## Anecdotal and case reports of human morbidity and mortality attributed to recreational or occupational field exposure to freshwater cyanobacteria

| Year | Season | Location | Number affected | Estimates of number unaffected | Age | Water activity | Signs & symptoms | Dominant plankton | Time of onset after exposure | Symptom duration | Diagnostic criteria | Predisposing conditions | Notes | References |
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| **Hayfever-like symptoms (conjunctivitis, rhinitis, sneezing)** | | | | | | | | | | | | | | |
| 1934 | Late summer | Muskego Lake, Waukesha County, WI, USA | Report of single subject, male | N/S | 57 | Swimming | Itching of eyes, nasal congestion | “weedy lake” | 3 hours | <48 hours | | History of frequent sinus infections | | [53] |
| 1935 | Late summer | Muskego Lake, WI, USA | Same subject | N/S | | Swimming | Same symptoms, + mild asthma | | As above | As above | | | | [53] |
| 1936-1946 | Late summer | North Lake, Waukesha County, WI, USA | Same subject | N/S | | Swimming | Nasal discharge and congestion, conjunctivitis, mild asthma | Oscillatoreaceae (sample taken in late summer, 1944) | N/S | N/S | Surface scum extracts gave immediate skin reactions. Cutaneous injection of 0.03mL of 1:1,000 dilution resulted in mild asthma within 20 mins. Control subjects did not react to scum extracts | | Subject swam in North Lake during summer months over the ten-year period, without incident until mid-August each year, when swimming was followed by symptom onset. Desensitisation injections over four years were successful | [53] |
| 1979 | Late summer | Lake Wallenpaupack, PA, USA | 5 (family group) | N/S | N/S (parents + son + daughter + friend) | Swimming | “Severe” hayfever-like symptoms (sneezing, nasal discharge, eye irritation): 3/5 earache: 2/5 | N/S. Lake developed a distinct green colour several days prior to incident. Three weeks later: heavy bloom of *Anabaena* | Hayfever symptoms: during exposure; earache: several hours after exposure | N/S | | N/S | | [68] |
| 1979 | Late summer | Lake Wallenpaupack, PA, USA | 20-30 | 60-90 (those affected comprised approx 25% of aquatic event participants) | N/S (high school students) | Participating in school aquatic event | Eye irritation, sore throat, earache, sneezing, nasal discharge, swollen lips | N/S. see above | During exposure or within 2-3 hours | Within 2-3 days<br><br>*Subsequent exposure reportedly caused re-occurrence of symptoms | | N/S | Affected individuals were members of a high school summer aquatic program. The event was cancelled because of these illnesses | [68] |
| N/S | N/S | N/S | Single male | N/S | N/S (adult) | Swimming | Hayfever-like symptoms | Bloom of *Microcystis* | N/S | N/S | | N/S | | [154] |

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| **Cutaneous symptoms** | | | | | | | | | | | | | | |
| 1949-1952 | Summer | Lake Carey, PA, USA | Report of single subject, female | Reported skin rash "never appeared in other bathers swimming in the same water" | 6 (condition first seen at age 3 years) | Swimming | Seasonal erythematous papulo-vesicular rash, occasionally progressing to oozing and crusting. Rash limited to face, neck, shoulders, upper chest and extremities; rash never seen on areas covered by swimsuit | *Anabaena* | 1-2 hours | < 2 weeks (if no further contact with lake water) | Skin patch testing: strong positives to *Anabaena* filtered from lake water, chloroform extract of same, and phycocyanin extract | None (apart from reported condition) | Rash never seen after swimming in artificial pools or ocean. Only seen after water exposure at Lake Carey, and once after bathing in a Canadian lake | [54] |
| Late 1940s & mid 1950s | Late summer | Lake Ringsjön, Scania, Sweden | "several" members of a family | N/S | N/S ("young girl" + siblings) | Swimming | Pruritic skin rashes | *Gloeotrichia echinulata* | N/S | N/S | | | | [155, 156] |
| 1977 | Summer | Mingechaur Reservoir, Azerbaijan | 7 | 13 | N/S | Swimming | Slightly raised, erythematous spots, 2-6mm diameter; seen on skin bordering and outside swimsuit | Benthic *Lyngbya kützingii*; also "planktonic blue-green algae colouring the water" | 2nd day after swimming | 10-12 days | | | | [40] |
| 1985 | N/S | UK | N/S | N/S | N/S | Sail-boarding | Skin rashes | N/S ("toxic blooms") | N/S | N/S | | N/S | | [65] |
| 1989 | N/S | Japan (lake) | 1 | N/S | N/S (adult) | Collecting algal scum * | Rashes | *M. aeruginosa* containing microcystins | N/S | N/S | | N/S | | [65] |
| 1989 | Late summer – early autumn | Bewl Water, Kent, UK | 1 | N/S | N/S | Fishing | 'blotchy' skin on face and hands after handling water on three separate occasions | *Microcystis* sp | Within two hours | Several days | | N/S | | [65] |
| 1989 | N/S | NRA South West Region, UK | N/S ("some NRA staff") | N/S | N/S (adults) | Sampling water * | Tingling sensations on hands | "Potentially toxic cyanobacteria species" | N/S | N/S | | N/S | | [65] |
| 1989 | Early-mid autumn | Welton Water, Yorks, UK | N/S | N/S | N/S | N/S ("water users") | Rashes | *Anabaena* sp | N/S | N/S | | N/S | | [65] |
| 1991 | Late spring – early summer | Darling-Barwon river system, NSW, Australia | N/S | N/S | N/S (adults) | Sampling water* | Skin irritation | *Anabaena* spp | N/S | N/S | | N/S | | [157] |

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| **Cutaneous symptoms** | | | | | | | | | | | | | | |
| 2003 | Summer | Lake Salajärvi | 1 | N/S | N/S | Swimming | Rash | *Anabaena lemmermannii* (dominant) + low levels of *M. aeruginosa* and *M. flos-aquae*. | N/S | N/S | | N/S | Saxitoxin, microcystins and anatoxin-a products present in water samples | [158] |
| 2003 | N/S | Lake Sompanen, Finland | 1 | N/S | 7 yo male | N/S | "extensive" generalised rash | Cyanobacteria visible in water; saxitoxin found in water samples in 2002 & 2004 | N/S | N/S | | N/S | | [158] |
| **Gastro-intestinal symptoms (nausea, vomiting, diarrhoea, abdominal pain)** | | | | | | | | | | | | | | |
| 1959 | Summer | One of Katepwa Lakes, SK, Canada | Report of single subject, male | N/S | N/S (adult) | Swimming | Headache, nausea, G-I upset | N/S | During night after swimming | <48 hours. | Stool sample showed "many tiny greenish spheres which resembled in size and morphology the cells of *Microcystis*". Stool specimen negative for *Salmonella* and *Entamoeba* | N/S | Subject sought medical advice for gastroenteritis, admitted to hospital, given oral chloramphenicol. Recovery within 24 hours of admission | [55] |
| 1959 | Summer | Long Lake, SK, Canada | 10 | N/S | N/S (children) | Swimming | Diarrhoea, vomiting | N/S. Subjects swam in "algae-covered lake water". Dried *Microcystis* and *Anabaena* scum found later on shore | N/S. Reported to local medical officer with illness on the day after exposure | N/S | Stool specimen from one child contained cells resembling *Anabaena* "in great numbers" | | Local farmer reported that two cows died after drinking from the lake 12-16 hours previously, during an algal bloom. A third sick cow recovered after receiving penicillin injections | [55] |
| N/S | N/S | N/S (lake) | Single subject, male | N/S | 4 | Fell into lake, swallowed water # | Abdominal pain, nausea, vomiting, diarrhoea, "wooziness", headache, thirst | N/S | Day of exposure: G-I illness. Next day: wooziness, headache, thirst | N/S | *Aphanizomenon* found in stool and vomitus specimens | N/S | | [67] |
| 1961 | N/S | N/S | 4 | N/S | N/S (students) | Swimming | Headache, malaise, diarrhoea | Heavy growth of *Microcystis* and *Anabaena* | N/S | N/S | | N/S | | [67] |

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| **Gastro-intestinal symptoms (nausea, vomiting, diarrhoea, abdominal pain)** | | | | | | | | | | | | | | |
| 1989 | Early autumn | Rutland Water, Leics, UK | N/S | N/S | 2 & 3 year-olds | Playing at edge of scum | Vomiting & diarrhoea | *M. aeruginosa* | N/S | N/S | Microcystin-LR found to be principal cyanobacterial toxin present | N/S | 20 sheep and 15 dogs died over approx 3 weeks in late summer – early spring after contact with bloom scum | [6] |
| 1990 | N/S | Unnamed lake, Tiel, The Netherlands | N/S | N/S | N/S | Swimming | "G-I complaints" | *Anabaena flos-aquae* | N/S | N/S | Water quality parameters and food-borne pathogen testing negative | N/S | Mouse bioassay and HPLC-UV confirmed presence of anatoxin-a | [159] |
| 2003 | Summer | Lake Iso-Kukkanen, Finland | 1 | N/S | 10 yo male | Swimming | Abdominal pains | *A. lemmermannii* sole or dominant cyanobacterium. | N/S | Several hours | | N/S | Saxitoxin measured at 13-270 µg/L (depending on methods). Low levels of microcystins found. Anatoxin-a and degradation products reported | [158] |
| **Progression to fatal illness** | | | | | | | | | | | | | | |
| 2002 | Mid-summer | Golf course pond, Milwaukee, WI, USA | 5 | 0 | 17 yo male and 4 friends | "splashing and diving". Two most severely affected boys had their heads under water for varying periods of time # | 17-year-old developed nausea, vomiting, progressed to "shock" and "seizure", acute heart failure; death occurred approx. 48 hours after exposure. One teenager who also apparently ingested water developed severe diarrhoea and abdominal pain. The other three youths developed "minor symptoms" | Presumably *A. flos-aquae* containing anatoxin-a, determined from blood and stool samples of the boy that died and the other severely affected youth | N/S | N/S | Analysis of "tissue, blood and other fluid samples" from the two severely affected teenagers. Anatoxin-a found in unspecified sample/s. Autopsy showed "acute heart damage" but no evidence of meningitis or encephalitis. Analyses for pesticides, parasites and other pathogens negative | N/S | The unusual feature of this case is the length of time – 48 hours – between exposure and ingestion of contaminated water and subsequent death. Uncertainty exists regarding the identification of anatoxin-a in tissue samples | [43, 44, 62-64] |

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| **Cold & flu-like symptoms (incl. fever, headache, myalgia, arthralgia, sore throat, respiratory and gastro-intestinal)** | | | | | | | | | | | | | | |
| 1959 | Summer | Echo Lake, SK, Canada | Report of single subject, male | N/S | N/S (adult) | Intending to swim – fell into lake, swallowed an estimated half-pint of water # | Abdominal cramps and pain, nausea, vomiting, painful diarrhoea, fever, severe headache, weakness, pain in limb muscles and joints. Stools and vomitus were slimy and green | N/S. Lake had a visible bloom on day of exposure. *Microcystis* and *Anabaena* bloom 35 days prior to exposure | 3 hours: abdominal pain, nausea, vomiting 5 hours: diarrhoea; next morning: fever, headache, myalgia, weakness | Recovering when questioned on 2nd day after exposure | Stool specimen showed "innumerable spheres of *Microcystis* and 2-3 well-preserved curved chains of *A. circinalis* per high-power field" | N/S | During bloom 35 days prior to exposure, an unknown number of dogs and geese died after swimming in the lake. Other dogs sickened after drinking lake water. Also fish kills | [55] |
| N/S | N/S | N/S (swimming hole) | Single subject, male | N/S | 12 | Swimming | Fever, loss of consciousness for six hours, dyspnoea, pneumonia, myalgia, arthralgia | Abundant *M. aeruginosa* | N/S (onset reported as sudden, with subsequent myalgia and arthralgia) | N/S | Stool sample: *Aeromonas* (Gram-negative bacteria), *Spirogyra* and *Mougeotia* (both green algae) | N/S | | [67] |
| 1979 | Late summer | Lake Wallenpaupack, PA, USA | 15 | N/S | N/S | Swimming | Vomiting, nausea, diarrhoea, eye irritation, sore throat, fever, earache | N/S. See above. | Symptoms occurred "a short time after contact with lake water" | G-I symptoms: 24-48 hours | | N/S | Affected individuals all holidaying in rental cottages. Well water to cottages free of bacterial contamination | [68] |
| 1979 | Late summer | Arrowhead Lake, PA, USA | Single female | N/S | N/S ("young girl") | Swimming # | Chills, sore throat, fever, nausea, diarrhoea | N/S | "within several hours" | Approx. 3 days | | N/S | | [68] |
| 1989 | Early autumn | Rudyard Lake, Staffs, UK | 2 | N/S | 16 | Swimming and canoeing exercises, the latter involving $360^0$ rolls * # | Malaise, sore throat, circum-oral blistering, left-sided pleuritic pain, dry cough, vomiting, central abdominal pain, diarrhoea, fever | *M. aeruginosa* | Day after exposure | <2 weeks | Microcystin-LR found to be principal cyanobacterial toxin present | N/S | Both were hospitalised, having developed left lower-lobe pneumonia accompanied by thrombocytopenia | [23, 57, 74, 160, 161] |
| 1989 | Early autumn | Rudyard Lake, Staffs, UK | 8 | N/S | N/S (soldiers) | As above * # | Sore throat, headache, abdominal pain, dry cough, diarrhoea, vomiting, blistered mouth | *M. aeruginosa* | N/S | N/S | See above | N/S | All subjects were soldiers engaged in canoeing exercises, subsequently admitted to barracks medical centre | [23, 57, 74, 160, 161] |

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| **Cold & flu-like symptoms (incl. fever, headache, myalgia, arthralgia, sore throat, respiratory and gastro-intestinal)** | | | | | | | | | | | | | | |
| 1992 | Mid-spring | Darling River, Wilcannia, NSW, Australia | 2 | N/S | N/S - teenagers | Swimming | Gastroenteritis and myalgia | *Anabaena* sp | N/S | Symptoms resolved after 48 hrs | One subject required admission to hospital. | N/S | Some town residents reported itchy skin rashes after showering, even after town water supply was carbon-filtered | [162] |
| N/S | N/S | Unnamed reservoir, UK | Single subject, male | N/S | 39 | Windsurfing | Fever, nausea, vomiting | N/S, but microcystin isolated from reservoir; several sheep and dogs died | N/S "shortly after windsurfing trip" | N/S | Liver function tests, liver biopsy | No significant past history, no medications | Mild hepatic dysfunction investigated six weeks after exposure | [163] |
| **Mixed symptoms** | | | | | | | | | | | | | | |
| 1945 | Late summer | Lake Keesus, Waukesha County, WI, USA | Report of single subject, female | N/S | 39 | Swimming | Gross eyelid oedema, nasal congestion, generalised urticarial rash | N/S | "while swimming" | N/S | Skin test with Oscillatoreaceae extract (0.03mL of 1:10,000 dilution) resulted in immediate and severe local reaction treated by local injection of adrenaline | Long-standing history of autumn hay-fever and seasonal asthma | Oscillatoreaceae extracts elicited positive (but unspecified) reactions in "many individuals who knew that swimming caused hay fever" at dilutions up to 1:100,000 | [53] |
| 1946 | Late summer | Lake Keesus, WI, USA | Same subject | N/S | | Swimming | As above | N/S | N/S | N/S | | | | [53] |
| 1973-4 | Summer | Belgrano Park pond, Santa Fe City, Argentina | N/S | N/S | N/S | Swimming and bathing | G-I symptoms, dermatitis, otitis, conjunctivitis | Mainly *M. aeruginosa*; bloom contained "up to 60,000 colonies/mL" | N/S | N/S | N/S | N/S | | [164] |
| 1979 | Late summer | Arrowhead Lake, PA, USA | Initial reports: 20-30 children, several adults. 12 children + I adult investigated | N/S | 4-12, + adult | Swimming | Headache: 8/13<br>stomach cramps: 9/13<br>nausea: 5/13<br>vomiting: 7/13<br>diarrhoea: 11/13<br>fever: 5/13<br>rash: 1/13<br>sore or inflamed throat: 3/13 | N/S | During exposure, to 12 hours after exposure. Rash on arms & legs of adult ♀ developed "shortly after wading along lake edge" | Most symptoms: <72 hours<br>All symptoms: ≤5 days | Stool samples of four children negative for *Salmonella* and *Shigella*. Throat swab of one child with sore throat negative for viral involvement | N/S | Routine weekly monitoring for faecal coliforms showed counts were ≤40/100mL prior to incident | [68] |

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| **Mixed symptoms** | | | | | | | | | | | | | | |
| 1980 | Mid-summer | Pocono Highlands Lake, PA, USA | N/S "swimmers" | N/S | N/S | Swimming | Eye irritation, earache, sore throat | *Anabaena* sp. | N/S | N/S | Water samples produced signs of poisoning in mice suggestive of hepatotoxin. $LD_{50}$ = 90 mg/kg (i.p. mouse) | N/S | | [56] |
| 1980 | Late summer | Lake Lahonton, NV, USA | N/S "several… affected " | N/S | N/S | Water skiing, swimming | Erythema, eye irritation, dizziness, nausea, stomach cramps, diarrhoea | *Aphanizomenon flos-aquae* | N/S | N/S | $LD_{50}$ = 500 mg/kg body weight (i.p. mouse) | N/S | | [56] |
| 1980 | Mid-summer | Camp William Penn, PA, USA | 75-100 | N/S | N/S | N/S ("campers affected from contact with water") | Conjunctivitis, sore-red throat, headaches, diarrhoea, nausea | *Anabaena* sp. | N/S | N/S | | N/S | | [56] |
| 1981 | Mid-summer | Harveys Lake, PA, USA | N/S ("many reports…") | N/S | N/S | N/S | Skin irritation, nausea, dizziness, diarrhoea | *Anabaena flos-aquae* | N/S | N/S | Mouse toxicity testing of water: neurotoxins and hepatotoxins present. $LD_{50}$ = 125 mg/kg | N/S | Lake closed to public access until early spring | [56] |
| 1989 | Early autumn | Rutland Water, Leics, UK, and other UK lakes | N/S ("several") | N/S | N/S | Sail-boarding # | Skin rashes, nausea, vomiting, blistering inside mouth, severe thirst | *M. aeruginosa* | N/S | N/S | Microcystin-LR found to be principal cyanobacterial toxin present | N/S | 20 sheep and 15 dogs died over approx. 3 weeks in late summer – early spring after contact with bloom scum | [6, 65, 160] |
| 1990 | Spring | Lake Cargelligo, NSW, Australia | 2 or 3 | N/S | N/S | Swimming | Two cases of conjunctivitis, one case of rash | *Anabaena circinalis* | N/S | N/S | | N/S | Lake closed as water supply for one month while bloom evident | [66] |
| 1991 | Summer-Autumn | Lakes Alexandrina and Albert, SA, Australia | 1 | N/S | N/S (adult) | Crayfishing | Skin and/or eye symptoms (pruritus, skin rash, sore red eyes) | *Nodularia* sp | N/S | N/S | Case identified retrospectively by either interview with local residents, local health workers or surveillance through local GPs | N/S | Seven more cases identified with skin and/or eye symptoms. Two of them also had asthma symptoms, one had hay fever symptoms, another a sore throat. Water contact was by showering or bathing | [165] |

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| **Mixed symptoms** | | | | | | | | | | | | | | |
| 1991 | Late spring – early summer | Darling River, Wilcannia, NSW, Australia | 1 | Sole report after surveillance requests to report confirmed or suspected cyanobacteria -related illness during an extensive riverine bloom | N/S (adult) | Water skiing | Skin rash, conjunctivitis, diarrhoea, respiratory difficulty | *Anabaena* spp | N/S | N/S | | N/S | All schools along the river system were asked to report increases in illness-related absenteeism, especially for G-I symptoms. No such increase was reported | [157] |
| 1991-2 | Summer | River Murray, SA, Australia | 11 | N/S | 1-64 | "water sport…. particularly skiing". One of these cases had skin contact through both water sport and residential water use | Contact exposure (n=2): rash, itching, mouth blistering, eye irritation; oral ingestion (n=3): diarrhoea, vomiting, nausea, muscle weakness, sore throat, respiratory difficulty, headache; contact + oral exposure (n=6): mixture of above symptoms | Predominantly *A. circinalis* | N/S | N/S | Cases investigated following telephone or personal complaints to health authorities and water supply management | N/S | 15 further cases with exposure to River Murray water from reticulated water supply | [166] |
| 1994 | N/S | Lake Velencei, Hungary | 100-150 | N/S | Children at a youth camp | N/S | skin and eye irritation | "heavy bloom" of *M. aeruginosa* | N/S | N/S | N/S | N/S | | [167] |
| 1996 | N/S | Hollingworth Lake, UK | 11 | N/S | N/S (sea cadets) | Canoe capsizing trials * | Facial rashes, asthmatic signs, dry sporadic cough, vomiting | *Planktothrix agardhii,* containing three microcystins | Day of, and after exposure | N/S | | N/S | | [23] |
| 1997 | Autumn | Lake Sammamish, WA, USA | N/S ("several") | N/S | "young children" | Swimming | G-I complaints, rashes | *M. aeruginosa*, microcystins measured at approx. 500 µg/g dry weight | N/S | N/S | N/S | N/S | A dog began "heaving and coughing", died four hours after exposure to bloom | [45, 46] |

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| **Mixed symptoms** | | | | | | | | | | | | | | |
| 2003 | N/S | Lake Iso-Kukkanen, Finland | 1 | N/S | 2 yo child | Swimming | Fever and eye irritation | *A. lemmermannii* sole or dominant cyanobacterium. | N/S | N/S | | N/S | Saxitoxin measured at 13-270 µg/L (depending on methods). Low levels of microcystins found. Anatoxin-a and degradation products reported | [158] |

# – cyanobacteria-affected water reportedly ingested (table column: “Water activity”)

* – occupational exposure (table column: “Water activity”)

N/S – not stated