

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

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-neutralising 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 to be acidic 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 that indicate corrosion problems.

Water from Norwegian waterworks 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 acidic, 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 microbes' oxygen consumption. The difference will make electrons move from areas with residue to areas without residue. 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 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 form, especially in older pipe systems. The clusters are formed by bacteria that convert dissolved iron to solid corrosion clusters. The corrosion clusters are hollow and can disintegrate when the force of the water flow and flow direction is changed, see figure 4.4.

Iron and copper can cause other problems too:

- High iron content can give turbid water which is red to brown. Fittings, sinks, bathtubs and toilets become rust coloured. Stagnant water may develop an unpleasant taste, and white clothes may develop brownish-red stains after washing due to iron deposits.
- High copper content can cause an unpleasant taste. Consumers may experience stomach problems if concentrations are very high. High copper content may cause a green discolouration of sanitary equipment and hair.

When good quality metal piping of 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 for the life span of the unit. Unfortunately, there have been cases where parts or entire distribution systems had to be replaced due to corrosion at great cost.

Corrosion can cause leakages, and as pipes often are concealed in the walls, the water damage can become extensive before discovery. Corrosion control is covered in chapter 8.1.

4.2.4 Itching and skin irritation

Some people working offshore complain of itching and other skin irritation. This is often seen in relation to showering, especially if there is doubt about the treatment methods of the potable water (chlorination, alkalising, reverse osmosis, etc). It is often difficult to find the cause for such symptoms. The problems may vary between people and places. Many components, water-related or not (like dry air etc.), may trigger the problems. If the problems are only related to showering, here is a list of possible causes and remedies:

- One important explanation is frequent showering, using soap that removes the natural fatty protection of the skin. It is also possible that people shower more often offshore than at home. It is advisable to shower less frequently or avoid using soap every time. Use of body lotion after showering may also help.
- Some people display symptoms in winter, even if they do not shower often. This is probably a cold weather eczema caused by the skin's protective layer being washed away. Use of body lotion often reduces problems.
- People who experience itching and irritated skin should try a milder type of soap or shower oil. Some may also react to the soap used in the laundry.
- Even if the potable water is not the cause of these skin problems, some microbes existing in the pipe systems may produce substances that sensitive people react to. Disinfection of the cold and hot water systems once a year can prevent growth of these microbes.
- Hard water will also affect how the skin feels 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. Individuals who are used to hard water will react to the soft water and vice versa. In Norway, most water is originally soft, but alkalising/hardening makes the potable water harder, see 4.2.3.
- Treatment methods used offshore are not known to cause itching or other skin reactions under normal circumstances.

4.2.5 Water temperature

Cold water temperatures above 20 °C and hot water temperatures below 60 °C increase the risk for microbial growth in the system, including *Legionella*, see 9.2.7. To document sufficient temperatures everywhere in the system, establish a test programme, based on an analysis of where the risk of unwanted temperatures is high. Once sufficient temperatures are documented throughout the system, monthly testing (random locations) should suffice. Appendix 14 is a procedure for water temperature testing.

Cold water tastes better than lukewarm water, so water should be kept as cool as possible. 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

Water tests are an important tool to show that the system is well-managed and will also help to improve the management. This section describes the analysis programme suggested by the NIPH, which is based on potable water regulation requirements. The authority may, based on the potable water regulations, give other requirements if necessary.

It is a common misunderstanding that water analyses ensure good quality potable water but only high quality technical systems and adequate internal control can ensure this. Water analyses will only document whether the water was of good quality or not afterwards.

The potable water regulations list several analysis parameters, and give the minimum requirements for analyses, thereby documenting that the water quality meets the requirements. Some limit/action values are set 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/action values does not pose any immediate health hazard, but may indicate that the potable water contains other components hazardous to health. Exceeding values may also reveal that the waterworks is operated incorrectly and consequently may not produce safe potable water.

Offshore waterworks differ from waterworks onshore, for example by producing potable water from seawater. Bunkered water comes from onshore waterworks with approved control routines. Some pollutants are thereby absent in the offshore systems but special conditions offshore make units susceptible to other types of pollution. More tests may be necessary to have sufficient control of the water, and other parameters must supplement the programme when contamination is suspected.

Analysis frequency, limit values and the consequences of exceeding such parameters are commented on below, whilst recommendations for sample points are detailed in 4.4. When the limits are exceeded, steps to find the causes must be taken and normal water quality restored, see 3.5. The supervision authorities must be informed. In addition to the analysis programme required in the potable water regulations, water temperatures must be measured, 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:

Odour: Should not be noticeable. Odour may be a sign of contamination by 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 odour.

Clarity: The water should be clear. This must be evaluated by using strong light and a white or 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 stable between 8 and 8.5. Chlorination functions best at a pH level below 8, requiring chlorination before alkalisation. Minor deviations from the pH limit values do not cause any health hazard but a pH value above 11 can cause cauterisation 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 should 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 alkalisation unit 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 may imply seawater contamination.

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 daily chlorine analyses are unnecessary.

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 detected, disinfection has failed. It is then important to take immediate measures to avoid infections and prevent future problems.

The higher limit value of 0.5 mg/l is set to prevent the water from smelling and tasting of chlorine. It is not harmful 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 to inform the crew that the Potable Water Regulation 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 pipelines, see 9.2.9, as the potable water regulations requirements for odour and taste are not fulfilled. During normal operation of the potable water system the total chlorine amount should not exceed 1.0 mg/l, unless it is necessary to reach adequate levels of free chlorine.

4.3.2 Analyses when bunkering

Take water samples for quality testing from each of the tanks the bunkering vessel delivers water from Appendix 5 contains a suggested bunkering log. Before the water is accepted, measure the following parameters:

Odour, taste, clarity and pH: See 4.3.1. Evaluate odour and taste indoors, and use good lighting to test for clarity.

Conductivity: Water delivered offshore should have similar conductivity to when it was in the onshore pipes. In the past Norwegian onshore waterworks had conductivity levels below 10 mS/m (=100 µS/cm). Several onshore waterworks 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 waterworks to the offshore unit, which may indicate seawater contamination. When entering into an agreement on water delivery to an offshore unit, identify the normal conductivity level for the onshore waterworks, see appendix 6.

Colour value: Should be below 20 mg Pt/l, but subtract the measuring equipment margin of error from the limit value. A higher colour value is normally caused by a high content of natural organic material (humic particles) in the water delivered by the onshore waterworks, see figure 4.5. High colour value reduces the effect of disinfection and may also cause disinfection by-products to form.

Free chlorine: Verify 30 minutes after bunkering/circulation ends, see 4.3.1.

4.3.3 Monthly routine control

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

Colour: See 4.3.2.

Odour and taste: See 4.3.1.

Turbidity: Shall be below 1 FNU when the water passes the UV units. High turbidity makes the water unclear, normally due to a high content of small particles. The effect of disinfection is reduced, see 4.2.2, and the water appears less appetising.

Clostridium perfringens**:** Should not be present in 100 ml water. If the limit value is exceeded, investigate the entire water system 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.

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)

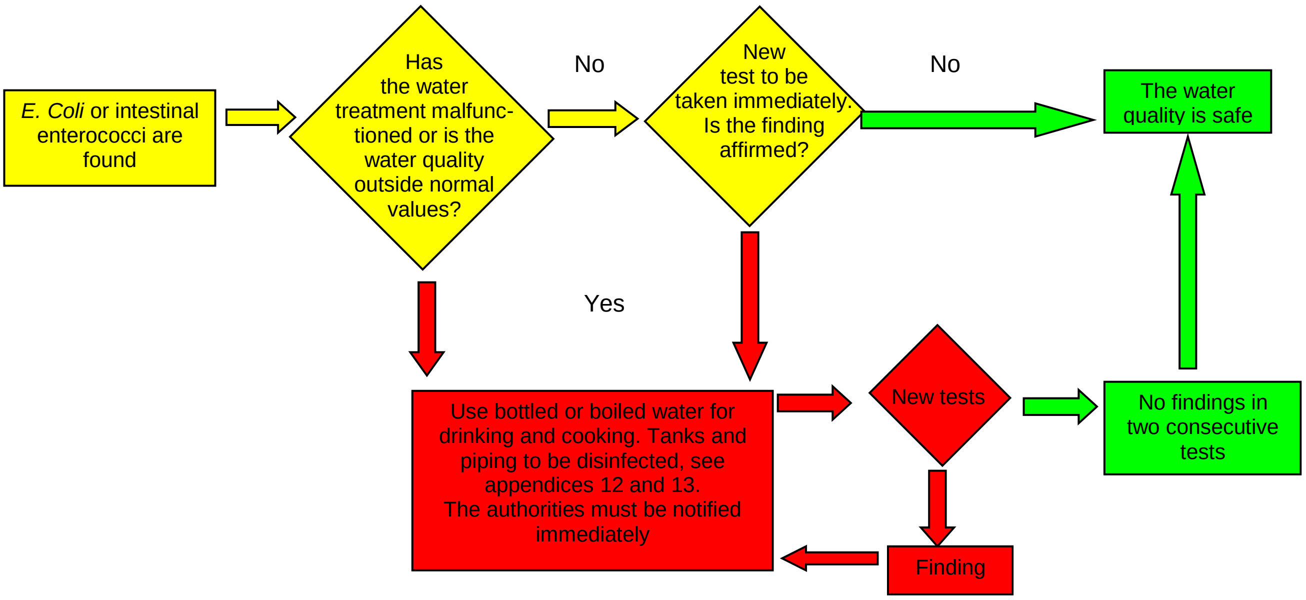

Figure 4.6: What to do when E. coli *or intestinal enterococci are found in potable water samples (Illustration: Karin Melsom)*

E. coli: Should not be present in 100 ml water and if discovered must be reported immediately to the authorities. *E. coli* has a similar 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 detected, take immediate measures 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. Pay special attention to disinfection. Are the chlorine levels sufficient and is the UV radiation unit functioning?

Once all systems are functioning properly, send new water samples for analysis by an onshore laboratory. If malfunctions in the system are found, take immediate action to prevent disease outbreaks. This includes announcements 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: Should not be present in 100 ml of water. If intestinal enterococci are found, this indicates faecal contamination which must be reported immediately to the authorities. Intestinal enterococci can survive for longer in salt water than *E.coli*, and are used as an indicator of disease causing intestinal bacteria. Take the same preventive measures as described for *E.coli*.

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

Coliform bacteria: Should 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, take the same preventive measures as described for *E.coli*.

Iron: Limit value is 0.2 mg/l (milligram/ litre). Exceeding the limit value indicates corrosion in the potable water system. This is not usually a health problem but may indicate potential for other types of corrosion, like heavy metals. Keep the iron values as low as possible because deposits of iron may reduce the disinfection effect. High iron content will discolour the water, as well as clothes and sanitary installations, and give the water an unpleasant taste.

Conductivity: See 4.3.1.

Copper: Limit value is 1.0 mg/l, measured at the end of the piping. 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 alkalising system is not functioning 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 gastro-intestinal disorders. High copper content will give the water a bitter taste and cause discolouring of sanitary equipment and sometimes give blonde individuals a greenish hair colour tinge, 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 excessive copper content in the potable water (Photo: Bjørn Løfsgaard)

Supplementary analyses:

Calcium: If an alkalising filter, see 8.1, is used in the water treatment process, analyse calcium levels 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 annual routine control

Unless the potable water regulations state otherwise, an increased number of physical/chemical parameters should be analysed annually by an accredited laboratory. Appendix 8 describes how to collect the samples but the laboratory should specify what type of bottles to use. The annual programme should take place simultaneously with the monthly analyses and at the same locations on the distribution system (living quarters). The programme should include the following parameters:

Benzene: Should 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: Should be below 0.010 μg/l. The environment may be contaminated by polycyclic aromatic hydrocarbons and high content proves that the contamination has reached the potable water. It is most likely carcinogenic.

Bromate: Should be below 5 μg/l. By-product when water containing chlorine and bromide is treated with UV. May be formed when electro chlorinated seawater has passed an evaporator. Also found offshore as a pollutant after using hypochlorite that is not approved for potable water use, see 2.4. May be carcinogenic and genotoxic.

Cadmium: Should be below 5 μg/l. Higher content of cadmium is normally a sign of corrosion on the pipelines and fixtures. Cadmium is toxic, accumulating in the human body and affecting many organs. May be carcinogenic.

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

Lead: Should be below 10 µg/l. High content of lead is normally caused by corrosion in pipelines and fittings. Lead is toxic, accumulating in the human body and affecting many organs.

Polycyclic aromatic hydrocarbons (PAH): Should 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 from exhaust pollution via air vents for tanks. May be carcinogenic.

Trihalomethanes (THM): Should be below 50 µg/l (includes the sum of chloroform, bromoform, dibromochloromethane and bromodichloromethane). These substances have been found on offshore units following electro chlorination of the seawater inlets. THMs 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 waterworks already contains high levels of THMs, especially when the water is chlorinated several times (bunkering to tanks that contain much water). Chloroform and bromodichloromethane are most likely carcinogenic. More research is needed before the other substances can be classified.

Supplementary analyses:
Boron: Should be below 1.0 mg/l. Only needs to be measured for reverse osmosis produced water. Boron is a seawater component, and boron may pass reverse osmosis membranes. May cause adverse reproductive and developmental effects.

Glycols: Should be below 10 µg/l. Only needs to be analysed if there is a risk of pollution through leakages from evaporators etc.

Chromium: Should be below 50 µg/l. Only needs to be analysed the first year on new offshore units to detect chromium pollution from valves and fittings.

Nickel: Should be below 20 µg/l. Only needs to be analysed the first year on new offshore units to detect nickel pollution from valves and fittings.

4.3.5 Parameters that may be exempt

In general, all parameters mentioned in the potable water regulations are to be analysed. Some parameters are unlikely to be exceeded in offshore systems, and may be omittedt from the analysis programme. The regulations state how to do this. This applies to the following parameters:

1.2-dichlorethane: Not detected offshore.

Acrylamide: 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 met by analyses done by the onshore waterworks.

Ammonia: Not detected offshore.

Antimony: Not applicable for Norwegian water.

Arsenic: Not applicable for Norwegian water.

Chemical oxygen demand (COD) (or TOC): Not detected offshore.

Chloride: Should be below 200 mg/l. Only to be measured if the conductivity is high. High content leads to corrosive water, unpleasant taste and indicates seawater 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.

Cyanide: Not applicable for Norwegian water.

Epichlorohydrine: Not applicable for Norwegian water.

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

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

Mercury: Not applicable for Norwegian water.

Nitrate and Nitrite: Not used offshore. The analysis requirements are met by analyses done by the onshore waterworks.

Pesticides: Not used offshore. The analysis requirements are met by analyses done by the onshore waterworks.

Selenium: Not applicable for Norwegian water.

Sodium: Should be below 200 mg/l, ideally far below this level. Only to be measured if the values for conductivity are unnormal. High levels can be due to failure in the production unit or contamination from seawater. The sodium content offshore is no problem for 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 seawater contamination is revealed when measuring conductivity. Offshore water treatment does not carry risks for sulphate contamination.

Tetrachloroethene and trichloroethene: Not detected offshore.

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 available to the consumer. Normally this will via taps and applies to all taps on the unit. For testing purposes, a risk analysis is needed to find the most important taps and other testing points. If there are many points, it is normal to adopt 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 distribution 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

Bottled drinking water may supplement the water supply but there is no reason to compromise on quality. As a thirst quencher, in addition to normal intake of juice, milk, tea and coffee, water is recommended and unrivalled. Drinking water coolers placed at gathering points make it more tempting to drink water. Whether the water comes from a potable water system or is delivered in a bottle or water barrel has no significant health consequence. For those who are 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 as natural mineral water, and is covered by other rules and regulations. These products may have very high levels of sodium, fluoride or other substances (figure 4.9). 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

Chlorine: See 4.3.1. Free and total chlorine is measured in milligrams per litre (mg/l). Normal chlorine values during offshore operation 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 claims to

measure free chlorine values as low as 0.01 mg/l. Such low measured values may not be reliable. 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 can 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 milligrams per litre platinum (mg/l Pt) by photometer or spectrophotometer. The measuring equipment must measure colour values within 2-50 mg Pt/l. Subtract the margin of error of the measuring equipment from the colour limit, and if the margin of error is +/- 2 mg Pt/l, reject water with a higher colour than 18.

Conductivity: See 4.3.1. Measured in milliSiemens 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°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. Calibration of this equipment is critical.

Extra equipment:
For units operating on locations where no land-based laboratories are nearby, tests for colony counts, *E. coli* and other bacteriological parameters can be performed with simple tes tkits (they give results in 24-48 hrs). These test kits can also be used by units that want quicker and more frequent measuring under normal operations, i.e. when checking water to trace problems.

Figure 4.9: Some natural mineral water has very high sodium content, as shown by the conductivity meter (Photo: Eyvind Andersen)

5. General design requirements

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

Failure in the potable water system is troublesome as it is difficult to find other water sources. A water-borne epidemic can infect so many individuals within a short time that it will become difficult to maintain the operation of the unit.

The HSE regulations emphasise that potable water systems must be designed to minimise risks of failure as much as possible, by duplicating essential elements in the process, and choosing systems that are easy to operate, with minimal risk of technical malfunction

When deciding if an offshore unit will have water production equipment, it should be noted that the produced water is usually of very high quality and is the cheapest solution in the long term. Bunkering of water involves a long chain of operations, each of which may fail, see chapter 7.

Design suggestions for offshore potable water systems are 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 how to design a potable water system. The numbers given on the drawing refer to the following text:

1. Two seawater inlets supply the water. This makes it possible to use seawater from different locations and different depths, thereby avoiding local contamination. The inlets are closeable, and are not connected to the same sea chest that supplies cooling water for machinery or other types of seawater consumption that may occur close to shore.

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

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

4. Bunkering hoses should be flushed and samples taken before filling the tanks. Two bunkering stations increase the possibility for bunkering in bad weather. Flush the hose and pipe with full bunkering speed (often around 250 m^3/h). The flush water pipe size should match the capacity of the bunkering pipe. The piping needs a low point drain to empty the bunkering pipes after bunkering.

5. Flowmeter-controlled chlorination equipment ensures correct chlorination of bunkered and circulated water.

6. Minimum two separate storage tanks, see table 9.1, ensures available water even if one tank must be drained due to pollution, maintenance etc. The tanks have coffer dams/ clean areas on all sides except against adjacent potable water tanks. The tanks have drain valves, and tank suction is placed a little higher to avoid tank sediment 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 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 make it impossible to bunker water to a tank that is also supplying the distribution network.

7. Two frequency-controlled water pumps each have 100% supply capacity. Pumping will normally be a better solution than using hydrophore tanks due to cleaning requirements and microbial growth potential.

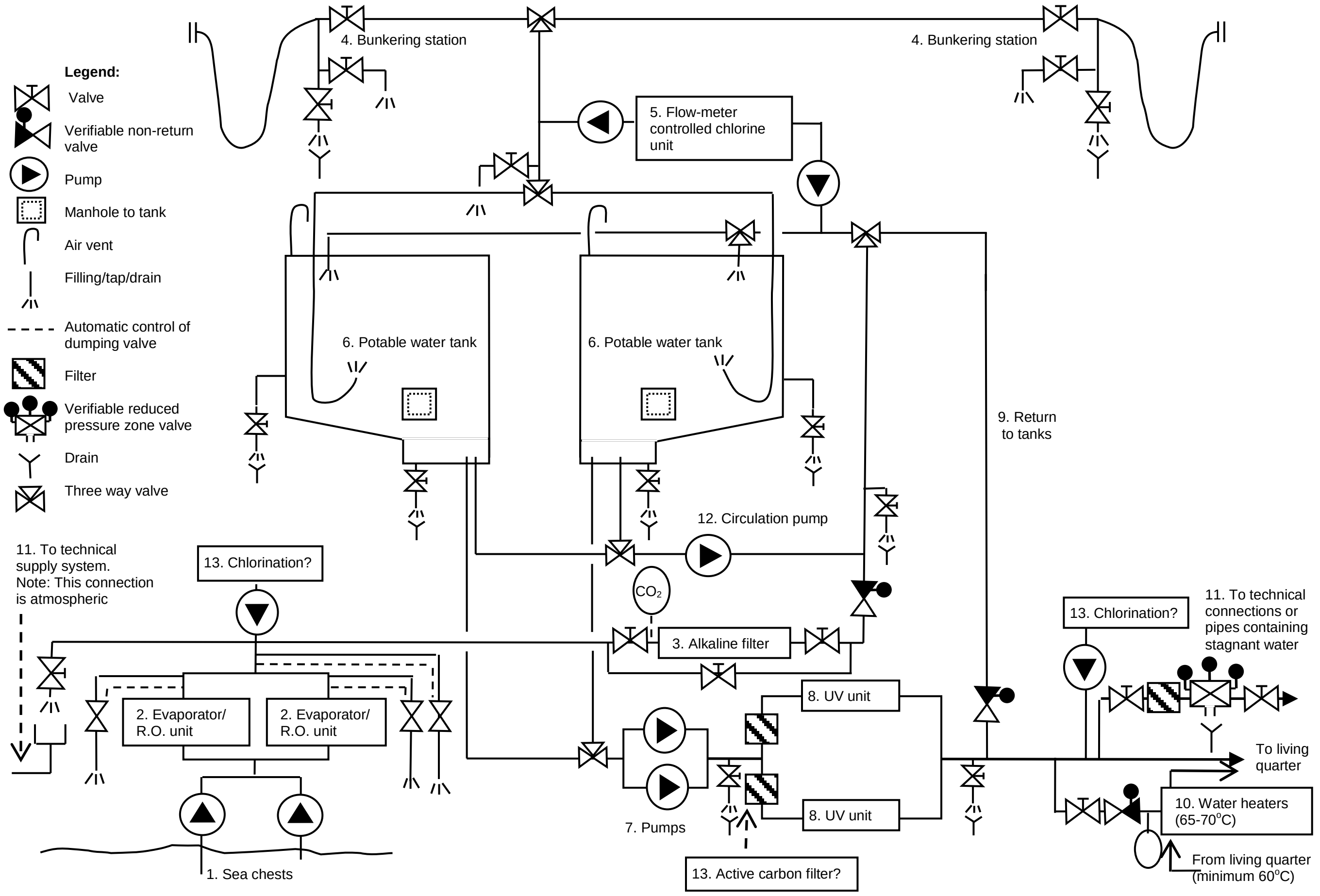

Figure 5.1: Outline of an offshore potable water system (Illustration: Karin Melsom)

8. Two or more UV units which, even with one unit out of action 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 valves that shut off the water flow if technical failure or treatment 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 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. An expansion tank keeps the pressure stable.

11. Where other systems are connected to the potable water system, such connections are atmospheric or in other ways separated to prevent back suction of dirty water, see 9.2.5. Avoid stagnant water and locate safety measures 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.

13. For units operating in hot climates, and for units that have problems with growth of biofilm, continuous chlorination may be an advantage (or other water treatment, like chlorine dioxide or silver/copper ionisation) to prevent problems with biofilm, *Legionella* etc. As continuous chlorination will increase the amount of chlorination by-products, we recommend the following design: Chlorine is added after the water production unit and may be topped up through circulation of the tanks. Prior to UV disinfection, chlorine and chlorination by-products are removed in an active carbon filter (location prior to UV is an advantage if bacteriological growth occurs in the carbon filter, can double as a particle filter). Fresh chlorine for the cold water distribution network is then added after the calorifier branch off (chlorine in the hot water system will increase corrosion). We recommend flowmeter controlled chlorination units.

5.2 Advice for design and construction

Most considerations when designing offshore potable water systems should be obvious. Nevertheless, it is easy to make mistakes, because some measures are forgotten or there are other technical, economical or practical factors. The NIPH suggests that individuals in charge of the project use the checklist in appendix 1 to evaluate if the project meets regulatory requirements. A person with broad experience in operating such system should be given the role as system responsible in the design phase. This person shall ensure that the entire system is functional with regard to technical solutions, operation and maintenance.

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 compression (Photo: Bjørn Løfsgaard)

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 clean up to 2 metres and very dirty above 4 metres (Photo: Eyvind Andersen)

Below we have listed the most important aspects when designing a potable water system. 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.

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. Inadequate ergonomic design can result in necessary work operations not being undertaken in a proper manner. The NIPH has experienced inferior ergonomic design in the following situations:

- The bunkering station flush valve is placed so that the crew on the unit or the supply vessel crew is subject to heavy splashes of water.
- Water tank height is too high or low, which obstructs cleaning and maintenance (figure 5.3). Ladders and platforms can be built inside the tank to make maintenance easy, see 9.1.2, but such equipment must also be constructed to facilitate cleaning and maintenance.

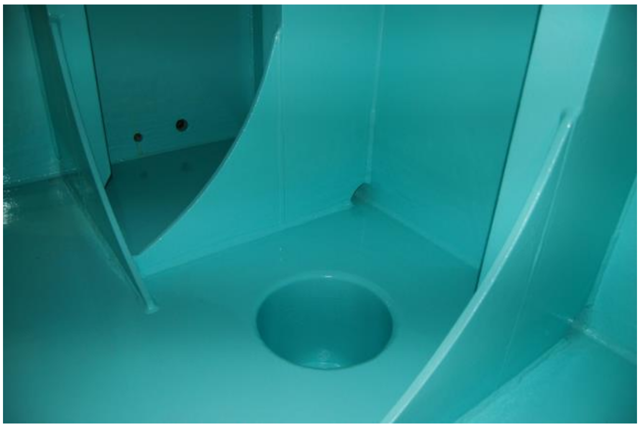

Figure 5.4: This tank has a drain well, and the stiffeners are placed vertically, with drain cavities against the tank floor. Consequently the tank is easy to drain (Photo: Eyvind Andersen)

- Existing potable water tanks often have compartments and braces on the inside, making cleaning and maintenance difficult. This should be avoided if possible, or be designed to make access easy, and to allow flush water drain away properly (figure 5.4).
- Potable water tanks lack an effective low point drain.
- The design of alkalising 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 (figure 5.5).
- Water heaters and hydrophore tanks often have limited access for internal maintenance.
- Manual valves 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 minimise mistakes that could jeopardise the water supply.

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 potable water system should be based on the use of simple and robust technical solutions, see the Facilities Regulations § 5. Avoid technical solutions with many different and complicated details that may fail and choose simple solutions to eliminate the risk of failure and minimise the risk for human error. Avoid the following solutions:

- 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 detect, 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 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.

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

If the water is stored too long, an unpleasant taste and odour may develop. Keep the storage tanks in operation to prevent this, and do not store water for more than 20 days. Under normal operation the tanks cannot 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, take non-conformity action, see 3.5. The regulations do not state minimum requirements for storage of bottled water, this is decided as part of the company's emergency preparedness planning.

5.2.4 Hygienic barriers – preventing contamination

A fundamental principle in Norwegian water supply, is the requirement for independent hygienic barriers against the various contaminants that could occur in a potable water system, see the Potable Water Regulations § 14. The barriers ensure that even if one barrier fails 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:

- Something preventing contamination of seawater used in potable water supply, see 6.1.1.
- Something diluting seawater contamination to a harmless concentration before the water reaches the seawater inlets, see 6.1.2.
- A treatment process removes or makes microbes harmless, breaking 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 being recontaminated, see chapter 9.

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

- Seawater inlet safety require restrictions in the discharge of polluted water from the offshore unit. The remaining wastewater should be diluted and the seawater inlet located in the most suitable place according to water depth, polluted discharge water and common current directions, see 6.1. These safety measures provide at least one barrier against most types of chemical pollution, and furthermore this is a premise for safe water production.
- Combined with safe water inlets, water production through evaporation or reverse osmosis is considered as a barrier against most types of pollution. Still, note possible evaporation problems with volatile substances, see chapter 6.
- The hose connections and routines for bunkering water from the onshore supply source represent a weakness 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 to be 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. Avoid contamination via leakage or pollution through chemical dosing tanks or air vents

by placing tanks in areas separated from other contamination sources.
- Suction risk due to differences in pressure in parts of the system should be evaluated.

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.
- Protect the equipment against pollution from other process equipment.
- Potable water pipes shall be physically secured, clearly marked and colour-coded to make the following easy in case of an emergency, and to prevent coupling with other fluid systems by mistake etc.

- Secure tanks for additives by using screw caps or equivalent and mark 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 and design 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 know how far it extends. A sufficient number of strategically placed sample points along the entire system are necessary. Place these sample points on bunkering stations, storage tanks, and subsequent to each main component in the system, such as production unit, disinfection unit, alkalising filter and other treatment units.

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

Placing, marking and protection of equipment are described in 5.2.5, but the following should be observed: Piping from the main pipeline to the sample valve should be as short as possible to avoid stagnant water. Piping after the sample valve should be self-draining, as short as possible and shaped to enable easy disinfection by means of chlorine, alcohol or heat, as otherwise they will contain stagnant water and will be difficult to disinfect (figure 5.8). An end cap on the pipe is recommended.

5.2.7 Paints and protective coatings

Paints and coatings used in storage tanks have often contaminated the potable water by improper use, shortened hardening processes or illegal use of thinners. The owner must be able to document that such products were used according to the manufacturer’s instructions, see 9.1.4.

5.3 System alterations

When parts of a potable water system are 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 5.8: Short and self-draining test tap with sufficiently small pipe diameter. The short distance from main pipe to valve eliminates stagnant water. By placing the outtake on the upper half of the pipe, trapping of particles is avoided. A shorter sample point end would have eased sample point disinfection (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 seawater used in the production is not polluted. If polluted seawater is suspected, water production must cease.

The water production capacity should be sufficient to cover potable water consumption and technical water consumption (if any), even at low seawater temperatures (5°C). Furthermore the production capacity should be large enough to cover re-filling of emptied tanks (with 2 x 100% production capacity, one unit can be used during normal operations, whilst the other is used in addition when tanks need to be re-filled).

6.1 Seawater inlets

A seawater system normally has two seawater inlets. The water is pumped through seawater pipes for the various types of use, for instance firefighting water or production unit for potable water. The seawater must be protected against pollution.

6.1.1 Possible pollution threats

Seawater used in the potable water production may be polluted by discharge from own or adjacent offshore units or from ships. Do not produce water when the water is polluted or near harbours etc., and routines for closing of seawater inlets must be established for units with this possibility. The following pollutants are the most common:

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

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

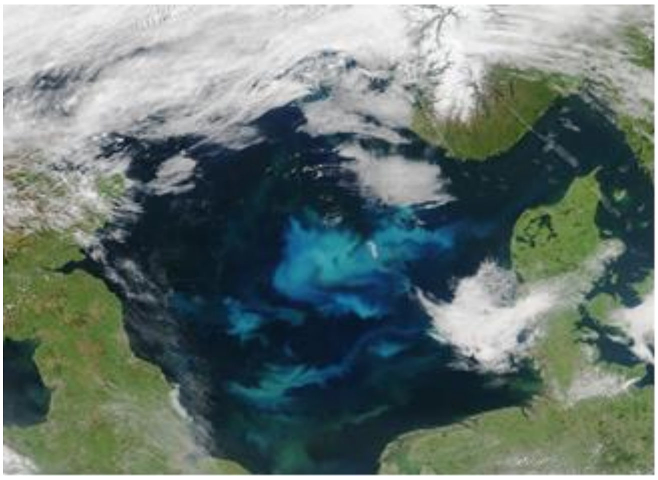

Figure 6.1: Intense plankton blooms, here observed in the North Sea from NASA's Earth Observatory, may occur from spring to autumn, and can sometimes cause problems with odour and taste on units that produce water (Photo: NASA/Jesse Allen)

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

Growth of microorganisms: Periodically some organisms have an intense growth in seawater (figure 6.1). Some will emit volatile components into the seawater, causing problems with odour and taste in the produced water. This occurs mostly from spring to autumn. Vertically separated seawater inlets can make it possible to use water from less affected depths.

Electrochlorination 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 (in comparison: copper ionisation poses no such threat). To minimise such problems, the company must make sure that the electrochlorination is performed without overdosing chlorine in periods with low seawater consumption. The company must also establish a sufficient analysis programme to document that the electrochlorination is conducted without health risks.

6.1.2 Placing seawater inlets

Placing seawater 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 recognised 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:

Seawater inlets should be located as far away from the discharge points as technically feasible. When waves hit platform legs the result is a strong shift in the water masses (figure 6.2). Discharge beneath the platform into turbulent water masses can cause spreading and thinning of pollution both horizontally and vertically. Seawater inlet and discharge points should be located on separate platform sides, preferably the seawater inlet on the outside of the leg and the discharge on the inside. By placing seawater inlets deep down, the influence from the surface is slight, temperatures are low and fewer microbes exist.

Placing seawater inlets favourable to currents Place the seawater inlets upstream of the discharge point, considering the most common current direction (figure 6.3).

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

Figure 6.2: Normally there is turbulence in the water around the platform legs. Seawater inlets should be placed where the danger of pollution is minimal (Photo: Eyvind Andersen)

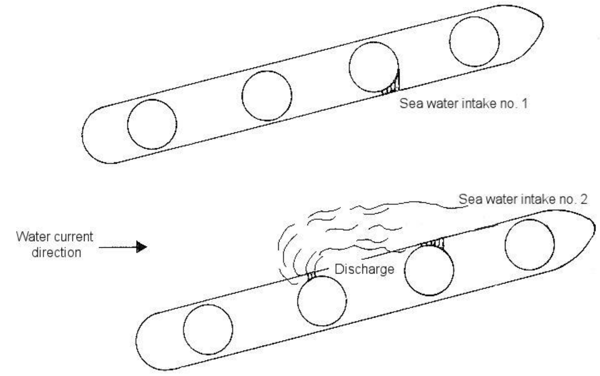

Figure 6.3: Seawater inlets must not be placed downstream from the discharge points, given prevailing current direction. Inlets should not be placed on the same side as the discharge, and the inlets above, should be moved to the outside of the pontoons (Illustration: NIVA's engineering office)

Design and size of discharge pipes influence the way discharge water is spread and diluted. A pipe ending in many small holes (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 seawater inlets operating separately should be installed. The unit should have at least two seawater inlets with a good separation. When local currents change so that polluted discharge water is directed towards the operational seawater inlet, use the other seawater inlet.

Other seawater connections must be designed to prevent contamination of the seawater pipe system by back-flow or back-suction. The seawater inlet can be secured by being the first connection on the seawater system and securing other branches against back flow, see 9.2.5.

The best solution is to have closeable seawater inlets. These inlets should not be used to supply machinery cooling water or other consumption that will occur close to shore, as this will increase the risk for biofilm formation, which may contain *Pseudomonas* or other harmful microbes, that may in turn contaminate the potable water system. Such separation is particularly important for units that have diving systems, as these are more vulnerable to the effects of contamination. For newbuilds this design is a requirement according to NMA potable water regulations section 11.2.

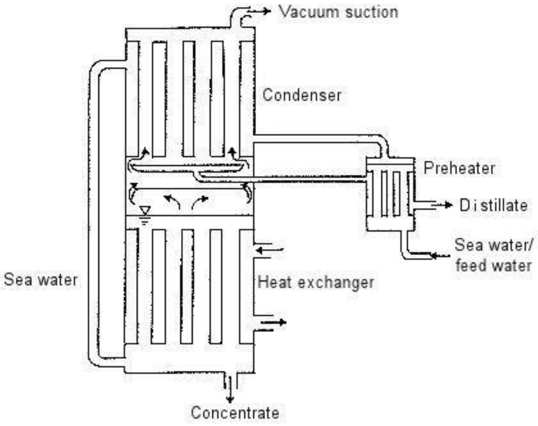

Figure 6.4: Scetch of a vacuum distillation unit (Illustration: NIVA's engineering office)

6.2 Evaporation

Evaporation is the most common method used in offshore water production in Norway. The evaporation process means that seawater is heated until it evaporates and then the vapor is cooled, resulting in fresh water. There are different types of evaporation units, but only vacuum distillation will be described here, see figure 6.4, this being about the only type of evaporation unit in use in Norway.

When pressure is reduced, the evaporation temperature is lowered to between 30 and 60° C. Seawater 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 to start the vaporisation process (figure 6.5). 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 seawater 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 seawater is electrochlorinated 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 electrochlorination, and by reducing the effect of the evaporator, thus producing cleaner water. Volatile substances can be removed, see 8.4.

Figure 6.5: Shows the inside of an evaporator. The net prevents seawater drops from passing on to the distillate (Photo: Bjørn Løfsgaard)

6.3 Reverse osmosis

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

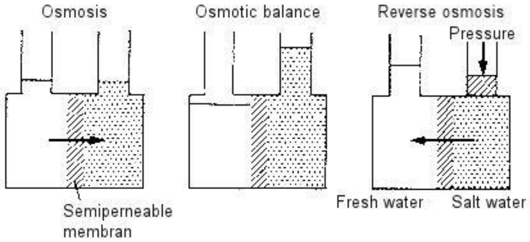

Figure 6.6: Process principles for osmosis and reverse osmosis (Illustration from B3/NIVA's engineering office)

Figure 6.7: Reverse osmosis unit. The membranes lay coiled within the white tubes on the right (Photo: Eyvind Andersen)

The principles for osmosis and reverse osmosis are shown in figure 6.6. 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 seawater salt content increases during the process, the concentrate must be drained into the waste water system and new seawater supplied.

Except for boron, see supplementary analyses in 4.3.4, reverse osmosis is safer than evaporation in eliminating contamination but if the membranes are damaged microbes and other substances can slip through. Membranes vary in design, see figure 6.7. To avoid damage to the membranes by pollutants in the seawater, the water requires treatment. Chlorine is often added in the seawater 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 or by using sodium bisulphite. The feed water may contain particles too small to be stopped in the seawater inlet filter, but large enough to clog the fibre membranes. Particles down to 5 micrometers must be removedby using different filter types. To reduce the manual maintenance work, the flushing and cleaning process should be automated. Some membranes will break if pressurised in the wrong direction and must be protected against this.

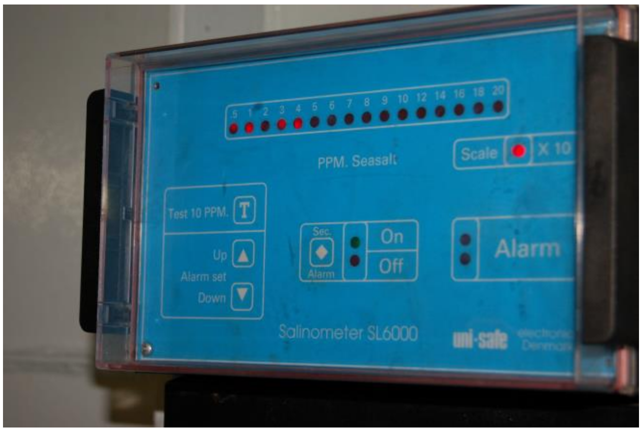

Figure 6.8: A conductivity meter automatically measures salt content in produced water and dumps it if the 6 mS/m limit is exceeded (Photo: Eyvind Andersen)

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. Seawater has a high conductivity level, and a possible malfunction in the production process can be detected by a rise in the conductivity (figure 6.8).

The conductivity meter, also called a salinometer, is placed at the production unit outlet. Conductivity determines the quantity of salt in the water. The limits are 6 mS/m for the evaporation 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 indicates that the system is not operating as it should. Conductivity is described under chapter 4.3.1.

There have been several incidents where malfunctions in conductivity meters or dump valves have resulted in saltwater contamination of the potable water. This is a hygienic problem and requires much work to reestablish good potable water quality. The NMA potable water regulations section 6.6 now requires that water production units are equipped with two stages of conductivity metering and dumping (figure 6.9).

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.

Figure 6.9: Evaporator with two independently controlled (blue colour) dumping valves (Photo: Eyvind Andersen)

6.5 Use of chemicals

All substances used in the potable water process should be certified, see 2.4. Filling pipes used for adding chemicals should 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.

Except for anti-scalants, chemicals are seldom continuously added in an osmotic process. Periodically, chemicals are used to clean the membranes and for preservation as membranes can easily be damaged when not in use.

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 on board the supply vessel and in the bunkering process through for example dirty hoses. Tests at the bunkering station have occasionally revealed pollution by seawater, hydrocarbons 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 practically 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. Check the disinfection units and control routines, as each disinfection unit should be able to deactivate the majority of microbes in the water independently. The risk 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: Bunkering 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 and 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 supplies accommodation.

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. Design the bunkering pipe system to ensure complete drainage after bunkering. Mark both bunkering stations and hoses to avoid confusion with hoses for other liquids, and keep the bunkering stations for potable water separate from bunkering stations for other types of fresh water.

Bunkering hoses (1) are either coiled up on a drum, or hang down the sides of the unit. The couplings are susceptible to pollution from seawater, various processes on board and pollution from birds. Dead birds have been found in potable water pipes so it is important to cover the hose ends (figure 7.4). 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.

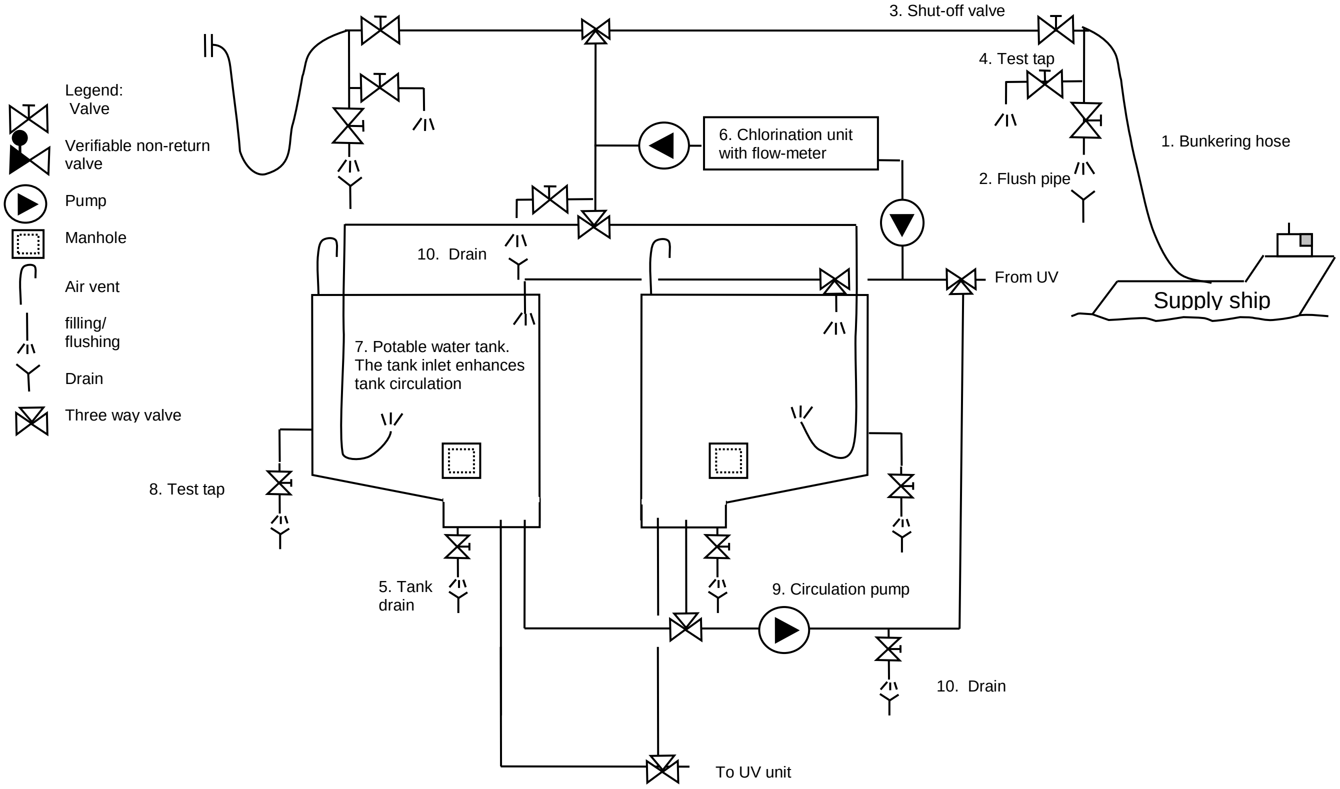

Figure 7.3: Bunkering system with recirculation pipe (Illustration: Karin Melsom)

Figure 7.4 Bunkering hose with safely secured end-cap (Photo: Eyvind Andersen)

Bunkering hoses are normally made of rubber, and may act as "food" for microbes. Dark coloured hoses with moisture inside warm up quickly in sunlight, resulting in excellent growing conditions for microbes. Flush hoses thoroughly before each bunkering, and after bunkering they should be drained before they are hanged and stored (figure 7.5). Hoses are difficult to clean and should therefore be regularly replaced.

At the connection point for the bunkering hose a flush pipe (2) should be installed as well as a shut-off valve downstream on the feed pipe (3). Sudden increase in water flow results in contaminants being dislodged from the walls of pipes and hoses. To prevent an increase in water flow after flushing, the flush water pipe must have at least the same dimension as the bunkering pipe. Design bunkering stations to prevent operating personnel or the supply vessel crew from being sprayed with water during flushing. 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 old potable water from storage tanks (5) before bunkering. This will wash out the sediment and make chlorination more effective, see 7.2, reducing the amount of chlorination by-products, since the water is chlorinated only once, see 4.1.2.

Figure 7.5: 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)

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 help with recirculation.

Test taps (8) make it possible to sample the chlorinated water in the tanks without simultaneously feeding it 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) can provide 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 after bunkering will have to be dumped and tanks refilled, increasing the risk of running out of water. Circulation is enhanced by separating the tank inlet and outlet. Low point drains on the bunkering and circulation pipes (10) make it possible to avoid stagnant water after bunkering.

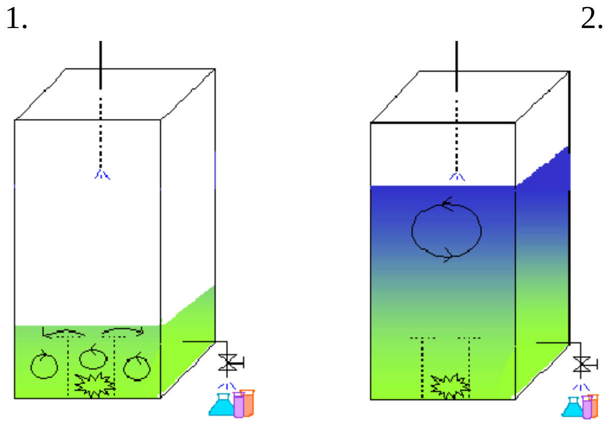

Figure 7.6: Pouring chlorine directly into storage tanks may result in lack of chlorination in parts of the tank and overdosing in other parts (Illustration: Bjørn Løfsgaard).

Figure 7.7: 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 in the water flow during the entire bunkering process. The shape of offshore potable water tanks may result in inadequately disinfected water, because of insufficient mixing when chlorine is poured directly into storage tanks before bunkering (figure 7.6). 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 Flow meter-regulated dosing

A flow meter on the bunkering pipe adjusts the chlorine pump speed (figure 7.7). The pump doses a calculated amount of chlorine per cubic metre water. To chlorinate bunkered water adequately, adjust the concentration of the solution. If bunkering is always into an empty tank, the same chlorine concentration can be used each time. When bunkering to a tank with residual water (avoid if possible), the chlorine concentration should either be increased to chlorinate the residual water as well, or the volume of chlorine that the flow meter 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. Use a diluted chlorine solution, 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 (avoid 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. Adjust the dosing according to experience from previous bunkering to achieve 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 flow meter-regulated, calculate the dosing speed, see appendix 11, as the dosing shall be uniform during all the bunkering time.

Figure 7.8: Dumping of potable water from tank. Dump "old" water prior to bunkering. This applies to both supply vessels and offshore units (Photo: Eyvind Andersen)

Figure 7.9: When flush valve and the bunkering hose have corresponding diameters the system can be flushed with maximum pressure. (Photo: Eyvind Andersen)

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. 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 problems with colony counts, chlorination by-products and other pollution of tanks and pipe system (figure 7.8).

7.3.2 Bunkering

Bunkering starts by flushing the hose and piping a few minutes under maximum pressure (figure 7.9). After flushing, take a sample to determine colour, odour, taste, clarity, conductivity and pH of the water, see requirements in chapter 4.3.2. As odour, taste and clarity are subjective, let two individuals share this responsibility. Water that does not fulfil the requirements should be rejected (figure 7.10). If a supply vessel delivers water from more than one tank, take samples from each tank. If the water is acceptable, the bunkering can start.

7.3.3 After bunkering

Isolate the storage tanks for 30 minutes after bunkering, then test a sample should 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 to take samples 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. Repeat until free residual chlorine can be measured. This practice is not ideal, since it might be difficult to mix the chlorine in the water. Set the chlorine dosage higher than the minimum requirements to avoid such unfortunate situations. Aim for a free chlorine level of 0.3 mg/l after 30 minutes.

If the concentration of free chlorine is too high, dilute the water with water from other storage tanks. The water can also be stored before consumption. 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 of chlorine, and this should be avoided if possible. If the water must 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 accidentally 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 water is evaluated visually (clear, without noticeable colour) and tested for odour, taste and conductivity.

7.4 Logging

Keep a log of the various details in the bunkering procedure, which allows 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 7.10: Determination of odour, taste and clarity 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 seawater must be treated to meet the quality requirements in the regulations. In this chapter the most frequently used methods are described. All additives to the potable water, such as chlorine, filter material, etc. have to be certified, see 2.4.

Potable water produced from seawater must be treated to make it less corrosive, see 8.1. All offshore potable water must be disinfected 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 should be disinfected as it is being distributed to the consumers. The NIPH no longer recommends disinfection only by use of chlorine, as UV treatment has been proven to be more effective against some microbes, see 8.3. Chlorine has advantages, both when disinfecting pipes and tanks, and its effect is easily verified by measuring chlorine residue.

8.1 Corrosion control

Corrosion in a potable water system means that the water attacks metal in the piping system, treatment units and fittings. Corrosion causes, their 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 to prevent corrosion, and does not require any filter.

8.1.1 Alkaline filter

Alkaline filters are known by different names, for example palatability filter, limestone filter and rehardening filter. The filters may be designed in several 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 stabilise 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.

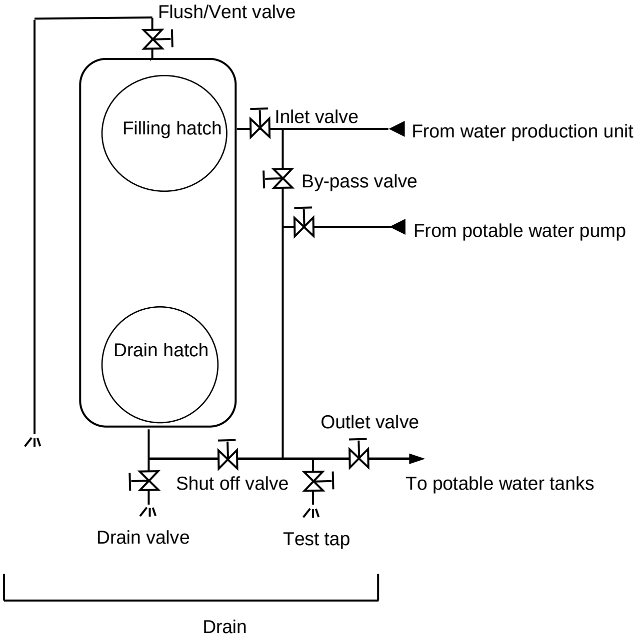

Figure 8.1: Design the filter with easy access for cleaning, changing of filter mass and maintenance (Illustration: Karin Melsom)

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.

Dolomite filter (half-burnt dolomite)
Filters with half-burnt dolomite are the most compact and are 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 alkalisation are achieved, simultaneously stabilising 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.

Limestone filter/marble filter
Crushed limestone ($CaCO_3$, 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 stabilises 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 must be replenished regularly to maintain an even mass grading.

Operation and maintenance
Maintain the filter to ensure sufficient water quality, according to the vendor's instructions. Most filters must be back flushed to prevent clogging and to remove dirt, and refilled to ensure that they always are at least 75% full. Some substances in the mass do not dissolve, and consequently accumulate in the filter. Some will be flushed out during return flushing, but after a while the tanks have to be emptied of these substances before refilling with new filter mass. Due to poor maintenance, microbes might settle in the filter mass, causing high colony counts in the potable water tanks. Empty, clean and disinfect the filter 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 mixed, but it can give similar corrosion protection as alkalisation. 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 galvanised iron, the corrosion compounds are washed away into the water before the water quality stabilises.

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. The precise mechanism in this process is not well known. Silicate ions can prevent metal ion deposits like trivalent iron, thereby reducing rust clusters 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 2.4. Dosing is normally done with a flowmeter-regulated pump. This system is easier to use than alkalising filters, and the risk of microbiological growth is avoided. Place the dosing point after UV units.

8.2 Disinfection by chlorination

Chlorine is still the most commonly used disinfectant of potable water worldwide, and chlorination of potable water offshore does not pose any health risks, 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 higher in bunkered water, consequently requiring more chlorine 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)

The effect of chlorine is a function of concentration x time, and the higher the concentration, the shorter time is needed for disinfection. Chlorine inactivates bacteria by attacking the cell wall, penetrating the cell and destroying the enzyme systems. Viruses are inactivated 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 require a free chlorine level of at least 0.05 mg/l after 30 minutes of contact. This is sufficient, even with the low concentration that is recommended for disinfection in Norway.

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 cannot be confirmed, the water is not satisfactorily disinfected. Reject the water unless the potable water system is equipped to *mix in* extra chlorine, see 7.3.3. Calculation of chlorine amounts and mixing of chlorine solutions etc., are described in appendix 11.

8.2.1 The significance of 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.

Predicting the amount of chlorine needed is often a greater problem for waterworks 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 is refused if the colour is unacceptable.

Unlike many other countries, Norway has a tradition of not accepting water tasting of chlorine. The free residual chlorine in the water should not exceed 0.5 mg/l after treatment, with the exception of disinfection of the pipe system, see 9.2.9. Generally, 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 show that chlorine is 50 times more effecttive in 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 less active hypochlorite ion (OCl^-) dominates at a level of pH>8. Consequently, disinfection preferably should be done before the water is alkalised.

8.2.2 Sodium hypochlorite

Sodium hypochlorite (NaOCl) is sold in liquid form and is 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 longer than 3 months after production date, but when refrigerated it may be good for 6 months. Some vendors supply chlorine of lower concentration that may be stored longer.

The chlorine solution can be added to the water without premixing, but if the chlorine pump has sufficient capacity, dosing a larger volume gives better control of the process. Sodium hypochlorite is a strong alkaline solution (pH 10-11), and precautions must 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. Follow instructions carefully read and use face protection, rubber apron, rubber gloves and other protective items as suggested in the instruction data sheet. Accidents in operation of swimming pools have been reported, where sodium hypochlorite has been mixed with acid to form 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.

Figure 8.3: Flow meter-controlled chlorination unit (Photo: Eyvind Andersen)

Sodium hypochlorite can be produced by sodium chloride electrolysis (NaCl), so called electrochlorination. Several offshore units use electrochlorination on the seawater inlet to stop marine growth. It is important to be aware of that chlorous acid evaporates at a lower temperature than water, and may result in higher concentration in water produced through evaporation. This can cause problems with taste, odour 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 environments, the same precautions as for sodium hypochlorite should be taken, see 8.2.2, but it should also be noted that the chemical must be stored safely as it may cause explosions and fires if mixed with some other chemicals. 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. Separate these components before dosing to prevent clogging of nozzles. Alternatively, lift the suction hoses to the chlorine-dosing pump 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 NMA potable water regulations section 6.3 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, add the chlorine before the water reaches the alkaline filter, since chlorine is most effective in acidic 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.

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 and not the chlorine. Essentialspare parts should always be available. Chlorine pumps are cheap compared to the consequences of inferior chlorination, 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
- 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 incorrect.

8.3 Disinfection by UV radiation

Ultraviolet rays are part of the sun light spectrum and are divided into UV A, -B and -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 and solariums. 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.

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 with UV disinfection, see 4.2.2, because the intensity in the chamber drops, thereby reducing the UV dose. However, coloured water can be disinfected by extending the radiation time and thus increasing the UV dose.

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

Particles in the water may “conceal” microbes. This is particularly problematic if tank sediments are sucked into the potable water inlet (figure 8.4). During bunkering or unstable weather conditions tank sediments may be stirred up. Avoid exceeding the particle limit (turbidity above 1 FNU) 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 alkalising filter. Regular cleaning is therefore important.

There have been some examples of problems with smell after UV disinfection because an odourless compound has been oxidized into something that smells. This has been reported due to unlawful thinner use when painting water tanks, where toluene has been oxidised into benzaldehyde.

Figure 8.5: This UV unit has two radiation chambers, each with 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)

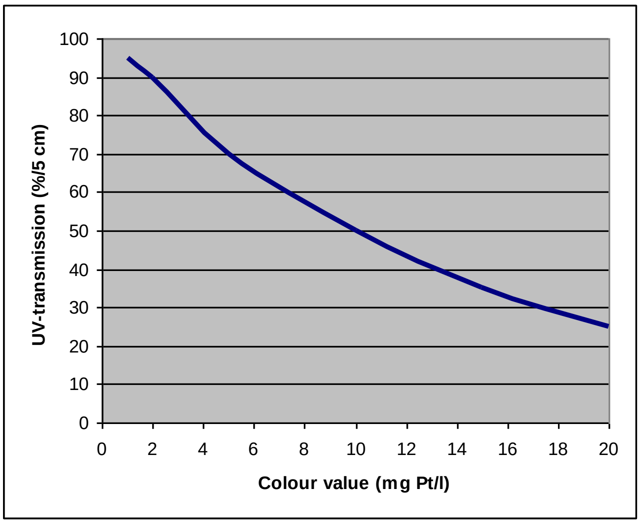

Figure 8.6: The figure shows how average values for UV transmission decrease as the colour number increases. The figure is based on water quality data from a large number of Norwegian water sources (Illustration: Karin Melsom)

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 2.4.

Only use biodosimetrically tested UV units

When building new offshore units, and when replacing old UV units, only install biodosimetrically tested UV units that give an UV dose of 40 mWs/ cm^2. Offshore, use the best available technology available, and these UV units have better systems for operation and control than units approved according to old methods. They also create a barrier against bacterial spores (alternatively 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 older 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 (preferably documented through flow metering); having two 50% chambers in parallel operation is unsafe unless the water is divided evenly.

Design for peak daily consumption

Maximum supply is normally much higher than the average water consumption, as the consumption varies, and the UV unit must be designed for peak flow. However, excess capacity in addition to this will lead to UV units that are large and costly. 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 occur, install a particle filter. 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 waterworks 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, 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 some 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 shows average values for Norwegian water. The real UV transmission of bunkered water of acceptable colour may be lower than 30%/5 cm. 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.

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

Prevent excess heating
By dimensioning the UV unit for the poorest quality of bunkered water, one will need much bigger UV units than 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. UV effect control which limits the UV dose is common for medium pressure UV units and is also increasingly common for low pressure units.

To avoid overheating and shutting of UV units, the suppliers recommended minimum water flow must be met at all times. One recommended solution 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.

About low- and medium pressure UV lamps
Both types of lamps are used offshore. Low pressure lamps emit most of their radiation in the part of the UVspectrum that is most effective against microbes, whilst medium pressure lamps emit radiation over a much broader spectrum. Medium pressure lamps have a higher effect than low pressure lamps and are physically smaller (due to smaller/fewer lamps within each UV unit), and they are not temperature dependent for operation (will not lose effect if they are located in hot or cold areas; low pressure units may lose effect in temperatures below 9^{o}C or above 45^{o}C). Medium pressure lamps will also reach full disinfection effect quicker after being turned on (typically after 60-90 seconds in cold water, where low pressure lamps may need more than 5 minutes to warm up). The disadvantages with medium pressure lamps are that they will have to be replaced more often, and to prevent the formation of un-desirable by-products, medium pressure lamps need to be supplied with doped quarts sleeves that remove radiation below 240 nanometres.

In UV chambers where the UV dose is high, bromate may be formed as a by-product if the water contains bromide and chlorine. Bromate formation can be reduced if the UV unit is equipped with a control device that limits the UV dose (to save power and prevent excess UV dosage at low consumption or when used for disinfecting crystal clear offshore produced water).

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 for how long the radiation tubes have been in operation. The alarm should go to a manned control room.

Each UV unit should have a fail close actuated valve that shutoff the water distribution in the case of electrical or valve failure, failure in one of the radiation tubes or if the sensor indicated the radiation intensity is too low. To ensure that disinfected water is available at all time the UV unit should be connected to a stable emergency power supply.

Air inside the UV chambers will reduce the effect. Avoid gas traps by having high-point vent 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 can be used to verify functioning disinfection (figure 8.7).

8.3.3 Operation and maintenance

Never expose eyes (or skin) to UV light. Symptoms usually appear after a few hours, and such injuries have happened on offshore units. Blurred sight and the feeling of gritty eyes are minor reactions, but temporary or permanent blindness, may be the consequence.

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

Figure 8.8: Here, the UV sensor is placed on top of the UV chamber (Photo: Eyvind Andersen)

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

Intensity meter
If the unit is not equipped with an automatic alarm system, read the UV intensity meter 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 (figure 8.8).

If low UV intensity is detected, the cause must be found and corrected without delay. If it is due to sedimentation on the tubes or sensor eye, the *entire* interior should be cleaned. Check other units in the system too. If the intensity of the radiation tubes is too low, replace the tubes. 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. Replace the UV lamps 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 7000-15000 hours and 1500-3000 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 8.9). The exception to this rule is a radiation tube that malfunctions shortly after replacement. At the next time of replacement all radiation tubes should be replaced, including the newest one.

Cleaning
Clean the radiation chamber (such as quartz sleeves, sensor eyes, reflectors) regularly, depending on water quality – minimum once per three months. If the system is equippedt with automatic mechanisms for cleaning (brushes, rubber rings or equivalent) the efficiency 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 should have the necessary spare parts for continuous operation, ref. approval document, including radiation tubes (a complete set), quartz glass, gaskets, 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.

Note: The type approval is only valid when using radiation tubes and quarts sleeves of at least the same effect as the ones that were a part of the type approval application. If type of radiation tube or quarts sleeve is changed, equal effect must be documented.

Figure 8.9: Control panel for UV unit with eight UV lamps. As both tube 6 and the signal lap for tube 1 is defect, the UV unit is unsafe. The UV intensity is still quite high. This may be due to clear water or long distance between UV sensor and the defect UV lamp (Photo: Eyvind Andersen)

8.4 Active carbon filters

Carbon filters solve certain water quality problems by efficiently removing pollutants in the water. Such substances often cause unpleasant odour 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 may point towards sub-standard operation or unfortunate technical solutions, and such problems should be solved through other means. 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 their 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 annual pipeline disinfection and be replaced according to recommendations made by the supplier. With the probability for bacterial growth, the filter should always be placed in front of the UV unit.

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.

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 increase maintenance work and costs and may also result in inferior water quality. Calorifiers, hydrophore tanks and day tanks are also common types of potable water tanks offshore.

9.1.1 Storage capacity

The owner should be able to document that a sufficient supply of hygienically safe potable water can always be guaranteed. The minimum requirement is 200 litres per day per person, with technical water consumption coming in addition. The amount of potable water to be stored in the tanks depends on how vulnerable the water system is.

A potable water system that exclusively depends on bunkered water is vulnerable because bad weather conditions may make bunkering impossible, and the quality of bunkered water is also often unpredictable. Consequently a larger storage capacity is required. 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 lowered for such units, and may be further reduced if several storage tanks are used.

Offshore units without potable water production on board should have a least three storage tanks. A unit with only two storage tanks cannot bunker water according to the requirements if one tank is out of operation. 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 coating is necessary. This means that one storage tank will be out of operation for several days while 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 odour and taste. Acute 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 for more than 20 days. This will prevent problems with odour or taste caused by the tank coating or decomposition 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 metres high potable water tank in stainless steel with no obstructing internal structures. Such tanks are easy to clean, with no problems with applying and maintenance of coating (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 (figure 9.1), problems related to 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. Avoid frames and other constructions breaking up the interior since this may form pockets of stagnant water that cannot be reached by disinfectants, creating opportunities for growth of microbes. Large interior surfaces, compared to volume, have created problems with odour and taste after protective coatings have been applied, see 9.1.4. Tank height should be at least 2 metres to allow for maintenance work to be carried out comfortably. Tank height should also be less than 4 metres, to avoid having to build permanent access platforms etc. for easy maintenance, see figure 9.2. Avoid scaffolding for maintenance as this takes much time, increases the risk of pollution and may damage the tank coating. For newbuilds the NMA potable water regulations section 7.1 require permanent access platforms for maintenance, minimum for every 4 metres of height.

Figure 9.2: Access platforms aid maintenance in tanks over 4 metres high. Internal structures in tanks should be minimised to enhance circulation and minimise maintenance. Circulation is achieved by placing the inlet in one upper corner of the tank, whilst the outlet is placed in the opposite lower corner (Photo: Eyvind Andersen).

Prevent tank contamination

Potable water tanks should not have joint walls with tanks containing petroleum products, liquid chemicals etc. Newbuilds should be designed with coffer dams or other rooms that do not pose any threat of pollution on all sides except against adjacent potable water tanks, ref. NMA potable water regulations section 7.1. 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. If overflow from potable water tanks is distributed to other tanks (service water etc.), safeguard the overflow line against pollution, see 9.2.5.

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

Figure 9.4: Tank suction (left) is elevated a few centimetres from the tank floor, whilst a drain suction pipe in the pump well in the middle makes it easy to empty the tank (Photo: Eyvind Andersen)

To avoid contamination of all potable water on board, separate the storage tanks 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

Locate the inlets for both bunkered water and return water from the distribution network away from the outlet to enhance water circulation in the tank. Use the high pressure of bunkered water by pointing the inlet in an angle that increases 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. Place the potable water outlet above the bottom level of the tank to prevent sediment entering the water distribution system. Sediment may carry bacteria through the UV unit and may also cause operational problems with the UV unit, pipeline system and filters.

Air vents

Potable water tanks should 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 must have an air vent. Protect the opening against seawater, birds and other substances that might contaminate the water (figure 9.3). The opening should be covered by a fine meshed net of a non-corrosive material.

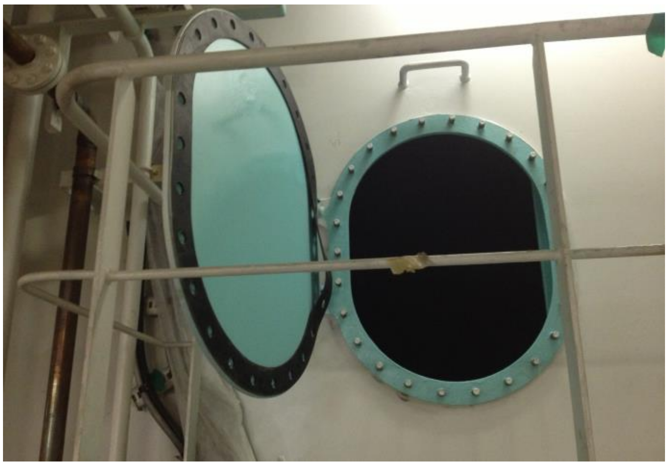

Figure 9.5: The picture shows a storage tank with an accessible manhole (Photo: Eyvind Andersen)

Drainage

The storage tanks should have efficient drainage. Cross braces should have openings near the tank bottom to enable complete drainage. The tank bottom should be sloped or supplied with a pump well leading the water towards the drainage point (figure 9.4). The drain valve should be placed at the lowest point. If such "natural" drainage is not possible, install a permanent pump. Unfortunately storage tanks are often built with a flat bottom and without a pump well. Therefore, the storage tanks are frequently drained by using the potable water pumps, which is unfortunate if a tank is drained because of contamination.

Water temperature

Potable water storage tanks should be placed where they are frost-free and will not be heated by the surroundings, by sun or other heat source. Keep the water temperature below 20^{o} C, even during the summer season (may not be possible in warmer climates, see 9.2.11).

Access possibilities

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

The manhole must have a size and location that provides easy access to the tank for both workers and equipment (figure 9.5). 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.

Figure 9.6: 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 for flushing
High pressure water for tank cleaning 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. Install a drain to handle flush water.

Water gauge
The water gauge system should be automatic. Water quantity in the storage tanks is constantly monitored from the control room, activating an alarm if the water level is low. Visual control is still used on some older offshore units, but use of a dipstick 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 interior cleaning and maintenance (figure 9.6). It must also be possible to take such tanks out of use without having to cut off the water supply on the offshore unit. The design must also ensure that stagnant water is avoided.

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 on board. 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. One example of such procedures is 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 utilised. Water budget, 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 consider the cleaning intervals. 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. Inspect he water gauge, air-vent net and float. Log all results.

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
It must be documented that coating systems are suitable for potable water use, see 9.2.6. Choose a product for potable water tanks recommended by

the supplier. Several products are unsuitable for offshore use, as it will be impossible to achieve the necessary curing conditions due to low temperatures, cold steel and short deadlines. Even if a product is suitable for potable water in general, it must be used within its limitations (figure 9.7).

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 pretreatment, application, curing and washing have been adhered to, see NMA potable water regulations section 7.3 and 4.

After coating new tanks, and after full renewal of old tank coating, the work should be approved by a certified paint inspector (FROSIO level III- or NACE level 2-certified). Before the tank is put into use, verify 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.

Figure 9.7: «White rust» in a potable water tank, is deposits of zinc carbonate. The tank is coated with a product that contains zinc, and that can be used in the pH interval 5.5 to 10. At higher pH, problems with deposits and high zinc levels in the water can occur. In this case poor pH management is the source of the problems, as the measured pH around 11 was far beyond the max limit of 9.5 in the potable water regulations. (Photo: Tjarda den Dunnen)

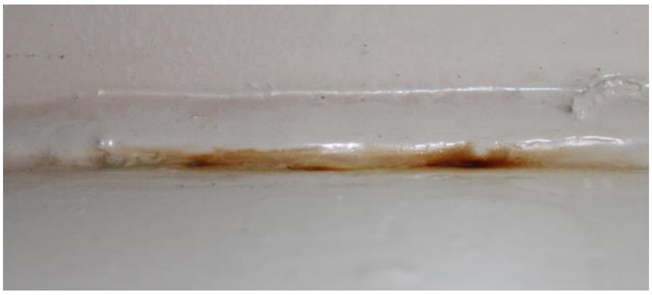

Figure 9.8: Insufficient washing of salts in welding seam before painting has resulted in corrosion (Photo: Bjørn Løfsgaard)

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 9.8).

Application
Spray painting is effective and give good results. A round paint brush is applied where spraying is impossible. Avoid the use of a roller which will give too thick layers and only poorly saturates the surface (gives pores). The supplier will state pretreatment 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 a 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.

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 the coating nearest the steel will not cure 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.

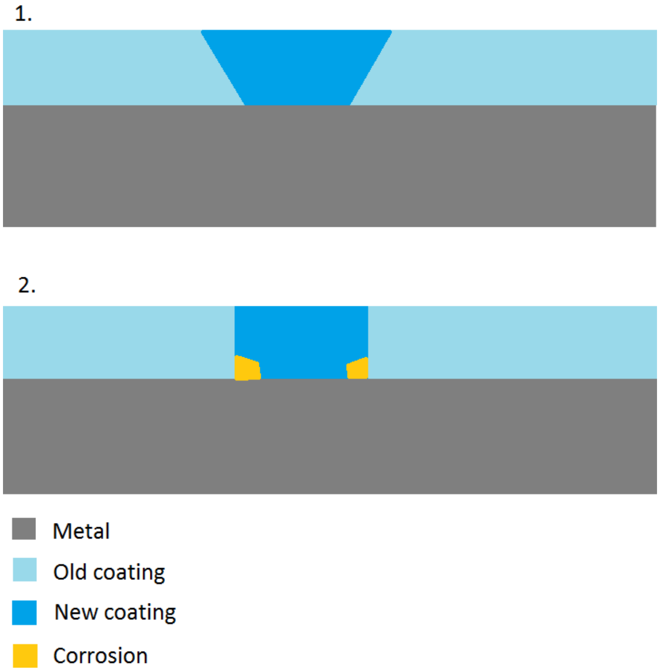

Figure 9.9: Cross section 1 shows correct patch coating, where the edge between old and new coating has been grinded. Cross section 2 illustrates starting corrosion where "sharp edges" makes it impossible to coat the wall sufficiently, even if a brush is used (Ill. Eyvind Andersen)

Patch coating and renewal of tank coating

During the annual tank maintenance, corroded areas should be patch coated, and the coating should be evaluated for hardness, smoothness and ease of cleaning. Start patch coating by removing all traces of rust, and grind the edges of the remaining coating, before the whole area is cleaned (figure 9.9). 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 should 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 9.10). The coating must be cured and washed according to the supplier's instructions. Where several spots of corrosion are located near each other, 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 spots), all coating should be renewed. Renewal should also be done if the coating is no longer sufficiently hard and smooth for cleaning purposes (such coating may lead to biofilm formation or problems with odour and taste). Even when the coating is applied correctly, a renewal 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 9.10: Incorrect coating. 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)

Problems with odour and taste after coating application

Unpleasant odour and taste, following protective coating inside a storage tank, is unfortunately a common problem on offshore installations (figure 9.11). Some substances that give the water smell and taste may, in high concentrations, be hazardous to the health. Water with odour and taste should not be used for human consumption, see 4.2.1 and 4.3. These problems are often caused by incorrect 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.Active carbon filters are effective in removing these substances, see 8.4.

Figure 9.11: Picture from a tank where incorrect coating has resulted in corrosion and need for touch ups. Coating applied wrongly and too thick on cold steel increases the risk for microbial growth, and may cause unpleasant odour and taste from tank coating (Photo: Eyvind Andersen)

9.2 Water distribution system

The water distribution system supplies water to living quarters, galley etc., and may consist of pipes, pumps, calorifier, valves, and other equipment. Inferior potable water quality may be a consequence of wrong system design, poor material quality, cross contamination or insufficient operation procedures. Detailed design advice is given in NS-EN 806.

9.2.1 General design advice

General advice to maintain good hygienic water quality throughout the distribution system

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 (after one minute flushing). 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 to 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 duct 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 taps, pipes and treatment units must be documented to be used or flushed on a weekly basis. The need for flushing can be eliminated through system design that maintains water circulation until mixers, toilets etc., leaving only a negligible amount of stagnant water (figure 4.8). A flow distributor that harnesses the venturi effect is one technical solution for maintaining circulation in all pipes (figure 9.12).

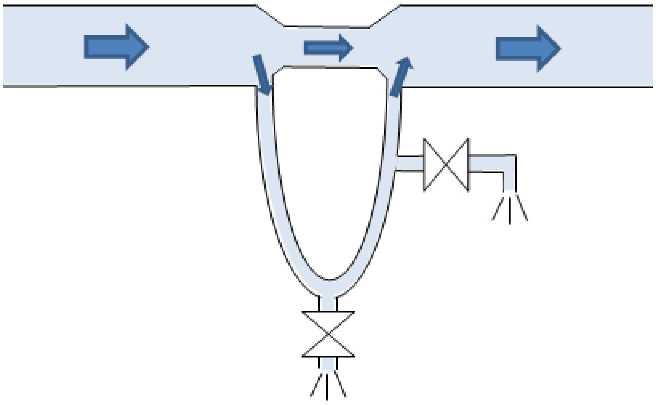

Figure 9.12: The narrow passage forces some of the water in the main pipe to circulate via the smaller pipe, before returning to the main pipe. This provides constant flow to connections with infrequent use (Ill. Karin Melsom).

Avoid blind pipes and pipes with stagnant water since the water will maintain room temperature (figure 9.13). Bacteria growing in blind pipes will not be reached by disinfectants during the annual 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 (figure 9.14). Long pipes supplying small units like coffee makers and water coolers etc. should be avoided due to possible corrosion contamination.

Figure 9.13: 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)*

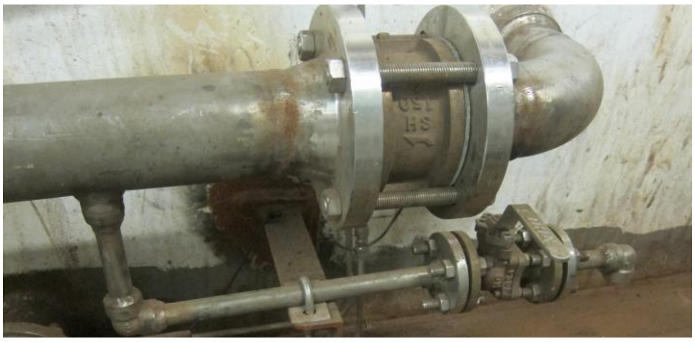

Figure 9.14: This test tap is not designed correctly, as it is too long and too big. In addition the outtake below the main pipe will increase the risk of biofilm formation, as dirt and particles will settle in the test pipe, and the water tests may not be representative (Photo: Eyvind Andersen)

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., must be protected against back flow/ back suction 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). 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 (figure 9.15).

High water speed may also cause some problems. Noise is one issue. For copper piping, water speed close to 1 m/s in circulation pipes and above 2.5 m/s in other pipes may cause corrosion. To balance the concerns for biofim, corrosion and noise, the NMA potable water regulations section 10.2 and 3 for newbuilds requires a maximalflow in circulation pipes of 0.7 m/s, and for piping without circulation, dimensioning according to NS-EN 806-3 is required.

Figure 9.15: Due to slower (and laminar) flow in the large pipe than in the small pipe supplying an eye-wash station, biofilm will grow more easily in the bigger pipe (Photo: Eyvind Andersen)

Prevent biofilm problems
Biofilm formation can be minimised through:

- Maintaining sufficient 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 pipelines 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 frequently used or which will need to be verified on a regular basis must be easily accessible. Drains are provided where necessary.

Avoid unnecessary maintenance
Use as few barriers against cross-contamination as possible, as such barriers must be function tested, see 9.2.5. The same barrier can cover several downstream connections.

Minimise the need for weekly flushing of pipes with stagnant water. Avoid designing tapping points that are not strictly necessary. Pipes that only supply tapping points that do not spread aerosols will not need flushing if they are connected downstream of a BA-valve, see 9.2.7.

9.2.2 Pressurising systems

The pressure is normally kept through continuous pumping or by using hydrophore tanks. Often the maximum static pressure in the distribution piping is 5 bar (ref. NS-EN806-3), and with taps and other equipment that are designed with 5 bar as maximum pressure. As there will always be pressure changes in the system, a small membrane pressure vessel may be useful.

Pressurising with pumps
Often a system will have two pumps, one in operation and the other on stand-by. Pumps

should be switched weekly, and preferably be operated from a control room. A recirculation pipeline going back to the distribution tank should always be installed. This pipeline feeds a small return stream in order to prevent the pump from overheating during periods of low consumption. Connect this line 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.

Pressurising 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 to be a better solution than hydrophore systems, as hydrophore tanks are often difficult to clean and are known to have caused problems with microbial growth. The pressurised air can also contain oil traces, and must be filtered if there is any risk of such substances. A membrane tank can be an alternative 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 use, design 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. The necessary pipe size for each branch must be calculated (e.g. the shower, sink and toilet in a cabin will not be used at the same time).
- Frequently used taps as end points for each branch (galley, washery etc.). Alternatively, an automatic flushing valve may be installed.
- Minimising branch lengths from supply line to tap points (stagnant when not in use)

For offshore units operating in cold climates (seawater below 20° C), it will normally be possible to achieve cold water temperatures below 20° 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° 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 section 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 UV unit. The connection must be secured against back-flow of hot water to the cold water system, see 9.2.5. Insulate the hot water pipes and place them 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.

To maintain correct temperatures at the taps, a circulation system is recommended. For balancing the complete circulation system, each section (floor) in the circulation system needs to be regulated by regulating valves. These valves must be installed (after the last user in a section) before the connection to the collective return line.

The temperature must be minimum 60 degrees in the complete circulation system (measured at heater outlet, circulation return just before the heater and each section in the system, preferably between 30 and 50 cm before connection to collective return line). At peak moments, the temperature may drop below 60 degrees to come back above 60 degrees, as soon as the taps are closed. The temperature at the taps and all other parts which are not continuously circulated must be minimum 60 degrees after one minute of flushing.

As water expands when being heated, the system must use an expansion vessel to avoid piping damage or release of the calorifier pressure relief valve when much cold water is heated after peak consumption. The expansion vessel has a membrane and shall empty completely when hot water is consumed (no stagnant water in the vessel). Recommended volume is 5.6% of calorifier volume.

Water is normally heated by electricity, but some units use surplus heat from cooling water or steam in a heat exchanger. Chemicals added to such water or steam shall be approved, see 2.4.

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

Some bacteria grow in hot water systems with too low temperature. *Legionella* in particular can cause problems. If the hot water in the distribution system is at least 60^o C (after one minute flushing), the risk for infection is minimised, see 9.2.7. With sufficient insulation, this may be possible to achieve with an outgoing temperature of 65^o C, thus reducing energy consumption, scalding risk and mineral deposits 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, mutagenic 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.

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

Figure 9.16: Full air gap of type «AA» is the best way of eliminating contamination from other systems supplied with potable water. Here water is supplied to a food grinder via pipe above the sink to the right (Photo: Eyvind Andersen)

9.2.5 Protection against pollution

The potable water system must be safeguarded against pollution via backflow from connected systems. Different methods are described in the ”EN 1717” standard. The distribution network must be evaluated with regard to risk and vulnerability 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.

Use the same branch-off from the potable water supply line to supply several potential sources of contamination. A single barrier may then be used for all the downstream connections, reducing the number of barriers that need to be maintained. If such a common barrier is to be used, it must be on a sufficient level for all downstream connections.

The best way to protect the potable water system is to separate it 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 9.16). 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.

Down-stream, the use of “air gap” will lead to loss of pressure, but air-gap modules with a down-stream pump are available. If pressure is needed and such solutions are considered too expensive, other technical solutions may be evaluated. When such barriers are applied, the equipment regularly must be opened and cleaned before the effect is verified. The recommended interval for this work is yearly. The choice of barrier depends on the risk each connection poses, and the greater the probability and/or consequences are, the stricter the safety requirements.

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 9.17). 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) give the lowest level of safety that should be applied offshore (figure 9.18). Level “EA” give protection against water that does not contain harmful substances, but where the water quality may have changed with regard to taste, odour, 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 in accommodation and pipes supplying washing machines etc. (such connections must also be protected by locating the connection above the fluid level). Showers can be safeguarded in the same way if the hose could 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 9.19).

Figure 9.17: If other liquid carrying systems must be supplied with pressurised potable water, a BA type backflow prevention device gives 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, and location over a drain is recommended, as it may open automatically (Photo: Eyvind Andersen)

9.2.6 Materials

For both newbuilds and repairs it is important that the pipeline material chosen withstands the particular type of water quality with regard to temperature, pressure, corrosiveness and chlorine content (figure 9.20). 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 major parts of the potable water system.

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

Figure 9.18: 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)

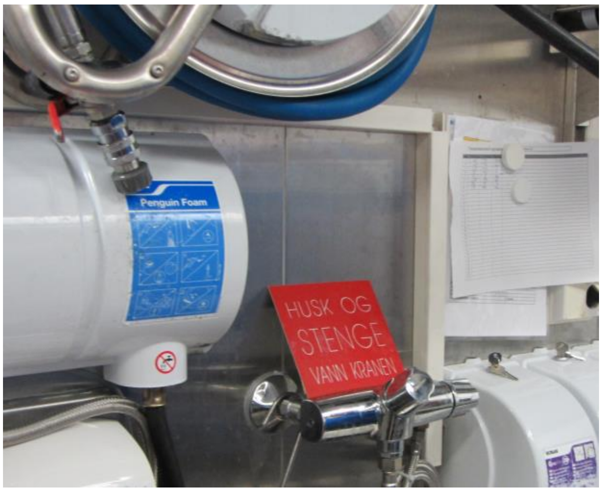

Figure 9.19: A hose station where water is leaking between the hot and the cold water when the mixer is left in open position and the hose is not in use. A sign to close the mixer is ***not*** *a barrier against such leaks (Photo: Eyvind Andersen)*

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. Titanium 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 seawater pipes and pipes between water production unit and alkalising filter. Plastic does not corrode, but questions of leakage of unwanted substances, mechanical strength and bacterial growth in the distribution system should be assessed. For all materials check manufacturer manuals and respect the need of expansion loops, maximum temperatures, maximum chlorine content, maximum pressure (will differ between floors), maximum water speed etc.

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. Inhaling aerosols (micro-sized water drops) emitted from for example air-conditioning units or showers can result in two types of disease. Legionnaire's disease is a very serious type of pneumonia with high mortality whilst Pontiac fever resembles influenza.

Figure 9.20: Hot water pipe damaged because of lacking expansion tank and too high pressure and temperature in the hot water system (Photo: Johan Ljungqvist)

Requirements for preventing the spread of *Legionella* via aerosols are detailed in section 3a in the Norwegian regulations for environmental health protection. Offshore there are several potential sources for such aerosols, including showers and high pressure washers.

When risk assessing systems, see section 3, the NIPH recommends that the technical risk assessment is supplemented with cultivation tests for *Legionella*. Such tests should be done monthly for at least a year, and on a sufficient number of locations to get a complete picture of the assessed systems. If *Legionella* is detected in more than 30% of the samples, the system must be decontaminated completely. If *Legionella* is detected to a lesser extent, the findings must be used in the risk assessment, and may be followed up through technical and treatment improvements to get a system where *Legionella* is only detected on rare occasions. During the risk assessment, the need for *Legionella* tests as a part of the ordinary operational monitoring also should be considered. 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 the EU is detailed in the SHIPSAN Act: www.shipsan.eu (content may differ somewhat from Norwegian advice).

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

Figure 9.21: Legionella *can be prevented by keeping the cold water cold and the hot water hot (Photo: Eyvind Andersen)*

- The cold water temperature should be below 20° C, see 9.2.3. The hot water system should be above 60° C (figure 9.21), see 9.2.4. Water temperatures in the distribution network are documented in a monthly test programme. See appendix 14 for temperature testing procedure.
- Remove blind pipes from the potable water system, see 9.2.1 (figure 9.22).
- Equip tap points that are rarely used and that do not spread aerosols with back flow protecttion 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, prevent the spread or inhalation of aerosols (use of respiratory filter type P3 is recommended). Flushing may be done manually or by using automated valves (where manual operations will be limited to control and maintenance).
- All piping and water treatment units (stand-by units etc.) must be used or flushed weekly.
- 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, such 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 9.23).

Figure 9.22: A sink has been removed whilst pipes and fittings remain, leaving dead ends where Legionella *may have good growing conditions and later infect the rest of the potable water system (Photo: Eyvind Andersen)*

In systems infected with Legionella, where preventive measures are not sufficient, water treatment with silver/copper ionisation or dosing of chlorine dioxide may be effective. Neither of these methods are "cure all" solutions that have instant effect everywhere, but are still the treatment methods that until now have been documented to be the most effective. Other treatment chemicals may be used intermittently or continuously (as required), if approved by the FSA for this purpose. For detailed information on *Legionella* and water treatment, please see the NIPH *Legionella* guideline (only in Norwegian).

With silver/copper ionisation, a low dose of silver and copper is added to the water (maximum 0.1 and 1 mg/l respectively). The typical dosage is 0.02-0.04 mg/l for silver and 0.2-0.4 mg/l for copper, but their effect has been documented for as low dosage as 0.01 mg/l silver. For chlorine dioxide, the necessary dosage is 0.1-0.4 mg/l. Experience shows that it often takes ½-2 years for chlorine dioxide to reach its full effect in a system infected with *Legionella* (in addition it will be effective against amoebas and biofilm). Chlorine dioxide treatment will also result in formation of chlorite and chlorate as by-products, and such formation must be limited to a total of 0.7 mg/l.

Figure 9.23: 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)*

9.2.8 Insulation

Cold water should be insulated with foam, which 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, use isolation thickness of 100% of outer pipe diameter.

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 odour and taste, see 4.2.1. Some of the bacteria may also be pathogenic, and pitting may begin underneath a biofilm, 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 (figure 9.24). One possible procedure 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 15 in the regulations for mobile offshore units state that "Tanks, pipes and pipe systems for drinking water should be kept clean on the inside. The potable water system should be cleaned and disinfected before the unit leaves the yard, thereafter at least once a year and after repairs of the potable water system". 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° 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 quickly by a second test). Flushing the system can be the first remedy to try. If the colony count does not decrease or soon increases again, flush and disinfect the entire distribution system once more. Ensuring sufficient chlorination of the entire distribution system is a major undertaking and is often delegated to external consultants. If high colony counts re-occur 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, disinfect the hot water system by increasing the temperature in the distribution system to 70° C for at least 5 minutes (pipe wall temperature). It is also possible to use hot water to disinfect the cold water system. This is acceptable if the piping is designed with this in mind and that the risk of scalding is minimised. If chlorine dioxide or silver and copper ionisation are used to prevent *Legionella*, see 9.2.7, these methods may also prevent the formation of biofilm.

Figure 9.24: Such biofilm is a consequence of insufficient cleaning. Microbes have ample possibility for growth (Photo: Eyvind Andersen)

If the potable water distribution system is connected to other systems, back-flow protection devices must be tested, see 9.2.5. Maintain pumps and other equipment in accordance with the manufacturer's recommendations, and disinfect them along with the rest of the potable water system.

9.2.10 Pressure/leakage testing

The potable water system should be made with pressure tested and approved components according to regulations (PED CE marked). Parts that must be pressure-tested on site should be tested with water up to the required pressure. The complete potable water system must also be tested for leakages before being put into operation. Leakage testing with water can be done according to the following procedure:

1. Fill the system 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/aerator etc. removed).
3. Connect the pressure source and the required sensors. Refit strainers etc.
4. Close all outlets.
5. Increase the pressure until maximum operation pressure and close the pressure source.
6. Verify that the pressure is stable.
7. Inspect the system for leaks.
8. Relieve the test pressure.
9. If normal operation of the system is delayed, drain the system by gravity and use compressed, oil-free air to dry the pipes.

9.2.11 Special considerations for units operating in warm waters

Offshore units operating in warm climates (seawater 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. Avoid pollution from the cooling medium through double walls, clean water-cooling systems or similar solutions.

As a minimum, the chiller must keep the cold potable water average temperature below 25 ^{o} C. During peak moments (when many people take a shower etc.) the temperature is allowed to increase but after this period the chiller has to reduce the temperature. If the distribution network water always contains free chlorine, the UV unit does not need to be in this circulation loop.

Flush tap points that are not in use on a weekly basis (manually or automatically). If the cold water temperature is above 25^o C, flush daily. When it is not possible to keep the average temperature below 25^o C, it is recommended to use chemicals, see 9.2.7, or continuously to dose chlorine, see 5.1 item 13 for design suggestions.

For continuous chlorination, remove chlorine and chlorination by-products in an active carbon filter prior to UV disinfection. Fresh chlorine is then added only to the cold water distribution system to achieve a chlorine residual above 0.1 mg/l throughout the distribution system. To achieve this one will often need to have a chlorine residual between 0.3 and 0.5 in the galley.

10. Water supply on diving vessels – special requirements

Diving vessels are equipped with units for deep-diving operations. These vessels are often in operation close to other units where divers do 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 on board 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 can be difficult, 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 particular for diving vessels. The general requirements for potable water described in chapters 1-9 will in some instances not be relevant because diving vessels have different requirements than other offshore units. For instance, the requirements for training of personnel will have to include the special considerations that are necessary on diving vessels.

Divers also need hot water to keep their diving suits warm in the cold seawater. Heated seawater is used, but is not discussed in this guide.

Living quarters and work environment for divers were studied in a medical research programme carried out by Statoil, Norsk Hydro, Saga Petroleum, Norske Esso and the Norwegian Petroleum Directorate. Divers often have skin infections, and *Pseudomonas aeruginosa* is usually 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* is present, curative actions should be taken.

10.1 Water analyses

The potable water regulations apply to ships as well. The recommended analyses in chapter 4, made by the NIPH, also apply to diving vessels. Take additional operation analyses for *P. aeruginosa* 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 if *P. aeruginosa* is found. For units that repeatedly experience infections among divers, consider increased analysis frequency.

Operational analyses are also recommended for *Legionella.* Take 1000 ml samples from showers, high-pressure units and rooms for rinsing diving suits before using the diving system.

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 alkalised holds a pH below 6. Feeding the diving system with this type of water will also limit growth of *P. aeruginosa*. Bunkered water

and alkalised water normally hold a pH between 7 and 9.
- *Legionella* is not found in seawater (may occur in brackish water).

10.3 Design

Consider the following criteria in the design and construction of a diving system:

Separate closeable seawater inlets, see 6.1.2.

Suitable pipe material
Non- alkalised water produced aboard is very corrosive, and a suitable quality material must be used. Titanium is the best material and is highly recommended. Hard plastic is sometimes suggested because of its resistance to corrosion, but should be avoided because *P. aeruginosa* is a bacteria that easily forms biofilm on several types of plastic materials and may “eat” PVC.

Dedicated tanks
Recommendations for non-alkalised water being produced on board require separate potable water storage tanks for the diving system. The water is fed 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* and *Legionella* 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 storage tank chlorination, and possibility to increase the chlorine concentration by circulation. Install two parallel UV units with particle filters in front as close as possible to the pressure chamber.

Replaceable shower heads with filters
Use shower heads with filters (pore size up to 200 nanometres) to remove *P. aeruginosa* and *Legionella*.

10.4 Maintenance

When the diving system is not in use, drain the water storage tanks and the pipe system. Before the storage tanks are refilled, they should be cleaned and disinfected, see appendix 13. If the diving system is used 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*, clean and disinfect the infected parts of the system. If the growth is located within the diving system, use the same procedures as described above. If the growth includes the entire potable water system, procedures described in appendices 12 and 13 apply.

Suggested procedures for water production on board 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 also safeguard against *Legionella pneumophila*.

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

Appendix 1 – Checklist 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 checklist 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 checklist should also be used in the planning of major changes of existing potable water systems.

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

2. Rules and guidelines

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

☐ Regulations of 12th February 2010 No. 158, relating to health, environment and safety in the petroleum activities and on certain onshore facilities (consisting of the HSE Framework Regulations with underlying regulations on management, activities and facilities)
☐ Regulations of 4th December 2015, No. 1406 concerning potable water and potable water systems on mobile offshore units
☐ Regulations of 4th December 2001 No. 1372, concerning potable water
☐ The NIPH guideline “Sufficient, safe and good potable water offshore”

3. Important decisions during early conceptual phase

☐ The person who has the overall system responsibility for the potable water system in the design phase should be designated. This person is experienced in operating such systems, and will ensure that the different parts of the potable water system is designed in a way that is functional, both in isolation and as an entire system, with regards to operation, maintenance and technical solutions

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 seawater inlets located at a safe distance from the unit’s discharge points, ref. item 5
☐ The inlets are closeable and are not connected to the same sea chests that supply cooling water for machinery or other types of water consumption that may occur close to shore, ref. item 5
☐ At least two water production units (evaporators or reverse osmosis units), ref. item 8
☐ Alkalising 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

☐ The potable water tanks have coffer dams or other rooms that do not pose any threat of pollution on all sides except against adjacent potable water tanks
☐ At least two UV units, ref. item 11

In addition to choosing technical units, 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 other purposes:_____________
☐ A potable water system completely separated from the technical water supply system
☐ Experienced personnel have through 3D-verification of drawings ensured that all system components requiring regular maintenance/service are easily accessible and ergonomically designed, including:
    ☐ Bunkering station
    ☐ Chlorination unit
    ☐ Potable water tanks
    ☐ UV units
    ☐ Water maker
    ☐ Alkalising 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
☐ It is documented that pipes, treatment units, fittings and other equipment (see 9.2.6):
    ☐ have sufficient quality with regard to corrosion
    ☐ will withstand the relevant water pressure
    ☐ will withstand the relevant water temperature
    ☐ will withstand the relevant chlorine content
    ☐ are suitable for potable water use
☐ All chemicals added to the potable water, or chemicals that may contaminate the system through leakage, maintenance work, back-suction etc., are certified, see 2.4
☐ 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. Seawater inlet and seawater system

☐ There are two separate seawater inlets that may be operated separately
The seawater inlets are well separated from each other both horizontally and vertically
☐ Inlets are closeable and are not connected to the same sea chests that supply machinery cooling water, or other types of water consumption that may occur close to shore
☐ The spreading pattern of discharges from the unit has been calculated in relation to positioning the seawater inlets to secure a minimum of risks of pollution via the seawater inlets
☐ If electrochlorination is used to prevent marine growth from blocking the seawater 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 %. “Water needed” is equal to the sum of potable water (200 l/p/d) plus produced water that is used for other purposes (technical water etc.)

☐ With all production units in use, the production capacity is sufficient to cover both refilling of tanks that have been emptied (e.g. during maintenance) and to cover the normal water consumption
☐ The production capacity is sufficient also at low seawater temperature (5°C)
☐ 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
☐ For additional 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.
☐ For reverse osmosis units: Pre-filters have sufficient capacity to cover maximum water production with all production units in use, and filters are easy to fill, empty and clean internally
☐ All additives are approved
☐ Excess potable water from potable water tanks can be led to other tanks via an overflow pipe, provided that the overflow is safeguarded against pollution, see 9.2.5.

7. Alkalising filter

☐ Pipes between water production units and alkalising filter can withstand corrosive water
☐ Alkalising filter(s) is placed ahead of the potable water tanks
☐ Alkalising filter(s) has/have sufficient capacity to cover maximum water production with all production units in use
☐ 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 of 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 connected to the filling pipes for the tanks
☐ A chlorine-dosing unit is permanently installed connected to the recirculation pipes for the tanks
☐ The chlorine-dosing unit(s) have sufficient capacity to disinfect all water at maximum supply speed. If a common chlorination unit is to be used for bunkering and recirculation, it must be suitable for both
☐ The chlorine-dosing is regulated by a flow meter
☐ The water from the bunkering station cannot be fed to the storage tanks without passing the chlorine-dosing unit
☐ The pipe length between the chlorine-dosing unit and the dosing point is minimised
☐ 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.

☐ Tanks have a height of 2 to 4 metres. Tanks with greater height must be designed with permanent access platforms to ensure easy maintenance (minimum for every 4 metres of height)

☐ The unit has a sufficient number of storage tanks with adequate storage capacity, ref. table 9.1. The table shows minimum total storage capacity for the different types of potable water systems. The values given state the total number of days all the tanks combined can supply water when the unit is fully manned, both potable and technical water consumption (if any). The tanks must be approximately the same size.

☐ The tank inlet and outlet are placed far away from 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 recirculated water 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 cannot be produced, bunkered or recirculated 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. Avoid water temperatures above 20^{o} C

☐ 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 uninterrupted water supply. These tanks do not contain stagnant water

☐ 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 that 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. Newbuilds should have potable water tanks with coffer dams or other rooms that do not pose any threat of pollution on all sides except against adjacent potable water tanks

☐ 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 open ducts

☐ 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, see section 9.1.4. After filling the tank, odour, taste and hydrocarbon content of the water has been verified

☐ When deciding upon protective coating, choose 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, see 8.3.2

☐ The UV units have been dimensioned to handle water with UV transmission of 30 %/5 cm, see 8.3.2

☐ 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 does not lead to excessive heating of the water, and the unit is, if necessary, equipped with effect control that limits the UV dose when the water consumption is low
☐ 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 or any UV bulbs fail, 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 filter/strainer connected upstream 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

☐ Potable water pipes outside living quarter areas are marked ”Drikkevann” and/or ”Potable water” in blue colour
☐ Pumping capacity corresponds with water consumption, automatically adjusted pump flow is recommended
☐ Potable water pipes are not carried through tanks carrying other products than potable water. If this is not possible, those pipes are carried in open ducts.
☐ External pipes are protected against frost and heat
☐ Piping for hot and cold water is sufficiently isolated and located to maintain correct temperatures, see 9.2.1
☐ The need for weekly flushing of pipes with stagnant water has been minimised, see 9.2.7. The system is designed with as few such connections as possible. Piping that supply only consumers that do not spread aerosols will not need flushing if connected downstream a BA-valve (see EN 1717)
☐ 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. By connecting several such connections downstream the same protection module costs can be saved and the need for maintenance minimised. NOTE: A BA-type valve needs to be installed with a pre-filter and stop valves before and after, and such valves will open automatically, so drainage for released water should be provided
☐ Normal hoses connected to the potable water system in accommodation are equipped with at least one verifiable non-return valve (EA, see EN 1717). This also applies to showers where the hose may fall in a toilet. In technical areas, hose connections are equipped with verifiable backflow protection devices (BA, see NS-EN 1717)
☐ If galleys etc. are equipped with hoses connected to mixing batteries (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 (EA, see EN 1717).
☐ The water consumption in the different branches of the distribution system has been analysed. Piping diameter is reduced to a minimum. Piping without circulation is dimensioned according to EN 806-3
☐ For copper piping with circulating water the maximum flow should be below 0.7 m/s to prevent corrosion. Other types of piping will tolerate higher flow, but rapid flow may cause noise
☐ A sufficient number of test taps fascilitates tracing potable water quality throughout the system
☐ The test taps are short and self-draining, see 4.4
☐ 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
☐ The hot water system is provided with a membrane expansion vessel with a capacity of 5.6% of the total calorifier volume, and the vessel drains regularly when hot water is consumed

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

The requirements are described in chapter 3. The operational documentation can be organised in various ways. 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. In this way, the manual simply becomes a key document, describing how the actual operational documentation is organised.

This checklist 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. Have Critical Control Points for the potable water system been defined and control routines for these established (where/page no.)? ____
8. Does the manual list individuals responsible for the various parts of the potable water operational system (platform manager, medical and technical personnel, onshore organisation etc.) (where/page no.)? ____
9. 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.)? ____
10. Does the manual describe how this level of knowledge is maintained, see 3.2 (where/page no.)? _____
11. 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.)? __________________
12. Are maintenance requirements of the system described, see 3.3 (where/page no.)? _______________
13. 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 2.4 (where/page no.)? ____________
14. Are routines for handling non-conformities according to chapter 3.5(where/page no.)? ____________
15. Are routines for applying for exemptions according to chapter 3.8 (where/page no.)? ____________
16. Are potable water problems included in the emergency preparedness plans for the unit, see 3.6 (where/page no.)? ____
17. 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.)? _____________
18. Are there routines safeguarding the notification of authorities of any significant system changes that may be made in the future (where/page no.)? __________________________________

Seawater system:

19. Is there a general drawing of the seawater system (where/page no.)? __________________________
20. Is there a general drawing showing vertical and horizontal distances between the seawater inlets and the various discharge points (where/page no.)? ____

21. Is it explicitly emphasised that water production has to stop (and seawater inlets closed if possible) if the seawater may be contaminated (where/page no.)? ______________________________________
22. Are equipment and chemicals to be used in seawater production described (where/page no.)? ____
23. Can it be guaranteed that methods of anti-fouling that are being used for the seawater system will not pollute the potable water (where/page no.)? ____

Water production units:

24. Are operational routines for the water production units described and illustrated on drawings (where/page no.)? ____
25. 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.)? ____
26. Is the measurement of conductivity of produced water described, and procedures described in case the conductivity is too high and sets off the alarm (where/page no.)? _____________________________
27. Is the alarm limit for the conductivity meter listed (maximum 6mS/m for evaporation and 75 mS/m for reverse osmosis) (where/page no.)? ____
28. Are routines for calibration of conductivity meters described (where/page no.)? ___________________

Bunkering potable water:

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

Alkalising unit:

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

Chlorination unit:

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

UV unit:

39. 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.)? ______________________________________
40. Is the maximum lifetime for the UV radiation tubes stated (where/page no.)? ___________________
41. Are routines for calibration of the UV sensors described (where/page no.)? ______________________
42. Is it clearly described how the UV unit, including quartz glass, UV sensors etc, is to be cleaned if radiation intensity falls (where/page no.)? ____
43. Is it stated at what intensity level the automatic shut-off valve is activated (where/page no.)? _______
44. Are routines for function testing of the UV alarm described (where/page no.)? ___________________

Potable water tanks:

45. Are operation routines for storage tanks described (where/page no.)? __________________________

46. Are procedures for cleaning and disinfection of the storage tanks in accordance with recommendations made by the NIPH, see appendix 13 (where/page no)? ________________________
47. 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.)? ____
48. Will coating be applied in accordance with routines described in section 9.1.4 (where/page no.)? ____
49. Have procedures been established for documenting that requirements for method of application, coating thickness, cleaning and hardening have been followed when coatings have been applied in potable water tanks (where/page no.)? ____
50. Are routines for cleaning and disinfection of calorifiers, hydrophore tanks and other potable water tanks described (where/page no)? ____

Potable water distribution system:

51. 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.)? _______________________
52. Are operation and maintenance routines for pressure tanks described (where/page no.)? ___________
53. Are routines for function testing of technical barriers against pollution of the potable water distribution system described, see 9.2.5 (where/page no.)? _________________________________
54. Is it emphasised that all hose couplings should be disconnected after use (where/page no.)? ________
55. Is it emphasised that connection 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.)? __________________________
56. Is it stated that the thermostat of the water heater must be set to ensure that the water in the coldest place in the distribution network holds at least 60°C after one minute of flushing (where/page no.)? ____
57. Is there established a routine for temperature measurement ensuring that the cold water temperature evreywhere in the distribution network is kept below 20°C and the hot water above 60°C (where/page no.)? ____
58. 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:

59. Is the daily logging procedure in accordance with the recommendations given by the NIPH, see appendix 3 (where/page no)? ____
60. Are the monthly and yearly potable water analyses in accordance with recommendations given by the NIPH, see appendix 4 (where/page no)? ____
61. 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)? ___________
62. 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)? __________________
63. Is the use of measuring devices described (where/page no)? _________________________________
64. Is a daily, separate log kept for the technical equipment of the water production system (where/page no.)? ____
65. Are routines established for tracking malfunctions in the potable water system (where/page no.)? ____

Appendix 3 – Example of a daily potable water logbook*

Month: ______________________ Year:_________

Date	**Odour**	**Taste**	**Clarity**	**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, log water temperatures, 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

This is a suggested programme. The authorities may, based on the potable water regulations, give other requirements if necessary.

Parameter	**Frequency***	**Unit**	**Remarks**	**Limit values**	**Action type****
Odour	D/B/M	Subjective evaluation	Cf. with taste samples ”	Not obvious	C
Taste	D/B/M	Subjective evaluation	Cf. with odour samples ”	Not obvious	C
Clarity	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 25º 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 bunkered water:* Same conductivity as supplying onshore waterworks. *For produced water:* Shall be stable. All increases must be possible 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: Produced water will have colour > 2	20	B
Turbidity	M	FNU		1	B
Clostridium perfringens	M	Number/100 ml		0	C
E. coli	M	Number/100ml	Report findings immediately to supervisory control authorities	0	A
Intestinal enterococci	M	Number/100ml	Report findings immediately to supervisory control authorities	0	A
Calcium	M	Milligram Ca/l	No analysis needed unless the water is alkalised	Recommended values: between 15 and 25	-
Colony count at 22º C/ 72T	M	Number/ml		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
Hydrocarbons, mineral oils	A	Microgram/l	Should also be analysed after tank coating, see 9.1.4	10	C
Polycyclic aromatic hydro-carbons (PAH)	A	Microgram/l		0.10	B
Trihalomethanes	A	Microgram/l		50	B
Boron	A	Milligram B/l	Analysis necessary only when reverse osmosis is used for water production	1.0	B
Chromium	A	Microgram/l	Need only be analysed on new offshore units	50	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
Nickel	A	Microgram/l	Need only be analysed on new offshore units	20	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 potable water regulations**

- **Action type A:** Take immediate action to bring the parameter within the limit. Exemptions are not allowed. Notify the Authorities immediately, see figure 4.5.

- **Action type B:** Take the necessary actions as soon as possible to bring the parameter within the limit. Notify the authorities. The supervision authority may grant exemptions from the limit values, provided that this poses no risk to health and that water supply from other sources is impossible. The exemption should be given for as short time as possible, and should not exceed 3 years. Notify the central Norwegian Food Safety Authority of the exemption and its basis, only they can extend the exemption for more than 3 years.

- **Action type C:** Take the necessary actions as soon as possible to bring the parameter within the limit. Notify the authorities, they may grant exemptions from the limit values for a period so that corrective action can be taken if 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 waterworks onshore: ______________________________________

Normal conductivity at the onshore waterworks (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 (minus margin of error, see section 4.6)
Odour:**				Not obvious
Taste:**				Not obvious
Clarity:**				Clear***
Conductivity (mS/m):				Equal to delivering waterworks****
pH value:				6.5 – 9.5
Is the water acceptable (Y/N)?				

Water sample results from each tank the water is being bunkered to. Take samples 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 odour, taste, appearance and conductivity still satisfactory?
Is the water acceptable (Y/N)?				

Signature by person responsible for bunkering: ______________________________

* In general, supply vessels do not need to chlorinate the water, as disinfection is ensured by both chlorine and UV treatment 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. However, as this is in one extra step of chlorination, the offshore unit should increase the monitoring frequency for chlorination by-products.
** Preferably tested by two people, 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 waterworks. Several Norwegian waterworks have introduced water treatment that is increasing the conductivity level to be between 10 and 15 mS/m. Higher values can be accepted if it is documented that the values are normal at the onshore waterworks where the supply vessel bunkers the water.
***** Perform some simple tests before distribution to check if the supply vessel deliberately or by mistake has delivered sub-standard water from a tank that was not sampled when bunkering..

Appendix 6 – Recommended requirements to supply bases and vessels

The water quality should 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 when signing a contract for delivery of potable water. The list is meant as an example on procedures to ensure a safe and well-documented potable water quality.

Requirements to supply bases:

1. Only use supply bases receiving potable water from approved waterworks with good quality water.
2. The supply base should document the normal water quality from the supplying waterworks. The waterworks must 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 waterworks on the maximum pump speed applied when pumping to the supply vessel, and should 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, see section 7.1.
6. Before bunkering takes place, flush bunkering hoses and pipes for 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 any remaining water in tank before bunkering from onshore.
9. After flushing the hoses and pipes on the supply base, the supply vessel crew should take samples to document the quality of the received water before bunkering starts. The tests should include colour, odour, taste, clarity and conductivity. Only accept the water if the requirements stated in chapter 4.3.2 are fully met, and when conductivity is within the limits stated by the waterworks, see item 2. Log the results as they be used as documentation if the water is contaminated after the supply vessel received the water from the supply base.
10. The maximum bunkering speed is determined by the supply base. Flushing should be done at maximum 100% speed, and bunkering at a slower speed (to avoid disturbing organic material in land pipes).
11. 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.
12. Clean the storage tanks and disinfect at least every 3 months, see appendix 13. Water tests will show if this frequency is sufficient.
13. 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.
14. Protective coating in the storage tanks must be suitable for potable water and should be applied in accordance with recommendations in section 9.1.4.
15. The supply vessel must have a quality system that ensures training, safe operation and maintenance.

Annual quality test of the entire supply chain:

16. Once a year, check how the potable water quality varies throughout the supply chain. Take samples 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 through the supply chain will indicate improvement possibilities.

Appendix 7 – Instructions for bacteriological testing of potable water

Methods

Methods for analyses are defined by the potable water regulations, and the analysing 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 them.

Sampling from tap

1. Remove any strainers from the tap.
2. Sterilise the tap spout with a spirit flame (a match will suffice). If open flames are not allowed, disinfect the sample point thus: empty the tap spout 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 minutes before taking the sample.
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 rim.
7. After the test sampling, measure the water temperature at the sample point.

Packing and shipment

1. Clearly mark the bottles with sender, sample point, date, time, and water temperature. Use waterproof ink.
2. Send the bottles as soon as possible in a clean container (for instance a thermos box). The samples should preferably reach the laboratory within 4 hours after sampling. If the transportation time exceeds this, chill the samples 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 analysis shall not exceed 24 hours.
3. Send 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. Arrange analysis with the laboratory before sending the samples.

Appendix 8 – Instructions for physiochemical sampling, including annual analyses

Monthly physiochemical 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 physiochemical potable water analysis
Several annual analyses require use of special bottles that are available from the laboratory performing the analyses. Test the water in the piping at the test point. First, fill the bottles for heavy metal analyses, then the special bottles for the different organic parameters, and finally fill a one litre bottle, all from the same sample point.

If the values of heavy metals such as lead or cadmium are exceeded, 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
Request special bottles for heavy metal analyses from the analysing laboratory. Do not clean these bottles before use.

1. The sample point must not have been in use for the 10 hours before the sampling takes place.
2. Take a sample of the first cold water being tapped.
3. Take a new sample after one minute continuous flushing with the tap fully opened.
4. Analyse the water samples for relevant parameters, if necessary also for lead, cadmium, chrome, mercury and nickel.

Appendix 9 – Troubleshooting guide

PROBLEM	**POSSIBLE CAUSE**	**CORRECTIVE MEASURES**
A. Unpleasant odour/taste	1. Contaminated water from the supply vessel	Do not accept ater with unpleasant odour/taste 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 seawater inlet (e.g. algae)	Change seawater inlet or stop the fresh water production. Active carbon filter may remove some smell and taste components
	5. Oil polluting the seawater 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	Do not accept water containing humic particles 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	Do not accept water containing particles
D. Low pH	1. Water delivered from the supply vessel with low pH value	Do not accept water with a pH lower than 6.5 unless the water can be alkalised before distribution
	2. The by-pass valve on the alkalisation filter is "too open"	Adjust the by-pass valve to increase amount of water flowing through the filter. This should be followed with a new pH control sampled after the alkalisation filter
	3. The alkalising filter contains an insufficient amount of filter mass	Refill and back flush the filter. Check the pH level after the alkalising 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, add new filter mass
	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	Use smaller dose of CO_2
	b. Not enough filter mass in the alkalising filter	See item 3
	c. A "CO_2-pillow" fills the downstream alkalising filter	Use smaller dose of CO_2, or change design to upstream filter

PROBLEM	POSSIBLE CAUSE	CORRECTIVE MEASURES
	6. Error in measuring pH level	See problem F
E. pH value exceeds requirements	1. The water from the supply vessel exceeded the required pH level	Do not accept the water 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 alkalisation filter is not adequately opened	Adjust the by-pass valve to decrease the amount of water flowing through the filter. Follow up with a new pH control taken after the alkalising 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 alkalising filter	Use a higher dose of CO$_2$ See item 2
	4. Error in measuring pH level	See problem F
F. Error in pH measurement (deviation of more than one pH unit between offshore and onshore tests)	1. Old buffer solution	Replace buffer solution and calibrate the pH meter. 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 should 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 should have a liquid inner electrolyte
	6. Old battery	Replace battery and recalibrate
	7. Error in the instrument	Repair/replace the instrument
G. High conductivity (= high salinity	1. Water from the supply vessel is polluted by seawater	With a conductivity above 10 mS/m (100 µS/cm) at 25º C, reject the water if it cannot be confirmed as normal conductivity for that particular water
	2. Salt water in the bunkering hoses	Flush bunkering hoses 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. Leak in the evaporator condenser c. Damage to the reverse osmosis membrane d. Sediment in the reverse osmosis/-evaporator unit e. Defect dumping valve	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 Install extra dumping valve, increase maintenance
H. Insufficient UV disinfection	1. ”Dirty” radiation tubes in the UV unit	Clean the radiation tubes
	2. Malfunction in the UV lamps, or the maximum operation time allowed has been exceeded	Change UV lamps. Check the time recorder regularly. Replace radiation tubes 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 lamps	See maintenance instructions
	5. Malfunction in the magnetic valve	Shut down the UV unit until the valve has been repaired

PROBLEM	POSSIBLE CAUSE	CORRECTIVE MEASURES
		or replaced
	6. The UV unit is not working properly	Check the effect by testing the colony count before and after the UV unit
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 due to 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, locate the origin of the problem in the distribution system by testing the water quality in the tank, before and after the different treatment units, and from some taps in the distribution network. 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 seawater to the potable water production	Make sure that the disinfection unit is working correctly. See problem H or I. Make sure that the most suitable seawater 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	Adjust pH 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 electrochlorinating seawater inlets and since they are volatile may increase in concentration over evaporators	Reduce chlorination in the seawater inlets or install active carbon filter

PROBLEM	POSSIBLE CAUSE	CORRECTIVE MEASURES
	2. Limit value offshore may be exceeded if water is bunkered from onshore waterworks containing a lot of trihalomethanes	Adjust the chlorination on the offshore unit, change to supply from another waterworks or install active carbon filter
O. Bromate	If electrochlorination 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 electrochlorination, reduce the effect of the evaporators, thus producing cleaner water, or installing active carbon filter
P. High temperature	1. Lack of cooling of evaporated water	Cooling
	2. Heating of tanks and pipes	Better insulation Cooling of surrounding areas Cooling of water
	3. Leakage between hot and cold water systems in mixers etc.	Fit new or fix existing non-return valves Ensure equal pressure in hot and cold water systems

Appendix 10 – Recommended procedures for bunkering potable water

Adjust the procedures to the system on the specific unit.

Before bunkering:

1. Bunkering to empty potable water tanks is recommended. If possible, dump any remaining water in the tank via the drain valve.
2. Check that a sufficient amount of hypochlorite with the correct concentration is prepared. The solution must not be too old. Adjust the hypochlorite amount according to experiences from earlier bunkerings. If the pump is not operated by a flow meter, calculate the dosing speed.
3. Check that the valves on the chlorine-dosing system are open. Start the pump to ensure that it is operating properly.
4. Check that water is not exiting 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 the number of tanks that 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, take a water sample. If water is bunkered from more than one tank on the supply vessel, take a water sample from each of the supply tanks. Colour should be measured and odour, taste and clarity should be logged (preferably by two people to ensure the quality of these judgements). Reject water that does not meet the requirements for potable water. The measured conductivity 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 at the supplying waterworks onshore, and normal onshore values should be obtained from this waterworks. To avoid long discussions with the supply vessel captain, get a second opinion before rejecting water due to odour, taste and clarity.
10. If the water is accepted, the bunkering can begin. Close the drain valve, start the chlorine-dosing pump and pump the water to the storage tanks on the offshore unit.
11. Stop the chlorine-dosing pump when the necessary calculated amount of chlorine has been added.

After bunkering

12. Isolate the storage tank 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. If too little chlorine has been added during bunkering, either dump the water or add more chlorine 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. Repeat points 12 and 13.
14. A quick visual evaluation, combined with control of odour, 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. Log the measured results, see appendix 5. Adjust the dosing 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. Regard the following calculations as examples only, and adjust to the water quality being treated. When experience builds up regarding dosage, bunkering time and so forth, calculations may be unnecessary, 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 the 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 tha the same amount of chlorine is always 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:

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

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

For calcium hypochlorite:

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

- *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. 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

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

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

(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:

$$\frac{\text{Number of grams (g) chlorine to be added to the entire bunkering volume}}{\text{Bunkering speed (l/hour) x bunkering time (hour)}}$$

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

10 g/l equals 1 % chlorine solution. If the tank is emptied before bunkering, it is not necessary to calculate every time the required amount of chlorine concentration, 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 of 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 and 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:

$$\text{Dosing speed (in l/ hour)} = \frac{\text{Bunkering speed (m}^3\text{/ hour) x chlorine dose (g/m}^3) x 100\,\%}{\text{Solution strength (\%) x}1000\text{ (g/l)}}$$

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:

$$\text{Dosing speed} = \frac{200\text{ m}^3\text{/hour x }1\text{ g/m}^3 x 100\,\%}{5\,\% x 1000\text{ g/l}} = \underline{4\text{ l/hour}}$$

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 can 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 (a reasonably clean system is needed for the chlorination to be effective). Lower doses of chlorine than those described below are not recommended as this often will not result in satisfactory distribution system disinfection. If more concentrated chlorine doses are used, the water is not acceptable as potable water in this period. The chlorine effect is a function of dose x time.

1. Preparations:

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

- The distribution system will be cleaned and disinfected with chlorine.
- The high chlorine concentration may give the water an unpleasant odour and taste, especially if there is much biofilm in the system. Use bottled water for cooking and drinking.
- The water can 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,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. After further flushing of all taps in the area, take new chlorine samples. The water can be used during the disinfection. After 12 hours, take samples from different locations in the distribution system (including one sample at farthest location), to document enough remaining free chlorine.

4. Repeating 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 odour 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 a lot of biofilm. Every three months, disassemble and clean these fixtures (using soap or acid as necessary) before they are disinfected. Disinfection may be done by chlorination (soaking in 50 mg/l free chlorine for an hour, dilute a 5% chlorine solution 1:1000), rapid boiling (5 minutes), or hanging (until they are completely dry internally).

If the procedures described above do not give low colony counts, the cause must be found. Possible solutions may be use of chemicals that clean and disinfect, or piping renewal.

Appendix 13 – Cleaning and disinfection of potable water tanks

Below is one possible method for cleaning and disinfecting potable water tanks. Alternative methods may also be used, for example by using other disinfectants or by spraying all surfaces within the tank with sufficiently concentrated chlorine (the product of concentration’time shall at least be equal to 5ppm over 12 hours, and the work must be risk assessed).

1. Preparation

Only use clean equipment and protective gear. Use the storage capacity in all other potable water tanks. 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

Drain the tank completely, if necessary with a mobile drain pump.

3. Inspection/supervision

Assess the frequency of cleaning/disinfection 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. Log the inspection results.

4. Cleaning

Only use water of potable water quality for cleaning. The surfaces in the tank should be flushed under high pressure, and better results may be achieved with cleaning agents. If necessary, scrub the surface with stiff brushes. After scrubbing and flushing, drain the tanks completely.

5. Inspection/supervision

After draining, inspect the tank to evaluate the cleaning. Check the protective coating and completely or partly renew if necessary. The air-vent opening, including float ball and corrosion proof net, should be checked and repaired if necessary. Log the inspection results.

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 to disinfect the distribution system, must hold a chlorine content of approximately 5 mg/l chlorine (5ppm). If the water is not intended for this purpose, 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 should have a free chlorine content of at least 4 mg/l (ppm). Do not use the water for at least 12 hours, but preferably let it circulate in the tank.

8. Control

After 12 hours, take a sample 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 odour and taste. The water may also be used to disinfect the distribution system, provided that the free chlorine content is approximately 5 mg per litre, see appendix 12.

Appendix 14 - Procedure for water temperature testing

Hot and cold water temperature measurements need to be carried out in order to:

- Detect any problems with equipment.
- Detect any problems with mixing valves.
- Locate possible risk points for bacteriological growth.

General

- Start the measurements at least 1 hour after peak use in the system. Ideally the tested taps should not have been used during the last 2 hours.
- Make sure a sufficient amount of measurements are carried out to be representative for the complete vessel (approximately 1 of 15 tap points).

Measurements

1. Measure the water temperature in the fresh water tanks (basic temperature).
2. Measure the water temperature after the pumps or hydrophore unit (start temperature for distribution).
3. Check the hot water temperature that leaves the calorifiers (min. 65 ^{o}C).
4. Check the cold water temperatures at different tap points. Reference tap points can be the galley and bridge. Make sure there are no temperature restrictions (e.g. mixing valves that restrict water temperature to maximum 48 ^{o}C).
5. After measuring cold water, open the hot water tap and measure hot water temperature.

How to measure temperature

- Open the cold water tap.
- Start measuring the temperature immediately (quick response time for thermometer is essential).
- Note the starting temperature and the temperature after 1 minute.
- Repeat the test for the hot water tap.

Recommended temperatures

- Cold water starting temperature shall be below 25 ^{o}C (or daily flushing is advised).
- Cold water shall be below 20 ^{o}C after one minute of flushing (if this is not possible, evaluate the need for risk mitigating measures).
- Hot water starting temperature shall not be below room temperature (indicates cold water leaking in).
- Hot water shall be above 60 ^{o}C after one minute of flushing.
- If there is a difference of > 5 ^{o}C between the cold water start temperatures of different tap points (that cannot be explained with difference in ambient temperature of the rooms etc.), this may indicate a leaking mixing valve. NOTE: The cold water starting temperature may be considerably below room temperature if the tap has been used recently and the main pipes contain colder water. If the start cold water temperature is above room temperature, leakage is likely.
- If there is a difference of > 5 ^{o}C between the cold water temperatures after one minute flushing of different tap points, further investigation is needed. Is this difference due to pipe routing, leaking valves nearby or other heating sources?
- In case there is a suspicion of leaking mixing valves this can also be checked by running the tap and feeling the hot and cold waterline when closing the tap. Sudden changes in temperature indicate leakage.

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