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Reaserch Article

A review on heavy metal levels in sea cucumbers

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Abstract

Heavy metals can remain in the marine ecosystems for a long time, they may affect biota in the food chain as a result. Sometimes the existence of xenobiotics causes so great a alter in the ecosystem that a return to earlier, natural conditions is not viable. Human pressure on the sea's resources is increasing, it affects the health of many organisms, leading to changes in the food chains and influencing accumulation in the tissues of biota. Sea cucumbers are being used for heavy metal pollution studies. They are preferred with their many features such as easy collection from the land, feeding with organic matter, contact with sediment, maintenance in laboratories, obtaining sufficient tissue, consuming some species. This review covers heavy metal studies with sea cucumbers in different seas. The results are compared with each other. In addition, the evaluation of the consumed sea cucumber species in terms of human health has been discussed.

Keywords: Sea cucumbers, metals, bioindicator, accumulation, monitoring

Introduction

Marine pollution is the entrance of contaminants into the sea, and includes mainly the dumping of domestic, industrial, agricu1tural and chemical wastes, oil spills from ships and wastes from fishing and touristic activities. The outcomes of marine pollution range from short-term economic losses owing to the unsightly fouling of coasts by litter, oil spills, microplastics and other floatable substances to lesser noticeable but longer-term effects on the whole ecosystem. The most of the accidental and deliberate incidents of marine contamination occur mostly in the coastal ecosystems.

Marine coastal ecosystems are heavily inhabited areas because of the extensive range of economic possibilities attracting industry, new residential growths and other anthropogenic activities that affect coastal ecosystems mainly by waste or sewer discharge to coast, causing pollution. Coastal areas are complex and dynamic ecosystems. Unfortunately, many chemicals are discarded or discharged to seas, especially the shores, which are the final receiving environment (Bat et al., 2018; Balkıs et al., 2017; Burak et al., 2009). Pollution status is determined by meteorological and oceanographic processes that tend to modify the contaminant's amount over time and space. The ecological component is explained as the effects that contaminant amounts have on marine organisms. The most important of these are heavy metals. Heavy metals tend to accumulate in water, sediment and biota in the marine ecosystem (Bryan, 1976; Phillips and Rainbow, 1994; Gazioğlu, 2018). Heavy metal levels in marine organisms are generally significantly higher than other components of the marine environment. Due to their ability to concentrate heavy metals from their habitats, it is important to know the changes in metal levels that should be considered in a normal range, and to know how much their levels can be increased above these levels before commercial species become suitable for food (Ober et al., 1987). Farrington et al. (1987) indicated that the two principal reasons for evaluating the status of chemical contamination in coastal environment were: to keep human health safe and estimate the exposure via the way back to man to protect valuable living natural sources. Many metals are important for organisms, results in their absence an organism can neither grow nor reproduce. However, non-essential metals are not useful at any concentration. All metals, whether essential or not, accumulate in their bodies by marine organisms. Heavy metals can damage aquatic organisms if they are above a certain level. It can even put human health at a significant risk through the food chain.

Heavy metals reaching the sea eventually sink to the bottom (Bat and Özkan, 2019) and affect benthic organisms the most (Bat and Arici, 2018). This can cause heavy metals accumulated in sediments in contaminated areas to accumulate by sea cucumbers (Ahmed et al., 2018a; Fretes et al., 2020), since some sea cucumbers are non-selective deposit feeder, and are mainly found in the bottom of sea waters (Xing and Chia, 1997).

There are many studies on heavy metals in sea cucumbers from across the world and these studies are increasing rapidly. The main object of the review to compare the metal concentrations in sea cucumber species from other regions of the World and evaluate the results in terms of human health.

Importance of sea cucumbers

Sea cucumbers are unusual marine invertebrates and belonging to the phylum Echinodermata, and are found in the benthic zones and deep seas across the world (Bordbar et al., 2011). The number of holothurian species worldwide is about 1250 with the greatest number being in the Asia Pacific region (Du et al., 2012). They are major component of the marine ecosystem. The scientific names, habitat, consumption and distribution of common sea cucumber species are given in Table 1.

They are significant member of the marine ecosystem and distributed all oceans of the world, habitually living near corals, rocks, sea weeds in warm shallow waters (Ridzwan, 2007; Higgins, 2000). Sea cucumbers are usually soft bodied, elongated, worm like animal with a leathery skin and gelatinous body animal. They are generally scavengers, feeding on organic substances and mud, which they catch with their tentacles in the benthic zone of the marine ecosystems. They play important roles in the marine ecosystem as they accelerate recycle nutrients, breaking down detritus and other organic matter later which bacteria can proceed the degradation process (Du et al., 2012). Behavior and biology of sea cucumbers have major effects on physico-chemical processes of soft-bottom and reef ecosystems (Purcell et al., 2016). Gao et al., (2014) found that selective feeding of the sea cucumber *Apostichopus japonicus* was the primary source of the different bacterial communities between the fore-gut contents and surrounding sediments. Purcell et al. (2016) pointed out the role of sea cucumbers sediment-clearing in modified coastal habitats. Moreover, İşgören-Emiroğlu and Günay (2007) noted that sea cucumbers such as *Holothuria tubulosa* may both eliminate biological pollution and recover water quality in fish farming areas. Hence, it was recommended a polyculture of fish and sea cucumber might be realized in future (İşgören-Emiroğlu and Günay, 2007).

The use of sea cucumbers as a food item and a commodity began in China about 1000 years ago (Purcell et al., 2012). A total of 58 consumed sea cucumber species are well defined (Purcell et al., 2012). Especially, *Stichopus hermanni*, *Thelenota ananas*, *Thelenota anax*, *Holothuria fuccogilva* and *Actinopyga mauritiana* are used for human consumption mainly in Asia countries (Lin et al., 2018; Pangestuti and Arifin, 2018) and some species are cultivated in aquaculture systems (Zamora et al., 2016). They are traditionally consumed raw, dried, and boiled in many tropical and subtropical countries (Özer et al., 2004; Rasyid, 2017). Sea cucumbers fishery provide an essential source of income for developing countries (Bordbar et al., 2011). They contain large amounts of nutrients such as Vitamin A, Vitamin B and minerals, proteins, fatty and amino acids (Özer et al., 2004; Bordbar et al., 2011; Haider et al., 2015; Pangestuti and Arifin, 2018). Also, they are using in biological and pharmacological activities including such as anti-angiogenic, anticancer, anticoagulant, anti-hypertension, anti-inflammatory, antimicrobial, antioxidant, antithrombotic, antitumor and wound healing (Bordbar et al., 2011; Pangestuti and Arifin, 2018).

Sea cucumbers have been fishing commercially for many years (Bordbar et al., 2011). They are very targeted and high nutritional value fisheries resource in the inshore subsistence fishery so it is very important to the local communities harvesting these resources for continuation of life. All over the world sea cucumber catch abundantly in the tropical region and the total annual global catch is in the order of 100,000 tons of live animals (Toral-Granda, 2008; Purcell, 2010). The major fisheries exist in China, Ecuador, Indonesia, Japan, Republic of Korea, Malaysia, Philippines, Madagascar, Australia and New Caledonia. Recently, abundance and distributions (Ahmed and Ali, 2014), the length-weight relationships and condition assessments (Ahmed et al., 2018a), sexual reproduction (Ahmed et al., 2018b) and rediscoveries (Ahmed and Ali, 2020) of sea cucumber species in the Pakistani coasts of the Arabian Sea have been intensively studied.

Metals in sea cucumber species

Comparisons were made with levels reported in the literature for sea cucumbers from elsewhere, where possible, on those from different waters (Table 2).

Cd in sea cucumbers

Warnau et al. (2006) found a maximum value of 2.84±1.25 mg / kg dry wt. in *Holothuria tubulosa* collected from the Calvi Bay in Corsica. Cd levels reported in Tale 2 for *Acaudina leucoprocta* (0.05±0.01 mg / kg dry wt.) from Xiangshan China (Lin et al., 2018), *Actinopyga lecanora* (0.02 mg / kg), *Stichopus vastus* (0.04 mg / kg) and *Thelenota anax* (0.04 mg / kg) from Sabah Malaysia (Hashmi et al., 2014), *Actinopyga miliaris* (0.05266±0.01361 mg / kg dry wt.), *Bohadschia similis* (0.05497±0.03079 mg / kg dry wt.), *Holothuria scabra* (0.04162±0.00695 mg / kg dry wt.) and *Holothuria spinifera* (0.048.3±0.01242 mg / kg dry wt.) from Sri Lanka (Jinadasa et al., 2014) were significantly lower. Moreover, Cd levels were below the limit of detection for *Actinopyga mauritiana* and *Holothuria arenicola* from Pakistan (Haider et al., 2015).

Cu in sea cucumbers

Cu levels have shown considerable variations in sea cucumber species. The highest concentrations occurred in *Holothuria leucospilota* (97.69±0.61 mg / kg dry wt.) and *Holothuria scabra* (81.16±1.05 mg / kg dry wt.) from Qeshm Island, Persian Gulf (Mohammadizadeh et al., 2016). This was followed by *Holothuria fuscopunctata* with a value of 74±9 mg / kg dry wt. from Guangzhou in China (Wen and Hu, 2010).

Table 1. The scientific, habitat, consumption and distribution of common sea cucumber species (adapted from Purcell et al., 2012: Commercially Important Sea Cucumbers of the World Catalogue).

Species	Habitat	Consumption	Distribution
Acaudina leucoprocta (H.L. Clark, 1938)	It is distributed between 0-31 m. (Anonymous, 2020a)	Yes (Lin et al., 2017)	Tropical, east Indo-west Pacific ocean, and also distributed in Australia (Anonymous, 2020a)
Actinopyga bannwarthi Panning, 1944	It is distributed shallow waters (Anonymous, 2020a)	Unknown	Indian ocean, Madagascar and Red Sea also distributed in SE Arabia, Australia (Anonymous, 2020a)
Actinopyga caerulea Samyn, VandenSpiegel & Massin, 2006	This species is characteristic of somewhat deeper tropical waters; it has been observed from 12 to 45 m (Conand et al., 2013)	Yes	Comoros; Indonesia; Mayotte; New Caledonia; Papua New Guinea; Philippines; Solomon Islands; Taiwan, Province of China; Thailand (Conand et al., 2013)
Actinopyga lecanora (Jaeger, 1835)	It lives in coral and coral rocks and reef ledges, between 0.5 and 7 m. It prefers hard substrates (i.e. coral reefs)	Yes	The Mascarene Islands, East Africa to the Red Sea and Oman, Madagascar, Sri Lanka, Bay of Bengal, East Indies, north Australia, the Philippines, China and southern Japan, South Pacific Islands. In India, it is found only in Andamans and Lakshadweep regions
Actinopyga mauritiana (Quoy and Gaimard, 1833)	Prefers outer reef flats and fringing reefs, in very shallow waters, near low water mark where surf breaks, generally in 1–3 m water depth.	Yes	Islands of western Indian Ocean, Mascarene Islands, East Africa, Madagascar, Red Sea, Maldives, Sri Lanka, Bay of Bengal, East Indies, north Australia, the Philippines, China and southern Japan, South Pacific Islands (see SPC PROCFish/C surveys) as far east as Pitcairn Islands. In India, it is distributed in the Gulf of Mannar, the Andamans and Lakshadweep.
Actinopyga miliaris (Quoy and Gaimard, 1833)	It is distributed commonly between 0 and 10 m deep, on sandy beds and intertidal areas.	Yes	Islands of western Indian Ocean, Mascarene Islands, East Africa, Madagascar, Red Sea, Sri Lanka, Bay of Bengal, East Indies, north Australia, the Philippines, China and southern Japan, South Pacific Islands east to French Polynesia. In India, it is known from the Gulf of Mannar, Palk Bay, the Andamans and Lakshadweep.
Apostichopus japonicus (Selenka, 1867)	It occurs from the shallows of the intertidal zone to about 20 or 30 m depth.	Yes	Western Pacific Ocean, the Yellow Sea, the Sea of Japan, the Sea of Okhotsk. The northern limits of its geographic distribution are the coasts of Sakhalin Island, Russian Federation and Alaska (USA). The southern limit is Tanega-shima in Japan. In China, it is commonly distributed on the coast of Liaoning, Hebei and Shandong Province, Yantai and Qingdao of Shandong Province. Its southern limit in China is Dalian Island in Lian Yungang, Jiangsu Province.
Bohadschia argus Jaeger, 1833	A typical reef species. Generally occurs in 2 to 10 m depth on reef flats and back reef lagoons with clear water.	Yes	Sri Lanka, Bay of Bengal, East Indies, north Australia, the Philippines, China and southern Japan, south Pacific Islands. In India, it is distributed in the Andamans and Lakshadweep regions and occurs in the far eastern Indian Ocean to French Polynesia in the Pacific.
Bohadschia marmorata Jaeger, 1833	Occurs in shallow water rarely deeper than 3 m. Inhabits seagrass beds in muddy-sand sediments, in sheltered or semisheltered sites.	Yes	Mascarene Islands, East Africa, Madagascar, Red Sea, Sri Lanka, Bay of Bengal, East Indies, north Australia, the Philippines, China and southern Japan, South Pacific Islands. Widely distributed in Southeast Asia and the Pacific Islands, where its reported range extends to French Polynesia in the east. Occurs throughout the Indian Ocean to East Africa.
Bohadschia similis (Semper, 1868)	This species is reef associated. It can be found in very shallow waters, and occurs in coastal lagoons and inner reef flats, generally burrowing in sandy-muddy bottoms between 0-3m (Kinch et al. 2008, Purcell et al. 2008; taken from Samyn, 2013)	Yes (Samyn, 2013)	American Samoa; Australia; Brunei Darussalam; Cambodia; Cook Islands; Fiji; French Polynesia; Guam; Indonesia; Kenya; Kiribati; Malaysia; Marshall Islands; Mauritius; Micronesia, Federated States of ; Myanmar; Nauru; New Caledonia; Niue; Northern Mariana Islands; Palau; Papua New Guinea; Philippines; Pitcairn; Réunion; Samoa; Singapore; Solomon Islands; Somalia; Thailand; Timor-Leste; Tokelau; Tonga; Tuvalu; Vanuatu; Viet Nam; Wallis and Futuna (Samyn, 2013)
Bohadschia vitiensis (Semper, 1868)	Found in shallow waters, rarely in depths of more than 20 m. Mostly in sheltered coastal lagoons and inner reef flats on sand or occasionally among rubble and coral patches.	Yes	Widely distributed in the Indo-Pacific, being reported as far east as French Polynesia and west to Madagascar and eastern Africa.

Holothuria atra Jaeger, 1833	Inhabits the inner and outer flats, back reefs, shallow lagoons, sand-mud and rubble, and seagrass beds between 0 and 20 m.	Yes	Widespread in the Indo-Pacific. This species is found at Mascarene Islands, East Africa, Madagascar, Red Sea, southeast Arabia, Persian Gulf, Maldives, Sri Lanka, Bay of Bengal, India, North Australia, the Philippines, China and southern Japan, South Sea Islands, Hawaiian Islands. It can be found in the islands in the central and eastern tropical Pacific, including Coco and Galápagos islands, Panama region, Clipperton Island and Mexico.
Holothuria arenicola Semper, 1868	Abundant in intertidal and shallow areas but can also be found in deeper waters. It can be found under stones, in coral debris and on sand flats.	Poorly known.	This species is believed to be found at some localities in the Western Pacific, parts of Asia, and the Indian Ocean, including the Red Sea and the Comoros. Reported along the Pacific coast of Central America. This species is reported from the Caribbean and Brazil, but those sightings probably represent a different species.
Holothuria cinerascens (Brandt, 1835)	It lives in the outer reef over hard substratum generally between 0 and 3 m, but believed to be found at up to 20 m depth.	Yes	The gonads of this species are eaten in subsistence fisheries. The body wall is also consumed by Asians.
Holothoria edulis Lesson, 1830	Found mostly on silty-sand or sand mixed with coral rubble. Occupies semi-sheltered reef habitats, namely reef flats and lagoon patch reefs near the coast from 0 to 20 m depth.	Yes	East Africa, Madagascar, Red Sea, southeast Arabia, Sri Lanka, Bay of Bengal, East Indies, North Australia, the Philippines, China and southern Japan, South Sea Islands. In India, this species is distributed in the Gulf of Mannar and the Andamans. Widespread in the Pacific and Southeast Asia, extending to French Polynesia in the southeast and Hawaii in the northeast.
Holothuria fuscogilva Cherbonnier, 1980	Commonly inhabits outer barrier reef slopes, reef passes and sandy areas in semi-sheltered reef habitats in 10 to 50 m water depth.	Yes	Mostly, the reconstituted body wall (bêche-de-mer) is consumed by Asians and is highly regarded.
Holothuria fuscopunctata Jaeger, 1833	It lives in shallow waters, generally from 3 to 25 m depth. Inhabits reef slopes, lagoons and seagrass beds over sandy bottoms. Generally found on coarse sand or coral rubble.	Yes	It can be found in the western central Pacific, Asia and the Africa and Indian Ocean and also occurs at least as far east as Tonga.
Holothuria impatiens (Forsskål, 1775)	It lives in shallow coral reef habitats. In the Comoros and Mascarene Islands, it can be found under rocks in shallow waters between 0 and 2 m; however, it can be observed up to 30 m depth.	Yes	It can be found from East Africa and the Indian Ocean to the western central Pacific including Hawaii, in the Pitcairn Islands group, and including much of the Pacific coast of Central America.
Holothuria leucospilota Brandt, 1835	Lives in shallow habitats up to 10 m depth. Found mostly on outer and inner reef flats, back reefs and shallow coastal lagoons. Commonly found in seagrass beds, sandy and muddy bottoms with rubble or coral reefs.	Yes	This species has one of the broadest distributions of all holothurians, and it can be found in most tropical localities in the western central Pacific, Asia and most Indian Ocean regions.
Holothuria mexicana Ludwig, 1875	In Colombia, this species prefers coral reefs, seagrass beds, sandy or rubble bottoms and mangrove habitats. In the wider Caribbean, it inhabits shallow waters with sandy or coral patches or seagrass beds.	Yes	Distributed widely along the Florida Keys, Bahama Islands, Cuba, Puerto Rico, Jamaica, Barbados, Tobago, Aruba, Yucatan Peninsula, Belize, Bonaire, Venezuela (Bolivarian Republic of) and islands off Colombia, at depths from 0.5 to 20 m.
Holothuria pardalis Selenka, 1867	In Kenya, it has been observed buried under coral rubble or coral boulders. In the Comoros, it inhabits shallow waters between 0 and 10 m depth on coral rock or buried among coral rubble. In La Réunion, it is found in crevices on reef flats.	Unknown	Ranges from the western central Pacific to the Hawaiian Islands, Asia and the Africa and Indian Ocean region. Also found on the Pacific coast of Central America.
Holothuria scabra Jaeger, 1833	Found in shallow waters, but occasionally to about 20 m. Commonly found on inner flat reefs of fringing and lagoonal reefs, and	Yes	Widespread in the tropical Indo-Pacific, excluding Hawaii, between latitudes 30°N and 30°S and not found further east than Fiji.

	coastal sandflats and seagrass beds with muddy sandy substrates, near mangroves		
Holothuria spinifera Théel, 1886	It can completely bury itself in sand in shallow waters from 2 to 10 m.	Yes	Red Sea, Persian Gulf, Sri Lanka, northern Australia, the Philippines. In India, it is known only from Gulf of Mannar and Palk Bay.
Holothuria tubulosa Gmelin, 1791	This species is found in seagrass beds with larger individuals occurring at the deepest depths of the beds (Bulteel *et al.* 1992, Coulon and Jangoux 1993) (Samyn, 2013)	There is a commercial fishery in Turkey (Aydın, 2008)	Albania; Algeria; Belgium; Bosnia and Herzegovina; Croatia; Cyprus; Egypt; France; Gibraltar; Greece; Guernsey; Ireland; Israel; Italy; Jersey; Lebanon; Libya; Malta; Monaco; Montenegro; Morocco; Portugal (Portugal (mainland), Azores); Slovenia; Spain; Syrian Arab Republic; Tunisia; Turkey; United Kingdom (Northern Ireland, Great Britain) (Samyn, 2013)
Holothuria verrucosa Selenka, 1867	It is a cryptic species that is found buried in sand, seagrasses and rubble (Conand et al., 2013)	low commercial value, may be locally consumed (Conand et al., 2013)	American Samoa; Australia; China; Cook Islands; Djibouti; Egypt; Eritrea; Fiji; French Polynesia; Guam; Indonesia; Israel; Jordan; Kenya; Kiribati; Madagascar; Malaysia; Marshall Islands; Micronesia, Federated States of ; Nauru; New Caledonia; New Zealand; Niue; Northern Mariana Islands; Palau; Papua New Guinea; Philippines; Samoa; Saudi Arabia; Seychelles; Singapore; Solomon Islands; Sudan; Taiwan, Province of China; Tanzania, United Republic of; Thailand; Tokelau; Tonga; Tuvalu; United States (Hawaiian Is.); Vanuatu; Viet Nam; Wallis and Futuna; Yemen (Conand et al., 2013)
Ohshimella ehrenbergii (Selenka, 1868)	In rock crevices or under stones (Anonymous, 2020a)	Unknown	distributed in SE Arabia, W India, Pakistan, Maldive area and Ceylon (Clark & Rowe, 1971).From India, Maldives and Ceylon, round Arabia to the Red Sea and east coast of Africa (Anonymous, 2020a)
Phyllophorus spiculata Chang, 1935	depth range 0 - 30 m. It lives in aggregations and are found at low tide marks on sandy muddy substrates. It is observed to be partly buried and attached by their tube feet to buried stones or gravel (Lane, 2008)	Unknown	Western Central Pacific: Singapore (Anonymous, 2020b)
Stichopus chloronotus Brandt, 1835	An inhabitant of coral reefs, in shallow waters from the intertidal to depths of 10 m. Found mostly on coarse coral sand and sheltered habitats with coral rubble.	Yes	Islands of western Indian Ocean, Mascarene Islands, East Africa, Madagascar, Maldives, Sri Lanka, Bay of Bengal, East Indies, North Australia, the Philippines, China and southern Japan, most of the islands of the Central Western Pacific but apparently absent from the Marshall Islands.
Stichopus herrmanni Semper, 1868	Occurs in a wide range of shallow tropical habitats. In the western central Pacific, It prefers seagrass beds, rubble and sandy-muddy bottoms between 0 and 25 m. In the Africa and Indian Ocean region, it can be found in lagoons, seagrass beds and rubble over sandy-muddy bottoms between 0 and 5 m.	Yes	Mascarene Islands, East Africa and Madagascar, Red Sea, southeast Arabia, Gulf of Aqaba, Persian Gulf, Maldives, Sri Lanka, Bay of Bengal, East Indies, North Australia, the Philippines, China and southern Japan. It occurs in most countries of the western Pacific as far east as about Tonga and as far south as Lord Howe Island.
Stichopus vastus Sluiter, 1887	This species is found on inshore reefs edges on sand, coral rubble or muddy sand in shallow waters, generally to about 8 m depth.	Yes	Indonesia, the Philippines, Papua New Guinea, Palau Islands, Yap (Federated States of Micronesia) and northeastern Australia. Although also reported from Uri, Vanuatu, it does not appear to occur in New Caledonia.
Stolus buccalis (Stimpson, 1855)	depth range 0-21 m. Found concealed under rock or in narrow crevices (Thandar, 1990).	Unknown	distributed in SE Arabia, Persian Gulf, W India, Pakistan, Ceylon, Bay of Bengal, East Indies, north Australia, Philippine, China and south Japan (Clark & Rowe, 1971); Australia (Rowe & Gates, 1995).
Thelenota ananas (Jaeger, 1833)	In the western central Pacific, it prefers reef slopes and passes, hard bottoms with large coral rubble and coral patches in waters between 1 and 25 m.	Yes	Red Sea, Mascarene Islands, Maldives, East Indies, North Australia, the Philippines, Indonesia, China and southern Japan, and islands of the Central Western Pacific as far east as French Polynesia.
Thelenota anax Clark, 1921	It primarily inhabits reef slopes and outer lagoons on sandy bottoms between 10 and 30 m. It may be found less commonly in shallower waters to about 4–5 m depth, and on hard bottoms or on coral rubble	Yes	Tropical Indo-west Pacific. In the tropical Indian Ocean, this species is known from East Africa, the Comoros and Glorieuses Islands. It is present in much of Southeast Asia, including Indonesia, the Philippines and the south China Sea. In the tropical Pacific, from northwestern Australia to Enewetok, Guam, and the Ryukyu Islands southwards to most of the islands of the Central Western Pacific and as far east as French Polynesia.

Pb in sea cucumbers

They were determined quite high levels of Pb in *Holothuria leucospilota* (23.24±0.70 mg / kg dry wt.), *Holothuria tubulosa* (18±12.9 mg / kg dry wt.) and *Holothuria atra* (15.67 mg / kg dry wt.) collected from Qeshm Island Persian Gulf, Calvi Bay Corsica, Terengganu (Mohammadizadeh et al., 2016; Warnau et al., 2006; Ismail et al., 2004). In contrast, low Pb levels or below detection level were found in *Holothuria atra* and *Bohadschia argus* (<0.3 mg / kg dry wt.) taken from Guam (Denton et al., 1999), *Apostichopus japonicus* (0.065 mg / kg wet wt.) taken from China (Jiang et al., 2014), *Holothuria atra* (0.09752±0.07514 mg / kg dry wt.), *Holothoria edulis* (0.0337±0.1122 mg / kg dry wt.), *Holothuria scabra* (0.03471±0.04774 mg / kg dry wt.), *Stichopus chloronotus* (0.01620±0.00271 mg / kg dry wt.) taken from Sri Lanka (Jinadasa et al., 2014) and *Actinopyga mauritiana* (ND) taken from Pakistan (Haider et al., 2015).

Hg in sea cucumbers

Hg levels in *Stichopus herrmanni, Acaudina leucoprocta, Apostichopus japonicus, Actinopyga miliaris, Holothuria arenicola, Stichopus vastus, Ohshimella ehrenbergii, Holothuria atra* and *Holothuria leueospilota* examined by references in Table 2 are low (Ismail et al., 2004; Lin et al., 2018; Jiang et al., 2014; Jinadasa et al., 2014; Ahmed et al., 2018c; Rasyid, 2017; Ahmed et al., 2019) or near the limits of analytical detections (Denton et al., 1999) or non-detectable (Ahmed and Bat, 2020). The highest Hg concentration was found in *Stichopus herrmanni* species with 3.754 mg / kg wet wt. from Kayeli Bay, Indonesia (Fretes et al., 2020), followed by *Holothuria scabra* with a value of 0.44569±0.19632 mg / kg dry wt. from Sri Lanka (Jinadasa et al., 2014).

Zn in sea cucumbers

High Zn levels were found in *Holothuria leucospilota* (97.27 mg / kg dry wt.) from Hong Kong (Xing and Chia, 1997), *Holothuria scabra* (77±6 mg / kg dry wt.) and *Thelenota ananas* (46±5 mg / kg dry wt.) from Guangzhou China (Wen and Hu, 2010), *Holothuria impatiens* (61±7.21 mg / kg dry wt.) and *Actinophyga bannwarthi* (46.29±8.85 mg / kg dry wt.) from Gulf of Aqaba Jordan (Al-Najjar et al. 2018) and *Holothuria leucospilota* (46.18±1.87 mg / kg dry wt.) from Persian Gulf (Mohammadizadeh et al., 2016).

Fe in sea cucumbers

There are excessive differences between Fe amounts in sea cucumber species. Fe levels were lowest in *Holothuria scabra* (5.03±5.35 mg / kg dry wt.) from Sri Lanka (Jinadasa et al., 2014) and highest in *Actinopyga mauritiana* (660±36 mg / kg dry wt.) from Guangzhou China (Wen and Hu, 2010).

Mn in sea cucumbers

Mn amounts in sea cucumber are also very variable. The minimum Mn amount was *Actinophyga bannwarthi* (0.08 ± 0.05 mg / kg dry wt.), while the maximum value was in *Holothuria impatiens* (209.65 ± 21.53 mg / kg dry wt.) from Gulf of Aqaba, Jordan (Al-Najjar et al., 2018). It seems interesting that both sea cucumber species were collected from the same region.

Ni in sea cucumbers

The highest Ni concentration was found in *Holothuria tubuosa* (24.16±2.62 mg / kg dry wt.) from Dardanelles Strait Turkey (Turk Çulha et al., 2016). Ni levels in the rest of sea cucumber species ranged from 0.19±0.02 to 5.1±1.0 mg / kg dry wt. (see Table 2).

Cr in sea cucumbers

The results of available Cr data showed that highest level was recorded in *Actinopyga mauritiana* with 9.6±0.9 mg / kg dry wt. from Guangzhou China (Wen and Hu, 2010). On the other hand, Cr levels in *Actinopyga mauritiana* and *Holothuria arenicola* from Pakistan were found to be below the measurable value (Haider et al., 2015). Similarly, Cr values were found very low in *Actinopyga miliaris* with 0.00385±0.00206 mg / kg dry wt., *Bohadschia* sp. with 0.00117±0.00066 mg / kg dry wt., *Bohadschia marmorata* with 0.00046±0.00012 mg / kg dry wt., *Bohadschia similis* with 0.00470±0.00271 mg / kg dry wt., *Holothoria edulis* with 0.003±0.00185 mg / kg dry wt., *Holothuria scabra* with 0.00059±0.00022 mg / kg dry wt., *Holothuria spinifera* with 0.00131±0.00042 mg / kg dry wt., *Stichopus chloronotus* with 0.00099±0.00018 mg / kg dry wt. and *Thelenota anax* with 0.00020±0.00016 mg / kg dry wt. from Sri Lanka (Jinadasa et al., 2014).

As in sea cucumbers

Few studies have focused on accumulation of As in sea cucumber species. As amounts varied considerably between species. Denton et al. (1999) determined As in *Bohadschia argus* and *Holothuria atra* from Guam and found very different levels ranged from <0.01 to 17.7 and from <0.01 to 23.2 mg / kg dry wt., respectively. This was followed by *Apostichopus japonicus* from China between 4.26±0.87 and 12.39±0.25 mg / kg dry wt. (Mohsen et al., 2019).

Co in sea cucumbers

Co levels have not been studied much, however Co levels in almost all species of echinoderms studied are low, with maximum value 0.00025±0.00002 mg / kg dry wt. in *Stichopus chloronotus* from Sri Lanka coasts (Jinadasa et al., 2014).

Table 2. Metals in sea cucumber species from seas of the World

Species	Region	d/w	Tiss.	Metals											References
				Cd	**Cu**	**Pb**	**Hg**	**Zn**	**Fe**	**Mn**	**Ni**	**Cr**	**As**	**Co**	
Acaudina leucoprocta	Xiangshan, China	d	Body wall	0.05±0.01	2.13±0.01	1.38±0.21	0.06±0.01	9.06±0.14	-	9.06±0.14	-	0.33±0.11	5.64±0.24	-	Lin et al., 2018
Actinophyga bannwarthi	Gulf of Aqaba, Jordan	d	Body wall	0.13±0.07	7.37±3.54	1.43±1.43	-	46.29±8.85	148.7±32.18	0.08±0.05	1.43±0.39	-	-	-	Al-Najjar et al., 2018
Actinopyga caerulea	Guangzhou, China	d	-	-	4±1	-	-	20±1	41±6	1.1±0.1	0.5±0.1	1.3±0.1	-	-	Wen and Hu, 2010
Actinopyga lecanora	Sabah, Malaysia	-	-	0.02	1.13	0.16	-	9.67	-	2.46	-	2.46	0.16	-	Hashmi et al., 2014
Actinopyga mauritiana	Pakistan	d	Body wall	ND	5.11±0.1	ND	-	5.23±0.04		5.85±0.07	0.25±0.03	ND	-	-	Haider et al., 2015
Actinopyga mauritiana	Guangzhou, China	d	-	-	14±2	-	-	57±3	660±36	9.2±0.5	4.2±0.9	9.6±0.9	-	-	Wen and Hu, 2010
Actinopyga miliaris	Sri Lanka	d	Body wall	0.05266±0.01361	9.18±2.14	2.28705±0.91715	0.07284±0.01208	12.11±2.90	43.58±12.15	-	-	0.00385±0.00206		0.00008±0.00003	Jinadasa et al., 2014
Apostichopus japonicus	China	d	Body wall	0.31±0.03 0.85±0.02	1.55±0.16 8.21±0.19	1.05±0.13 4.25±0.23	-	20.30±1.02 36.21±0.15		16.37±0.42 58.91±2.83	1.18±0.11 1.77±0.10	2.29±0.23 4.61±0.18	4.26±0.87 12.39±0.25	-	Mohsen et al., 2019
Apostichopus japonicus (Juvenile)	China	w	-	0.161	0.179	0.065	0.034	2.634	-	-	-	0.108	0.372	-	Jiang et al., 2014
Bohadschia sp.	Sri Lanka	d	Body wall	0.12893±0.04486	4.30±3.66	0.49164±0.43710	0.16633±0.05251	12.68±5.18	55.46±59.51	-	-	0.00117±0.00066	-	0.00016±0.00009	Jinadasa et al., 2014
Bohadschia argus	Guangzhou, China	d	-	-	18±3	-	-	100±19	330±41	3.7±0.1	5.1±1.0	4.9±0.6	-	-	Wen and Hu, 2010
Bohadschia argus	Guam	d	body wall muscle tissue	0.1	0.6-2.3	<0.3-<0.6	0.000001-0.000007	8.3-18.0	-	-	0.3-1.4	<0.1-0.4	<0.01-17.7	-	Denton et al., 1999
Bohadschia marmorata	Sri Lanka	d	Body wall	0.137±0.02932	2.81±1.02	0.22702±0.19389	0.11622±0.12974	16.06±12.06	23.06±8.23	-	-	0.00046±0.00012	-	0.00007±0.00003	Jinadasa et al., 2014
Bohadschia similis	Sri Lanka	d	Body wall	0.05497±0.03079	5.70±0.67	0.45053±0.29131	0.12703±0.04146	16.22±6.26	56.68±17.77	-	-	0.00470±0.00271	-	0.00009±0.00002	Jinadasa et al., 2014
Bohadachio vitiens	Sabah, Malaysia	-	-	0.03	0.87	0.12	-	7.83	-	2.27	-	1.35	0.25	-	Hashmi et al., 2014
Holothuria arenicola	Northern Arabian Sea	d	Body wall	0.12–1.42	0.43–2.23	0.92–2.33	-	11–28	47–33	2.45–5.32	-	-	-	-	Ahmed et al., 2017
Holothuria arenicola	Karachi, Pakistan	d	muscle	-	-	-	0.018	-	-	-	-	-	-	-	Ahmed et al., 2018c
Holothuria arenicola	Pakistan	d	Body wall	ND	0.95±0.01*	ND	-	4.28±0.06*	-	5.23±0.04*	0.19±0.02*	ND	-	-	Haider et al., 2015* Mg/100 g
Holothuria atra	Guam	d	body wall muscle tissue	<0.1-0.1	0.7-2.5	<0.3-<0.6	0.000007-0.000022	12.6-21.2	-	-	<0.2-<0.3	<0.1-0.3	<0.01-23.2	-	Denton et al., 1999
Holothuria atra	Pulau Pangkor, Perak and Pulau Kapas, Terengganu	d	body wall	8.0-33.03	31.32-41.13	10.32-15.67	0.08-0.17	30.38-51.67	-	-	-	-	-	-	Ismail et al., 2004
Holothuria atra	Northern Arabian Sea	d	Body wall	0.52–1.11	2.03–3.89	0.69–1.23	-	18–24	19–26	1.09–2.49	-	-	-	-	Ahmed et al., 2017

Holothuria atra	Sri Lanka	d	Body wall	0.07252± 0.00888	3.18±1.02	0.09752± 0.07514	0.03112± 0.01282	24.38±3.96	11.72±12.11	-	-	<0.04	-	0.00009± 0.00006	Jinadasa et al., 2014
Holothuria atra	Karachi, Pakistan	d	muscle	-	-	-	0.036	-	-	-	-	-	-	-	Ahmed et al., 2018c
Holothuria cinerascens	Northern Arabian Sea	d	Body wall	2.67	8.93	2.12	-	37	52	4.64	-	-	-	-	Ahmed et al., 2017
Holothoria edulis	Sabah, Malaysia	-	-	0.12	1.12	0.14	-	7.26	-	1.25	-	1.14	0.54	-	Hashmi et al., 2014
Holothoria edulis	Sri Lanka	d	Body wall	0.11447± 0.07601	1.84±3.71	0.0337±0.1122	0.02463± 0.01676	20.95±6.75	39.82±23.17	-	-	0.003±0.00185	-	0.00013± 0.0001	Jinadasa et al., 2014
Holothuria fuscogilva	Guangzhou, China	d	-	-	57±5	-	-	11±2	250±36	9.4±0.3	1.5±0.5	1.3±0.1	-	-	Wen and Hu, 2010
Holothuria fuscopunctata	Guangzhou, China	d	-	-	74±9	-	-	25±2	100±20	12±0.6	3.0±0.7	5.5±0.5	-	-	Wen and Hu, 2010
Holothuria impatiens	Gulf of Aqaba, Jordan	d	Body wall	0.12±0.06	1.06±0.49	8.35±1.14	-	61±7.21	107.9±17.3	209.65±21.53	0.42±0.18	-	-	-	Al-Najjar et al., 2018
Holothuria leucospilota	Hong Kong	d	muscle digestive tract body wall	-	0.25 5.53 2.11	-	-	97.27 42.96 8.14	-	-	-	-	-	-	Xing and Chia, 1997
Holothuria leucospilota	Northern Arabian Sea	d	Body wall	1.02	8.64	2.19	-	46	73	7.12	-	-	-	-	Ahmed et al., 2017
Holothuria leucospilota	Qeshm Island, Persian Gulf	d	Body wall	0.16±0.01 0.45±0.05	64.81±1.64 97.69±0.61	19.09±0.68 23.24±0.70	-	40.00±1.26 46.18±1.87	-	-	-	-	-	-	Mohammadizadeh et al., 2016
Holothuria leueospilota	Sabah, Malaysia	-	-	0.05	0.87	0.3	-	16.27	-	2.24	-	1.55	2.43	-	Hashmi et al., 2014
Holothuria leueospilota	Karachi, Pakistan	d	muscle and skin	-	-	-	LOD-0.0034 LOD-0.0046	-	-	-	-	-	-	-	Ahmed and Bat, 2020
Holothuria mexicana	Guangzhou, China	d	-	-	30±2	-	-	16±2	190±29	1.6±0.2	1.1±0.3	2.2±0.2	-	-	Wen and Hu, 2010
Holothuria pardalis	Karachi, Pakistan	d	muscle	-	-	-	0.026	-	-	-	-	-	-	-	Ahmed et al., 2018c
Holothuria scabra	Guangzhou, China	d	-	-	18±3	-	-	77±6	130±19	1.4±0.1	0.6±0.2	1.1±0.1	-	-	Wen and Hu, 2010
Holothuria scabra	Qeshm Island, Persian Gulf	d	Body wall	0.13±0.02 0.17±0.01	44.48±0.89 81.16±1.05	1.52±0.17 2.55±0.09	-	19.30±0.93 29.12±0.88	-	-	-	-	-	-	Mohammadizadeh et al., 2016
Holothuria scabra	Sri Lanka	d	Body wall	0.04162± 0.00695	3.45±1.0	0.03471± 0.04774	0.44569± 0.19632	3.68±0.45	5.03±5.35	-	-	0.00059± 0.00022	-	0.00012± 0.00003	Jinadasa et al., 2014
Holothuria spinifera	Sri Lanka	d	Body wall	0.048.3±0.01242	4.42±3.12	0.20456± 0.48047	0.1337±0.09633	8.77±3.07	20.09±12.79	-	-	0.00131± 0.00042	-	0.00008± 0.00006	Jinadasa et al., 2014
Holothuria tubuosa	Dardanelles Strait, Turkey	d	Body wall	0.09±0.01 0.63±0.23	ND-6.60±0.12	0.71±0.03 5.34±0.10	-	12.40±1.00 21.27±2.04	50.86±6.80 117.63±3.29	-	8.31±0.36 24.16±2.62	-	-	-	Turk Çulha et al., 2016
Holothuria tubulosa	Calvi Bay, Corsica	d	Body wall	0.38±0.16 2.84±1.25	0.76±0.16 1.48±0.24	1.62±0.09 18±12.9	-	10.1±4.14 15.5±4.52	12.5±13 216 ±194	-	-	-	-	-	Warnau et al., 2006
Holothuria tubulosa	Ischia Island, Italy	d	Body wall	0.50±0.27 2.28 ± 1.63	1.06±0.27 5.78±3.73	1.94±0.12 6.71 ± 3.75	-	8.87±3.71 26.0 ± 7.16	18.5 ± 17 191±187	-	-	-	-	-	Warnau et al., 2006

Holothuria tubulosa	Marseille, France	d	Body wall	0.44±0.18 1.85±0.65	1.12 ± 0.23 2.28 ± 0.40	1.23±0.84 4.69 ± 4.80	-	14.9±2.24 21.0 ± 5.36	18±17 106 ± 128	-	-	-	-	-	Warnau et al., 2006
Holothuria verrucosa	Northern Arabian Sea	d	Body wall	0.76–1.76	1.98–3.76	0.52–1.03	-	12–30	23–29	0.76–2.47	-	-	-	-	Ahmed et al., 2017
Holothuria verrucosa	Karachi, Pakistan	d	muscle	-	-	-	0.024	-	-	-	-	-	-	-	Ahmed et al., 2018c
Ohsimella ehrenbergii	Northern Arabian Sea	d	Body wall	0.31–0.52	2.23–3.98	2.54–3.02	-	24–32	32–34	2.11–3.91	-	-	-	-	Ahmed et al., 2017
Ohshimella ehrenbergii	Karachi, Pakistan	d	edible tissues	-	-	-	0.0176	-	-	-	-	-	-	-	Ahmed et al., 2019
Phyllophogius spiculata	Sabah, Malaysia	-	-	0.05	0.75	0.13	-	9.33	-	32.67	-	2.16	0.3	-	Hashmi et al., 2014
Stichopus chloronotus	Guangzhou, China	d	-	-	3±1	-	-	16±2	80±23	2.2±0.2	0.3±0.1	1.5±0.1	-	-	Wen and Hu, 2010
Stichopus chloronotus	Sri Lanka	d	Body wall	0.08611± 0.02537	7.25±8.49	0.01620± 0.00271	0.24328± 0.05932	16.20±2.7 1	39.51±8.8 4	-	-	0.00099± 0.00018	-	0.00025± 0.00002	Jinadasa et al., 2014
Stichopus herrmanni	Pulau Pangkor, Perak and Pulau Kapas, Terengganu	d	body wall	10.48-12.09	29.45-38.87	9.87-15.77	0.09-0.10	43.54-59.13	-	-	-	-	-	-	Ismail et al., 2004
Stichopus herrmanni	Guangzhou, China	d	-	-	3±1	-	-	33±3	94±27	9.1±0.4	0.3±0.1	1.6±0.2	-	-	Wen and Hu, 2010
Stichopus herrmanni	Kayeli Bay, Indonesia	w	meat	-	-	-	3.754	-	14.6	-	-	-	-	-	Fretes et al., 2020
Stichopus vastus	Indonesia	d	-	<1.0	-	<1.5	<1.0	-	520.8	-	-	-	<1.0	-	Rasyid, 2017
Stichopus vastus	Sabah, Malaysia	-	-	0.04	0.76	0.18	-	28.37	-	4.77	-	2.86	0.54	-	Hashmi et al., 2014
Stolus buccalis	Karachi, Pakistan	d	edible tissues	-	-	-	0.0155	-	-	-	-	-	-	-	Ahmed et al, 2019
Stolus buccalis	Northern Arabian Sea	d	Body wall	0.11	2.46	0.82	-	19	14	3.02	-	-	-	-	Ahmed et al., 2017
Thelenota ananas	Guangzhou, China	d	-	-	33±2	-	-	46±5	210±39	16±1.6	2.5±0.6	2.7±0.3	-	-	Wen and Hu, 2010
Thelenota ananas	Sabah, Malaysia	-	-	2.43	1.34	0.24	-	15.22	-	5.65	-	3.33	0.42	-	Hashmi et al., 2014
Thelenota anax	Sabah, Malaysia	-	-	0.04	0.95	0.19	-	9.98	-	4.04		1.46	0.23	-	Hashmi et al., 2014
Thelenota anax	Guangzhou, China	d	-	-	4±1	-	-	28±2	200±30	10±0.9	0.7±0.2	1.5±0.1	-	-	Wen and Hu., 2010
Thelenota anax	Sri Lanka	d	Body wall	0.08451± 0.02241	2.92±0.82	0.29757± 0.47955	0.02867± 0.00599	22.81±7.5 1	53.82±30. 98	-	-	0.00020± 0.00016	-	0.00019± 0.00003	Jinadasa et al., 2014

Discussion

Ismail et al. (2004) measured Cd, Pb, Zn, Cu and Hg levels in the body walls of *Stichopus hermanni* and *Holothuria atra* from Pulau Pangkor, Perak and Pulau Kapas, Terengganu. Pb amounts in the body walls of both *Stichopus hermanni* and *Holothuria atra* were quite larger than the permissible levels for human consumption (Ismail et al., 2004). Cd levels in both sea cucumbers seem too high for human consumption.

Mohammadizadeh et al. (2016) found that Cu and Zn amounts in *Holothuria leucospilota* and *Holothuria scabra* from the northern part of Qeshm Island, Persian Gulf were below permissible limits, but Cd and Pb amounts were much higher than the permissible limits for human consumption. Similarly, Pb and As amounts in *Acaudina leucoprocta* from the East China Sea were above the maximum residue limits permitted in foodstuffs (Lin et al., 2018).

Hashmi et al. (2014) determined Pb, Cd, Zn, Cu, Cr and Mn levels in eight sea cucumber species from the market in Kota Kinabalu, Sabah. It was concluded that *Holothuria leueospilota* and *Thelenota ananas* species pose health risks, whereas *Holothoria edulis, Thelenota anax, Actinopyga lecan, Bohadachio vitiens, Stichopus vastus* and *Phyllophogius spiculata* were safe for people consumption. It has been proposed that these six sea cucumber species, which are safe, can be exported (Hashmi et al., 2014).

Jiang et al., (2015) determined Cu, Zn, Cr, Pb, Cd, As and Hg levels in the juveniles of *Apostichopus japonicus* from coastal areas of Bohai and Yellow seas in northern China. They found the average amounts lower than the permissible limits for human consumption except As in 10 % samples exceeded the safety threshold. It is emphasized that better awareness should be paid to toxic heavy metals such as Pb, Cd, As and Hg in the future standard monitoring program (Jiang et al., 2015).

On the other hand, the amounts of Hg in *Holothuria* (*Thymiosycia*) *arenicola*, *Holothuria* (*Lessonothuria*) *pardalis*, *Holothuria* (*Lessonothuria*) *verrucosa* and *Holothuria* (*Halodeima*) *atra* (Ahmed et al., 2018c), and *Ohshimella ehrenbergii* and *Stolus buccalis* (Ahmed et al., 2019) from the Karachi coasts in Pakistan do not show any health problems for human consumption. Similarly, Jinadasa et al. (2014) determined Cu, Fe, Zn, Pb, Cd, Co, Cr and Hg levels in *Holothuria edulis, Holothuria atra, Thelenota anax, Holothuria scabra, Holothuria spinifera, Bohadschia* sp., *Bohadschia similis, Bohadschia marmorata, Actinopyga miliaris* and *Stichopus chloronotus* from the North-western sea of Kalpitiya and Dutch Bay area, Sri Lanka. It was concluded that although the amount of Fe was high in these sea cucumber species, they did not generally pose a health risk for human consumption (Jinadasa et al., 2014).

Rasyid (2017) measured toxic heavy metals Hg, Cd, As and Pb in the dried sea cucumber *Stichopus vastus* from Salemo Island in Indonesia. As these metals cannot be detected, it has been stated that it does not pose a threat to human health (Rasyid, 2017).

Actinophyga bannwarth demonstrated higher capability to accumulate Cd, Cu, Ni, and Zn than *Holothuria impatiens* (Al-Najjar et al., 2018). They showed that Cu, Mn, Zn, Ni and Fe levels in the small sizes (<25 cm) of these both species were greater than their levels in the large sizes (>30 cm).

Amounts of the metals in sea cucumber species seemed to decrease with increased distance offshore, a trend presumably related to the proximity of contamination sources. Different amounts of heavy metals in different sea cucumber species have proven to vary temporally, spatially and climatically (Ahmed et al., 2017). They showed that biota sediment accumulation factor (BSAF) values of Cu, Fe, Mn and Pb for *Holothuria arenicola, Holothuria pardalis, Holothuria verrucosa, Holothuria atra, Ohshimella ehrenbergii, Holothuria cinerascens, Stolus buccalis* and *Holothuria leucospilota* were low, indicating the species as de-concentrators. Zn amounts in all these species from Karachi coast in Pakistan was very bio-accumulative (biota concentration factors were higher than 5000, whereas Cu, Fe, Mn and Pb were considered as bio-accumulative (Ahmed et al., 2017). Ahmed et al. (2017) suggested that these sea cucumber species might be served as good bioindicators. Ahmed and Bat (2020) showed similar result that Hg levels in *Holothuria leucospilota* from Karachi coast in Pakistan was very bio-accumulative (BCF > 5000). Since, BSAF values of Hg for the muscles of *Holothuria leucospilota* ranged from 1.44 to 1.63, considered as micro-concentrator, but this value is higher than 2 on the skin of *Holothuria leucospilota*, it was evaluated as macro-concentrator (Ahmed and Bat, 2020). Moreover, Mohsen et al. (2019) reported that BSAF showed that *Apostichopus japonicus* was a macro-concentrator for Cd in China. It was suggested that this sea cucumber species could be regarded as a bio-monitor for Cd (Mohsen et al., 2019).

Fretes et al. (2020) showed that the accumulation of heavy metals in the intestine of *Stichopus herrmanni* caused damage to villi in the form of necrosis. The body wall of *Acaudina leucoproctais* apt to absorption and accumulation of heavy metals, which may be considered as a precious bioindicator for assessing and monitoring metals contamination in surrounding seawater (Lin et al., 2018). The amount of Hg in the muscles of *Holothuria leucospilota* from Karachi coasts in Pakistan was found to be less than its skin (Ahmed and Bat, 2020).

Al-Najjar et al. (2018) determined that Zn, Pb, Fe and Mn levels were lower in *Actinophyga bannwarth* and *Holothuria impatiens* than in the sediments. It was concluded that it might consider binding of large amounts of metals in the sediments and differential mean of regulating these metals in tissues of these sea cucumber species. It is also pointed out that the determination of metal amounts in sediment makes notice regarding the total content not the bioavailable fraction (Al-Najjar et al. 2018). Similarly, Xing and Chia (1997) suggested that *Holothuria leucospilota* was not a potential bio-indicator organism of Zn and Cu in sediment, because of these metal levels in faeces of this species was almost identical to that of the sediment, considering that little or no metal was absorbed through sediment ingestion. Zn amounts in various tissue/organs of *Holothuria leucospilota* were much higher than that of Cu (Xing and Chia, 1997).

Warnau et al. (2006) determined Cd, Cu, Fe, Pb and Zn levels in *Holothuria tubulosa* from the Mediterranean *Posidonia oceanica* ecosystem. It was pointed out that, if *Holothuria tubulosa* used as a bio-indicator species for surveying and monitoring metal pollution in the Mediterranean *Posidonia oceanica* seagrass, care should be done to compare only concentrations measured in the same body compartments of individuals collected during the same period of the year. It was noted that, preferably, the body compartments that should be considered for metal analysis are primarily the haemal system and secondarily the gut (Warnau et al., 2006). Finally, they pointed out that since *Holothuria tubulosa* as a deposit feeder and lives on the sediments, this species could be effectively used to understand for bioindicators available so far for appraising metal pollution in the *Posidonia oceanica* ecosystem.

Conclusion

Studies on metal accumulation in sea cucumbers have been carried out for years and have been increasing more recently. Because sea cucumbers change or renew the structure of the water and sediment they are in, they are very important for the benthic region. In addition, many species increase their popularity due to the importance of being consumed and cultivated and being used intensely medically. There are many advantages to using sea cucumbers in marine pollution monitoring studies. The reasons why sea cucumbers are preferred in pollution monitoring studies are that they are spread over very large areas, they are relatively easy to collect, they are easy to maintain in the laboratory, they have enough tissues or organs for analysis. Studies show that many sea cucumber species accumulate heavy metal. Metal accumulation of sea cucumbers is higher in ambient waters than sediment. Many sea cucumber species are also recommended as bio-indicators. At the same time, many researchers strongly recommend carrying out monitoring studies with sea cucumbers in the future.

Conflict of interest statement

We declare that we have no conflict of interest.

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