Ocean Science Journal (2024) 59:41
https://doi.org/10.1007/s12601-024-00168-9
Online ISSN 2005-7172
Print ISSN 1738-5261

EDITORIAL

Safety Management of Marine Biotoxins in South Korea: Analytical Methods, Occurrence, and Risk Assessment

Seongjin Hong[1] · Hyun-Ki Hong[2] · Kwang-Sik Choi[3]

Received: 23 June 2024 / Revised: 6 August 2024 / Accepted: 19 August 2024

Abstract

Over the past few decades, various marine biotoxins, including paralytic shellfish poison, diarrheal shellfish poison, neurotoxic shellfish poison, and amnestic shellfish poison, have become international oceanographic concerns. These toxins are closely linked to global warming and the subsequent northward migration of toxic marine organisms, such as microalgae, fish, and benthic invertebrates, from tropical and subtropical regions. In South Korea, the bioaccumulation of marine biotoxins and incidents of seafood poisoning have also emerged as critical issues. Clear evidence indicates that the presence of toxic marine organisms in Korean coastal waters has increased, likely due to recent increases in seawater temperature. Since 2020, supported by the Ministry of Food and Drug Safety, the R&D project 'Establishment of the Safety Management System for Marine Biotoxins' has been carried out. This project aims to identify various regulated and unregulated marine biotoxins present in Korean coastal waters and seafood. This comprehensive project encompasses: (1) analytical methods, (2) causative organisms, (3) seafood contamination status, (4) novel and rapid detection method, (5) alternative toxicity testing method, (6) standard materials, and (7) risk assessment. The purpose of this special issue is to share the accumulated knowledge and technological advancements related to marine biotoxins by Korean researchers. The issue includes nine papers covering various types of marine biotoxins, as well as innovative bioassays and rapid detection kits. Additionally, it covers topics such as risk assessment and biotoxin management to ensure the safety of marine products.

Keywords Marine biotoxins · Seafood management · Paralytic shellfish poison (PSP) · Risk assessment · Analytical methods

Marine biotoxins, produced by certain microalgal species of dinoflagellates and diatoms, pose serious health risks when these organisms are stressed by environmental factors such as changes in water temperature, salinity, and pH (Rigby et al. 2022). Biological stressors, including competition for nutrients and trace elements between species and the threat of predators, also promote toxin production (Tatters et al. 2013; Brandenburg et al. 2020). These biotoxins can accumulate in marine organisms such as bivalves, crustaceans, and fish, with accumulation patterns being species-specific and toxin-specific (Liu et al. 2019; Zhao et al. 2022). Poorly metabolized and excreted toxins can persist in organisms, including bivalves, for extended periods, sometimes several months (Kim et al. 2022, 2023).

Shellfish toxins are categorized based on their symptoms into paralytic shellfish poison (PSP), diarrheal shellfish poison (DSP), neurotoxic shellfish poison (NSP), and amnestic shellfish poison (ASP) toxins (Chen et al. 2017). They are also classified based on chemical properties into hydrophilic and lipophilic toxins. Hydrophilic marine algal toxins include saxitoxin (STX) and gonyautoxin (GTX) (Gerssen et al. 2010). Lipophilic toxins include okadaic acid (OA), dinophysis toxin (DTX), yessotoxin (YTX), pectenotoxin (PTX), brevetoxin (BTX), azaspiracid (AZA),

✉ Seongjin Hong
hongseongjin@cnu.ac.kr

✉ Hyun-Ki Hong
hyunki@gnu.ac.kr

✉ Kwang-Sik Choi
skchoi@jejunu.ac.kr

1 Department of Marine Environmental Sciences, Chungnam National University, Daejeon 34134, Republic of Korea

2 Department of Marine Biology and Aquaculture, Gyeongsang National University, Tongyeong 53064, Republic of Korea

3 Department of Marine Life Science (BK21 FOUR), Jeju National University, Jeju 63243, Republic of Korea

Published online: 11 September 2024

and cyclic imines (CIs) (Wang et al. 2015). Over recent decades, marine biotoxins have become an international oceanographic concern due to increasing reports of poisoning worldwide (Nicolas et al. 2017; Hallegraeff et al. 2021; Accoroni et al. 2024).

In South Korea, the Ministry of Food and Drug Safety (MFDS) has established standards for managing PSP, DSP, ASP, and tetrodotoxin (TTX) (Table 1). However, numerous other biotoxins remain unregulated. Meanwhile, the US Food and Drug Administration (FDA) and the European Food Safety Authority (EFSA) acknowledge the potential risks posed by a broader range of biotoxins and have established standards to ensure the safety of marine products. With global warming, toxic marine species from tropical and subtropical regions, including microalgae, fish, and benthic invertebrates, are migrating northward (Gobler et al. 2017). This trend necessitates more comprehensive toxin management due to the potential introduction of new toxins. The diversification of seafood import sources further underscores the need for enhanced biotoxin regulation. Consequently, in South Korea, the bioaccumulation of marine biotoxins and incidents of seafood poisoning have emerged as significant issues. Recent observations confirm the presence of more toxic marine organisms in Korean coastal waters, correlated with increasing seawater temperatures (Kim et al. 2023). Recent advancements in cutting-edge analytical instruments have enabled more sensitive and high-resolution quantitation of these marine biotoxins (Panda et al. 2022).

Table 1 Current guidance on marine biotoxins in seafood developed by various countries and international organizations

Biotoxins	Unit	South Korea	Japan	USA (FDA)	Canada	FSANZ	EFSA	FAO/WHO (CODEX)
Saxitoxin (STX)	μg STX-EQ[a] kg^{-1}	800	800	800	800	800	800	800
Okadaic acid (OA)	μg OA-EQ kg^{-1}	160[b]	160[b]	160[c]	160[c]	160[b]	160[d]	160[b]
Domoic acid (DA)	mg DA-EQ kg^{-1}	20	20	20	20	20	20	20
Tetrodotoxin (TTX)	mg kg^{-1}	10 MU[e]	2	–[f]	–	–	–	–
Yessotoxin (YTX)	μg YTX-EQ kg^{-1}	–	–	–	–	–	3750	–
Pectenotoxin (PTX)	μg kg^{-1}	–	–	–	200[g]	–	–	–
Azaspiracid (AZA)	μg AZA1-EQ kg^{-1}	–	–	160	–	–	160	–
Brevetoxin (BTX)	μg BTX2-EQ kg^{-1}	–	–	800	–	200 MU[g]	800	200 MU
Ciguatoxin (CTX)	μg CTX1-EQ kg^{-1}	–	–	0.1[h]; 0.01[i]	–	–	0.01[i]	–
Palytoxin (PlTX)	μg kg^{-1}	–	–	–	–	–	–	–
Cyclic imine (CI)	μg kg^{-1}	–	–	–	–	–	–	–
References		MFDS (2016)	MAFF (2015)	FDA (2021)	Health Canada (2020)	FSANZ (2024)	EFSA (2010)	FAO (2004)

<*Ocean Science Journal*: VSI-Marine Biotoxins in South Korea>

[a]EQ: Equivalent concentration

[b]OA + DTX1 + DTX2

[c]OA + DTX1 + DTX2 + DTX3

[d]OA + DTX1 + DTX2 + PTXs

[e]MU: mouse unit

[f]–, not available

[g]PTX1 + PTX2 + PTX3 + PTX4 + PTX6 + PTX11

[h]C-CTX1-EQ

[i]P-CTX1-EQ

In response, the MFDS initiated the "Establishment of Safety Management System for Marine Biotoxins" R&D project (20163MFDS641) for 2020–2024, with a total budget of 16,793,000,000 KRW. This project involves 14 institutions and 124 researchers, focusing on:

1. Enhancing the management of currently regulated marine biotoxins;
2. Developing analytical methods and conducting surveys for unregulated toxins;
3. Developing rapid detection techniques for marine biotoxins;
4. Developing standard materials for marine biotoxins; and
5. Advancing marine biotoxin toxicity evaluation techniques.

This initiative aims to improve technology and understanding of marine biotoxin contamination characteristics and analytical methods in South Korea. Expected outcomes include establishing infrastructure for marine biotoxin analysis and training specialized personnel.

In this special issue of the *Ocean Science Journal*, we aim to disseminate accumulated knowledge and technological advancements related to marine biotoxins by Korean researchers for both domestic and international readers. The special issue comprises nine papers covering topics such as analytical methods for lipophilic biotoxins and cyclic imines, distribution characteristics of toxic microalgae along Korean coasts, bioaccumulation of TTX, PSP production mechanisms, separation for quantitative accuracy of palytoxin, and toxicity testing methods for biotoxins. These results will serve as baseline data for future research on marine biotoxin contamination, causative organisms, and newly introduced toxins in coastal waters and seafood in South Korea. We extend our gratitude to the editors and reviewers of the *Ocean Science Journal* for their support in publishing this special issue.

Declarations

Conflict of interest The authors declare no competing interests. Kwang-Sik Choi is an editor of Ocean Science Journal.

References

Accoroni S, Cangini M, Angeletti R, Losasso C, Bacchiocchi S, Costa A, Taranto AD, Escalera L, Fedrizzi G, Garzia A, Longo F, Macaluso A, Melchiorre N, Milandri A, Milandri S, Montresor M, Neri F, Piersanti A, Rubini S, Suraci C, Susini F, Vadrucci MR, Mudadu AG, Vivaldi B, Soro B, Totti C, Zingone A (2024) Marine phycotoxin levels in shellfish-14 years of data gathered along the Italian coast. Harmful Algae 131:102560. https://doi.org/10.1016/j.hal.2023.102560

Brandenburg K, Siebers L, Keuskamp J, Jephcott TG, Van de Waal DB (2020) Effects of nutrient limitation on the synthesis of N-rich phytoplankton toxins: a meta-analysis. Toxins 12:221. https://doi.org/10.3390/toxins12040221

Chen J, Li X, Wang S, Chen F, Cao W, Sun C, Zheng L, Wang X (2017) Screening of lipophilic marine toxins in marine aquaculture environment using liquid chromatography–mass spectrometry. Chemosphere 168:32–40. https://doi.org/10.1016/j.chemosphere.2016.10.052

EFSA (2010) Scientific opinion of the panel on contaminants in the food chain on a request from the European Commission on marine biotoxins in shellfish–Emerging toxin: Ciguatoxin group. EFSA J 1627:1–38

FAO (2004) Marine biotoxins. Food and Nutrition Paper 80. http://www.fao.org/docrep/007/y5486e/y5486e00.HTM. Accessed 2 Feb 2023

FDA (2021) Fish and fishery products hazards and controls, Appendix 5: FDA and EPA safety levels in regulations and guidance. https://www.fda.gov/media/80400/download. Accessed 28 Aug 2023

FSANZ (2024) Schedule 19 Maximum Levels of Contaminants and Natural Toxicants; Australia New Zealand Food Standards Code. https://www.legislation.gov.au/F2015L00454/latest/text Accessed 2 Feb 2023

Gerssen A, Pol-Hofstad IE, Poelman M, Mulder PP, Van den Top HJ, De Boer J (2010) Marine toxins: chemistry, toxicity, occurrence and detection, with special reference to the Dutch situation. Toxins 2(4):878–904. https://doi.org/10.3390/toxins2040878

Gobler CJ, Doherty OM, Hattenrath-Lehmann TK, Griffith AW, Kang Y, Litaker RW (2017) Ocean warming since 1982 has expanded the niche of toxic algal blooms in the North Atlantic and North Pacific oceans. Proc Natl Acad Sci USA 114:4975–4980. https://doi.org/10.1073/pnas.1619575114

Hallegraeff GM, Anderson DM, Belin C, Bottein M-YD, Bresnan E, Chinain M, Enevoldsen H, Iwataki M, Karlson B, McKenzie CH, Sunesen I, Pitcher GC, Provoost P, Richardson A, Schweibold L, Tester PA, Trainer VL, Yñiguez AT, Zingone A (2021) Perceived global increase in algal blooms is attributable to intensified monitoring and emerging bloom impacts. Commun Earth Environ 2:117. https://doi.org/10.1038/s43247-021-00178-8

Health Canada (2020) Maximum levels for chemical contaminants in foods. https://www.canada.ca/en/health-canada/services/food-nutrition/food-safety/chemical-contaminants/maximum-levels-chemical-contaminants-foods.html#a5. Accessed 2 Feb 2023

Kim M, Hong S, Lim YK, Cha J, Gwak J, Kim Y, An SA, Lee HS, Baek SH (2022) Spatiotemporal distribution characteristics of yessotoxins and pectenotoxins in phytoplankton and shellfish collected from the southern coast of South Korea. Mar Pollut Bull 180:113776. https://doi.org/10.1016/j.marpolbul.2022.113776

Kim M, Hong S, Lim YK, Cha J, Kim Y, Lee CE, Yoon JN, Lee HS, Baek SH (2023) Monthly distribution of lipophilic marine biotoxins and associated microalgae in the South Sea Coast of Korea throughout 2021. Sci Total Environ 898:165472. https://doi.org/10.1016/j.scitotenv.2023.165472

Liu Y, Yu RC, Kong FZ, Li C, Dai L, Chen ZF, Geng HX, Zhou MJ (2019) Contamination status of lipophilic marine toxins in shellfish samples from the Bohai Sea, China. Environ Pollut 249:171–180. https://doi.org/10.1016/j.envpol.2019.02.050

MAFF (Ministry of Agriculture, Forestry and Fisheries) (2015) Guidelines for Risk Management of Shellfish Toxins in Bivalves. http://www.maff.go.jp/j/syouan/tikusui/gyokai/g_kenko/busitu/pdf/150306_kaidoku_guide.pdf. Accessed 5 Nov 2018

MFDS (2016) Ministry of food and drug safety notice No. 2016–294. https://foodsafetykorea.go.kr/foodcode/01_03.jsp?idx=12. Accessed 2 Feb 2023

Nicolas J, Hoogenboom RL, Hendriksen PJ, Bodero M, Bovee TF, Rietjens IM, Gerssen A (2017) Marine biotoxins and associated outbreaks following seafood consumption: prevention and surveillance in the 21st century. Glob Food Secur 15:11–21. https://doi.org/10.1016/j.gfs.2017.03.002

Panda D, Dash BP, Manickam S, Boczkaj G (2022) Recent advancements in LC-MS based analysis of biotoxins: present and future challenges. Mass Spectrum Rev 41:766–803. https://doi.org/10.1002/mas.21689

Rigby K, Kinnby A, Grønning J, Ryderheim F, Cervin G, Berdan EL, Selander E (2022) Species specific responses to grazer cues and acidification in phytoplankton-winners and losers in a changing world. Front Mar Sci 9:875858. https://doi.org/10.3389/fmars.2022.875858

Tatters AO, Flewelling LJ, Fu F, Granholm AA, Hutchins DA (2013) High CO_2 promotes the production of paralytic shellfish poisoning toxins by *Alexandrium catenella* from Southern California waters. Harmful Algae 30:37–43. https://doi.org/10.1016/j.hal.2013.08.007

Wang Y, Chen J, Li Z, Wang S, Shi Q, Cao W, Zheng X, Sun C, Wang X, Zheng L (2015) Determination of typical lipophilic marine toxins in marine sediments from three coastal bays of China using liquid chromatography-tandem mass spectrometry after accelerated solvent extraction. Mar Pollut Bull 101:954–960. https://doi.org/10.1016/j.marpolbul.2015.10.038

Zhao Y, Li L, Yan X, Wang L, Ma R, Qi X, Wang S, Mao X (2022) Emerging roles of the aptasensors as superior bioaffinity sensors for monitoring shellfish toxins in marine food chain. J Hazard Mater 421:126690. https://doi.org/10.1016/j.jhazmat.2021.126690