Phycotoxins by harmful algal blooms (HABs) and human poisoning: an overview

Abstract

Phycotoxins are potent natural toxins synthesized by certain marine algae and cyanobacteria species during “Harmful Algal Blooms”, (HABs), often seen as water discoloration known as “Red Tides”, “Green Tides”. They are grouped by chemical structure, mechanisms of action, target tissues, biological and health effects. A constant threat to public health, and economy, environmental contaminants in aquatic ecosystems, seafood, drinking water, requiring multidisciplinary action at the local and international level to manage their potentially harmful effects. The 2015 bloom of toxigenic Pseudo-nitzschia along the west coast of North America resulted in domoic acid contamination of crab and clams, numerous harvesting closures and Consumer Warning issued by local public health authorities. Thereafter, in September 2016 the Oregon coast was closed to razor clam and mussel harvesting. Whereas, the massive cyanobacteria blooms reported in Florida in June 2016 lead to banning drinking water in some locations. Public health vigilance, monitoring, and research need to be maintained and enhanced. Despite scientific advancements, phycotoxin research relating to human exposure and health consequences are sparse, while, blooms of toxigenic species have become more prevalent worldwide. At present, phycotoxins poisonings diagnosis and management is largely based on the ability of health care provider to interpret presenting clinical symptoms, collect exposure history, identify and establish the exposure event. Several phycotoxins are neurotoxic, potentially lethal, and/or associated with chronic adverse health effects. Human intoxications are often misdiagnosed, under-diagnosed, and under-reported to public health authorities, hampering proper management and epidemiology data. Regulatory standards, alertness by public health organizations and primary health care providers, in regions with a history of HABs, helps to minimize and manage human health risks. Nonetheless, there are populations at higher risk of exposure due to cultural practices: recreational shellfish pickers, anglers children, aboriginals in coastal regions. Human exposure and poisoning can occur worldwide after consuming contaminated seafood while traveling or products imported from world location with limited analytical facilities and regulatory implementation.

Keywords: phycotoxins, harmful algal blooms, cyanobacteria, cyanotoxins, marine algal toxins, poisonings, human health

Introduction

Phycotoxins by Harmful Algal Blooms (HABs) are a public health concern worldwide, outbreaks continuously occur, geographic distribution changes and expand, and new toxins are detected, increasing the risk of human exposure and toxic events. Climate change and environmental pollution are factors implicated in the appearance, geographical distribution and frequency of HABs, and phycotoxins. Geographical expansion of HABs such as Pseudo-nitzschia species, known to synthesize domoic acid, are continuing to occur. HABs adversely impact the economy, food, and water availability, locally and/or through trade; sports, recreation and tourism. Several recent events portray the extent of HABs environmental contamination of aquatic ecosystems and food produce, its impact on the economy and population risk in some North American regions.

HABs and phycotoxins are natural environmental contaminants of fresh, brackish and seawater, and encompass:

i. Cyanobacteria blooms (CyanohABs) toxins “cyanotoxins”, preferentially contaminants of soft water reservoirs and drinking water, with direct risk to human health.

ii. Marine biotoxins/marine algal toxins by dinoflagellates and diatoms can accumulate at high concentrations in various tissues of aquatic organisms such as bivalve mollusks and fish, entering the food chain, threatening consumer’s health.

Public health warnings are issued for specific blooms and toxins based on data collected on identified toxin, contamination levels on water or specific seafood products, depuration times, and regulatory levels for each product and toxin group. A practical example is the domoic acid contamination of crab and clams that occurred in California November 2015, which lead to a Consumer Warning by California Department of Public Health (CDPH), showing levels of domoic acid in crabs that exceed US federal safety limits of 20 parts per million (ppm) in the meat and 30ppm in the viscera, with the highest level recorded of 190ppm in a yellow rock crab in the Monterey region. The event prompted closing the year-round rock crab fishery and delaying the recreational and commercial Dungeness crab seasons. Established regulatory parameters, monitoring and infrastructure capabilities allowed the local preventive actions taken to minimize the risk of acute human exposure.
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Diagnosis and treatment of intoxication are based on the history of exposure, identification of the contamination event, isolation of toxic compound and producing organism at the source, presenting symptoms associated with each group of toxins.\textsuperscript{4,13,20–25} Emergency clinical management may help to prevent serious complications, including death. Long-term impairments may follow the acute event e.g. amnesia and epilepsy seen during the domoic acid human poisoning event in Canada in 1987.\textsuperscript{26} Although less is known about toxic effects induced by chronic, repeated exposure, some phycotoxins are carcinogenic or are linked to chronic degenerative neurologic disorders such as Amyotrophic Lateral Sclerosis (ALS).\textsuperscript{27}

Human’s health effects associated with most common phycotoxins from HABs: cyanobacteria and marine algae are summarized. Although not discussed here, information from domestic animals and wildlife intoxication have been key in the identification and follow-up of health effects, acute and chronic exposure in mammals, acting as sentinels for human health risk e.g. sea lions and domoic acid.\textsuperscript{28–30} Experimental data helps to understand mechanisms of action, distribution, target tissues, biological effects and to establish guidelines, policy, and regulations.\textsuperscript{16,31–36}

Phycotoxins health effects

In mammals, adverse health effects associated to phycotoxins and HABs can occur through oral, respiratory or dermal exposure to the toxins, their metabolites and/or theirs producing organisms, in aquatic or terrestrial environments.\textsuperscript{14,16,20–24} For humans, the highest risks are:

1) Ingestion of seafood contaminated with toxins produced by diatoms and dinoflagellates; respiratory exposure through aerosols.\textsuperscript{16,24,25,34,37} 2) Exposure to soft water contaminated with cyanotoxins, through drinking water, freshwater fish, dermal exposure e.g. bathing in contaminated lakes, or through contaminated equipment’s or fluids.\textsuperscript{20,22,36–40} Tables 1 and Table 2A, Table 2B summarizes the toxic effects of cyanotoxins and marine algal toxins described in humans, mechanism of action, presenting symptoms, clinical syndromes and prognosis. Most of the information available deals with acute exposure and effects. Several toxins are neurotoxic, can be lethal, but with proper clinical management, some may fully recover.\textsuperscript{24,39,41,42} Table 2C includes marine algal toxins, identified as contaminants of aquatic environments, with harmful biological effects, but without identified adverse health effects in humans.\textsuperscript{16,43,44}

### Table 1 Cyanotoxins biological and human health effects\textsuperscript{51,14,20,22,27,39,40,44,47,58}

<table>
<thead>
<tr>
<th>Cyanotoxins</th>
<th>Mechanism action</th>
<th>Symptoms</th>
<th>Prognosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hepatotoxins</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Microcystin MCs</td>
<td>Inhibition of protein phosphatases type 1 and 2A Repeated low-level exposure: carcinogenesis, genotoxicity</td>
<td>Within 4–24h to few days: Diarrhea, vomiting, liver hemorrhage, shock, abdominal pain, jaundice, weakness, dyspnea, respiratory distress, multiple organ failure</td>
<td>Can be lethal. Exposure: drinking water, contaminated dialysis fluid, soft water recreational environments</td>
</tr>
<tr>
<td>Nodularin</td>
<td>Inhibition of protein phosphatases type 1 and 2A</td>
<td>Diarrhea, vomiting, goose bumps, weakness, liver hemorrhage</td>
<td></td>
</tr>
<tr>
<td>Cylindrospermopsin (CYN)</td>
<td>Glutathione and protein synthesis as well as cytochrome P450. Repeated low-level exposure: carcinogenesis, genotoxicity</td>
<td>Symptoms up to several days after exposure or later. Gastroenteritis abdominal pain, vomiting, bloody diarrhea, acute liver inflammation. Liver and kidney failure, hay fever, asthma Chronic exposure linked to cancer e.g. colon</td>
<td></td>
</tr>
<tr>
<td><strong>Neurotoxins</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Anatoxin-a / Heteroanatoxin-a</td>
<td>Nicotinic receptors: Irreversible link to the nicotinic receptor S of acetylcholine in neuromuscular junction</td>
<td>Muscle twitching, cramping, staggering, paralysis, convulsions, gasping, respiratory failure, death Can be lethal by suffocation</td>
<td></td>
</tr>
<tr>
<td>Neurotoxins</td>
<td>Acetylcholinesterase</td>
<td>Salivation, muscle twitching cramping, paralysis Paralytic Shellfish Poison: Nausea, vomiting, paralytic shellfish poisoning, respiratory failure, death</td>
<td>Death can occur within 2-12 hours after exposure. Good prognosis after 24hr, requiring good medical support system.</td>
</tr>
<tr>
<td>Saxitoxins</td>
<td>Neurotoxic, target the peripheral nervous system. Selective high affinity to block sodium conductance in voltage-gated sodium channels, receptor site 1 at nerve fibers</td>
<td>Not fully elucidated. Implicated on chronic neurodegenerative diseases</td>
<td>Chronic exposure linked to chronic neurodegenerative conditions: Amyotrophic Lateral Sclerosis</td>
</tr>
<tr>
<td>beta-Methylamino-L-alanine (BMAA)</td>
<td>Exponentially acts predominantly on motor neuron - excitotoxic through glutamate receptors</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Irritants and Dermatotoxins</td>
<td>Potent tumor promoters</td>
<td>Skin irritation, asthma like symptoms</td>
<td></td>
</tr>
<tr>
<td>Aplysiatoxins</td>
<td>Potentiation of protein kinase C (PKC) Potent tumor promoters</td>
<td>Smooth muscle contraction. Skin irritation</td>
<td></td>
</tr>
<tr>
<td>Linbyatoxin</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
## Table 2A Marine algal toxins by diatoms and dinoflagellates: biological and human health effects

<table>
<thead>
<tr>
<th>Toxin group</th>
<th>Vector</th>
<th>Mechanism of action/effect</th>
<th>Exposure/symptom</th>
<th>Syndrome</th>
<th>Prognosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Azaspiracids (AZAs)</td>
<td>Shellfish, Bivalves, Mollusks</td>
<td>In vitro effect on actin cytoskeleton cell shape and adherence. Cytoskeleton damage is not reversible after toxin withdrawal</td>
<td>Food: Nausea, vomiting, diarrhea, abdominal pain.</td>
<td>Similar to DSP</td>
<td>AZAs Poisoning</td>
</tr>
<tr>
<td>Brevetoxins (BTX / PbTX)</td>
<td>Shellfish, Bivalves, Mollusks</td>
<td>Neurotoxic:</td>
<td>Paralysis, seizures and coma</td>
<td>Aerosol inhalation: Rhinorrhea</td>
<td>Neurotoxic</td>
</tr>
<tr>
<td>Ciguatoxins (CTXs): Pacific (P-CTX), Caribbean (C-CTX), and Indian Ocean (I-CTX)</td>
<td>Tropical and sub-tropical fish e.g.: eels, snappers, groupers, mackerels, jacks or barracudas</td>
<td>Neurotoxic: Opens sodium channels by binding site 5.</td>
<td>Food: Vomiting, diarrhea, nausea, tingling, itching, hypotension, bradycardia</td>
<td>Ciguatera</td>
<td>Fish Poisoning (CFP)</td>
</tr>
<tr>
<td>Saxitoxins (STXs) and related toxins</td>
<td>Shellfish, Bivalve, Mollusks, Crustaceans</td>
<td>Neurotoxic:</td>
<td>Food: Nausea, vomiting, peri-oral burning, ataxia, drowsiness, paraesthesia, fever, tachycardia, muscular paralysis, respiratory failure, death.</td>
<td>Paralytic Shellfish Poisoning (PSP)</td>
<td>Death can occur within 2-12 hours after exposure. Good prognosis after 24hr.</td>
</tr>
</tbody>
</table>
Table 2B: Marine algal toxins by diatoms and dinoflagellates: biological actions and human health effects

<table>
<thead>
<tr>
<th>Toxin group</th>
<th>Vector</th>
<th>Mechanism of Action/Effect</th>
<th>Exposure/Symptoms</th>
<th>Syndrome</th>
<th>Prognosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Okadaic acid (OA) and dynophysistoxins (DTXs)</td>
<td>Shellfish</td>
<td>Tumor promoter</td>
<td>Food: Abdominal pain, nausea, vomiting diarrhea, rarely fatal</td>
<td>Diarrheic Poisoning (DSP)</td>
<td>Symptoms start 30 minutes – few hours after ingestion – ends within three days. Potential long term effect as tumor promoter</td>
</tr>
<tr>
<td>Bivalve Mollusks</td>
<td>Inhibit essential serine/ threonine protein phosphatases 1 (PP1) and 2A (PP2A); genotoxic, cytotoxic</td>
<td>Mollusks</td>
<td>Cardiovascular</td>
<td>Long term sequel after acute intoxication: anterograde amnesia period</td>
<td></td>
</tr>
<tr>
<td>Domoic acid group</td>
<td>Shellfish</td>
<td>Neurotoxic:</td>
<td>Vomiting, diarrhea</td>
<td>Amnesic Poisoning (ASP)</td>
<td>Life threatening</td>
</tr>
<tr>
<td>Mollusks</td>
<td>Cardiotoxic, a Excitatory neurotoxin, analogue of glutamate – acts through glutamate receptors.</td>
<td>Sardines</td>
<td>Collapse, confusion, memory loss, seizure, death</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Crustaceans</td>
<td>Reproductive organs</td>
<td>Anchovies</td>
<td>Heart and renal failure, delayed haemolysis</td>
<td>PITX like toxin is myotoxic: myalgia</td>
<td></td>
</tr>
<tr>
<td>Fish e.g.</td>
<td>Reproductive organs</td>
<td></td>
<td>Inhalation: rhabdomyolysis, myoglobinuria, identified as “Haff Disease”</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palytoxins</td>
<td>Shellfish</td>
<td>Neurotoxic:</td>
<td>Food: Nausea, vomiting</td>
<td>Toxic syndromes in association with PITXs:</td>
<td>High mortality rate ingested and/or inhaled, cases described after exposure to coral fumes and fish tanks</td>
</tr>
<tr>
<td>(PITXs) and PITX like compounds</td>
<td>Bivalve Mollusks Crab, Fish e.g. Sardines Anchovies</td>
<td>Target the sodium potassium- ATPase pump in cell membrane; maintain the ionic gradients in cells. Membrane depolarization in excitable and non-excitable cells, contraction of muscle cell</td>
<td>Myalgia, fever rhabdomyolysis, vasoconstriction</td>
<td>PITX like toxin is myotoxic: myalgia</td>
<td></td>
</tr>
<tr>
<td>Pectenotoxins (PTXs)</td>
<td>Shellfish</td>
<td>Congestion and bleeding of the liver. Tumor promoter and cytotoxic</td>
<td></td>
<td>No cases of human intoxication</td>
<td></td>
</tr>
<tr>
<td>Cyclic imines</td>
<td>Bivalve Mollusks</td>
<td>Experimental data: Neurotoxic. Fast acting</td>
<td></td>
<td>No cases of human intoxication</td>
<td></td>
</tr>
<tr>
<td>Spirolides(SPXs), gymnodimines</td>
<td>Shellfish</td>
<td>Decrease cyclic AMP activate cellular phosphodiesterases (PDEs), cytoskeletal and adhesion molecules, caspase</td>
<td></td>
<td>No cases of human intoxication</td>
<td></td>
</tr>
<tr>
<td>(GYMs), pinnatotoxins (PnTXs) pteriatoxins (PtTXs)</td>
<td>Bivalves Mollusks</td>
<td>Experimental data: Neurotoxic. Fast acting</td>
<td></td>
<td>No cases of human intoxication</td>
<td></td>
</tr>
</tbody>
</table>
Health effects by cyanotoxins

Cyanotoxins is the term used for the secondary metabolites from cyanobacteria, toxic to living organisms including human.27,40,44 They are divided into chemical groups, i.e., cyclic peptides (microcystin and nodularin), alkaloids (anatoxin-a, anatoxin-a(s), saxitoxins, cylindrospermopsin, alysiatoxin, lyngbyatoxin-a), and lipopolysaccharides (LPSs). Grouped by biological effects, and target tissues affected: hepatotoxins, neurotoxins, cytotoxins, dermatotoxins, and irritant toxins (Table 1).14,15,16,22,38–40,45–47 Neurotoxic cyanotoxins are: Anatoxin-a /Homoanatoxin-a; beta-Methylaminol-L-alanine (BMAA).27 BMAA chronic, repeated exposure is linked to neurodegenerative diseases such as Amyotrophic Lateral Sclerosis (ALS),27 and its toxicity is best described in association to exposure to the seeds of the Cycas cincinalis plant in the diet of indigenous people of the Guam Island, and more recently from some diatoms.40–42

Bloom-forming toxic cyanobacteria are global hazards of increasing concern in waters affected by anthropogenic nutrient loads and climate change, occurring frequently in lakes and soft water reservoirs all over the world, causing damage to the biodiversity and equilibrium of aquatic ecosystems due to toxins released.48–50 Nonetheless, some phycotoxins have properties with potential beneficial applications: antibiotics, algaecides, cytotoxic, immunosuppressive agents, and enzyme inhibitors.51,52 Cyanotoxins acting as protease inhibitors and on cell cycle are some the compounds under investigation for antitumor activity e.g. Curacin A.53,54

Seafood poisoning syndromes by marine algal toxins

Marine algal toxins largely produced, but not exclusively, by dinoflagellates and diatoms are potent toxins, contaminate seawater environments, and accumulate at high concentrations in various tissues of aquatic animals such as bivalve mollusks, crustaceans, and fish, thus entering the food chain.14,15 Bivalve mollusks: mussels, oysters, clams, cockles, and scallops are filter-feeding organisms, and can accumulate chemical and microbiological. Consumption of contaminated fish and shellfish is one of the main causes of seafood poisoning. Marine algal toxins are an important source of seafood contamination worldwide with serious adverse impacts to human health, wildlife, the economy, and the ecosystem. International guidelines and regulatory standards aim to maximize seafood products safety as a major internationally traded commodity.15,16,32,34,36 Limited resources and analytical capabilities in developing countries, to detect toxins such as ciguatoxin, may hide serious environmental health problems and seafood safety.55

Table 2A, Table 2B summarize the principal clinical syndromes caused by marine algal toxins produced by dinoflagellates and diatoms, through ingestion of contaminated seafood,15,16,23–25,34,36,41,56 exposure to aerosols, or contact.7,57 The main and best-studied marine algal toxins seafood poisoning syndromes are diarrheic shellfish poisoning (DSP); paralytic shellfish poisoning (PSP); amnesic shellfish poisoning (ASP); neurologic shellfish poisoning (NSP); azaspiracid shellfish poisoning (AZP); ciguatera fish poisoning (CFP). Toxic syndromes associated with PITXs are Pyatoxicoxin, Clupeotoxism, and PITX-like myotoxop compound, characterized by myalgia, rhabdomyolysis, myoglobinuria (black urine) after ingestion of cooked freshwater and brackish water fish, identified as “Half Disease”.58 It differentiates from PITX toxicity by its preferential myotoxic rather than neurotoxic effects. Increasing public health concern exist for PITX poisonings through inhalation, cutaneous, ocular exposure during aquaria handling of soft corals contaminated with PITX.55

Neurotoxic and myotoxic phycotoxins

Neurotoxic phycotoxins produced by marine algae and/or cyanobacteria are potent toxins acting through various mechanisms at the cellular level, often involving ion channels modulation. SXTs selectivity blocks voltage-gated sodium channels receptor, site I sodium pump, affecting motor neurons;15,16,31,32,36 CTX opens sodium channels by binding site Leading to sodium cell influx and depolarization of nerve cell;16,31,32,38 Domoic acid induces excitatory toxicity (excitotoxicity) by an integrative action on ionotropic glutamate receptors (iGlurRs) on both sides of the synapse for which it has high affinity, preferentially the kainic acid (KA) subtype, coupled with an effect that prevents the channel from rapid desensitization.36,40 PITXs a complex molecule that binds to extra- cellular sodium and potassium channels inhibiting the active transport of sodium and potassium across the membranes leaving the channel permanently open and causing cellular death by the excess of intercellular cations.31,32,38 Neurotoxic cyanotoxins are: Anatoxin-a/Homoanatoxin-a, acting through an irreversible link to the nicotinic receptor receiver S of acetylcholine in neuromuscular junction; beta-Methylaminol-L-alanine (BMAA) experimentally acts predominantly on motor neuron-inducing excitotoxicity mediated through glutamate receptors (GlurRs).49,50

Medical management of phycotoxins poisonings

At present, diagnosis of phycotoxins poisoning is largely based on symptomatology and exposure history, identification of toxin in food or water, estimation of contaminated food/water consumption to calculate the amount of toxin ingested, while epidemiology is based on reports of acute events, toxic outbreaks of contaminated seafood, water or aquatic environments. Mild cases may not require medical attention or not be diagnosed. Respiratory and skin reactions may be confused with allergies.

Toxic symptoms appear within minutes to days following consumption of seafood product (fish or shellfish), freshwater fish, cooked or uncooked, local or imported, during traveling or after traveling to endemic regions. Public health warnings, population eating habits, recreational practices, are important for diagnosis. Populations at higher risk of exposure due to cultural practices include recreational shellfish pickers, anglers, aboriginals in coastal regions.21,45,62 Age, pre-morbid history such as renal insufficiency, amount and type of food consumed are factors influencing the severity of intoxication.36,40 The source of exposure and identification of toxin through analysis of food samples are important for public health management of outbreaks.

Despite that each toxin group has a different mechanism of action, characteristic clinical features and prognosis (Table 2A & Table 2B), acute intoxications by neurotoxic phycotoxins commonly affect: gastrointestinal (GI), cardiovascular, respiratory and nervous systems. The following combination of symptoms alert for a possible intoxication with these compounds: 1) self-limiting, non-specific gastrointestinal symptoms of various degree of severity: vomiting, nausea, diarrhea, abdominal pain; 2) nonspecific cardio-respiratory symptoms such as hypotension, tachycardia, arrhythmia, dyspnea;
3) appearance of neurological symptoms of various degree of severity, ranging from perioral burning, paresthesia, to convulsions and coma. Gastrointestinal symptoms are usually the first to appear and neurological symptoms may be later with a time lapse between exposures and clinical symptoms from minutes to days. Symptoms increase in frequency and severity over the subsequent hours after consumption of a contaminated seafood meal. Reporting of the events to public health authorities is paramount to track outbreak events and develop an epidemiologic database. Mild cases shall also be reported.

No specific biomarker is available to confirm diagnosis or exposure, nonetheless some laboratory test aids e.g. urine test to measure myoglobin in cases of “Haff Disease” by PITX-like myotoxic compound,66 or tests measuring STXs in urine,65 which still needs validation and standardization.

For the poisoned patient emergency medical management should be organized and thoughtful, as suggested by Thompson et al.44 Although the authors do not include phycotoxins in the list of poisoning substances, is a practical guideline. Phycotoxins poisoning is largely supportive and symptom-driven as no specific antidote are available for these toxins. Palliative measurements vary depending on the toxin group and its mechanism of action, e.g.: antiepileptic and drugs modulating glutamate receptors for potential domoic acid intoxication,27 respiratory support for STXs intoxication.45,66

Little is known about long-term repeated exposure to neurotoxic phycotoxins or their mixtures. At present, the issue of domoic acid developmental toxicity and epilepsy deserves special consideration because of its relevance to public health as a potentially preventable cause of epilepsy and neurobehavioral impairments.15,30,40,56,66 Rapidly accumulating data from experimental studies and episodes of wildlife intoxication and long-term repeated exposure support a cause-effect link.36,66 Furthermore, it has been demonstrated in experimental models that domoic acid crosses the placenta and can be present in milk.36 Consumer awareness of at-risk women during pregnancy and lactating require special attention, particularly during contamination outbreaks as those recently reported.19 Dietary assessment is required to estimate exposure.49

**Prevention and factors increasing the risk of human phycotoxins exposure**

The key management tools are prevention, through policies and regulations, and monitoring systems of each toxin group and HABs, and warning by public health organizations to minimize the risk of human poisoning episodes.24,44,72 Factors increasing the risk of human exposure include: 1) Marine algal toxins are odorless, tasteless, and do not deactivate by cooking; 2) Seafood product may appear normal in appearance and texture; 3) Seafood product may appear normal in appearance and texture; 4) Dense human population in coastal regions, and do not deactivate by cooking; 5) Recreational harvesting of shellfish, and do not deactivate by cooking; 6) HABs tend to follow environmental conditions and documentation of events are paramount for preventive management and development of forecasting systems. Detail clinical records, including food consumption history, symptoms, and reporting to public health authorities are essential for diagnosis and risk management.

**Conclusion**

Phycotoxins and associated human health effects are a public health concern worldwide. A summary of most common poisoning syndromes is presented here. Enhanced awareness by health care providers and consumers will improve clinical management, a collection of clinical history, reporting and epidemiology databases. However, a comprehensive insight into phycotoxins human health risk requires multidisciplinary, international collaboration, detail information on exposure: data on consumption and levels of contamination of seafood products or aquatic environments. Each toxin group involves specific parameters: synthesizing organisms, vectors, toxicology including toxic kinetics, biological effects, associated symptoms, and prognosis. Less is known about chronic effects. Biomarkers are needed to improve diagnosis, detection, and measurement of human exposure, allowing more accurate disease surveillance and epidemiology. At risk populations e.g.: arctic and American west coast native population, pregnant women, lactating infants need special attention and surveillance of potential chronic effects such as cancer and neurodegenerative disorders. Development of antidotes to phycotoxins with potentially lethal effects is an investigational challenge.

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None.

**Conflict of interest**

The author declares no conflict of interest.

**References**


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10. NOAA Science Briefing on Lake Erie Harmful Algal Blooms. HABs in the Great Lakes basin; 2015.


16. CDPH Issues Warning about dangers and rock crabs caught in waters along the central and northern California coast; 2016.

17. Memo from Office of Environmental Health Hazard Assessment (11/6/2015)


69. www.fda.gov/Food/FoodborneIllnessContaminants/CausesOfIllnessBadBugBook/ucm070772.htm