WHO/SDE/WSH/01.4
Distr: Limited
English Only

Sanitation on Ships

Compendium of outbreaks of foodborne and waterborne disease and Legionnaires' disease associated with ships 1970-2000

World Health Organization
Geneva, Switzerland
2001

This document is not issued to the general public, and all rights are reserved by the World Health Organization (WHO). The document might not be reviewed, abstracted, quoted, reproduced or translated, in part or in whole, without prior written permission of WHO. No part of this document may be stored in a retrieval system or transmitted in any form or by any means – electronic, mechanical or other- without the prior written permission of WHO.

The views expressed in documents by named authors are solely the responsibility of those authors

.TABLE OF CONTENTS

FOREWORD

The aim of this document is to provide a compendium of literature on outbreaks of foodborne and waterborne diseases and Legionnaires' disease associated with passenger ships, general cargo ships, naval vessels and ferries. For each outbreak data on pathogens, main modes of transmission, type of ships, factors contributing to outbreaks and remedial action taken are presented in detail.

Evidence from this review will assist in updating the revised WHO *Guide to Ship Sanitation*. This revised guide will be evidence based and it is proposed that it will cover management of potable water systems on board ships, food safety, waste disposal, swimming pool safety and prevention and control of Legionnaires' disease. This guide will have concluding chapters on management of outbreak investigations and regulatory activities.

I would like to thank several people for their assistance in the formulation of this document: Dr J Bartram, Co-ordinator, Water, Sanitation and Health Program, WHO; Dr Jenny Roberts, London School of Hygiene and Tropical Medicine; Dr Gordon Nichols, Principal Scientist, PHLS, UK; Franky Lever, Co-ordinator, European Working Group for Legionella Infections; Dave Forney, Chief, Vessel Sanitation Program, CDC, USA and Brian Shaw, Senior Port Health Officer, Port of London.

This document represents a work in progress and comments would be appreciated. Readers are invited to submit any further relevant information on outbreaks or incidents of foodborne or waterborne disease or Legionnaires' disease associated with ships not covered in this review to:

Roisin Rooney
Technical Officer
Water, Sanitation and Health Programme
PHE - office L.113
World Health Organization
20 Avenue Appia
CH -1211
Geneva 27
Switzerland

Tel: 41 22 791 2991
Fax:41 22 791 4159
E-mail: Rooneyr@who.int

LIST OF TABLES

SUMMARY

The shipping industry has grown dramatically in recent years with substantial increases in size and passenger capacity. The WHO *Guide to Ship Sanitation* is the global reference on health requirements for ship construction and operation. It was first published in 1967 and is directly referenced in the International Health Regulations (1981). However, the document was produced over 30 years ago and is in urgent need of updating. Revising the current International Health Regulations provides an opportunity to update the WHO *Guide to Ship Sanitation.*

A number of outbreaks and incidents of infectious diseases, particularly gastrointestinal disease and Legionnaires' disease, have occurred on ships. The aim of this compendium is to review all outbreaks of food and waterborne diseases and Legionnaires' disease associated with passenger ships, general cargo ships, fishing vessels and naval vessels. Evidence from this review will assist in updating the revised WHO *Guide to Ship Sanitation.*

A search was carried out on scientific databases to find articles reporting an outbreak or incident of infection associated with a ship, since 1970. The results show that over 100 outbreaks of food and waterborne diseases have been associated with ships. A wide range of pathogens affected passengers and crew during ship associated outbreaks. Over one third of the outbreaks were foodborne and one fifth waterborne. Pathogens included *Salmonella typhi*, *Vibrio cholerae*, *Vibrio parahaemolyticus*, *Salmonella* spp, Enterotoxigenic *E coli*, *Shigella* spp, Norwalk like virus (NLV), *Cryptosporidium* sp, *Giardia lamblia* and *Cyclospora* sp. Norwalk like virus is the most common viral gastroenteritis associated with ships and *Salmonella* spp the most common bacterial pathogen.

Most of the gastrointestinal disease outbreaks were linked to food or water consumed onboard the ship. Few outbreaks were associated with offshore excursions. Factors contributing to the foodborne outbreaks included deficiencies in food hygiene and infected food handlers. Factors contributing to the waterborne outbreaks included contaminated bunkered water, cross connections between potable and non-potable water, improper loading procedures, poor design and construction of potable water storage tanks and inadequate disinfection.

Almost 200 cases of Legionnaires' disease were associated with ships. Most incidents affected one or two people. The majority were associated with passenger ships. Very little information is available on the incidence of Legionnaires'disease among seafarers on general cargo vessels. However, serologic surveys of seafarers have suggested that one third have antibodies to *Legionella pneumophila.* Surveys have also shown that drinking water and air conditioning systems on general cargo ships have been contaminated with *Legionella pneumophila.*

1.0 Introduction

1.1 Ships and Public Health

The shipping industry has grown rapidly in recent years with dramatic increases in size and passenger capacity. Ten million people sailed on cruise ships in the year 2000 and this number is expected to double by the year 2010 (Passenger Shipping Association, 2001). The cargo shipping industry is also expanding. Over one million seafarers are employed on general cargo vessels or tankers around the world. The amount of cargo shipped by sea is expected to triple between the year 2000 and 2020 (Chamber of Maritime Commerce, 2001).

Outbreaks of food and waterborne disease have occurred on ships. Incidents of Legionnaires' disease have also been associated with ships. These diseases are of particular public health importance as ships are typically semiclosed with crowded living accommodation, shared sanitary facilities and common food and water supplies. Such conditions could facilitate the spread of infectious diseases. The majority of general cargo vessels have no medical personnel onboard. Passengers and crew could be at greater risk than people onshore if health care facilities onboard are limited.

1.1.1 Food and waterborne diseases

Food and waterborne diseases are diseases of an infectious or toxic nature caused by or thought to be caused by the consumption of food or water (Anon, 1994). These diseases include all food and waterborne illness regardless of the presenting symptoms and signs: they thus include not only acute illnesses characterized by diarrhoea and / or vomiting, but also illnesses presenting with manifestations not related to the gastrointestinal tract, such as scombroid fish poisoning, paralytic shellfish poisoning, botulism and listeriosis. They include illnesses caused by toxic chemicals.

The health and economic consequences of some of these diseases can be serious. Cholera can lead to rapid dehydration and renal failure. In untreated cases death may occur within a few hours. Severe forms of typhoid fever have been described with cerebral dysfunction (Benenson, 1995). Some strains of salmonellae are of particular concern because of multiple drug resistance (Threlfall, 1997). Infection with *Escherichia coli* O157: H7 can result in Haemolytic Uraemic Syndrome (HUS). This disease is the leading cause of acute renal failure in children (Bunning, 1997). Parasites such as *Cryptosporidium parvum* are a serious health threat for immunocompromised individuals, particularly AIDS patients. Immunodeficient people, if infected, may be unable to clear these parasites.

There is growing evidence that foodborne or waterborne infections may result in chronic sequelae such as rheumatoid disease. A low but consistent incidence of reactive arthritis, an acute inflammation of the joints, occurs after outbreaks of *Salmonella typhimurium*, *Shigella flexneri* and *Campylobacter jejuni*. Guillain Barre Syndrome, an acute inflammatory demyelinating polyradiculoneuropathy, occurs in some individuals following infection with *Campylobacter* spp. It is estimated that chronic, secondary after –effect illnesses may occur in 2-3% of cases of gastrointestinal infections. The long-term consequences to human health and the economy may be more detrimental than the acute disease. (Bunning, 1997).

Outbreaks of viral gastroenteritis, particularly Norwalk-like virus (NLV), can result in substantial economic costs to the travel and tourism industry. Outbreaks occur frequently on ships and attack rates are usually high. The tourism industry invests heavily in package holidays. Such investments could easily be jeopardized if passengers return home with symptoms of gastrointestinal disease.

1.1.2 Legionnaires' disease

Legionnaires' disease (LD) is a potentially fatal form of pneumonia, which principally affects those who are susceptible because of age, illness or immunosuppression. It is caused by the bacterium *Legionella pneumophila* and related bacteria (HSC, 2000). The disease was first recognized in 1976. The case fatality rate has been as high as 39% in hospitalized cases; it is generally higher in those with compromised immunity (Benenson, 1995).

Legionnaires' disease is normally contracted by inhaling legionella bacteria, either in tiny droplets of water (aerosols), or in droplet nuclei (the particles left after the water has evaporated) contaminated with *Legionella* spp, deep into the lungs. There is evidence that the disease may also be contracted by inhaling *Legionella* spp bacteria following ingestion of contaminated water by susceptible individuals. The incubation period is between 2-10 days (HSC, 2001).

Infection with *Legionella spp* can also lead to a milder infection called Pontiac fever. Outbreaks of Pontiac fever on ships and not covered in this review.

1.2 International Regulation of Sanitation on Ships

1.2.1 Evolution of the international health regulations

The first country to impose quarantine law was the Venetian Republic in 1377. This was in response to outbreak of plague during the Middle Ages, following the arrival of ships from other parts of the world. On arrival travelers were detained in isolation for 40 days before they were allowed to proceed to their final destination (Cossar, 1989). Overcrowding on ships, filth and lack of personal hygiene were often associated with epidemics of typhus fever. Preventive measures, such as quarantine, delousing, and maintaining personal cleanliness by use of soap, were gradually adopted, and the incidence of typhus decreased (Minooee, 1999).

The International Sanitary Regulations were developed in 1951 to prevent the spread of six infectious diseases – cholera, plague, yellow fever, smallpox, typhus and relapsing fever. These Regulations were revised and renamed the International Health Regulations (IHR) in 1969.

The purpose of the International Health Regulations is to maximize protection against the international spread of diseases with minimal interference with world traffic. The IHR were amended in 1973 and 1981. The diseases now subject these regulations are plague, yellow fever and cholera. In 1995 the World Health Assembly called for the regulations to be revised. The target date for submission of the revised IHR to the World Health Assembly is May 2004.

1.2.2 WHO *Guide to ship sanitation*

In 1967, the World Health Organization published a *Guide to Ship Sanitation*. Minor amendments were made in 1987. This guide is directly referenced in the IHR (Article 14) and its purpose is to standardize the sanitary measures taken in ships, to safeguard the health of travelers and to prevent the spread of infection from one country to another. (Lamoureux, 1967). The document is based on the results of a survey of 103 countries and represents a synthesis of best national practice at the time. It covers potable water supply, potable water system on board ships, swimming pool safety, waste disposal, food safety and vermin control. Before publication it was circulated to the International Labour Office (ILO) and a number of other international agencies for comment. The guide supplements the requirements of the International Health Regulations 1981 and is still the official global reference for health requirements for ship construction and operation.

The *Guide to Ship Sanitation* was produced over thirty years ago and the construction and size of ships have changed dramatically since the 1960s. The passenger ship industry has expanded rapidly in the last 10 years and a number of outbreaks of infectious diseases, particularly gastrointestinal disease and Legionnaire's disease, have occurred on ships. In 1967 the guide was based on models of good practice and, therefore, is not " evidence based". Revising the current International Health Regulations 1981(IHR) is an opportunity to update the WHO *Guide to Ship Sanitation.*

1.2.3 Types of ship

Four principal types of ship exist today: the passenger ship, the general cargo vessel (including tankers), the fishing vessel and the naval ship. These categories are not absolute as some cargo ships also carry passengers.

1.2.3.1 Passenger ships

Passenger vessels include cruise ships and ferries. Many cruise ships have passenger capacities of over 3,000 and some ferries carry 2,000 passengers per sailing. The world's cruise fleet is very diverse and many ships are traveling to new destinations worldwide. The fastest growing markets are in North America and Asia. In 1966, it was estimated that about 300,000 passengers sailed on cruise ships worldwide; by 1973 the number reached 750,000 (Merson, 1976); in 2000 ten million people traveled on cruise ships worldwide. (PSA, 2001). This number is expected to increase to 22 million by the year 2010. The cruise fleet is expected to double between 2000 and 2005.

A review of the scientific literature has shown that there are many reported outbreaks of ship- related illness, many of which are due to inadequate food handling and water sanitation (Minooee, 1999, Addis, 1989, Koo, 1996). Outbreaks of typhoid fever, salmonellosis, viral gastroenteritis, enterotoxigenic *E coli* infection, shigellosis, cryptosporidisis and trichinosis have occurred on passenger ships. The magnitude of the problem around the world is unknown, as surveillance systems are very variable in both the collection of data and the reporting of results. However, reported clusters of infection associated with ships demonstrate that passengers, and sometimes crew, are potential groups of susceptible persons at risk of disease (Minooee, 1999).

A review of legionellosis associated with passenger ships from 1977 to 1997 has shown that nearly two hundred cases of Legionnaires' disease have been linked to ships (Rowbotham,1998). Ten cases are known to have died. Most of the cases were associated with passenger ships and some of these ships have been linked repeatedly to cases of Legionniares' disease. Some cases had only limited onboard ship exposure e.g. on overnight ferries, thereby making implication of the vessel as a likely source difficult without an isolate from the patient and from the vessel.

1.2.3.2 Cargo ships

It is estimated that 1.2 million seafarers are employed on general cargo vessels, excluding fishing vessels, around the world (Appave, ILO, personal communication). Many spend months at sea, sometimes in remote regions of the world.

Good sanitation conditions on vessels are crucial the health of seafarers and the shipping industry's ability to attract and retain competent employees. The amount of cargo shipped by water is predicted to triple from the year 2000 to 2020 (Chamber of Maritime Commerce, 2001). It is estimated that the world's fleet of tankers is about 3,000. These vessels have increased in size substantially since the 1960s. Some tankers have a capacity of half a million tons.

Very little information is available on the incidence of infection among seafarers on cargo vessels. In 1996 a study was carried out looking at the risk of contracting Legionnaires' disease on a cargo vessel. Temeshnikova *et al*, 1996 reported that 87 /300(29%) serum specimens from the crew of six cargo ships had titres of >128 to Lp1. A survey showed that the drinking water and air conditioning systems on these ships were contaminated with *L. pneumophila*. Community serologic surveys onshore suggest a prevalence of antibodies to *L. pneumophila* serogroup 1 at a titre of >1:128 in 1% - 20% of the general population (Benenson, 1995). This suggests that the prevalence among crew in cargo ships is higher. Cases of Legionnaires' disease have also been reported in six sailors in three separate ships (Rowbotham, 1999).

In 1998 a study was carried out at the Port of Felixstowe, UK on the microbiological quality of water on board cargo vessels berthing. The author of this research estimated that 1052 vessels annually berth at the Port with unsatisfactory water on board. This was calculated to affect some 18,936 individuals. This research also showed that vessel age, water source and water treatment had a significant effect on the microbiological quality of the water (Jacobs, unpublished data, 1998).

1.2.3.3 Fishing vessels

Like seafarers working in general cargo vessels, many fishermen spend months at sea. Adequate sanitation standards are essential to ensure their health and welfare.

1.2.3.4 Naval ships

Naval ships include aircraft carriers, cruisers, destroyers, large amphibious ships, submarines and a variety of logistic ships. Outbreaks of acute gastroenteritis of probable viral aetiology are frequently reported aboard naval ships (Bohnker et al., 1993, Snyder, 1994, Corwin, 1999, Oyofo, 1999). These outbreaks cause substantial morbidity in military personnel during deployment. Outbreaks sometimes last for weeks and place extreme demands on the medical services. Such outbreaks can hinder the ability of deployed forces to respond to emergencies and fleet operational readiness. Outbreaks of salmonellosis, shigellosis, hepatitis A and giardiasis have also been reported on Naval ships (Robinson, 2000).

A study by Blood, 1990, found that sick rates on naval ships varied with ship size. There was a trend of higher rates of communicable disease aboard the smaller ships. These higher rates may have been the result of working and living within a more closed area where spread of infectious diseases is facilitated by restricted environments. Differing ventilation or air circulation systems aboard the smaller vessels could also explain the variation.

2.0 Aim of review

The aim of this document is to provide a compendium of literature on incidents and outbreaks of food and waterborne diseases and Legionnaires' disease associated with ships. This information is to be analyzed to provide better evidence for the prevention of disease in the future.

Evidence from this review will assist in updating the revised WHO *Guide to Ship Sanitation*. Readers of this document are invited to submit any further relevant information on the outbreaks/ incidents of infection associated with ships not covered by this review.

3.0 Methods

3.1 Paper Screening and Data Extraction

A search was carried out on scientific databases *e.g. Medline, Embase, Cab Health* using the terms "infection" and "ship" and "outbreak" and "ship" during the period 1970 –2000. All articles that reported outbreaks or cases of food poisoning/ gastrointestinal disease and Legionnaires' disease are included in the compendium.

Al l papers were pre-screened and data extracted on the following:

3.1.1 Food and waterborne diseases

For each outbreak

- Information on causal agent, year of outbreak, type of vessel, geographical region, mortality and morbidity, mode of transmission, factors contributing to outbreaks and remedial action were tabulated.
- The strength of evidence implicating a mode of transmission and / or contributing factor was reviewed

Whole dataset

- The number of outbreaks, associated with the consumption of food/ water in passenger ships, for the years 1970- 2000. The number of persons at risk, affected, hospitalized and who died were tabulated for each agent.
- The food/ water vehicles implicated in each outbreak, identified separately for each agent.
- The contributing factors were identified separately for each agent.

3.1.2 Legionnaires' disease

For each outbreak

- Information on year of outbreak, type of vessel, geographical region, mortality and morbidity, factors contributing to outbreaks and remedial action was tabulated.
- The strength of evidence implicating a mode of transmission and / or contributing factor was reviewed

Whole dataset

- Number of outbreaks associated with ship's water supply, ship's air conditioning system and spa pools were calculated.

3.2 Categorizing the Levels of Evidence

For each outbreak the mode of transmission of the infection, if known, is stated. However, it is often difficult to ascertain from an outbreak report or publication that a particular mode e.g. water, food or person to person spread, was definitely implicated. Sometimes microbiological or epidemiological evidence may be lacking but strong circumstantial evidence may implicate a particular mode of transmission.

Therefore a method of categorizing the degree of evidence used to implicate a mode of transmission has been developed for this review (adapted from Tillett *et al*, 1997). The categories take into account the epidemiology, microbiology and environmental health information. Thus outbreaks are classified as being associated with water or food or both either "strongly", "probably" or "possibly". This system allows the development of a broad database categorizing food and/ or waterborne infections and it is not confined to a few outbreaks that have been intensively investigated or have confirmation from environmental microbiology i.e. positive results in food or water samples (Figure 1).

Figure 1. Classifications

A. Pathogen identified in clinical case and also found in water or food. Exposure preceded infection by a period of time consistent with proposed biologic mechanisms.	**B**. Water/ food quality failure and /or water treatment problem/ food handling problem of relevance but outbreak pathogen not detected in food or water.
C. Evidence from an analytical study (i.e. case control or cohort) demonstrates association between water or food and illness	**D.** Descriptive epidemiology suggests that the outbreak is water or food related and excludes obvious alternative explanations. Food or water implicated in report but no information on epidemiology or microbiology.

Strongly associated **if** (A and C) or (A and D) or (B and C)
Probably associate **if** (B and D) or (C) only or (A) only
Possibly associated **if** (B) only or (D) only

4.0 Results

4.1 Food and Waterborne Diseases

4.1.1 Pathogens associated with outbreaks and main mode of transmission

From 1st January 1970 to 31st December 2000 over one hundred outbreaks of foodborne or waterborne diseases/ gastroenteritis associated with ships were recorded in the scientific literature. Table 1 lists the number of outbreaks associated with each pathogen and main mode of transmission. Over one third of the outbreaks were foodborne and one fifth waterborne. The mode of transmission was not known or not reported in 36% (39/108) of outbreaks.

Table 1 Pathogens/ toxins in outbreaks/incidents of foodborne and waterborne disease associated with ships: 1970 – 2000 and main mode of transmission.

Organism/toxin	Mainly foodborne	Mainly person to person spread	Unknown	Waterborne	Total
Norwalk –like virus	10	7	10	5	32
Enterotoxigenic *Escherichia coli* (ETEC)	4	0	2	5	11
Invasive *Escherichia Coli*	1	0	0	0	1
Salmonella typhi	0	0	0	1	1
Salmonella spp	12	0	1	1	14
Shigella spp	4	0	4	1	9
Vibrio spp[1]	4	0	0	2	6
Staphylococcus aureus	2	0	0	0	2
Clostridium perfringens	1	0	0	0	1
Cyclospora sp	1	0	0	0	1
Cryptosporidium sp	0	0	0	1	1
Giardia lamblia	0	0	0	1	1
Trichinella spiralis	1	0	0	0	1
Unknown agent	1	0	21	4	27
TOTAL	**42**	**7**	**38**	**21**	**108**
Frequency of occurrence	**38%**	**6%**	**36%**	**19%**	**100%**

[1]Multiple organisms were associated with two outbreaks.

Norwalk –like virus was the principal pathogen involved in 32 (30%) outbreaks, enterotoxigenic *E coli* (ETEC) in 11 (10%) outbreaks and *Salmonella* spp in 14 (13%) outbreaks. *Shigella* spp caused 9 (8%) outbreaks and *Vibrio* spp, six (6%) outbreaks. Other organisms included *Clostridium perfringens*, *Giardia lamblia*, Cyclospora sp, *Cryptosporidium* sp and *Trichinella spiralis*. The aetiological agent was not identified in one quarter of the outbreaks.

4.1.2 **Information on type of ship and geographical location**

Detailed information on year of outbreak, causal agent, type of ship, location, number of passengers affected and at risk is shown in Tables 2a, 2b, 2c and 2d (Appendix A). The main mode of transmission is tabulated and the strength of evidence implicating this mode (i.e. strong, probable or possible) is stated for each outbreak. Data on bacterial pathogens are presented in Table 2a, data on viral pathogens are presented in Table 2b, data on unknown pathogens are presented in Table 2c and data on parasitic infections are presented in Table 2d.

The majority of outbreaks, 86% (94/108), were associated with cruise ships. Outbreaks were also associated with naval ships, ferries and river cruises.

4.1.3 Mortality and morbidity

Information on mortality and morbidity was available in 69 outbreaks (63%). Over 16,000 people were affected and 136 admitted to hospital. Outbreaks due to *Shigella* spp accounted for 10% of outbreaks, yet 25% of hospital admissions. Two deaths were reported in 2 different outbreaks. The organisms associated with these deaths were *Salmonella typhi* and Shigella *flexneria* 2a. Both outbreaks were waterborne.

Table 3. Morbidity and mortality data on 69 outbreaks of foodborne and waterborne disease associated with ships: 1970- 2000.

Aetiology	No. of outbreaks	No. affected	No. Hospitalised	No. died
Norwalk –like virus	23	6709	0	0
Escherichia coli spp	7	1753	1	0
Salmonella typhi	1	83	83	1
Salmonella spp	9	981	14	0
Shigella spp	4	1294	34	1
Vibrio spp	7	2051	4	0
Staphylococcus aureus	1	215	0	0
Clostridium perfringens	1	18	0	0
Cyclospora sp	1	220	0	0
Giardia lamblia	1	200	0	0
Cryptosporidium sp	1	20	0	0
Trichinella spiralis	1	13	0	0
Unknown agent	11	2940	0	0
TOTAL	**69**	**16,461**	**136**	**2**

4.1.4 Factors contributing to outbreaks

The factors contributing to each outbreak and remedial measures taken are shown in detail in Tables 4a and 4b (Appendix B). The main contributing factors to outbreaks and mode of transmission are summarized below for each pathogen.

Norwalk–like virus (NLV). Out of 32 outbreaks due to Norwalk-like virus (NLV) reported in the literature, information on contributing factors was available in 16 outbreaks. NLVs may spread by several routes: faecal–oral, vomiting /aerosols, food and water. Viruses may be introduced into the ship environment by any of these routes and then propagated by person to person spread. In this review 14 outbreaks reported an association with food or water. Five outbreaks implicated specific food items (sauce, shrimp, chicken, fresh cut produce, seafood). In addition five outbreaks were associated with water or ice. A further two outbreaks reported deficiencies in food preparation or water treatment. Such deficiencies may have facilitated transmission of this virus.

Enterotoxigenic *Escherichia coli* (ETEC). Out of 11 outbreaks due to Enterotoxigenic *Escherichia coli* (ETEC), eight reported the mode of transmission. Five were associated with water. In three waterborne outbreaks, water bunkered in overseas ports was the likely source of ETEC. Brief failures in the water treatment systems on these ships appeared to have allowed ETEC to survive. One waterborne outbreak was associated with unchlorinated distilled water. In another outbreak, sewage on board the ship may have contaminated the potable water supply. This potable water was not adequately disinfected.

The remaining five outbreaks were associated with food. Three of these outbreaks were associated with seafood. The mode of transmission was not reported in the remaining two outbreaks.

Typhoid fever

In one outbreak of typhoid that occurred in 1970, sewage may have contaminated the drinking water tanks during dry-docking and repair. Subsequent partial disinfection failed to eliminate the pathogen from the water. One death was reported in this outbreak.

***Salmonella* spp**

Out of 14 outbreaks due to Salmonella spp, 13 reported a mode of transmission or contributing factor.

One outbreak was associated with water, ten outbreaks were associated with a specific food product and in the remaining two outbreaks, a food source was not found but deficiencies in food preparation and hygiene were noted. In the waterborne outbreak, contaminated water may have been bunkered directly into the potable water tanks by-passing the disinfection system.

***Shigella* spp.**

Out of nine outbreaks due to *Shigella* spp, five reported a mode of transmission. One large outbreak of *S. flexneri* 6, which occurred in 1973, was associated with water and ice. It was discovered that the water tank could have become contaminated during the water loading process by seawater in the fire system. The water chlorination system aboard the vessel was inadequate to disinfect the contaminated water. One death was reported in this outbreak.

Two outbreaks were associated with food served aboard the ship and two outbreaks were linked to meals eaten onshore.

***Vibrio* spp**

Information was available on contributing factors in all six outbreaks caused by *Vibrio* spp. Two outbreaks due to *Vibrio parahaemolyticus* were linked to the consumption of seafood. In both outbreaks seawater had been used in the galley and had possibly contaminated the food. Water under high pressure drawn directly from the sea through the ship's fire system was routinely used to hose down the galley decks. Food hygiene deficiencies reported included storing food at ambient temperature for too long.

Two other outbreaks caused by *Vibrio parahaemolyticus* were associated with onshore buffets. One outbreak caused by *V. cholera* O139 was associated with a restaurant on an onshore visit. Another outbreak was associated with seafood served onboard the ship.

Staphylococcus aureus

Two outbreaks of *Staphylpcoccus aureus* enteritis were associated with pastry products. One of these outbreaks probably originated from a food handler who may have been working while infected. In another outbreak, contributing factors included poor personal hygiene and inadequate temperature control.

Clostridium perfringens

One outbreak of *Clostridium perfringens* food poisoning occurred on a riverboat in Oxford, England in 1997. The vehicle of infection was smoked salmon. Factors contributing to the outbreak included inadequate storage and inadequate temperature control of food.

***Cyclospora* sp**

One outbreak of cyclosporiasis occurred in 1997 in the USA. It affected passengers on a cruise ship that departed from Florida. Eating raspberries from Guatemala was significantly associated with risk of illness.

***Cryptosporidium* sp**

One outbreak occurred on an USA Coast Guard Cutter in 1993. The Cutter filled its tanks with water from Milwaukee, Wisconsin, USA during a period when there was a large general waterborne outbreak. Confirmed cases consumed significantly more water aboard than non-cases.

Giardia lamblia

An outbreak occurred on an USA Naval vessel in 1998. Contaminated water was bunkered at a port in Indonesia. Chlorine residuals were reported as "trace". No additional treatment of the ship's tanks was performed. The water delivered to the ship was unapproved and from an unknown source.

Trichinella spiralis

One outbreak occurred in 1974 aboard a cruise liner en route from California, USA to Alaska, USA. Ground beef served on the ship was implicated as the vehicle of transmission. The beef was contaminated by pork, which had previously been frozen, thought presumably not under trichinacidal conditions. Cross contamination may have resulted from a meat grinder that was not thoroughly cleaned after each use.

Unknown aetiology
Twenty-six outbreaks of unknown aetiology were reported. Four outbreaks were reported to be associated with water and one with food. The mode of transmission was not known in the remaining twenty-one outbreaks.

4.2 Legionnaires' Disease

4.2.1 Information on type of ship, geographical region, mortality and morbidity.

Fifty-one incidents of Legionnaires disease. involving almost 200 cases, were reported to be associated with ships. Most were associated with cruise ships and ferries. Ten fatalities were recorded.

Table 5 (Appendix C) lists the number of incidents of Legionnaires' disease, associated with ships, described in the scientific literature. This includes data on the type of ship, geographical location, mortality and morbidity and information on factors contributing to the outbreak/incident and the evidence supporting this.

4.2.2 Factors contributing to outbreaks

Factors contributing to outbreaks included contaminated ships water supply, contaminated spa pool and contaminated ship's air conditioning system. The cause of the incidence was not established in the majority of incidents.

Table 6. Factors contributing to outbreaks/ incidents of Legionnaires' disease

Factor contributing to outbreak/ incident	**No. of outbreaks/ incidents**
Possible link with ship's water supply	9
Possible link with ship's air conditioning system	3
Link with spa pool on ship	2
Cause not established or not reported	37
Total	**51**

The largest culture confirmed cluster of Legionnaires' disease associated with a ship occurred in 1994. Inadequate bromination of the ships three whirlpool spas led to 50 cases spread over nine cruises. Risk of acquiring Legionnaires' disease increased by 64% for every hour spent in the spa water. Passengers spending time around the whirlpool spas, but not in the water, were also significantly more likely to have acquired infection. *Legionella pneumophila* serogroup 1 was isolated only from the sand filter in the ship whirlpool spa. (Rowbotham, 1998). This outbreak represented the first documented outbreak of Legionnaires' disease aboard a cruise ship docking in the USA. This outbreak occurred in April 1994 and went unrecognized until July 1994. (Jerigan, 1996).

In 1998 an outbreak of Legionnaires' disease occurred on a cruise ship that sailed to the Mediterranean and Norwegian Fjords (Arthur, 1998). Water samples taken from the hot water system at showerheads were contaminated with legionella bacteria. The ship had problems maintaining safe temperatures in both hot and cold water systems. The chlorine dosing system onboard the ship was also of serious concern. The age and health profiles of the typical passenger of this ship (predominantly retired elderly, many with pre-existing chronic health problems) was also significant, as was the revelation that the ship had been associated with a number of legionella cases since 1995.

5.0 Discussion

5.1 Food and Waterborne Diseases

Ship-associated gastrointestinal disease is of particular public health importance as passengers and crew share common food and water sources, live in close proximity and share common facilities. These conditions can facilitate the spread of infection on ships. A wide range of pathogens, including bacteria, viruses and parasites, affected passengers and crew during ship-associated outbreaks. This review has shown that over 16,000 people were affected in 67 outbreaks in which mortality and morbidity were cited. The number of people reported as being affected by food or waterborne diseases on ships is likely to be a small fraction of the total number of infections as this review has examined outbreaks reported in the scientific literature only. Many outbreaks on ships are not reported to public health authorities. Even when incidents are reported to the appropriate officials, only a small percentage of outbreak reports are published in detail. Many sporadic cases of infection are also likely to occur on ships and the numbers are underestimated in this review. Most of the outbreaks examined in this review were investigated and reported by CDC in the USA.

5.1.1 Foodborne outbreaks

Many foodborne outbreaks reported in the scientific literature were associated with passenger ships. Infection of passengers may take place prior to boarding or after landing at the various ports of call, but it more frequently takes place on board.

Factors contributing to these outbreaks included cross contamination, inadequate heat treatment, inadequate food storage, use of contaminated raw ingredient and infected food handlers. All of these factors are preventable. However, conditions on passenger ships can increase the risk of a foodborne outbreak. On passenger liners, elaborate menus with many dishes are often offered to passengers. Preparation of a wide variety of foods at the same time for a large number of people will increase the risk of mishandling and cross contamination. Prepackaged meals prepared for passengers to take on shore trips can also be a hazard. These meals are usually prepared in advance of needs, and are frequently carried around for many hours in unsuitable temperatures before consumption, giving ample time for bacterial multiplication to occur.

5.1.2 Waterborne outbreaks

Approximately one fifth of outbreaks described in this review were associated with water or ice onboard the ship. Factors contributing to these outbreaks include contaminated bunkered water, inadequate disinfection, sewage or bilge ingress into potable water tanks, use of seawater in the galley, backsiphonage, and cross contamination of potable water with water from the fire system.

The mechanics of water distribution to ships from shore facilities and onboard ships differs from water distribution on land and may involve a complex chain of events where microbiological contamination may arise. Improper loading techniques and multiple handling could easily result in contamination of potable water. In contrast to a shore facility, plumbing aboard ships consists of numerous piping systems fitted into a relatively confined space. The multiple piping systems carry potable water, seawater, sewage and fuel and offer distinct possibilities for cross connections, particularly during repair and maintenance.

Some ships uplift water in countries that do not have a high standard of water safety. Contaminated bunkered water was responsible for a number of outbreaks of infection caused by enterotoxigenic *Escherichia coli* (ETEC). Disinfection of source water at the appropriate residual level can provide a safety factor. However, this does not always eliminate the infectious agent. In many cases low residual disinfectant is easily overcome by gross contamination. Ships' operators should be aware of water quality standards in different countries and carry out checks if necessary.

Contamination of potable water from cross connections was responsible for many outbreaks. One outbreak of shigellosis was associated with ingress of contaminated water into the potable water storage tanks. The potable water became contaminated during the water loading process by seawater in the fire system. The potential for error in water loading was discovered during the outbreak investigation when it was observed that potable water from the pier was routinely used to wash the decks. This potable water was connected at the bunker station into the ship's fire fighting system – a system normally containing seawater. Crewmembers, after washing the decks, could then connect a hose from a fire hydrant to an adjacent air relief vent of a potable water holding tank to fill the tank. In this way any non-potable and potentially contaminated seawater remaining in the fire line could get into the tank. The potable water system was designed so that the water was pumped from the holding tanks through charcoal filters into the common distribution system. Chlorine was added as sodium hypochlorite before the water passed through the filters. Since the filters removed the added chlorine, the maximum chlorine contact time was less than four seconds, inadequate to disinfect the contaminated water.

This outbreak highlights the danger of cross connections between potable and non-potable water during the loading process. Charcoal filter equipment should not be connected to the potable water treatment or distribution system as these devices remove the residual halogen disinfectant from the water.

Two outbreaks of food poisoning, caused by *Vibrio parahaemolyticus,* were associated with the use of seawater, from the ships' fire system, in the galley. This seawater subsequently contaminated seafood. Recommendations for preventing future outbreaks emphasized that only potable water should be supplied to the galley.

Water can become contaminated onboard the ship by sewage or bilge if the water storage or waste disposal systems are not adequately designed and constructed. In one outbreak, due to enterotoxigenic *E coli*, bilge water could seep through the inspection cover of a potable water tank. This bilge water may have contained sewage. Contaminated seawater could also have entered the tank whenever there was a pressure difference between the tank and the seawater, most likely when the ship approached port. This outbreak could have been prevented if the potable water tanks and sewage systems were properly designed and maintained.

An outbreak of typhoid on a ship occurred after the potable water was contaminated with sewage while the ship underwent repairs while in dry dock. Passengers and crew were infected weeks after the repairs were carried out, suggesting massive contamination in the first instance. This outbreak highlights the risk of gross contamination of the potable water supply during repair and maintenance and the need for good hygienic practice and post repair disinfection.

Three outbreaks of viral gastroenteritis caused by Norwalk like virus (NLV), described in this review, were epidemiologically linked to the water supply onboard a ship.

In one outbreak of gastroenteritis caused by NLV bilge water sometimes covered the suction line from one of the water storage tanks. This could have been the source of the virus. Ship operators should give special attention to piping installed in the bilge area, particularly the piping on the suction side of the potable water pumps. Leakage can result in contamination of the potable water system. Another outbreak of viral gastroenteritis was linked with ice consumption. The ice machine could have become contaminated by sewage backup. It did not have appropriate safety devices. Proper installation of backflow preventers is necessary to prevent localized contamination of water or ice. In the third outbreak, the investigation found a statistical association with potable water. This water was free from bacterial indicator organisms and had the recommended residual chlorine levels. However, there was strong epidemiological evidence implicating the water as the source of the infection.

It is not easy to implicate water as a source of infection in NLV outbreaks because it is difficult to detect viable NLV in environmental samples. Water samples free of bacterial indicator organisms do not provide evidence that the water is free from viral contamination. The Norwalk agent is more resistant to destruction by chlorine than enteric bacteria. In a study involving volunteers, a residual chlorine level of 3.75ppm chlorine in drinking water failed to inactivate the virus. Some Norwalk viruses have remained infective at residual chlorine levels of 5-6ppm. (Jay, 1997). NLV may require higher residual levels to prevent and /or control outbreaks (Corwin, 1999).

These waterborne outbreaks emphasize the need for hygienic handling of water along the water supply chain from shore to ship. The application of a quality assurance management system such as HACCP could help ensure water safety. HACCP is an abbreviation for Hazard Analysis Critical Control Point. It is a management tool that has been used in the food industry for a number of years to ensure food safety by systematically identifying and controlling potential hazards in foods. It has been recommended that an HACCP-type approach be applied to the WHO Guidelines on Drinking Water Quality. HACCP could also be adapted to apply to the water supply chain from shore to ships and onboard ships. By identifying critical control points in the water supply chain and setting control standards, water safety on ships could be easily managed and outbreaks of waterborne diseases prevented.

5.1.3 Person to person spread of infection

Norwalk like viruses (NLVs) are the most common cause of outbreaks of viral gastroenteritis on cruise ships. Outbreaks often affect both passengers and crew, sometimes with very high attack rates. This review shows that person to person spread of infection was the main mode of transmission in one fifth of the NLV outbreaks.

Recurrences of NLV infection on successive cruises are common and these highlight the difficulty of establishing effective control measures for this virus. Susceptible populations are introduced onto cruise ships on a regular basis. This can enable an outbreak to continue for weeks or longer. Bridging between groups may be achieved either by a reservoir of illness in staff or by failure to decontaminate the environment (PHLS, 1995). There is no direct evidence to support the use of particular disinfectants for environmental decontamination as there is no viral culture system available for NLVs. (Chadwick, 2000).

5.2 Legionnaires' disease

There are a number of reasons why passenger ships may be high-risk environments for outbreaks of Legionnaires' disease. Passengers may be more susceptible than the general population for this disease because of their age, underlying illnesses and physical conditions. The various ports of call may present additional risks for Legionnaires' disease. Tropical regions may pose a greater risk than non-tropical regions because of greater exposure to air conditioning systems and the potential for bacterial growth in warm potable water. In addition, the heavy use of ship recreational spas by passengers can spread Legionnaires' disease if the spas are not properly designed and maintained. (Edelstein and Cetron, 1999).

Ship-related Legionnaires' disease should be preventable. General guidelines for reducing the risk of Legionnaires' disease in spas and buildings have been published; many of these apply to ships. In addition, specific guidelines for maintenance of ship water supplies and spas have been published (CDC, 1997). The general principles are simple: reduction of the chances of using *Legionella pneumonphila* contaminated water by proper disinfection, filtration, and storage of source water; keeping cold water cold and hot water hot; avoiding dead ends in pipes; properly cleaning and disinfecting spas; and periodically cleaning or replacing devices likely to amplify or disseminate the disease (Edelstein and Cetron, 1999). Prevention of legionella infections onboard ship incurs cost, but remedial measures following outbreaks of Legionnaires' disease may include extensive decontamination, and possible removal of the vessel from the service (Rowbotham, 1998).

References.

1. Addis DG, Yashuk JC, Clapp DE, Blake PA.(1989). **Outbreaks of diarrhoeal illness on passenger cruise ships, 1975 –85.** *Epidem. Inf.*, 103, 63-72.
2. Anon (1994). ***Management of outbreaks of foodborne illness.*** Guidance produced by a Department of Health Working Group, London.
3. Anon.(1983). **Outbreak of *Staphylococcal aureus* food poisoning on board a cruise ship**. *MMWR* 32(22); 294-5.
4. Anon.(1994).**Outbreak of *Shigella Flexneri 2a* Infection on a cruise ship**. *MMWR* Sept 9, Vol. 43/No. 35.
5. Anon.(1986)**Gastroenteritis outbreaks on two Caribbean Cruise ships.** *MMWR* 35(23); 383-4. Jun 13.
6. Anon. (1994) **Outbreak of Legionnaires' Disease Associated with a cruise ship**, 1994. *JAMA*, September 28, 1994 – Vol. 272, No 12.
7. Anon. (1998) Outbreak investigation on Regal Princess (June/July 1998). (CDC Website: http://www.cdc.gov/nceh/vsp/vsp.htm, Sept, 2000)
8. Anon**.** (1983) **Current notes.** *Communicable Diseases in Scotland.* 17(34): vii.
9. Anon.(1994) **Legionnaires' disease: Mediterranean cruise.** *Communicable disease and Environmental Health in Scotland weekly report.* 28(31):1

10. Anon**.** (1987) **Legionella infection.** *Communicable Diseases in Scotland*. 21(49): 20
11. Anon. (1986) **Gastroenteritis outbreaks on two Caribbean cruise ships**. *MMWR Morb Mortal Wkly Rep*. 35: 383 –4
12. Anon (1994). **Outbreak of *Shigella flexneri* 2a infections on a cruise ship**. *JAMA* 272: 1404
13. Anon (1983) **Staphylococcal food poisoning on a cruise ship** *MMWR Morb Mortal Wkly*. 32:294-5.
14. Anon (1998) **An outbreak of gastroenteritis on board a cruise liner**. *Commun Dis Rep CDR Wkly* 1998; 8:1
15. Anon.(1987) **Travel associated legionnaires' disease**. *Communicable Disease Report* 1987; (23): 1.
16. Anon (1993) **Respiratory tract infections, England and Wales: Laboratory reports, weeks 93/ 33-36**. *Commun Dis Rep CDR Wkly* 1993; 3: 174
17. Arthur J.(1998) **EHOs Steer cruise ship from unsafe waters**. *Environmental Health*. October 1998.
18. CDSC, UK (1998) Benons L, Rooney R, Stanwell-Smith R, Hale A. **Viral gastroenteritis on boards a cruise ship. An outbreak on three consecutive cruises**,(Unpublished report).
19. Benenson, AS. (1995) *Control of Communicable Diseases manual.* Sixteenth Edition. An official report of the American Public Health Association.
20. Berntsson E, Hogevik H, Lidin-Janson G *at al***.** (1986) **Infections among cruise ship passengers, a legionella –like organism.** Letter to the editor. *Infection* (14).
21. Berkleman RL *et al*. (1983) **Traveler's diarrhea at sea: two multi-pathogen outbreaks caused by food eaten on shore visits**: *Am J Public Health*. 73: 770-2
22. Blazer E.(1997) **Legionnaires' disease surfaces on cruiser. One sailor dies, several others report symptoms in mysterious outbreak**. *Navy Times*. March 24^{th} : 6
23. Blood, CG. (1990) **Ship size as a factor in illness incidence among US Navy Vessels**. *Military Medicine***,** 155, 7:310, pp. 310-314.
24. Bohnker B, Mc Ewen G, Feeks E, Palambaroa J (1993). **Explosive outbreaks of gastroenteritis on an aircraft carrier: An infectious disease mass causality situation**. *Aviation Space and Environmental Medicine* 64: 648-650
25. Boyce TG *et al*.(1995) ***Vibrio cholerae* 0139 Bengal infection among tourists to Southeast Asia: An intercontinental foodborne outbreak**. *Journal of Infectious Diseases*, Vol. 172, No. 5, pp. 1401-1404.
26. Bunning VK, Lindsay JA, Archer DL**.** (1997) **Chronic health effects of microbial foodborne disease.** *World Health Statistics Quarterly*, 50 . pp 51-56
27. Castellani-Pastoris M *et al*, (1987) Legionnaires' **disease on an oil-drilling platform in the Mediterranean: a case report.** *British Journal of Industrial Medicine*. 44: 645-6

28. CDC.(1997) ***Final recommendation to minimise transmission of legionnaires disease from Whirlpool Spas on cruise ship.***

29. CDSC, UK Unpublished report (1998). R Rooney A Rushdy, Susan G. Squires, O'Brien, Sonia Andersen, Fiona Warburton, E Owen Caul. ***Outbreak of Norwalk like virus on a cruise ship in the Caribbean.***

30. Chadwick, PR, Beards G, Brown D *et al*. (2000) **Management of hospital outbreaks of gastro-enteritis due to SRSV.** *J. Hos. Infect*. May; 45(1): -10. Review.

31. Chamber of Maritime Commerce.(2001) www.cmc.ccm.com. July 2001

32. Christenson B *et al*.(1986) **Outbreak of respiratory illness on board a ship cruising to ports in Southern Europe and Northern Africa** *J Infect.* 14: 247-54

33. Corwin *et al.(*1999) **Shipboard impact of a probable Norwalk virus outbreak from coastal Japan.** *American Journal of Tropical Medicine and Hygiene,* Vol. 61, No. 6, pp. 898-903, 23 ref.

34. Cowles D, (2000) **Mobilising forces against legionnaires disease**. *Environmental Health Journal.* Vol. 108/10.

35. Christe P, Abraham W, Lindsay DSJ *et al***.** (1997) **Legionella infection in Scotland**, 1997. *SCIEH Weekly Report*, 1998, Vol. 32, No. 45, pp 249-253.

36. Cramer EH**.** (2000) **Investigation summary: Outbreak of Gastroenteritis illness aboard the cruise ships, Disney Magic, June 2-5.** CDC website: http://www.cdc.gov/nceh/vsp/vsp.htm Aug 4 2000.

37. Cramer EH.(2000) **Investigation summary: Outbreak of GI illness aboard the cruise ship, M/V Nantucket Clipper, January 23-30 and February 6-13, St. Thomas, US Virgin Islands.** CDC Website: http://www.cdc.gov/nceh/vsp/vsp.htm June 5th 2000.

38. Crossar JH.(1989) ***Health Hazards of international travel.*** *World Health Stat Q.* 42:61-9.

39. Daniels NA, Neimann J, Karpati A, Parashar D, Greene KD, Wells JG, Srivastava N, Tauxe R, Mintz ED, Quick R. (2000) **Traveler's Diarrhoea at sea: three outbreaks of waterborne Enterotoxigenic *Escherichia coli* on Cruise Ships**. *Journal of Infectious Diseases* 181: 1491-5.

40. Davies *et al*. (1972) **Typhoid at sea: epidemic aboard an ocean liner**. *Can Med Assoc. J.* 1972; April 22, 106: 877-883

41. Edelstein PH, Cetron MS.(1999) **Editorial response: Sea, Wind and Pneumonia**. *CID.* 28 (January)

42. European Working Group for legionella infections. EWGLI.(2001) www.ewgli.org. July 2001.

43. Gikas A *et al*. (1996) **Shigellosis on an Italian cruise ship** (letter). *Lancet.* 1996; 348: 1593-4

44. Glynn MK, Mintz ED.(2000) **An outbreak of Gastroenteritis on the Royal Odyssey, March 4-14, 1997 Cruise**. CDC Website: http://www.cdc.gov/nceh/vsp/vsp.htm

45. Green J, Hunt T.(1999) **Investigation onboard a cruise ship**. Jan/ Feb 1999. (Unpublished report).

46. Gunn RA *et al*. (1980) **Norwalk virus gastroenteritis aboard a cruise ship: an outbreak on five consecutive cruises**. *American Journal of Epidemiology* 1980, Vol. 112. No 6.

47. Hawkins RE *et al.(*1992) **Risk of viral hepatitis among military personnel assigned to US Navy ships**. *Journal of Infectious Diseases*, 1992, Vol. 165, No. 4, pp. 716-719.

48. Health and Safety Commission(HSC) (2000) ***Legionnaire' disease. The control of legionella bacteria in water systems. Approved Code of Practice d Guidance***. HMSO. Norwich, UK

49. Herwaldt BL, Lew JF, Moe CL, Lewis DC *et al.* (1994) **Characterization of a variant strain of Norwalk virus from a Food-borne Outbreak of Gastroenteritis on a Cruise ship in Hawaii**. *Journal of Clincial microbiology*, Apr p861-866.

50. Ho MS, Glass RI, Monroe SS, Madore HP, Stine S, Pinsky PF, Cubitt D, Ashley C, Caul EO.(1989) **Viral Gastroenteritis aboard a cruise ship**. *The Lancet*, October 21, p. 961-964.

51. Hoffman T**.** (1984) **Febrile gastroenteritis after a Caribbean cruise**. *Hops Pract* (Off Ed) 19: 111-2

52. Jacobs RR. **The Microbiological quality of water on board vessels berthing at the Port of Felixstowe.** [Dissertation]. University of London, April 1998.

53. Jay, JM.(1997) ***Modern food Microbiology.*** Chapman and Hall. First edition. USA.

54. Jalaludin BB, Nguygen OTK, Goldthrope IC, *et al*.(1997) **Legionnaires' disease: co-infection with *Legionella pneumonphila* serogroups 1 and 5**. *Medical Journal of Australia*, Vol. 166, No. 5 pp. 277 –278.

55. Jernigen D, Hofmann Jo, Cetron M, *et al.* (1996) **Outbreak of Legionnaires ' disease among cruise ship passengers exposed to a contaminated whirlpool spa**. *The Lancet*, Vol. 347. February 24, 1996

56. Joseph *et al***.** (1995) **Legionnaire's disease surveillance; England and Wales 1994**. *Commun Dis Rep CDR Rev* 1995; 5: R 180-3

57. Joseph C. (1997) **Outbreak of legionnaires' disease among British tourists associated with Rhine Cruise**. *Eurosurveillance weekly* 1:971030 (http://www.eurosurv.org)

58. Kaye R. (2001). **Port health.** In: Cruise and ferry Conference. Olympic Conference centre London. May 2001.

59. Khan *et al*.(1994) **Norwalk Virus –associated gastroenteritis traced to ice consumption aboard a Cruise ship in Hawaii: Comparison and Application of Molecular Method-Based Assays.** *Journal of Clinical Microbiology*. Feb 1994 p 318-322

60. Koo D, Maloney K, Taux R**.** (1996) **Epidemiology of diarrhoeal disease outbreaks on cruise ships, 1986 through 1993.** *JAMA*, February 21, Vol. 275, No. 7, pp.545- 547

61. Korcok M, (1997) Sick at Sea: **Outbreaks prompt reinstatement of cruise ship inspections**. *CMAJ*, Vol. 136, June 15, 1987.

62. Lamoureux V B.(1967) ***Guide to Ship Sanitation***. WHO Geneva, Reprinted with amendments in 1987.

63. Lawrence DN *et al*. (1979) ***Vibrio parahaemolyticus* gastroenteritis outbreaks aboard two cruise ships.** *American Journal of Epidemiology.* Vol. 109, No 1.pp. 71-80

64. Lew Jf, Swerdlow DL *et al.* (1991) **An outbreak of Shigellosis aboard a Cruise ship caused by a multiple antibiotic strain of Shigella flexneri.** *American Journal of Epidemiology***.** Vol 134, no. 4. Pp. 413-419

65. Lumish RM *et al.* (1980)**Heat labile Enterotoxigenic *Escherichia coli* induced diarrhoea aboard a Miami based cruise ship.** *American Journal of Epidemiology*, Vol. 111. Pp. 432- 436

66. McKinney *et al* (1981) **Legionella longbeachae species nova, another aetiologic agent of human pneumonia.** *Ann Intern Med.* 1981; 94: 739- 43

67. Mahon BE *et al*.(1996) **Reported cholera in the United States, 1992-1994**. A reflection of global changes in cholera epidemiology. *JAMA*, Vol.276, No. 4, pp.307-312.

68. Martime matters. www.maritime matters.com. July 2001.

69. Meenhorst Pl *et al.(*1979) **Sporadic cases of legionnaires' disease in the Netherlands.** *Ann Intern Med*. 90: 529-32

70. Merson H *et al.(*1975) **Gastrointestinal illness on passenger cruise ships.** *JAMA*, Feb 17, Vol. 231, No 7.

71. Merson MH *et al*.(1975) **Shigellosis at sea: an outbreak aboard a passenger cruise ship.** *AM J Epidemi.* 101: 165-75

72. McEvoy *et al*.(1996) **An outbreak of viral gastroenteritis on a cruise ship**. *Communicable Disease Report.* 6: R188-192.

73. Minooee A, Rickman LS. **Infectious diseases on Cruise ships**. *Clinical Infectious Diseases*. 1999, 29: 737-44

74. Mintz *et al*. (1988) **An outbreak of Brainerd diarrhoea among travelers to the Galapagos Islands.** *J infect Dis* 1988; 177: 1041-5

75. Moss DM, Bennett DM, Arrowwood SN *et al.(*1998) **Enzyme-linked immunoelectrotransfer blot analysis of a cryptosporidiosis outbreak on a US coast Guard cutter**. *American Journal of Tropical Medicine and Hygiene*, Vol. 58, No. 1. PP 110 –118.

76. O' Mahony M *et al* (1986) **An outbreak of gastroenteritis on board a cruise ship**. *J Hyg (Lond).*

77. Oyofo, B *et al*. (1999) **Norwalk –like virus and bacterial pathogens associated with cases of gastroenteritis onboard an U.S. navy ship**. *American Journal of tropical Medicine and Hygiene*, 1999, Vol. 61, No. 6, pp. 904-908, 33 ref.

78. Passenger shipping Association (PSA). www.passengershipping association. com Statistics. July 2001

79. PHLS Annual Report 1983/84. 1985, p.90pp.

80. PHLS(1995). **Outbreaks of gastroenteritis associated with SRSV's. Viral *gastroenteritis Sub – Committee of the PHLS Virology Committee*.** PHLS *Microbiology digest* 10(1) 1995 pp. 2-9.

81. Pastoris MC, Monaco RL, Goldoni P, Mentore B, Balestra G, Ciceroni L, Visca.(1999) **Legionnaire's disease on a cruise ship linked to the water supply system: clinical and public health implications**. *Clinical Infectious Diseases*, Vol. 28, No. 1, pp. 33-38.

82. Q- net Australia. www.q-net.au

83. Robinson, C, Suraj R,(1998) **Foodborne and waterborne illness trends**, **US Navy**. *Naval Medical Surveillance report.* Vol 3 No. 1. January – March 1998.

84. R Rooney.(1998) **Food Safety on Nile Cruises**. *Health and Hygiene*.19, 61-65 (April 1998)

85. Rotheram P. (1999) **Port Health,** In *Clay's handbook of Environmental Health*. Ed Bassett. Spon. London 1999.

86. Rowbotham TJ. (1983) **Isolation of *Legionella pneumonphila* from clinical specimens via** amoebae, and the interactions of those and other isolates with amoebae. *J Clin Pathol* 1983; 36: 978-86

87. Rowbotham TJ,(1998) **Legionellosis associated with ships: 1977 to 1997**. *Communicable Disease and Public Health.* Vol. 1 No 3 September 1998.

88. Sharpe TW *et al*. (1995) **Epidemiology of Norwalk virus during an outbreak of acute gastroenteritis aboard a US aircraft carrier**. *Journal of Medical Virology*, 1995, Vol.45, No. 1, pp.61-67.

89. Singal M, Schanta PM, Werner SB.(1976) **Trichinosis acquired at sea – report of an outbreak**. *The American journal of Tropical medicine and hygiene*, Vol. 25, no 5.

90. Snyder JD, Wells JG *et al*. (1984) **Outbreak of invasive *Escherichia coli* gastroenteritis on a cruise ship.** *Am J Trop Med* 33(2), pp 281-284

91. Temeshnikova ND, Brudny PA, Marakusha BI, Tartaknvskii, IS and Prosorovskii SV. (1996) **The presence of *legionella* spp in the water system of ships**. In: Proceedings of the 11th meeting of the European Working Group on Legionella Infections. Norway, June 1996.

92. Threlfall E J *et al*. (1997) **Increase in multiple antibiotic resistance in non-typhoidal salmonellas from humans in England and Wales: a comparison of data for 1994 and 1996.** *Microb Drug Resist* (383): 263-266.

93. Tillett, HE, de Louvois J, Wall PG.(1998) **Surveillance of outbreaks of waterborne infections disease. Categorizing levels of evidence**. *Epidemiol. Infect.* 120, 37-42.

94. Thomas R. **Legionnellosis**. (1998) *Naval Medical Surveillance Report*. April – June 1998. http://www.nehc.med.navy.mil/prevmed/epi/nmsrpage.htm.

95. Werner *et al. (*1976) **Gastroenteritis on a cruise ship – a recurring problem**. *Public Health Rep*, 91: 433 –6

96. Waterman SH *et al*.(1987) **Staphylococcal food poisoning on a cruise ship**. *Epid Inf*. 99, 349-353.

97. WHO.(1990) **Epidemiology, prevention and control of legionellosis: Memorandum from a WHO meeting**. *Bull World Health Organ* 68:155-64

98. Yund J, (1998) Giardiasis aboard an Amphilibous Vessel. *Naval Medical Surveillance Report.* April-June 1998. http://www.nehc.med.navy.mil/prevmed/epi/nmsrpage.htm.

APPENDIX A

Table 2a. Food and waterborne disease outbreaks associated with ships, 1970- 2000. BACTERIAL PATHOGENS.

Year of outbreak	Reference	Causal Agent	Location	No. affected	No. at risk	Main mode of transmission (Evidence)
1970	Davies *et al*, 1972.	*Salmonella typhi*	Cruise ship. Southampton, UK to Vancouver, Canada.	83	NR	Water *(PrA)*
1973	Werner *et al* 1976	*Salmonella. infantis*	Cruise ship. Europe to California, USA	182	253	Food *(PosA)*
1973	Merson *et al*, 1975	*Shigella flexneri* 6	Caribbean cruise liner	690	949	Water *(SA)*
1973	Hobbs et al, 1976	Enterotoxigenic *Escherichia coli*	Three Caribbean cruise ships	67	NR	Food *(SA)*
Oct 1973/4	MMWR. 23:70-75 Feb 1974	*Salmonella bareilly* *S. senftenberg*	Caribbean cruise ship – 5 consecutive cruises	244	3,228	Food *(SA)*
Aug 1974	MMWR vol. 23 No39 Sept 1974	*Salmonella enteritidis*	Caribbean cruise	292	751	Water *(SA)*
Dec 1974	Lawrence *et al*, 1979, Addis *et al*, 1989	*Vibrio parahaemolyticus*	Caribbean cruise	252	NR	Seafood contaminated with sea water *(SA)*

Feb 1975	Lawrence *et al*, 1979, Addis *et al*, 1989	*Vibrio parahaemolyticus*	Caribbean cruise	445	NR	Seafood contaminated with seawater. *(SA)*
DEC 1975	Lumish *et al*, 1980	Heat labile Enterotoxigenic *Escherichia coli*	2 successive cruises on Miami, USA based cruise ship	919	1446	Consumption of water *(PrA)*
1976	Berkelman et al, 1983	*Vibrio parahaemolyticus Salmonella*, *Escherichia coli* and *Shigella* spp	Haiti cruise	313	700	Seafood dishes at onshore buffet *(PosA)*
1977	Dannenberg et al 1982	*Vibrio parahaemolyticus*	Caribbean cruise	90	689	Food – seafood salad *(PosA)*
1978	Dannenberg et al	*Shigella flexneri*	Caribbean cruise	305	709	Food borne *(PosA)*
1981	Berkelman *et al*, 1983.	*Vibrio parahaemolyticus*, *Salmonella*, *Escherichia coli* and *Shigella* spp	Mexico cruise	97	259	Seafood salads at luncheon buffets *(PosA)*
1981	Synder *et al*, 1984	Invasive *Escherichia coli*	Caribbean cruise	153	219	Cold buffets on ship *(PrA)*
Dec 1982	Finch et al, 1986	*Shigella flexneri* 2a	Caribbean cruise	215	737	Buffet served ashore *(PosA)*

1983	Waterman *et al* 1987.	*Staphylococcus aureus*	Caribbean cruise	215	715	Cream pastries *(SA)*
1983	Fitzsimons, 1984	*Salmonella java*	4 successive cruises from Southampton, UK	85	NR	Food, Poultry *(PrA)*
1984	Hoffman, 1984.	*Campylobacter* sp	Miami, USA to Caribbean cruise	1	NR	Not known
1986	O'Mahony *et al*, 1986	Enterotoxigenic *Escherichia coli* (ETEC)	Cruise ship in UK	301	NR	Cabin tap water *(SA)*
1989	Lew *et al*, 1991.	*Shigella flexneri* 4a	Caribbean cruise	84	900	Potato salad *(SA)*
1989	Kaye, 2001	*Salmonella typhimurium*	Ferry, UK	56	NR	Ham *(PosA)*
1989	Kaye, 2001	*Salmonella Hadar*	Ferry , UK	49	NR	Packed lunch *(PosA)*
1994	Boyce *et al*, 1995, Mahon *et al*, 1996	*Vibrio cholera* O139.Bengal.	Cruise ship in SE Asia	630	62	Yellow rice at onshore buffet *(SA)*
1992	CDSC report. 060.	*Salmonella Infantis*	Cruise ship. Plymouth, UK	20	435	Food *(PosA)*

1993	CDSC report. 039	*Salmonella enteritidis* PT5A	River cruise, UK	10	21	Raw eggs *(PosA)*
1986-1993	Koo et al, 1996	Enterotoxigenic *Escherichia coli*	5 outbreaks on cruise ships.	NR	NR	Scallops associated with 3 outbreaks *(PosA)*
1986- 1993	Koo et al	*Shigella species*	3 outbreaks on cruise ships.	NR	NR	No information
1986- 1993	Koo et al	*Salmonella enteritidis*	2 outbreaks on cruise ships.	NR	NR	Eggs implicated in one *(PosA)*
1986-1993	Koo et al	*Staphylococcus aureus*	One outbreak on a cruise ship.	NR	NR	Flan *(PosA)*
1994	CDC, 1994	*Shigella flexneria* 2a	California, USA to Mexico cruise	610	2183	Unknown mode
1994	CDSC report. 016.	*Salmonella enteritidis* PT4	Transport trawler in UK	6	NR	Corned beef hash *(PosA)*
Aug 1996	Gikas *et al*, 1996	*Shigella dysenteriae*	Eastern Mediterranean cruise	330	1322	Fish *(PrA)*

1997	CDSC report, 90337D	*Clostridium perfringens*	Riverboat In Oxford, UK	18	90	Fish *(PosA)*
2000	Cramer 2000	Multiple organisms	Miami, USA based cruise ship	224	405	Shellfish *(SA)*
2000	Dudley MDC, UK	*Salmonella enteritidis* PT6a	Mediterranean cruise	47	NR	Packed lunch *(PosA)*
April 1997	Daniels, 2000	Enterotoxigenic *Escherichia coli* (ETEC)	Mexico to USA cruise	97	1701	Water, ice *(SA)*
December 1997	Daniels 2000	Enterotoxigenic *Escherichia coli* (ETEC)	Florida, USA to Mexico cruise	19	1117	Water, Ice *(SA)*
May 1998	Daniels 2000	Enterotoxigenic *Escherichia coli* (ETEC)	Jamaica cruise ship	197	1021	Water, Ice *(SA)*
September 2000	Kaye, 2001	*Salmonella bareilly* *Escherichia coli* O157	Norwegian cruise ship	NR	NR	Beef *(PosA)*

NR = Not Reported

APPENDIX A.

Table 2c. Food and waterborne disease outbreaks associated with ships, 1970- 2000. UNKNOWN AETIOLOGY

Year of outbreak	Reference	Causal Agent	Location	No. affected	No. at risk	Mode of transmission *(Evidence)*
1975	Dannenberg et al, 1982	Unknown (possibly viral, nonbacterial)	Caribbean Cruise	244	697	Water *(PosA)*
1975	Dannenberg et al, 1982	Unknown (possibly viral, nonbacterial)	Caribbean Cruise	77	265	Water *(PosA)*
1975	Dannenberg et al, 1982	Unknown (possibly viral, nonbacterial)	Mexico cruise	107	564	Unknown
1975	Dannenberg et al, 1982	Unknown (possibly viral, nonbacterial)	South America cruise	46	100	Unknown
1976	Dannenberg et al, 1982	Unknown (possibly viral, nonbacterial)	Caribbean cruise	260	745	Unknown
1976	Dannenberg et al, 1982	Unknown (possibly viral, nonbacterial)	Caribbean cruise	267	582	Unknown
1977	Dannenberg et al, 1982	Unknown (possibly viral, nonbacterial)	Mexico, Caribbean and Alaska, USA, 5 cruises.	1655	4245	Unknown

1978	Dannenberg et al, 1982	Unknown (possibly viral, nonbacterial)	Caribbean cruise	27	79	Water *(PosA)*
1979-85	Addis et al, 1989	Unknown 15 outbreaks	Cruise ships	NR	NR	NR
1992	Mintz et al, 1992	Brainerd's diarrhoea	Galapagos islands. Cruise ship	207	394	Water *(PosA)*
1986-1993	Koo et al, 1996	Unknown	Cruise ship	NR	NR	Unknown
1994	CDSC report. 94/391	Unknown	London, UK. River cruise.	4	35	Food *(PosA)*
Sept 1998	CDSC report 98714D	Unknown	River, Teeside, UK. River cruise.	46	87	Unknown

NR = Not Reported

APPENDIX A

Table 2d. Food and waterborne disease outbreaks associated with ships, 1970- 2000. Parasitic infections.

Year of outbreak	Reference	Causal Agent	Location	No. affected	No. at risk	Mode of transmission *(Evidence)*
1974	Singal, 1976	*Trichinella spiralis*	Cruise from California to Alaska, USA	13	NR	Contaminated pork *(SA)*
1993	Moss *et al*, 1998	*Cryptosporidium* sp	US Coast Guard cutter in Milwaukee, Wisconsin, USA.	42	NR	Water *(SA)*
1997	CDC, 1997	*Cyclospora* sp	Cruise ship departed from Florida, USA	220 cases	NR	Raspberries from Guatemala *(SA)*
April 1998	Yund, J	*Giardia lamblia*	US Naval ship in Indonesia	200	900	Water. water uplifted from unknown source. No additional treatment of the ship's tanks were performed.

NR = Not Reported

APPENDIX B

Table 4a. Factors contributing to outbreaks of foodborne and waterborne diseases associated with ships, 1970- 2000. Bacterial pathogens.

Year	Reference	Causal agent	Mode of transmission	Factors contributing to outbreaks	Remedial action taken
1970	Davies *et al*, 1972	*Salmonella typhi*	Water	**Sewage contaminated drinking water. Chemicals added to potable water manually partially disinfected the water. Some water tanks could not be disinfected. All tanks interconnected. Sand pressure filters by –passed under heavy demand. Poor food hygiene practices. Toilet facilities limited. Two typhoid carriers aboard the ship. Sewage contamination may have occurred six weeks prior to outbreak during dry-docking and repair.**	Entire water system cleansed by flushing it out with superchlorinated water, followed by cement washing. A vacuum feed system for chlorine was connected at the water pump.
1973	Werner *et al* 1976	*Salmonella infantis*	Food	Poor personal hygiene among waiters. Food left at ambient temperature for too long. Poor temperature control. Kitchenware not cleaned adequately.	
1973	Merson *et al*, 1975	*Shigella. flexneri* 6	Water	**Epidemiological and microbiological evidence incriminated the ship's water supply, including ice, as the vehicle of**	Improvement in the loading and chlorination of potable water were recommended. Water supply superchlorinated, all ice machines sanitized. A

				transmission. The uniform distribution of cases throughout the ship suggested a contaminated central water source, rather than a local cross connection, was responsible. A water tank could have become contaminated during the water loading process by seawater in the fire system. Crewmembers connected a hose from the fire hydrant to an air relief vent of the potable water holding tank to fill the tank. The water chlorination system, which allowed a maximum chlorine contact time of only 4 minutes, was inadequate to disinfect the contaminated water. Testing for residual chlorine carried out sporadically. Two shrimp dishes, which had prolonged contact with ice, could also have been secondary vehicles of transmission.	system for continuous automatic chlorination of the ship's potable water supply installed. Water not bunkered through air relief vents following outbreak.
1973	Hobbs et al, 1976	Enterotoxigenic *Escherichia coli*	Food	Organism isolated from fresh cream. Faults in hygiene and storage.	
Oct 1973/4	MMWR. 23:70-75 Feb 1974	*Salmonella bareilly*, *Salmonella senftenberg*	Food	Cross contamination and poor temperature control. Pots and pans inadequately washed. Food served at the midnight buffet was not refrigerated while on display and was reused at subsequent meals.	Food handlers excluded from work
Aug 1974	MMWR vol. 23 No39 Sept 1974	*Salmonella enteritidis*	Food and Water	Cross contamination between raw chicken and cooked meats. Elevated refrigerator temperatures. Potable water disinfected by ultraviolet light. Water	Galley cleaned and disinfected. All raw and potable water tanks disinfected. Chlorine monitoring carried out daily. Positive food

				in the potable water tanks was routinely batch chlorinated each week. No coliforms detected. One water sample grew *S. enteritidis.* No evidence of cross connections between potable water system and sewage system. Epidemiological investigation failed to clearly implicate food or water. Although the manner in which the water system became contaminated was not clearly established, circumstantial evidence suggested that water might have been bunkered directly into the potable water tanks, bypassing the distribution system.	handlers excluded from work.
Dec 1974	Lawrence *et al*, 1979, Addis *et al*, 1989	*Vibrio parahaemolyticus*	Seafood contaminated with sea water	Seawater used to cover the seafoods because seawater outlets readily available in the galley. Water under high pressure drawn directly from the sea through the ship's fire system and routinely used to hose the galley deck.	Seawater no longer used in galley.
Feb 1975	Lawrence *et al*, 1979, Addis *et al*, 1989	*Vibrio parahaemolyticus*	Seafood contaminated with seawater	Seawater used to clean galley. Seafood may have been washed in seawater. Precooked lobster thawed in seawater. Seafoods mishandled after exposure to seawater – left at ambient temperature for hours, and when refrigerated, were in large buckets that would not cool rapidly. Although ships normally pump seawater into their seawater systems only while at sea, these ships may have drawn in water while in coastal water.	Only potable water supplied to galley and other food handling areas. Food not to be held at ambient temperature for long periods. Both ships permanently closed the seawater outlets located in or adjacent to the food preparation areas and no subsequent outbreaks occurred.
DEC 1975	Lumish *et al*, 1980	Enterotoxigenic *Escherichia coli*	Consumption of water. Seafood	Two cruises. Infection associated with water on one and seafood on the next. Positive association between water and illness. Main water system adequately chlorinated. Freshly distilled water not chlorinated.	An automatic chlorinator for the distillation system was installed.

1976	Berkelman *et al*, 1983	*Vibrio parahaemolyticus, Salmonella spp*, *E coli spp* and *Shigella spp*	Seafood dishes at onshore buffet	Unrefrigerated seafood dishes served at onshore buffets.	
1977	Dannenberg et al 1982	*Vibrio parahaemolyticus*	Food – seafood salad	Seafood salad	
1981	Berkelman *et al*, 1983.	*Vibrio parahaemolyticus, Salmonella*, *E coli* and *Shigella* sp	Seafood salads at luncheon buffets	Unrefrigerated seafood dished served at onshore buffets. The number and the identity of pathogens suggest that coastal water, perhaps contaminated with sewage, may have been the source of these organisms. The multiple pathogens also suggest multiple errors in preparation and \or storage of food	
1981	Synder *et al*, 1984	Invasive *Escherichia coli*	Cold buffets on ship	Eating macaroni or potato salad at the midnight buffet significantly associated with illness. Multiple contaminated cold foods served during a period of several days. Possible causes – preparation by infected food handler or contaminated raw ingredient.	
Dec 1982	Finch et al, 1986	*Shigella flexneri 2a*	Food	Buffet served ashore	
1983	Waterman *et al* 1987.	*Staphylococcus aureus*	Food	**Cream filled pastries. Pastry prepared in large quantities. Poor temperature**	

				control. Storing food in large quantities that would not cool properly.	
1983	Fitzsimons, 1984	*Salmonella java*	Food	Infected food handlers. Poultry might have been vehicle	
1986	O'Mahony *et al*, 1986	Enterotoxigenic *E. coli* (ETEC)	Cabin tap water	Epidemiological and microbiological evidence implicated the water supply. Sewage contaminated a water tank. Bilge water could seep through the inspection cover of the tank. Contaminated seawater could enter through loose plates which would happen whenever there was a pressure difference between the tank and the seawater, most likely when the ship approached port. Galley water from the butcher's shop collected in a tank which allowed it to overflow, which then mixed with the bilge water close to the water pumps. In addition, when the ship went into dry dock, a leak in tank 15 was found, caused by loose rivets in the base of the tanks. Water not adequately chlorinated. Manual chlorination method did not ensure water adequately treated	Drinking water levels were kept at 0.6p.p.m. free residual chlorine. It was advised that automatic proportional chlorination pumps be installed. The damaged water tanks and inefficient sewage pipes were repaired.
1989	Lew *et al*, 1991.	*Shigella flexneri* 4a	Potato salad	Infected food handler. Only one toilet available in the galley area for over 100 food handlers. No disposable towels. Secondary person to person spread may have taken place.	
1994	Boyce *et al*, 1995, Mahon *et al*, 1996	*Vibrio cholera* O139.Bengal.	Yellow rice at onshore buffet	Linked to meal at onshore restaurant	
1986-	Koo *et al*, 1996	Enterotoxigeni*c*	Food	Scallops implicated in three outbreaks	

1993		*Escherichia coli*			
1986-1993	Koo et al	*Shigella species*	Food	Three outbreaks. One outbreak implicated a locally produced potato salad eaten at an off shore excursion	
1986-1993	Koo et al	*Salmonella enteritidis*	Food	Two outbreaks. Eggs implicated in one	
1986-1993	Koo et al	*Staphylococcus aureus*	Food	Flan. Probably originated from an infected food handler.	
1994	CDSC report. 016.	*Salmonella enteritidis* PT4	Food	Corned beef hash. Poor hygiene conditions on trawler.	
Aug 1996	Gikas *et al*, 1996	*Shigella dysenteriae*	Food	Probable transmission vectors were smoked swordfish with salted cod.	
1997	CDSC report, 90337D	*Cl. perfringens*	Food	Fish dish. Inadequate storage and temperature controls on hot day	
2000	Cramer 2000	Multiple bacterial organisms	Food	**Shellfish. Contamination of shrimp could have occurred off ship at any stage of produce preparation before shrimp was loaded onto the vessel. Also, mishandling of shrimp by food handlers including possibility of cross contamination of cooked shrimp with raw shrimp and use of contaminated transport bins.**	
2000	Dudley MDC,UK	*S. enteritidis* PT6a	Food	Packed lunches for shore trips were prepared early	

				and left out at ambient temperature for long periods of time. Lightly cooked eggs present on the menu. Water shortage at times on ship, with people asked to shower less frequently. Mechanical problems with some of the toilets.	
April 1997	Daniels, 2000	Enterotoxigenic *Escherichia coli*	Water	Illness associated with consuming the ship's tap water and beverages with ice. No deficiencies in foodhandling and storage practices or water disinfection.	To ensure the microbiologic safety of water, the VSP recommends that free chlorine residuals be maintained at 2-3ppm during bunkering and more than 0.2ppm at all times throughout the ship's water distribution system. Recommended to ensure microbiologic safety of water at foreign ports
Dec 1997	Daniels, 2000	Enterotoxigenic *Escherichia coli*	Water	Illness associated with beverages with ice and ice water obtained from pitchers in the dining room. No deficiencies in food storage, preparation or handling. After bunkering water in Costa Rica, free chlorine residuals were below the VSP recommended minimum of 0.2ppm	To ensure the microbiologic safety of water, the VSP recommends that free chlorine residuals be maintained at 2-3ppm during bunkering and more than 0.2ppm at all times throughout the ship's water distribution system. Recommended to ensure microbiologic safety of water at foreign ports.
May 1998	Daniels, 2000	Enterotoxigenic *Escherichia coli*	Water	Illness associated with unbottled water and any beverage with ice. Several food storage, preparation and handling deficiencies. After bunkering water in Costa Rica, free chlorine levels recorded on the ship were below the VSP recommended minimum of 0.2ppm. Water positive for coliform bacteria	To ensure the microbiologic safety of water, the VSP recommends that free chlorine residuals be maintained at 2-3ppm during bunkering and more than 0.2ppm at all times throughout the ship's water distribution system. Recommended to ensure microbiologic safety of water at foreign ports.
Septem	Kaye, 2001	*Salmonella bareilly*	Food.	During September 2000, Brazilian beef tenderloins	

ber 2000		*Escherichia coli* O157		infected with *Salmonella bareilly* and *E coli* O157: H7 caused food poisoning on a Norwegian ship. The infected meat was subject to the EC " Rapid Alert System for Food".	

APPENDIX B

Table 4b. Factors contributing to outbreaks of foodborne and waterborne diseases associated with ships, 1970- 2000. Viral pathogens.

Year	Reference	Causal agent	Mode of transmission	Factors contributing to outbreaks	Remedial action taken
April 1977	Greenberg et al, 1979 MMWR 26: 176, 1977	Norwalk –like virus(NLV)	Unknown\ water	Series of outbreaks. Risk of illness increased with increasing consumption of water but no evidence of deficiencies from sanitary inspection. The environmental investigation revealed that bilge water sometimes covered the suction line from one of the fresh water storage tanks.	Defects relating to water tank corrected before ship departed
1977	Gunn *et al*, 1980	Norwalk –like virus(NLV)	Food or Person to person	Analysis of food consumption data showed a significant association between illness and eating bearnaise sauce served the evening before the outbreak. Residual chlorine levels low at the beginning of the cruise. Water not epidemiologically linked.	
1986	CDC, 1986 MMWR 35(23); 383-4 Jun 13 1986	Norwalk –like virus(NLV)	Unknown	Deficiencies relating to water chlorination record keeping and food preparation.	
1986	CDC, 1986 MMWR 35(23); 383-4 Jun 13 1986	Norwalk –like virus(NLV)	Unknown	A sanitation inspection revealed deficiencies related to water chlorination record keeping and food preparation.	

1988	Ho *et al* 1989	Norwalk –like virus(NLV)	Person to person	Sharing toilet facilities a risk. Coliforms isolated from water samples, but not of faecal origin.	Recommendations made to ship's management emphasized repeated and thorough cleanup and disinfection of communal bathrooms, rapid disinfection of rooms where people were ill, and improved early surveillance of illness by not charging the physician for visits.
1990	Herwaldt *et al*, 1994	Norwalk –like virus(NLV)	Food	Fresh cut fruit served at two buffets. Although the cooks who prepared the meals reportedly were well, crewmembers may be reluctant to report illness because of concern about job security. Six food handlers were ill. Food hygiene problems noted in galley.	
1992	Khan *et al*, 1994	Norwalk –like virus(NLV)	Water	Associated with consumption of ice. Inspection revealed that the ice machines could have been readily contaminated by a server's hands or possibly from sewage backup because of the lack of appropriate safety devices. Some evidence of person to person spread because of environmental contamination.	After the investigation the ship was wet docked for one week to discard the ice and thoroughly clean the ice machine and cabins.
1992	Sharp et al, 1995	Norwalk –like virus(NLV)	Person to person	It was speculated the NLV was initially introduced into the ship's population around the time of departure by one or more crewmembers infected in their communities. Limitations on the use of water for hygienic purposes and common toilet facilities may have been contributing factors. Normal tests for chlorine residual and coliform bacteria make water a less likely vehicle, although NLV has been shown to survive in chlorinated water.	
1993	CDSC report, 93/254.	Norwalk –like virus(NLV)	Food	One food handler positive. Navy ship	

1994	Bristol City Council,UK. Unpublished report.	Norwalk –like virus(NLV)	Person to person	Poor hygiene standards. Cockroach infestation.	
1995	Mc Evoy *et al*, 1996	Norwalk –like virus(NLV)	Person to person spread\ water	Inappropriate food hygiene and storage. During a 24hr period no chlorine detected in water. Food handlers known to be ill	The ship was cleaned and disinfected at the end of the 4th cruise in order to interrupt transmission. Galley required several improvements to comply with good food handling practices. Recommended that water continuously chlorinated, that written exclusion policy for food handlers be available, that disembarkation take place several hours before boarding to prevent passengers mixing.
1996	Oyofo, 1999	Norwalk –like virus(NLV)	Food or water	Eating and drinking in a port city in SE Asia	
1997	Corwin, 1999	Norwalk –like virus(NLV)	Unknown	Two consecutive outbreaks of gastroenteritis occurred on this ship in 1998 perhaps due to continued persistence of NLV within this shipboard environment.	
1997	Glynn *et al*, 1997	Norwalk –like virus(NLV)	Water	Associated with drinking water. During the previous week one water sample was positive for coliforms.	The report recommended that the ship operator consider testing all water before bunkering as a proxy for the potential presence of NLV. Recommended that ship evaluate bunkered water and water processing practices; investigate improved methods of detecting NLV in water; evaluate the efficacy of routine chlorination practices in inactivating NLV on cruise ships.
1998	CDC, 1998	Norwalk –like virus(NLV)	Unknown	Source of outbreak not discovered.	Ship dry-docked for one week. Linens disinfected.

1998	CDSC,UK	Norwalk –like virus(NLV)	Person to person	Deficiencies in food handling water chlorination, swimming pool water treatment and housekeeping. Epidemiological association with visiting, eating and drinking on a Caribbean island. Chlorination monitor for the potable water supply not calibrated, bunkered water positive for coliforms, lack of backflow valves in certain areas, manual chlorination of swimming pool inadequate, recorded levels of chlorine below the recommended minimum level, potable water lines submerged in seawater, no marking of pipes.	Recommendations relating to water treatment, food preparation and environmental cleaning.
1998	CDSC, UK	Norwalk –like virus(NLV)	Person to person	Recorded coliform counts in drinking water high over the previous 3 cruises. Water could have been a possible route of transmission. Seawater taken up at 10 miles at sea (as opposed to 20 miles) Crew felt that drinking water might have contributed to the outbreak as many passengers drank tap water as opposed to bottled water at meal times.	General hygiene recommendations. Recommendation to check water tanks during outbreaks and correlate these with infection.
Jan 2000	Cramer 2000	Norwalk –like virus(NLV)	Person to person	Potential sources of spread of NLV included consumption of contaminated food, water, and ice.	Ship voluntarily removed from service to carry out recommendations provided by VSP.
May / June 2000	Cramer, 2000	Norwalk –like virus(NLV)	Food or water	**Chicken, associated with illness. Potable water hoses stored without ends capped to protect from contamination. Potable and non-potable water fitting together. Shower hoses not equipped with backflow**	Next three cruises cancelled to accommodate recommendations.

				preventers. There were numerous incidents in the past when sewage system had backed up flooding bathroom decks and sewage. Clothes washing machines not equipped with backflow preventers. Potable water system had not been periodically superchlorinated. Source of the virus and mode of transmission not found. Deficiencies could have facilitated its transmission.	
Aug 2000	East Kent Health Authority, UK	Norwalk –like virus(NLV)	Person to person	Two sister ships. Investigating officers raised concerns over water chlorination levels. Confirmed case of legionnella on the ship.	Investigating officers recommended that the water quality treatment on board the ship be improved and proper procedures for cleaning swimming pools and Spas. Officers recommended improved chlorination of the water supply. Fully automatic chlorination plants were installed on two ships

APPENDIX C

Table 5. Review of legionnaires' disease associated with ships, 1977- 2001. Information on type of ship, geographical region and mortality and morbidity.

Reference	Year of incident	Type of ship	Geographical region	Mortality and morbidity	Comments. *(Evidence)*
Meenhorst PL, et al, 1979	**1977**	**Cruise ship**	**Mediterranean**	**One case. Dutch tourist**	***(PosA)*. First report of a ship associated case of legionnaires' disease.**
Mc Kinney et al, 1981	**1981**	**Cruise ship**	**Mexico**	**One case. USA tourist**	***(PosA)***
Rowbotham et al, 1983	**1982**	**Cruise ship**	**UK to canary Islands**	**One case. English tourist**	***(PosA)***
Anon, 1983	**1983**	**Cruise ship**	**Cadiz**	**One case Scottish tourist**	***(PosA)***
Berntsson, 1984 Christenson et al, 1986	**1984**	**Cruise ship**	**Gothenburg to Mediterranean and London**	**71 cases. 295/335 passengers known to have been ill with influenza like illness. Mainly Swedish tourists.**	**Ventilation and water systems on board could have been reservoirs for the pathogen. Outbreak occurred after air conditioning was turned on at Bordeaux. Ship was built in 1948. *(PosA)***
Rowbotham, 1998	**1984**	**Cruise ship**	**Mediterranean**	**One case. English tourist**	**Ship built in 1957 *(PosA)***
Rowbotham, 1998	**1986**	**Cruise ship**	**Mediterranean**	**One case English tourist**	**Case noted shower water discoloured after docking in Tunis *(PrA)***
Castellani-Pastoris et al, 1987	**1986**	**Oil drilling platform**	**Silicy**	**Case diagnosed with Lp1 two days before end of five weeks on platform**	**Water positive for Lp1 *(SA)***
Rowbotham,	**1987**	**Cruise ship**	**Mediterranean**	**One case.**	**Onset four days after 28 day cruise. Third**

1998				**English tourist**	**case associated with this ship.** ***(PosA)***
Rowbotham, 1998	**1987**	**Cargo ship**	**No details**	**One case in sailor**	***(PosA)***
CDSC,UK, 1997	**1987**	**Cruise ship**	**Caribbean**	**Three cases. UK and USA tourists**	**Ten day spring cruise** ***(PosA)***
Rowbotham 1998	**1989**	**Cruise ship**	**Canary Islands**	**One case English tourist**	**Onset on day six of seven day cruise. Symptoms after first used shower. Case on this ship in 1982.** ***(PosA)***
Rowbotham	**1989**	**Ferry**	**Felixstowe, UK**	**One case**	**Onset 20th Sept. Travel dates 2nd Sept and 9th Sept.** ***(PosA)***
Rowbotham 1998	**1990**	**River Cruise**	**Rhine river, Germany**	**One case**	**One case following a four day cruise.** ***(PosA)***
Rowbotham, 1998	**1991**	**Cruise ship**	**Spain**	**One case. Scottish tourist**	**Onset three days from end of cruise. Did not go ashore. Case had pre-existing severe respiratory disease.** ***(PosA)***
Rowbotham, 1998	**1991**	**Cruise ship**	**USA, West Indies and Mexico**	**One case**	**Case traveled on 27th November to 12th December. Onset was on 11th December.** ***(PosA)***
Rowbotham, 1998	**1991**	**Two different ferries**	**Corsica, France**	**Two cases**	***(PosA)***
Rowbotham 1998	**1992**	**Cruise ship**	**Mediterranean**	**One case**	**Ship identity not known** ***(PosA)***
Rowbotham 1998	**1992**	**Cruise ship**	**Caribbean**	**One case. Scottish tourist.**	***(PosA)***
Rowbotham, 1998	**1992**	**Cruise ship**	**Mediterranean**	**Fatal pneumonia. Diagnosed in UK**	**Onset two weeks after start of two week cruise. Ship used as floating hotel for US troops during gulf war.** ***(PosA)***
Rowbotham, 1998	**1992**	**Russian training ship**		**Four cases**	**Legionellae organisms isolated from water on ship.**

					(SA)
Rowbotham, 1998	**1992**	**River Cruise**	**Nile , Egypt**	**One case. British tourist. Fatal.**	**Case spent seven days on Nile cruise followed by seven days in an hotel and one night at an airport hotel.*(PosA)***
CDSC 1993,	**1993**			**One case in a Danish sailor**	***(PosA)***
Rowbotham, 1998	**1993**	**Ferry**	**Scotland to Germany**	**One case**	**Case took overnight ferry five days before onset of symptoms *(PosA)***
Anon, 1994 Rowbotham, 1998	**1994**	**Cruise ship**	**Eastern Mediterranean**	**Two case**	**Onset in case two days after 13 day cruise. Another case followed. This case had an onset on the last day of a 15 day cruise. *L. fallonii* and amoebae isolated from the ship. *(SA)***
Jernigan et al , 1996	**1994**	**Cruise ship**	**USA**	**50 passengers identified in nine different cruises. One fatal case.**	**Exposure to a whirlpool spa strongly associated with disease. *Legionella pneumophila* serogroup 1 was isolated from the sand filter in the ship's whirlpool spa. *(SA)***
Rowbotham, 1998	**1994**	**Cruise ship**	**Israel and Egypt**	**One case**	**Onset one day after four day cruise. *(PosA)***
Joseph, et al, 1995	**1994**	**Cruise ship**	**Two consecutive Mediterranean cruises on the same ship**	**One case**	**On investigation , problems with the air-handling units were revealed. *(PrA)***
Rowbotham, 1998	**1994**	**Ferry**	**Germany to UK**	**One case**	**Case had onset four days after overnight crossing.*(PosA)***
Rowbotham, 1998	**1994**	**Ferry**	**Spain to England**	**One case. Fatal.**	**Onset six days after ferry crossing. *(PosA)***
Rowbotham, 1998	**1994**	**Ferry**	**Greece**	**One case**	**Onset three days after ferry crossing. (*PosA)***
Rowbotham	**1995**	**Cruise ship**	**Canary Islands**	**One case. Fatal.**	***Legionella pneumophila* isolated from ship.**

1998			**and N. African coast**		**Air conditioned cabin. Ship built in 1966.** ***(SA)***
Rowbotham, 1998	**1995**	**River cruise**	**Rhine river, Germany**	**One case**	**Onset one day after nine day cruise.** ***(PrA)***
Rowbotham, 1998	**1995**	**River cruise**	**Rhine river, Germany**	**Two cases. One fatal. Another case associated with cruiser.**	**Onset four days after seven day cruise.*(PosA)***
Pastoris et al, 1999	**1995**	**Cruise ship**	**Italy**	**One case . Fatal. Two other cases associated with ship. English tourist.**	**Same serogroup isolated from water supply and from case. This is the first documented evidence of the invovement of a water supply in the transmission of legionella infection in ships.** ***(SA)***
Rowbotham, 1998	**1996**	**Cruise ship**	**Spain and N. Africa**	**One case. English tourist.**	**Case was the first to use shower in cabin. Second case associated with this ship.** ***(PrA)***
Rowbotham, 1998	**1996**	**Cruise ship**	**Sydney, Australia.**	**One fatal case**	The case spent most of his incubation period on board the ship. Water samples not obtained from ship. ***(PosA)***
Rowbotham 1998, Blazer, 1997, Thomas, 1998.	**1996**	**USA Navy Cruiser.**		**Fatal case. Four other cases of pneumonic illness on the same ship**	**Epidemiological investigation revealed no clear source of infection. The sailor lived on board ship and reportedly rarely went ashore. Two water samples grew *Legionella cherii,* which has never been associated with human disease. The cultures of the water supply aboard the vessel did not grow *Legionella pneumophila*. The ships water system was hyperchlorinated to 200ppm for four hours to eliminate any *Legionella***

					bacteria that might have been present. *(PosA)*
Rowbotham, 1998	**1997**	**Cruise ship**	**UK, Ireland and Baltic ports**	**One case of pneumonia in boiler repair mN**	**Case joined the ship 16 days before onset of symptoms. His symptoms began eight days after exposure to warm rusty water leaking into a stream boiler from a tank external to the boiler. *(PrA)***
Christi et al, 1998	**1997**	**Fishing vessel**	**Spain**	**One case**	**Water supply onboard found to be the source of infection for one of its crew. *(SA)***
Rowbotham, 1998	**1997**	**Ferry**	**Trieste to Pastras Greece**	**Fatal case from Austria**	**Case spent four nights on ferry before onset of symptoms.*(PosA)***
Rowbotham, 1998, Joseph, 1997	**1997**	**River cruise**	**Germany**	**Six cases. All British tourists.**	**Whirlpool spa suspected source. *Legionella pneumophila* isolated from spa. Chlorine was not applied to the water or monitored. *(SA)***
CDR 1998, Arthur , 1998	**1998 May and June**	**Cruise ship**	**Mediterranean and Norwegian Fjords**	**Three cases, British tourists**	**Legionella found in hot water samples from showerheads. Defective temperature control of hot and cold water systems. Ship had been associated with two legionella cases since 1995. The pipework for both the hot and cold supplies was treated by pasteurisation followed by shock dosing with chlorine dioxide and the installation of a continuous chlorine dioxide dosing plant.*(SA)***
Q-net, Australia Feb, 99	**July 1998**	**River cruise**	**Rotterdam, the Netherlands**	**One case , American tourist**	**Investigated by the Port of Rotterdam. *(PosA)***

Q-net, Australia Feb, 99	**Nov 1998**	**Boat**	**New Zealand**	**No cases**	**Bacteria found in water supply**
EWGLI	**1999**	**Cruise ship**		**One case**	
EWGLI	**July 1999**	**Cruise ship**		**One case**	
EWGLI	**Nov 1999**	**Ferry**		**One case**	
East Kent HA, UK	**Aug 2000**	**Cruise ship**	**Norwegian ship in UK**	**One case**	
EWGLI	**Aug 2000**	**Ferry**		**One case**	
Maritime matters, 2000	**Sept 2000**	**Cruise ship**	**South Pacific cruise**	**12 cases, 2 deaths**	**Not confirmed**
EWGLI	**June 2001**	**Cruise**		**One case**	
EWGLI	**Jan 2001**	**Two ferries ,**	**Corsica**	**One case**	**Water samples positive for Lp1 on both ferries.** ***(SA)***