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# Bacteriological threats in water sports: Challenges and Health Risks in the Lead - Up to Major Sporting Events

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## ABSTRACT

**Introduction:** Water quality is a critical issue affecting human health, with contamination by pathogens leading to various diseases. Pathogens in water, often transmitted through the fecal-oral route, pose significant risks, causing gastrointestinal diseases and bacterial diarrhea. The World Health Organization (WHO) has set water quality standards for recreational use, and sports events like triathlons and the Olympics may involve waterborne infection risks. Additionally, athletes in water sports face health risks from physical exertion and environmental conditions, including exercise-induced bronchoconstriction, hypothermia, hyperthermia and swimming-induced pulmonary edema. Understanding these risks and implementing preventive measures are crucial for ensuring the safety and health of athletes and participants in water-based sports events.

**Purpose of the work:** The purpose of this study is to review the impact and risks of pathogenic microorganisms found in water on the health and physical performance of athletes. Special attention is given to the organization of water sports competitions in the context of microbiological threats.

**Materials and methods:** A comprehensive analysis of research articles available on PubMed, Google Scholar, Web of Science, Embase, and Scopus was conducted using search terms related to: "water sports", "microbiological hazards", "water pathogens", "water quality", "athletes" and "prevention."

**Results:** Microbiological threats included in water expose participants in major sporting events to potential infection that can cause various health issues. To reduce these risks, water quality standards must be monitored, and actions should be taken when limits are exceeded. Event organizers must prioritize athlete safety, considering factors like weather and water quality, and involve public health authorities in decision-making. If health risks are identified, rescheduling or changing the event location should be considered.

**Keywords:** microbiological threats, water sports, water quality, sporting events, prevention.

## INTRODUCTION

A significant issue that affects various aspects of human life, particularly human health, is the global problem of water quality. This is associated, among other factors, with the contamination of water resources by pathogens that cause various diseases. Nearly all types of water bodies now show the risk of the presence of pathogenic microorganisms, which makes it important to understand how to combat their contamination. Ensuring proper water quality can significantly reduce the potential risk of infections caused by various disease agents. [1]

The greatest microbiological risks to human health are caused by microorganisms transmitted via the fecal-oral route. They are present in the aquatic environment as a result of contamination with human or animal feces. Among others, gastrointestinal diseases and bacterial diarrhea transmitted via water have caused many epidemics in the past. [1, 2] Diseases transmitted by microorganisms present in water affect both developing and developed countries. [2, 3]

The issue of exposure to pathogens also applies to the use of water bodies for recreational purposes. There is a wide range of waterborne diseases, some of which are harmless and self-limiting, while others can have dramatic effects on human health. Recreational water users may be exposed to a variety of microorganisms that naturally occur in water bodies. However, many of these, which may include infectious agents of concern to human health, result from fecal contamination of water. Fecal contamination comes from sewage as well as surface runoff. Domestic and wild animals can also be sources. [4, 5, 6] Water quality can also be affected by weather conditions. For example, heavy rainfall can increase the levels of bacteria and other pathogenic microorganisms in the water. [7, 16]

The World Health Organization (WHO) has classified recreational activities into three categories. The first category includes those with no direct contact with water (e.g., walking along a lake shore). The second category includes incidental or secondary contact, such as through rowing or fishing. The last category involves full-body contact with water. These activities often involve full-body immersion, or the face is frequently splashed with water (e.g., swimming, diving, or whitewater kayaking). Microbiological hazards in recreational water include marine and coastal waters, natural freshwater reservoirs, as well as swimming pools, and jacuzzis. [6]

Water quality standards have been established through the World Health Organization (WHO) to ensure the safe use of water for recreational purposes. Additionally, guidelines from the Australian National Health and Medical Research Council (NHMRC) identify seven key aspects in the assessment of recreational water. These include natural hazards, environmental factors, microbiological quality, the presence of cyanobacteria, the presence of hazardous aquatic organisms, chemical quality, and aesthetic quality. [8]

Currently, there is a great deal of interest in major sports events, both national and international. These include, for example, triathlons and the Olympic Games. However, organizing major sports competitions also involves the potential risk of transmitting infectious diseases, which can occur in various ways. Based on the main transmission routes, infectious diseases reported by organizers can be divided into five categories: respiratory tract infections, gastrointestinal tract infections, vector-borne infections, blood-borne infections, and infections through contact with water. [7]

Water-based sporting events can take place in swimming pools, but open water swimming (OWS) competitions are becoming increasingly popular worldwide. These events are held in rivers, lakes, oceans, and seas. In order to prevent waterborne infections during competitions and races, both organizers and participants should be aware of the potential risks associated with accidental ingestion or inhalation of water contaminated by pathogenic microorganisms. The risk of various infections following OWS events has been particularly noted among triathlon competitors. [7, 8]

For athletes, the preparation period and participation in competitions already place a significant stress on their physical condition. Additional exposure to waterborne infectious

diseases further impacts their health. Negative effects caused by inadequate conditions and poor water quality during the race can occur both during and after the event. [8, 16]

Athletes in water sports face a variety of health risks associated with prolonged and intense exertion in challenging conditions. A common issue is exercise-induced bronchoconstriction (EIB), which affects up to 50% of swimmers. These athletes may also suffer from hypothermia or hyperthermia caused by physical exertion. Hyperthermia is the leading cause of death in endurance sports. Furthermore, a potential threat to their health and life is the risk of swimming-induced pulmonary edema (SIPE) or even sudden cardiac death (SCD). Most cases of sudden cardiac arrest related to swimming occur during open water competitions. [8] Athletes should also be aware of the dangers posed by diseases transmitted by harmful bacteria present in water bodies. [7, 8]

It is crucial to understand the risk factors of infectious diseases, their proper surveillance, and the potential health consequences for athletes. The information collected can help introduce appropriate preventive measures and optimize the planning of future major sports events around the world. This is essential to ensure safe conditions for the health and safety of athletes, as well as passive participants in the competitions. [7, 8]

## CHARACTERISTIC OF WATER BODIES AND CHALLENGES IN MONITORING WATER QUALITY

Water is an essential element of many sports disciplines, from swimming, sailing, kayaking, to surfing – each of these activities involves close contact with water and often with soil. Practicing sports that include contact with aquatic environments poses a risk of bacterial, viral, or protozoal infections.Increased exposure to pathogens present in water and soil creates a serious challenge to the health of athletes, especially during periods of preparation for major sports events. [9] Long swimming in open water in the case of triathlon competitions, as well as numerous training sessions to prepare for competitions can be considered a relatively high risk of infection. This is due to the long time spent in water and the consumption of a significant volume of water by athletes. [10] The number of pathogenic microorganisms present in water is extensive and diverse in terms of geographical distribution, affecting both freshwater and saltwater bodies. [11] The main bacteria posing a threat to swimmers include enteric bacteria such as *Escherichia coli*, *Enterobacter*, *Salmonella*, *Shigella spp.*, and *Yersinia enterocolitica*, as well as other bacteria like *Campylobacter spp.*, *Leptospira*, *Vibrio vulnificus*, and *Vibrio cholerae*. [9, 11] The occurrence of a specific bacterial species varies depending on the location, the type of water present in the reservoir (fresh or saltwater), and factors affecting the water body, such as rainfall, sewage pollution, proximity to animals, or agricultural activities. [11]

### Saltwater

Coastal waters and estuaries (areas connecting a river with the sea or ocean, creating a transition between fresh and saltwater) belong to salt waters, and their bacterial

contamination results mainly from the discharge of polluted urban waters and sewage.Numerous studies have been conducted to identify the species of bacteria, taking into account their survival mechanism in the water body. The predominant species among the studied bacteria was *Escherichia coli*, but bacteria such as *Vibrio cholerae, Giardia, Cryptosporidium, Salmonella, Campylobacter, Clostridium perfringens* were also identified in water. [11]

The presence of bacteria in saltwater is due, among other factors, to the discharge of rainwater into coastal waters through drainage systems, even if they are separate from the sanitary sewage system. Urban wastewater discharged into estuaries also contributes to the increase in bacterial pollution, accounting for approximately 12% of total pollution in the USA [12]. Rivers that drain water from undeveloped and wetland areas can be a natural source of bacteria. Additionally, coastal algae beds serve as reservoirs for fecal bacteria, and their removal from tidal areas can help improve water quality in neighboring regions [13].

**Groundwater**

Groundwater is widely used in daily life as a source of drinking water, with one-third of the global population dependent on it for this purpose. These waters are also extensively used in industry and agriculture. The diversity of contaminants detected in groundwater is steadily increasing, coming from both natural and anthropogenic sources [14]. Bacteria that can be found in groundwater include *Salmonella, Escherichia coli, S. faecalis, Pseudomonas aeruginosa, Salmonella i Staphylococcus aureus.* There have been many studies regarding their survival, which conclude that microbial pathogens such as *Salmonella, Escherichia coli, S. faecalis* and enteroviruses are relatively stable in groundwater [11], and chlorine-resistant *Cryptosporidium* bacteria pose a significant risk to human health. [11, 15, 16, 17]

One of the main sources of bacteriological contamination is the presence of wetlands without a lining. These are areas that naturally accumulate water (swamps, marshes) and do not have an appropriate protective layer at the bottom that would prevent water from penetrating the underground layers. [11, 15] Another factor contributing to biological contamination of groundwater is the presence of macropores in the soil, especially in agricultural areas where manure is used to fertilize the soil. Such conditions promote the movement of bacteria from agricultural land to groundwater through macropores in the soil. [11]

**Rivers and lakes**

Rivers and lakes are freshwaters, often used for recreation and as a source of drinking water. Despite increased control of drinking water, they are still a source of numerous gastrointestinal infections caused by fecal bacteria as well as *Vibrio cholerae* or *Cryptosporidium parvum* [18, 19]. Surveillance data from the United States of America showed that in 2009 and 2010 there were 24 outbreaks of diseases in recreational waters and the main pathogens were: *Campylobacter jejuni, E. coli O157:H7, Shigella sonnei, Cryptosporidium spp., Giardia intestinalis ,* noroviruses and avian schistosomes. [19] The

presence of bacteria is caused by water contamination by sewage from sewage treatment plants. An increase in fecal bacteria may result from elevated nutrient levels or the direct introduction of pathogens [18]. Another factor contributing to the contamination of rivers and lakes is surface runoff and the feces of domestic and wild animals [19].

**Cyanobacteria**

The presence of cyanobacteria and their excessive blooms can prevent the use of water for both recreational and consumption purposes [18]. *Cyanobacteria*, also known as blue-green algae, are a group of unicellular organisms classified in the kingdom Bacteria. Their excessive growth causes water turbidity and reduces the availability of light for organisms located deeper. [19] Moreover, they produce strong toxins (cyanotoxins) that cause many health problems such as skin irritation, gastrointestinal problems, and liver damage. [18] Studies have shown that the hepatotoxicity of cyanobacterial toxins is partly due to the inhibition of protein phosphatases, which play a key role in cellular regulation [19]. Therefore, during cyanobacterial blooms, swimming and other water activities are prohibited due to significant health risks.

**Water quality monitoring methods**

Due to the potential health risks from exposure to pathogenic bacteria present in recreational waters, monitoring methods for pollution and criteria for assessing water quality have been developed [19]. One of the primary indicators of water contamination is the bacterium *Escherichia coli*. This Gram-negative rod primarily inhabits the lower gastrointestinal tract of warm-blooded animals, including humans. It is excreted into the environment with feces, and thus can be a source of water contamination through sewage. Depending on the host species, its concentration per gram of feces ranges from $10^7$ –$10^9$ in humans and $10^4$–$10^6$ in domestic animals [20].

Epidemiological studies conducted in the 1980s by the United States Environmental Protection Agency (USEPA 1986) [20, 22] and Edberg (2000) [20, 23] revealed a correlation between *Escherichia coli* levels in recreational waters and the incidence of gastrointestinal diseases [20]. This led to the recognition of *E. coli* as a Fecal Indicator Bacteria (FIB). However, the limitations of this method were noted, as FIB indicators correlate with health risks to varying degrees depending on the location, which complicates standardization. [21] Traditional tests for *E. coli* presence are performed using the multiple-tube fermentation technique or by filtration through a membrane. Detection of bacteria through the membrane is a very sensitive method because it allows for detection of a single bacterial cell even in 1000 ml of water [24]. However, these methods are time-consuming, partly due to the approximately 24-hour incubation period. This created the need for alternative, faster methods

of bacterial detection. As a result, improved technology based on PCR (Polymerase Chain Reaction) was introduced [19]. It was determined that the results obtained through this method are sufficiently accurate in most cases [11], however, the results obtained by classical methods and PCR are often different [11, 19]. Additionally, commercial kits such as Colilert-18 and the Quanti-Tray/2000 system (IDEXX Laboratories) have been developed, enabling rapid and cost-effective detection of *E. coli* in water samples [20].

**Other methods**

Another simple method used to assess the risk of microbiological contamination of water is turbidimetry, used for example in water treatment plants. Turbidimetry measures the turbidity of suspended solids and is based on the relationship between the amount of light emitted by the source and the amount of light reaching the spectrophotometer detector. Unfortunately, this method has low sensitivity because there is no direct correlation between the density of pathogens in water and turbidity. Moreover, the turbidity measurement in freshwater is influenced by the presence of plankton, the size, and the shape of suspended solids. Thus, interpreting turbidity levels as an indicator of sanitary risk is difficult and imperfect due to the previously mentioned dependencies [25].

An alternative method is fluorescence measurement, which involves using the fluorescent properties of various organic substances to analyze their origin and type of contamination. This method uses the life cycle of the bacteriophage and its species-specificity, which allows for the detection of *Escherichia coli* in environmental samples. [25]

Another approach that can be used is Quantitative Microbial Risk Assessment (QMRA). QMRA consists of four steps: hazard identification, exposure assessment, dose-response assessment, and risk characterization. QMRA is a statistical model used to estimate the risk associated with exposure to pathogens. It can be applied to both drinking water and water used for recreational purposes [26].

**Water quality standards**

During bathing in a water body, a person is exposed to infections not only through drinking water but also through contact with the skin and respiratory tract. To ensure the safety of people using water bodies, acceptable limits for the concentration of indicator bacteria have been established, allowing for safe use of bathing areas.

The Environmental Protection Agency (EPA) is responsible for protecting the environment and public health by creating and enforcing environmental protection regulations. It defines acceptable limits as follows: for an estimated illness rate of 36/1000 people, the geometric mean of the measurement results should not exceed 126 CFU of *E. coli* bacteria per

100 ml of water, and the statistical threshold value (STV): 320 CFU per 100 milliliters. For an illness rate of 32/1000, this is 100 CFU/100 ml GM and 320/100 ml STV, respectively. [27]

| | Recommendation 1<br>Estimated Illness Rate: 36 per 1,000 | |
|---|---|---|
| Indicator Organism | Geometric Mean (cfu/100 mL) | Statistical Threshold Value (STV- 90th percentile) (cfu/100 mL) |
| *E. coli* (freshwater) | 126 | 410 |

| | Recommendation 2<br>Estimated Illness Rate: 32 per 1,000 | |
|---|---|---|
| Indicator Organism | Geometric Mean (cfu/100 mL) | Statistical Threshold Value (STV- 90th percentile) (cfu/100 mL) |
| *E. coli* (freshwater) | 100 | 320 |

**Table 1.** Two sets of E.coli criteria based on two different estimated illness rates.
Source: Anderson and Rounds (2003)

The EPA recommends weekly water sampling and analysis. The geometric mean (GM) of the samples should not exceed the criterion selected from the two recommendations within any 30-day period, while the statistical threshold value (STV) is similar to the 90th percentile, meaning that no more than 10% of the samples should exceed this value. Exceeding the recommended values may indicate fecal contamination and pose a risk to recreational water users, so immediate action should be taken. If the value is exceeded,
a public notice is issued and an appropriate announcement is made to inform the public about the closure of the water body. The source of the bacteria should be identified, and appropriate measures should be taken to prevent similar occurrences in the future [27].

Water quality standards for bathing waters in European Union countries are defined by the European Parliament Directive of February 15, 2006. According to it, the permissible level of *E. coli* CFU for "sufficient" water quality is 500 CFU/100 ml for transitional and coastal waters and 900 CFU for inland waters. The CFU level for "excellent" water quality is 250 CFU per 100 ml for coastal and transitional waters and 500 CFU per 100 ml for inland waters. Bathing water should be classified as "poor" if the microbiological results are worse than the minimum requirements for "sufficient" quality. [28]

**For inland waters**

| | A | B | C | D | E |
|---|---|---|---|---|---|
| | Parameter | Excellent quality | Good quality | Sufficient | Reference methods of analysis |
| 1 | Intestinal enterococci (cfu/100 ml) | 200 (*) | 400 (*) | 330 (**) | ISO 7899-1 or ISO 7899-2 |
| 2 | Escherichia coli (cfu/100 ml) | 500 (*) | 1 000 (*) | 900 (**) | ISO 9308-3 or ISO 9308-1 |

(*) Based upon a 95-percentile evaluation. See Annex II.
(**) Based upon a 90-percentile evaluation. See Annex II.

**For coastal waters and transitional waters**

| | A | B | C | D | E |
|---|---|---|---|---|---|
| | Parameter | Excellent quality | Good quality | Sufficient | Reference methods of analysis |
| 1 | Intestinal enterococci (cfu/100 ml) | 100 (*) | 200 (*) | 185 (**) | ISO 7899-1 or ISO 7899-2 |
| 2 | Escherichia coli (cfu/100 ml) | 250 (*) | 500 (*) | 500 (**) | ISO 9308-3 or ISO 9308-1 |

(*) Based upon a 95-percentile evaluation. See Annex II.
(**) Based upon a 90-percentile evaluation. See Annex II.

**Table 2.** Two sets of water standards for inland, coastal and transitional waters.
Source: Directive 2006/7/EC of the European Parliament and of the Council of 15 February 2006 concerning the management of bathing water quality and repealing Directive 76/160/EEC.

The International Triathlon Union (ITU) adopted in 2010 the water quality standards contained in the aforementioned European Union Directive 2006/7/EC [28] regarding the quality of water intended for bathing. Especially for international triathlon competitions, meeting these standards is absolutely essential. The ITU recommends that triathlons be held only in swimming water that falls into the category of "excellent" water quality. If the water quality does not meet this criterion, the swim will be canceled unless the ITU Medical Committee allows swimming in "good" water. [10, 29]

It is crucial to control water quality and take action to avoid or reduce bacteriological threats. Exposure of athletes or recreational water users to pathogens present in the water can

lead to various consequences and may cause infections. Therefore, adhering to water quality standards during the organization of sporting events, as well as in daily life, is essential.

## THE IMPACT OF PATHOGENS ON ATHLETES' HEALTH

Water-related sports, especially freshwater sports, are very popular worldwide. Participants are exposed to various injuries and health issues. The risk of infectious diseases transmitted by pathogenic microorganisms present in the aquatic environment is well documented. [30, 36]

The infections that may occur depend on the geographical location and the surrounding environment (such as the type of soil, standing water, mud, and the presence of wild and domestic animals). Weather conditions preceding or occurring during major sporting events are also believed to have a significant impact on water quality. This is particularly concerning, as in recent years, there has been an increase in the frequency of extreme rainfall and associated floods worldwide, which in turn affects water quality. [36, 37]

Exposure to aquatic pathogens may be associated with sports that have been popular for many years, such as swimming, triathlon, kayaking, rafting, and water skiing, but also with newer extreme sports, such as ultramarathons and adventure racing (AR), which are becoming more popular. Immersion in water during these activities may be total (for example, when swimming in long-distance triathlons) or only partial. [36]

### Skin infections

Spending time in bodies of water is associated with the potential risk of developing dermatological conditions. Skin conditions related to water exposure, commonly observed in swimmers, can be categorized into various groups. These may include contact dermatitis, dermatoses caused by pathogenic microorganisms, allergic dermatoses, or other conditions (e.g., irritation-related issues).

Exposure to freshwater (lakes, ponds, and swimming pools) and saltwater can lead to different consequences. The vast majority of skin conditions in water sports result from the presence of pathogenic microorganisms or chemical substances in the aquatic environment. [30]

### Aquarium granuloma

Aquarium granuloma is caused by atypical mycobacteria such as *Mycobacterium marinum* and *Mycobacterium scrofulaceum*. These microorganisms are found in both freshwater and saltwater. Infection can occur during occupational or recreational exposure. Potential vectors include fish, snails, crustaceans, dolphins, and water fleas.

Clinically, the infection may present as wart-like plaques or nodules, occasionally ulcerative, typically appearing on the extremities (primarily the fingers). The infection can also affect deeper tissues such as tendon sheaths, bursae, bones, and joints. In cases where the infection spreads via lymphatic vessels, a sporotrichoid pattern may be observed, which is present in approximately 20% of patients. [30, 31]

**Swimmer's Ear (Otitis Externa)**

The primary causes of otitis externa in swimmers and other athletes engaged in water-related activities are *Pseudomonas aeruginosa* and *Staphylococcus aureus*. This condition occurs up to five times more frequently in this group compared to non-swimmers. [30]

Risk factors for developing *Pseudomonas aeruginosa*-related otitis externa include time spent in water, age (below 19 years), a history of prior ear infections, and repeated exposure to contaminated water. [42] Clinically, patients experience pain and itching in the external auditory canal. Symptoms intensify with movement of the auricle. Discharge from the ear and hearing loss may occur as a result of swelling and the presence of exudate. Some medical conditions, such as diabetes, predispose individuals to the development of malignant otitis externa, in which the infection also affects the temporal bone. [30, 31, 32]

**Vibrio vulnificus infections**

*Vibrio vulnificus* is a gram-negative, motile bacterium that causes wound infections and gastrointestinal diseases. Infection can occur as a result of an injury in the marine environment or through the consumption of raw or undercooked shellfish. In swimmers, it can cause two distinct clinical syndromes. [32, 33]

The first is primary sepsis, resulting from the intake of undercooked seafood, especially raw oysters. Patients present with fever, diarrhea, nausea, and vomiting. Septic shock may develop. Within 24 hours, patients typically develop skin lesions, including severe cellulitis, petechiae, and blisters. [31, 33]

The second possible clinical manifestation is necrotizing wound infection, causing painful, rapidly progressing cellulitis. It may present with systemic symptoms, and the mortality rate exceeds 50%. Localized tissue swelling and hemorrhagic blisters are common. The infection affects men more frequently than women, possibly due to the presence of the female hormone estrogen, which, through an unknown mechanism, provides protection against the endotoxin of *Vibrio vulnificus* [33].

**Impetigo**

Impetigo is a primary or secondary bacterial infection of the superficial layers of the skin resulting from its damage. In athletes, abrasions are potential entry points for pathogenic microorganisms. It is caused by *Staphylococcus aureus* or, less commonly, by *Streptococcus pyogenes* (group A β-hemolytic *Streptococcus*) [34]. There is probably a strong association between exposure to seawater and staphylococcal skin infections [35].

In the early stage of the disease, erythematous papules develop. Later, these lesions merge into an erythematous plaque, covered by honey-colored crusts. They most commonly

appear on the face or limbs. There is also a vesicular form, in which lesions typically appear on the trunk. [33, 34].

When selecting antibiotics for treatment, it is important to be aware of the increasing frequency of methicillin-resistant *Staphylococcus aureus* (MRSA) [35].

**Gastrointestinal infections**

Since the 1950s, evidence has shown an association between recreational water use and the risk of gastrointestinal illnesses. [8] Given the presence of pathogenic microorganisms in water bodies used during major sporting events, it is important to carefully monitor the symptoms that athletes may experience in the days following the competition, or even on the day of the event. [37, 38] A variety of gastrointestinal illnesses can occur, ranging from bacterial and viral infections to those caused by protozoa. Most infections are mild, meaning many cases may go unreported and undiagnosed. [8] Gastrointestinal symptoms that may occur include diarrhea (with or without blood), vomiting, nausea, stomach cramps, abdominal pain, and general symptoms such as weakness or fever. [37, 38]

Difficult weather conditions occurring before or during competitions involving bodies of water, such as extreme rainfall, significantly increase the risk of gastrointestinal illnesses caused by pathogenic microorganisms. Inadvertent ingestion of even small amounts of water contaminated with sewage can lead to pronounced symptoms in individuals who are exposed. [37]

Gastrointestinal bacteria transmitted through fecal contamination in the environment, such as *Shigella spp*. and *Campylobacter spp.*, are common sources of acute gastrointestinal illnesses. The risk of infection increases with the ingestion of contaminated water. To prevent these illnesses, athletes should wash their hands regularly and take precautions to avoid accidental ingestion of contaminated surface water. [36] Gastrointestinal infections can also be caused by *Pseudomonas aeruginosa*. [42]

A higher amount of swallowed water is associated with an increased risk of illness. [38, 39] Significant risks have been identified with contact with sewage-contaminated recreational water, especially when levels exceed 500 *E. coli* or 200 *Enterococci* per 100 ml. [37]

**Respiratory tract infections**

**Infections caused by *Pseudomonas aeruginosa***

The gram-negative bacterium *Pseudomonas aeruginosa* is responsible for many episodes of infection associated with the use of water bodies. It belongs to a large group of free-living bacteria that are ubiquitous in the environment and capable of adapting to various environmental conditions. This pathogen is commonly found in natural waters such as lakes

and rivers, but can also be present in swimming pools, hot tubs, jacuzzis, and even in sewage. Due to its ability to form biofilms, *Pseudomonas aeruginosa* is found on virtually all surfaces, including around faucets, and can consequently be present in drinking water. [40, 41, 42]

One of the routes that poses the greatest health risk is inhaling water contaminated with *Pseudomonas aeruginosa* bacteria, which can lead to respiratory infections. This bacterium can be acquired not only by inhaling aerosolized water, but also through the digestive tract, skin, ears, eyes, and even through direct immersion of wounds in contaminated water. [40, 42]

This pathogen can cause pneumonia, endocarditis, osteomyelitis, urinary tract infections, gastrointestinal infections, and meningitis, and it can also lead to sepsis. Patients who wear contact lenses are also at risk of developing keratitis. [40, 41]

**Leptospirosis**

Leptospirosis is a zoonotic disease caused by spirochetes of the *Leptospira genus.* The bacteria are transmitted to humans through exposure to the urine of infected animals, as well as through contaminated soil and water. The most common source of infection is rats. The infection portal can be broken or scratched skin, mucous membranes (including inhalation of microorganisms), and conjunctiva. The incubation period ranges from 3 to 25 days. [43, 44]

Clinical symptoms can range from mild flu-like symptoms to a life-threatening illness with jaundice, impaired kidney function, and hemorrhage. Fulminant multiple organ failure may also occur. About 10% of patients develop a severe form of the disease. [36, 43] The course of leptospirosis is biphase.

The disease begins with an acute (septic) phase, during which patients experience flu-like symptoms, including fever, chills, headaches, and muscle aches. Severe pain in the back, thighs, and calves is characteristic and lasts for about a week. In one-third of cases, conjunctivitis may occur.

When it seems that patients are recovering, a second phase may emerge. This is the immunological phase, known as jaundiced leptospirosis. Leptospires are excreted in the patient's urine. This can lead to the classic 'Weil's disease,' characterized by jaundice, kidney failure, hemorrhages, and myocarditis. [44]

Many cases remain asymptomatic or show only mild symptoms, which makes it difficult to diagnose the disease correctly. Diagnosing leptospirosis is challenging, so knowledge of the risk factors and possible clinical manifestations is crucial when organizing large sporting events. [36, 43, 44]

## INCIDENCE OF BACTERIAL INFECTIONS AMONG ATHLETES DURING MAJOR SPORTING EVENTS

Currently, sports involving swimming in open waters, such as rivers, lakes, and seas, are becoming increasingly popular. Many sports events are being organized with competitions in both artificial and natural water bodies. Society is becoming more enthusiastic about

participating in such activities, leading to an increase in the number of these events. This trend benefits public health, as it promotes sports and an active, healthy lifestyle, which positively impacts overall functioning and well-being. It aims to replace sedentary habits and address the growing issue of obesity within the population. However, the reality is not entirely rosy. Organizing large sports events can also pose significant risks to the health and even the lives of athletes. One potential danger is organizing competitions in water of poor quality that is not classified as safe for bathing. [45, 46]

Various factors may contribute to poor water quality in reservoirs. For sports event organizers, it is important to anticipate and identify potential irregularities in water quality early. [37] Swimmers participating in open-water events in water that is not classified as safe for bathing are at significant risk of gastrointestinal diseases

The River Thames is not classified as bathing water by the Environment Agency. Occasionally, especially during heavy rainfall, untreated sewage is discharged into it via a combined sewer overflow (CSO), which significantly lowers water quality. For example, in October 2012, a large outbreak of gastrointestinal symptoms occurred during a competitive swimming event on the Thames. At least 338 of the 1,100 swimmers reported these symptoms. The most commonly reported symptoms were nausea (78%), diarrhea (75%), and abdominal cramps (70%). Among competitors questioned at the time, the illness rate was alarmingly high at 53%. The average duration of symptoms was four days. No primary pathogen was identified as the cause of the outbreak. [45]

In 2010, the international Ironman triathlon competition took place in Copenhagen. It consisted of a bike race, a marathon, and a 3.8-kilometer saltwater swim. The event was preceded by exceptionally heavy rainfall, which led to severe flooding in the Danish capital and its surrounding areas. It caused the overflow of the sewage system. To assess the risk of gastrointestinal illness from both polluted and unpolluted seawater, a questionnaire was conducted following the 2011 competition. The aim was to compare the results with those from the 2010 event. To ensure reliable results, the swimming competitions were held on the same route, covering the same distance, and at the same location.

During the 2010 competition, 42% of survey respondents reported suffering from diarrhea or vomiting after participating in the triathlon. In the 2011 survey, only 8% of participants met the criteria for gastrointestinal illness. After the 2010 event, stool samples submitted for analysis yielded the following results: *Campylobacter jejuni* was isolated in three samples, *Giardia lamblia* in three samples, and *E. coli* in five samples. Of the *E. coli* samples, two were enteropathogenic *E. coli* (EPEC) strains, and three were enterotoxigenic *E. coli* (ETEC) strains. After the 2011 event, three participants submitted stool samples for analysis, all of which tested positive for *Campylobacter* bacteria. [37]

Another example of a sporting event impacted by poor water quality was the swimming competitions at the 2024 Olympic and Paralympic Games in Paris, which took place in the Seine River. The water quality in the Seine has been a subject of controversy since the Games began. A major issue during the organization was the delayed reporting of water quality data.

Furthermore, there were no established criteria to determine whether the water was safe for athletes to compete in. The World Triathlon Water Quality Statement recommends that triathlons be held in waters where the *E. coli* levels are kept below 500 CFU/100 ml and the *Enterococcus* levels below 200 CFU/100 ml.

During the 2024 Paris Olympic Games, the water quality limits were not met. The levels of *E. coli* bacteria were found to be 1,000 CFU/100 ml, while Enterococcus bacteria reached 400 CFU/100 ml. [46, 47] After competing in the contaminated Seine, Belgian triathlete Claire Michel was hospitalized due to an *E. coli* infection, which led to Belgium withdrawing its triathlon team. Athletes from other countries also reported gastrointestinal symptoms, probably related to the presence of pathogenic bacteria in the French river. [46]

Problems with water quality were also observed during the Olympic Games in Sydney in 2000, Beijing in 2008, London in 2012, and Rio in 2016. [46]

The famous Dutch canals in many cities across the Netherlands are used as tourist attractions, as well as venues for swimming events and competitions. Since city canals are not official bathing areas, the water quality is not regulated or monitored according to European Union bathing water standards. The water in these canals comes from rivers and rural areas and is also contaminated by sewage, which increases significantly after heavy rainfall and floods. The quality of the water may also be compromised by the presence of bird droppings, as well as rats and mice. Before swimming competitions, local authorities sometimes measure the levels of *Enterococci* and *E. coli* in these unofficial swimming waters to assess the general water quality. Unfortunately, this only addresses a small fraction of the potential pathogens that such waters may contain, and whose presence is not monitored. [48]

In 2015, a triathlon event in the inner-city waters of Utrecht, Netherlands, led to an outbreak of acute gastroenteritis, with 73 cases diagnosed (31% incidence rate). Following this event, two swimming events held in the city canals in 2015 were reviewed. One of these events, the Amsterdam City Swim, resulted in an outbreak of gastroenteritis affecting 427 people (31% incidence rate). In the second event, 7 cases were reported among swimmers (9% incidence rate). Heavy rainfall causing sewage overflows before the events was the likely cause of the high incidence. [38, 48, 49]

Leptospirosis is a zoonotic bacterial infection caused by spirochetes of the *Leptospira genus*. It has been identified as the cause of infections in athletes after exposure to contaminated water during several sporting events. Exposure to freshwater is frequently cited as a risk factor. [44] Outbreaks of leptospirosis are often associated with recreational activities that involve close contact with water contaminated by pathogenic leptospires. [49]

Outbreaks of leptospirosis have been reported during adventure races worldwide, particularly in the Philippines, Malaysia, and the USA. A case of leptospirosis also occurred in Florida after swimming and kayaking sessions in swamps. [36]

In September 2016, French health authorities received a report of a group of kayakers presenting clinical symptoms of leptospirosis. After a thorough investigation, 14 cases were diagnosed, all involving kayakers. Three separate areas of water contamination with

*Leptospira* bacteria were identified along a 30-kilometer stretch of the Vilaine River. None of the individuals who became ill had been vaccinated against leptospirosis. [50]

A leptospirosis outbreak also occurred among athletes following a triathlon in Springfield, Illinois. Heavy rains before the event likely increased the contamination of Springfield Lake with leptospires. After the triathlon, 98 athletes (12%) reported illness. Serum samples from some of these athletes were tested, and 52 (11%) were found to be positive for leptospirosis. The main risk factor for illness was identified as the ingestion of one or more sips of lake water. This event is considered the largest leptospirosis outbreak reported in the United States. [51]

In August 2006, a case of leptospirosis was diagnosed in an athlete following a triathlon near Heidelberg in the Neckar River. As a result of this diagnosis, several triathletes were contacted, and five additional cases of leptospirosis were reported. Heavy rains before the swimming competition likely increased the contamination of the Neckar River with leptospires. This was the first documented outbreak of leptospirosis associated with a water sports competition in Germany. [43]

Three clinical cases of leptospirosis were diagnosed in young, previously healthy individuals following river surfing in Switzerland. Serological testing revealed serovar Grippotyphosa infection in all cases. In view of reports of beavers with leptospirosis in the region, a waterborne infection, associated with surfing in a contaminated area, was considered probable. [52]

An outbreak of leptospirosis also occurred among triathletes on the island of Reunion in the Indian Ocean. Leptospirosis was biologically confirmed in 9 out of 10 suspected cases. Rats were primarily responsible for the water contamination. Epidemiological studies indicated that protective measures, such as neoprene suits, should be implemented to reduce the potential risk of infection in athletes. These suits have proven effective in protecting swimmers from infection. [53]

The first documented outbreak of leptospirosis in Austria occurred in July 2010, with four cases of serologically confirmed leptospirosis in athletes after a triathlon in Langau. The event was preceded by heavy rainfall, which increased the risk of leptospirosis infection. [54]

The health of athletes should be a priority for organizers. In the presence of any risk to their safety, the decision to hold a competition should be made by independent public health authorities, not by sports federations. [46] If sport events do take place, the medical staff present should be on standby at all times to quickly identify any signs of health problems in athletes. [55]

Sports event organizers worldwide should pay special attention to environmental factors and meteorological events both preceding and occurring during their events. In recent years, the occurrence of extreme rainfall and flooding has increased globally, leading to sewage system overflows that potentially present a significant risk to human health. Appropriate and thorough inspections should be conducted, and safety measures must be enforced. [36, 37]

The risk of health problems in athletes can be minimized, among other measures, by considering weather data, temperature, and water quality before planning the event. Organizers should also consider the possibility of postponing the event if unfavorable weather conditions, which could impact water quality, are forecasted. Athletes should be informed about potential logistical changes, such as event rescheduling. Route modifications or alternative routes should also be considered. Another important question that organizers of major sports events should ask themselves is whether it is advisable to hold competitions in locations not designated as safe for swimming. [45, 55, 56]

It is also important to note that mass outbreaks of infectious diseases during large sporting events have generally been rare in the past, primarily due to thorough preventive and control measures. However, failure to comply with these measures can lead to significant consequences. To prevent waterborne infectious diseases, it is essential to monitor the levels of bacteria and other pathogenic microorganisms in the water to reduce the risk of infection. Providing clean water for races is extremely important nowadays. [7]

Athletes should receive daily updates on the current water quality, along with appropriate recommendations. It is also essential to educate them to increase awareness and understanding of the dangers associated with contaminated water. To minimize the chance of infection, athletes should avoid swallowing contaminated water. After the competition, they should properly wash their hands and body to effectively remove pathogenic microorganisms from their surfaces. [45, 56]

To further prevent water sports athletes from contracting infections, it is important to limit their exposure to contaminated water before the event. Athletes should reduce their contact with poor-quality water by training in cleaner bodies of water or swimming pools, which can help minimize the risk of accidental ingestion. In the case of heavy rainfall and temporary water contamination, athletes should be provided with access to clean swimming facilities to ensure safe and proper training conditions. The health and safety of participants must always be the primary concern for event organizers. [56]

## SUMMARY

The problem of water quality is a global concern, posing significant challenges in controlling and preventing pollution. Water sports, a highly popular form of recreation, expose participants to water and soil, increasing their risk of contact with potentially infectious agents, including bacteria, viruses, fungi, and protists. [15] Numerous bacteria present in water are the cause of various ailments, posing greater or lesser threats to human health. They contribute to gastrointestinal diseases, skin infections, respiratory tract infections, as well as infections of mucous membranes and ears. [8, 9, 11, 12, 19, 20, 21] Symptoms such as diarrhea, vomiting, and abdominal pain may be caused by the consumption of contaminated water by athletes. [16, 17] This is not the only way bacteria can enter the body. Water can also be inhaled, contributing to respiratory infections [19, 21], or cause skin infections through direct contact. [9]

To mitigate these risks, it is essential to adopt specific water quality standards, monitor recreational waters, and take appropriate actions when recommended values are exceeded. [51] Ensuring the safety of competition participants and other recreational water users requires continuous improvement of water quality monitoring methods. The most commonly used methods based on the presence of microbiological indicators are not perfect and have their limitations. [45] For sports event organizers the most important thing should be to ensure the safety of athletes, therefore in the event of a risk, the decision to organize a sports event should be made by independent public health authorities, not sports federations. [25] Organizers should consider factors such as weather conditions, temperature, and water quality data when planning competitions. If risks to athletes arise, rescheduling the event or selecting an alternative route should be seriously considered. [24, 34, 35] Ensuring the health and safety of participants should be a priority, and competitions should not take place at all costs.

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