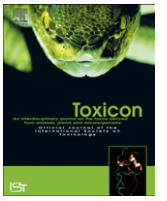
Toxicon 56 (2010) 108–122

Contents lists available at ScienceDirect

Toxicon

journal homepage: www.elsevier.com/locate/toxicon



Paralytic shellfish poisoning: Seafood safety and human health perspectives

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ARTICLE INFO

Article history:
Received 25 September 2009
Received in revised form 12 November 2009
Accepted 11 December 2009
Available online 24 December 2009

Keywords:
Paralytic shellfish poisoning
Saxitoxin
Dinoflagellates
Seafood
Shellfish
Puffer fish
Lobster
Detection methods
Monitoring
Management
Urine
Serum

ABSTRACT

Paralytic shellfish poisoning (PSP) is the foodborne illness associated with the consumption of seafood products contaminated with the neurotoxins known collectively as saxitoxins (STXs). This family of neurotoxins binds to voltage-gated sodium channels, thereby attenuating action potentials by preventing the passage of sodium ions across the membrane. Symptoms include tingling, numbness, headaches, weakness and difficulty breathing. Medical treatment is to provide respiratory support, without which the prognosis can be fatal. To protect human health, seafood harvesting bans are in effect when toxins exceed a safe action level (typically 80 μg STX eq 100 g^{-1} tissue). Though worldwide fatalities have occurred, successful management and monitoring programs have minimized PSP cases and associated deaths. Much is known about the toxin sources, primarily certain dinoflagellate species, and there is extensive information on toxin transfer to traditional vectors – filter-feeding molluscan bivalves. Non-traditional vectors, such as puffer fish and lobster, may also pose a risk. Rapid and reliable detection methods are critical for toxin monitoring in a wide range of matrices, and these methods must be appropriately validated for regulatory purposes. This paper highlights PSP seafood safety concerns, documented human cases, applied detection methods as well as monitoring and management strategies for preventing PSP-contaminated seafood products from entering the food supply.

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1. Paralytic shellfish poisoning toxins and sources

Paralytic shellfish poisoning (PSP) is a common seafood toxicity problem with worldwide distribution, and typically this illness is due to the consumption of contaminated molluscan bivalves and other shellfish. A similar seafood-related syndrome involves puffer fish contaminated with the same family of toxins. To distinguish these puffer fish poisonings from those caused by tetrodotoxin, this food poisoning syndrome is becoming known in the literature as saxitoxin puffer fish poisoning (SPFP; Landsberg et al., 2006; Deeds et al., 2008a). The toxins responsible for both of these seafood-borne illnesses are the neurotoxins known collectively as the saxitoxins (STXs), also referred to as PSP toxins (or PSTs). At least 24 saxitoxin-like congeners have been identified (Fig. 1), with a range of hydroxyl, carbamyl, and sulfate moieties at four sites on the backbone structure. These substitutions result in congeners varying more than three orders of magnitude in potency (Oshima et al., 1993). The carbamate toxins are the most potent, and they include saxitoxin (STX), neosaxitoxin (NEO), and the gonyautoxins (GTX1–4). The decarbamoyl toxins (dcSTX, dcNEO, dcGTX1–4) have intermediate toxicity and are reported in certain bivalves, but are not commonly found in toxic dinoflagellates. The N-sulfocarbamoyl toxins (B1 [GTX5], B2 [GTX6] and C1–4) are less potent. There is a fourth group known as the deoxydecarbamoyl toxins, but their potency has not yet

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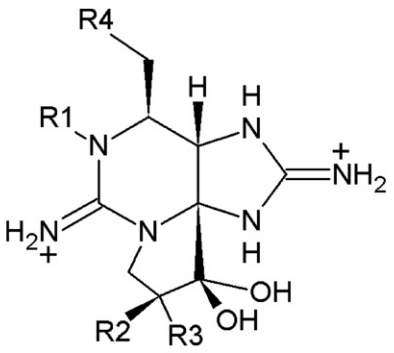
0041-0101/$ – see front matter Published by Elsevier Ltd.
doi:10.1016/j.toxicon.2009.12.013



R1	R2	R3	Carbamate Toxins	Decarbamoyl Toxins	N-Sulfocarbamoyl Toxins	Hydroxybenzoate Toxins
H	H	H	STX	dc-STX	B1	GC3
OH	H	H	NEO	dc-NEO	B2	
OH	H	OSO_3^-	GTX 1	dc-GTX 1	C3	
H	H	OSO_3^-	GTX 2	dc-GTX 2	C1	GC1
H	OSO_3^-	H	GTX 3	dc-GTX 3	C2	GC2
OH	OSO_3^-	H	GTX 4	dc-GTX 4	C4	

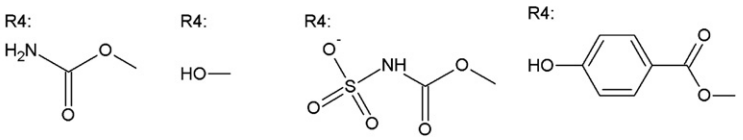


Fig. 1. Molecular structure of saxitoxin congeners.

been adequately assessed. A review of the chemistry, origin and distribution of saxitoxins can be found in Hall et al. (1990). PSP-related toxins known as GC toxins have also been specifically identified from the dinoflagellate *Gymnodinium catenatum*, and the molecular structure of GC1–GC3 was found to contain a hydroxybenzoate moiety instead of the carbamoyl group (Negri et al., 2003, 2007). The binding affinity of GC3 was reported to be similar to the GTXs, and GC1 and 2 epimers were similar to the C toxins (Llewellyn et al., 2004). It has been proposed that the hydroxybenzoate moiety on this particular group of toxins may result in an increased lipophilic nature that could enhance uptake and elimination in victims and shellfish (Llewellyn et al., 2004).

There is a substantial knowledge base on the sources of PSP toxins. Major toxin sources include certain species of microalgae, notably marine dinoflagellates of the genera *Alexandrium* (formerly *Gonyaulax*), *Gymnodinium* and *Pyrodinium* (see reviews by Cembella, 1998; Landsberg, 2002; FAO, 2004 and references therein). More specifically, *Alexandrium tamarense*, *Alexandrium fundyense*, *Alexandrium catenella*, *G. catenatum*, and *Pyrodinium bahamense* are responsible for most reports of PSP (Shumway, 1990, 1995). There are also numerous reports of STXs being produced by certain freshwater and brackish cyanobacteria, as well as calcareous red macroalgae (see review by Deeds et al., 2008a and references therein). These species include *Anabaena circinalis*, *Anabaena lemmermannii*, *Aphanizomenon gracile*, *Aphanizomenon issatschenkoi*, *Cylindrospermopsis raciborskii*, *Lyngbya wollei*, *Planktothrix* sp., and *Rivularia* sp. Regardless of which specific source, each species contains a suite of the toxin congeners, and both the composition and concentration of which determine its overall toxicity. An extensive list of source species can be found in Deeds et al. (2008a), along with their reported toxin profiles. It is noteworthy that toxin composition and concentration for given species have been found to vary with geographic region and environmental factors (e.g. Cembella et al., 1988; Anderson et al., 1990, 1994; Etheridge and Roesler, 2005).

The GC toxins described above are produced by strains of *G. catenatum* (Negri et al., 2007). Negri et al. (2007) reported that these toxins are produced in strains isolated from Australia, China, Portugal, Uruguay and Spain which demonstrate the globally widespread nature of the GC toxins. The discovery of these toxins highlights the need for shellfish monitoring programs to include them in surveillance in areas where *G. catenatum* serves as the toxin source. However, more research is needed on this toxin