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Recommendations for assessing water quality and safety on board merchant ships

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ABSTRACT

Introduction: *Health and diseases on board ships may depend on water. Interventions to improve the quality of water may bring to significant benefits to health and water stores/supply and should be controlled to protect health. This paper has reviewed the main regulations for the control of water safety and quality on board ships and presents some practical recommendations for keeping water healthy and safe in passenger and cargo merchant ships.*

Methodology: *The main international regulations and guidelines on the topic were analysed. Guidelines for Water Quality on Board Merchant Ships Including Passenger Vessels of Health Protection Agency, World Health Organisation (WHO) Guide to Ship Sanitation, WHO Guidelines for Drinking Water Quality, WHO Water Safety Plan and the United States Center for Disease Control and Prevention Vessel Sanitation Program were examined. Recommendations for passenger and, if available, for cargo ships were collected and compared.*

Recommended questionnaire: *A questionnaire summarising the main information to collect for assessing the enough quality of water for the purposes it should be used on board is proposed. The need of having a crew member with water assessment duties on board, trained for performing these activities properly is discussed.*

Conclusions: *Water quality on board ships should be monitored routinely. Monitoring should be directed to chemical and microbiological parameters for identifying possible contamination sources, using specific kits by a designed crew member. More detailed periodic assessments should be under the responsibility of specialised personnel/laboratories and should be based on sample collection from all tanks and sites of water distribution. It is important to select a properly trained crew member on board for monitoring water quality.*

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Key words: water quality, water safety, merchant ships, recommendations

INTRODUCTION

Navigation has always affected human health. This is due to the enhanced diffusion of communicable diseases in the isolated environment like the ship, as well as presence of many people of different extraction and cultures (crew members and passengers in passenger ships) at the same time in a confined space. Ships represent therefore the environment in which communicable disease spread is favoured for several reasons.

Outbreaks on board ships involve mainly passenger ships and are of public health relevance because of confined spaces and due to the fact that food and drinking water supplies are shared by potentially large groups of people. This can expose individuals to the risk of diseases [1, 2]. Since 1970, more than 100 outbreaks involving ships have been reported, being approximately 40% of them food-related. An underestimation of these events on cargo ships is possible, as many of them may have not been reported and/or are

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undetected. This is due to different reasons. Outbreaks on cargo ships often involve small numbers of crew members and may not be reported because of fear of quarantine or delays in ports [3]. One third of the outbreaks not associated with specific exposure routes could have been caused by unsafe water. Water contamination may be caused by chemical or biological agents. Bacterial contamination is the main cause of diseases on ships, whereas chemical pollution is less common [4].

Water supplies are reported to interfere with seafarers health. Diseases occurring on board ships may depend on water, and can occur in any type of the ship. Causal hazardous agents associated with waterborne disease outbreaks on ships are represented mainly by the so called enterotoxigenic agents such as: *Escherichia coli*, *Noroviruses*, *Salmonella typhi, Salmonella* spp., *Shigella* spp., *Cryptosporidium* spp., *Giardia lamblia* [4]. Another health problem is represented by proliferation of *Legionella* spp. and is associated with cold-water systems. *Legionella pneumophila* has also been found in drinking-water systems on general cargo ships [5].

A survey conducted in 2005 on 950 potable water samples and 48 pool water samples collected from 342 ships revealed, that 8.6% of these samples contained coliforms agents, such as *Escherichia coli* or Enterococci [6]. The presence of these bacteria in potable water is a marker of faecal contamination. This suggests the potential presence of water-borne pathogens, arising from source waters or contaminating water during loading, storage or distribution. A range of improper practices on ships related to storage, repairs, cross-connection between potable and non-potable water and insufficient residual disinfection of water supplies are the most common causes of these contaminations. A relevant risk for human health associated with drinking water is represented by pathogenic bacteria, viruses and parasites transmitted by faeces from humans or animals (including birds). Pathogenic bacteria (i.e. *Salmonella typhi, Shigella*), viruses (i.e. Hepatitis A virus), protozoa (i.e. *Cryptosporidium),* and helminthes that can be found in faeces and pathogens transmitted through contaminated drinking-water are diverse in characteristics, behaviour and resistance.

The outbreaks of waterborne disease can cause the simultaneous infection of a large number of people and potentially of a high percentage of the community living in a given place. Several of these diseases may be waterborne or transmitted by other routes, including person-to-person contact, food intake and droplets and aerosols (i.e. *Legionella*) [7]. If water used on board for drinking or bathing contains a sufficient number of contaminating microorganisms, it can also cause skin or localised infections affecting mucous membranes of eye, ear, nose and throat (i.e. *Pseudomonas aeruginosa, Acinetobacter, Klebsiella, Serratia, Aeromonas*).

INTERVENTIONS TO IMPROVE THE QUALITY OF WATER

Interventions to improve the quality of drinking water result in significant benefits to health. Therefore, water monitoring and evaluation of its characteristics are the first actions necessary to protect human health.

The Guidelines For Water Quality On Board Merchant Ships Including Passenger Vessels [8] establish the microbiological criteria for indicator organism levels, above which action should be taken to restore acceptable water quality. *Escherichia coli*, coliform bacteria and Enterococci should be absent from a 100 mL potable water sample and Aerobic Colony Counts should not exceed 1000 in 1 mL [6]. *Escherichia coli*, coliforms, and Enterococci, as already mentioned, indicate the risk of faecal contamination and suggest the potential presence of water-borne pathogens. Unlike methods followed to detect pathogens, the use of indicator organism tests provides sensitive and rapid results and serves to protect from drinking water-related diseases [6]. Cargo ships may remain at sea for a long time and crew members should use drinking water obtained from coastal countries or from sea water after desalinisation. This is linked to the risk of microbiological contamination of drinking water with the necessity of corrective measures to assure its quality on board. An unknown quality of drinking water and the formation of biofilms require strong disinfection of it as a precautional measure [9]. The World Health Organisation (WHO) Guide to Ship Sanitation, third edition [4], establishes that “a disinfectant residual should be detectable in water samples at the port, on the water barge and on the ship. Presence of a measurable disinfectant residual contributes to ensuring that water is microbiologically safe for the intended use” [4]. The WHO Guidelines for drinking water quality also indicate a free chlorine residual of 0.2–0.5 ppm (mg/L) to be maintained to ensure that the water is free from pathogens [10]. To obtain a free chlorine residual of 0.2–0.5 ppm, doses of chlorine of about 2 mg/L for clear water (< 10 nephelometric turbidity units [NTU]) and twice that (4 mg/L) for turbid water (> 10 NTU) are recommended. It should be mentioned that these free chlorine doses may lead to a residual of the substance, exceeding the suggested residual for water centrally treated at the point of delivery (0.2–0.5 mg/L). These doses are considered suitable for household water treatment to maintain a free chlorine residual of 0.2 mg/L in stored household water treated by chlorination [7].

The WHO Water Safety Plan (WSP) for passenger ships recommends that during bunkering the free halogen, residual should be monitored hourly, and the operational limits should be more than 2.0 mg/L and less than 5 mg/L. According to WSP, the operational limit of the free chlorine in all sites of the distribution system should be maintained at a minimum of 0.2 mg/L and not more than 5.0 mg/L of free chlorine [11]. Guidelines for Food Hygiene on Merchant Ships and Fishing Vessels of Marine Guidance Note (MGN 61) recommend to monitor the levels of residual free chlorine [12]. Despite the above recommendations, a study of the Association of Port Health Authorities and United Kingdom Health Protection Agency on water samples collected from 342 ships revealed that only 20% of samples contained a free chlorine residual within the suggested range (0.2–5 mg/L) [6, 11, 12].

The problem of possible water contamination on board leads to the use of bottled water. In the past, isolated incidences of chemical contamination of drinking water by solvents like xylene and ethylbenzene were reported. These chemicals were found by the crews because the tap water on board had aromatic smell. Consequently, bottled mineral water was used instead of tap water [13]. Also mineral water, if stored not properly, could become contaminated, because chemicals can migrate through the plastic bottle. There is a possibility that pollutants (i.e. fuels, solvents, etc.) present in the environment cross the polyethylene terephthalate (PET) bottle and pollute water [14]. This suggests the importance of the correct storage of mineral water on board ships, identifying places far from chemicals or other pollutants. In general, the respect of the indications written on the label of the bottle is enough to guarantee a good quality of it. Mineral water is commonly considered as a food product, and, according to the Guide to Ship Sanitation, it should follow the guidelines for the production of food [4].

SOURCES OF WATER CONTAMINATION

Ships must use safe water for drinking, toileting purposes, preparing food, fire control, dishwashers, laundry, air conditioning, boilers, deck washing and toilets. This is to protect the health of transported individuals (passengers and crew members) [11]. Potable water must be provided in appropriate quantity and quality to avoid immediate or long term harms. The main outbreaks on board modern ships have been associated with the poor quality of drinking water bunkered [4]. For such a reason, primary prevention measure should be to check that water loaded or produced on board complies the standards of the WHO Guidelines for Drinking-water Quality (GDWQ) [7] or relevant national standards, if they are stricter. Although water loaded in a port is in general safe, contamination could occur during transfer to the ship and storage activities on board. The main causes of contamination are represented by: a) port water; b) transferring and delivery systems (hydrants, hoses, water boats, and water barges); c) the ship water systems (storage, distribution, and onboard production) [4].

PORT WATER

Ports should supply safe potable water for ships, according to the recommendations of the WHO GDWQ [7]. Outbreaks due to the so-called ETEC (enterotoxigenic *E. coli*) microorganisms, *Noroviruses*, *Giardia lamblia,* and *Cryptosporidium* were associated with the supply of contaminated water in irregular ports [15, 16]. Guidelines establish that if water is loaded in irregular ports, where proper water treatment cannot be guarantee, ship should carry the equipment for basic testing (turbidity, pH, chlorine residual, faecal indicator bacteria) of it. In case of suspect of unsafe water, superchlorination or filtration is mandatory.

TRANSFER AND DELIVERY SYSTEM (HYDRANTS, HOSES, WATER BOATS, AND WATER BARGES)

Microbial contamination could occur during water loading by hoses. The ship structure could worsen the quality of water (ship movements, contamination during repair and maintenance of parts of the ship, cross-connections, back siphonage, inadequate treatment, and insufficient residual disinfectant). Outbreaks of typhoid fever associated with contamination of potable water by excreta during repairs and maintenance in dry dock were reported [17].

SHIP WATER SYSTEM (STORAGE, DISTRIBUTION, AND ONBOARD PRODUCTION)

Water can become contaminated onboard a ship by sewage or bilge, if storage or waste disposal systems are not properly designed and constructed. The proximity of bilge area to piping system of potable water sometimes causes pollution. Another problem is related to low pressure and air gaps that could facilitate the entry of contaminants into the distribution system.

Water can be produced directly onboard using different systems. They include desalination, reverse osmosis or distillation. These systems are not free of risk of contamination. After desalinisation procedures, water gets demineralised and has high pH and low conductivity. High pH can result in unsatisfactory disinfection, whereas reduced hardness may lead to leaching of metals in water [4]. These particular physico-chemical characteristics of desalinated water require its stabilisation by adding chemicals such as calcium carbonate. WHO Guide to Ship Sanitation emphasises that in case water evaporation occurs at low temperatures (< 80°C) and in low-pressure units, it cannot be guaranteed to obtain a distillate free from pathogens. According to ISO standards, water that has been produced at temperatures below 80°C needs to be disinfected before it can be defined as potable [4]. The WHO Guide to Ship Sanitation establishes that a distillation plant or other processes of supply potable water to the ship should not operate in polluted waters or harbor areas, as some volatile pollutants may be carried through this process [4].

The complexity of contamination chain highlights the necessity of plans of control to protect health on board. In line with WHO recommendations, the International Water Association guidance and Hazard Analysis Critical Control Points system have implemented their WSP for the provision of safe water on passenger ships [18]. WSP implementation recommends the sequence of steps listed below: 1) assemble the team; 2) document and describe the system; 3) assess hazard and prioritise risks; 4) identify control measures; 5) define operational limits; 6) establish monitoring; 7) establish corrective actions; 8) establish record keeping and supporting plans; 9) validation and verification [18]. The United States Center for Disease Control and Prevention has established the Vessel Sanitation Program (VSP) to protect the health of passengers and crew members by minimising the risk of gastrointestinal disorders on cruise ships and to prevent the introduction, transmission, or spread of gastrointestinal diseases in the United States of America. The VSP provides an Operations Manual with indications on how to manage drinking water stores in compliance with the WHO standards for potable water. The European Union legislation has so far neither established requirements nor indicated minimum or maximum residual concentration for disinfectants for the ship potable water system [19].

The article IV of the Maritime Labour Convention (MLC) 2006 [20] states that every seafarer has the right to decent working and living conditions on board ship, and ensure that seafarers have access to good quality food and drinking water provided under regulated hygienic conditions. Each country should adopt laws and regulations or other measures to provide minimum standards for the quantity and quality of food and drinking water. Each Member State should ensure that ships under its flag meet minimum standards of food and drinking water supplies. These supplies should take into account the number of seafarers on board, their religious requirements and cultural practices as they pertain to food. The quantity of food and drinks on board should also be adjusted according to the duration and nature of the voyage and should be suitable in terms of quantity, nutritional value, quality and variety [20]. Hence, compliance to the MLC will require paying more attention to the water quality on board.

RECOMMENDATIONS FOR WATER QUALITY CONTROL ON BOARD CARGO SHIPS

Water quality on cargo ships is as important as on cruise ships to protect human health. This suggests the necessity to establish/implement water safety plans also on merchant (cargo) ships. To achieve these results, this paper presents a form summarising the main information that should be collected to ascertain the enough quality of water for the purposes it should be used (Table 1).

If the appropriate procedures will be followed, the correct management of water resources on board cargo vessels will be obtained with the advantage of avoiding outbreaks between crew members, and preventing health problems caused by low attention to water as a vector of biological and chemical pollutants. Similarly as required for passenger ships, a documented report of water quality loaded on board should be required for cargos. An assigned crew member should periodically control the amount of free chlorine residual (not less than 0.2 mg/L) and register data obtained. It is essential that free residual chlorine is regularly checked to ensure a sufficient disinfectant activity. Loss of chlorine residual in distribution could indicate contamination (intrusion) or chlorine consumption by other substances present in water, by a reaction with the materials of the tanks, electrolytic phenomena, etc. Of course, a specific training for performing these activities on board properly should be followed by the crew member with water assessment duties on board.

Another point requiring specific attention are potable water hoses. They should be designed exclusively for the delivery of potable water and should have unique fittings. Potable water hoses should also be adequately labeled and handled to avoid improper use for other purposes.

Our recommended good practices represent the equivalent for cargo ships of the steps that WSP provides for passenger ships. In our opinion, more attention should be paid to training of selected crew members to manage ship's water system. Their competence and collaboration will ensure water quality on board.

CONCLUSIONS

According to us, it is essential to monitor routinely water quality on board ships. This monitoring should be performed taking into account chemical and microbiological parameters, with the purpose of identifying possible contamination sources and early changes of the hygienic characteristics of water. It is desirable that these activities are performed by a designed crew member, using specific kits. More detailed assessments should be under the responsibility of specialised personnel/centers at least twice a year. Specific analyses should involve samples collected from all tanks and sites of water distribution.

It is important that at least 1 crew member is trained to know and understand proper water handling procedures in loading and know how to disinfect water. A simple form should be filled in for any step followed (Table 1). This will help in monitoring handling of the ship water system. Appropriate training courses and the publication of a manual of good practices for water handling on board merchant ships should be followed and prepared by institutions/organisations with recognised experience in the field.

Table 1. Information to collect for verifying the quality of water on board ships

Ship's name ______________________________ IMO/Official number _______________

Port's of water loading name __________________ Country ______________________

Date of water sampling ______________________

Sampling via: ☐ Hose ☐ Water barge ☐ Hose/Hydrant

Potable water document issued by Port authority ☐ Yes ☐ No

(*if yes, please attach a copy*)

Are hoses/couplings owned by the ship? ☐ Yes ☐ No

Are hoses/couplings labeled "for potable water only"? ☐ Yes ☐ No

Are hoses/couplings stored in dedicated lockers? ☐ Yes ☐ No

Is the piping of the potable water system indicated by a colour? ☐ Yes ☐ No

(*should be blue, or striped with blue bands, or a light blue stripe at fittings*)

Are hoses/couplings disinfected before use? ☐ Yes ☐ No

(*if yes, please specify the disinfectant used and its concentration*)

disinfectant _________________________________ concentration ___________ [mg/L]

Please fill in the following table on the characteristics of the tanks on board:

	Tank 1	Tank 2	Tank 3	Tank 4	Tank 5
Type of water	______	______	______	______	______
Capacity of water contained	______	______	______	______	______
Material of tank	______	______	______	______	______
Is the tank insulated?	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
Location close to chemicals, fuel, bilge well, etc.	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No	☐ Yes ☐ No
Average days of storage in the tank	______	______	______	______	______
When was the tank last cleaned and disinfected	Date ______ ☐ Not known	Date ______ ☐ Not known	Date ______ ☐ Not known	Date ______ ☐ Not known	Date ______ ☐ Not known

(*if there are other tanks on board, please provide information also about them*)

Is water produced on board? ☐ Yes ☐ No

If yes, it is by: ☐ Reverse osmosis ☐ Evaporation techniques ☐ Distillation

☐ UV ☐ Other (*specify*)______________________________

Is the free chlorine residual routinely checked? ☐ Yes ☐ No

If yes, how frequently? ☐ Weekly ☐ Fortnightly ☐ Monthly

☐ Other (*specify*) ____

Is there a designed crew member to analyse free chlorine residual? ☐ Yes ☐ No

Is the free chlorine residual value registered? ☐ Yes ☐ No

If the free chlorine residual value is less than 0.2 mg/L, what are the remedial actions applied?

(*please indicate*) ____

____

Is bottled mineral water used on board? ☐ Yes ☐ No ☐ Sometimes

If yes, where is it stored? ____

Date________________ Signature ____

Rank of the signing person _______________________________

Seafarers are a particular working category since they spend long periods of time at sea. They are exposed to health risks more than the general population due to their activity and because of the limited health resources on board. In this situation if food, water, etc. are unhealthy or unsafe, these risks increase remarkably. This is the reason why in sailing cargo ships it is important to manage correctly water resources, with particular attention to the water potable system. Appropriate handling of water resources on ships represents a preventive measure to counter the development of communicable diseases, which are a serious problem in people like seafarers, with difficult access to medical care.

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