19 Potentially Toxic Metals in Africa, Fresh and Marine Environment

Marine Green Contamination, Ecological and Human Health Risk

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19.1 INTRODUCTION

The marine environment makes up more than 70% of the Earth's surface (USGS 2019). It contains about 97% of the world's total water (USGS 2019). It plays important roles in the hydrogeological and biogeochemical cycles (de Moura *et al.* 2012). About 78% of global precipitation happens around the world's oceans, and about 86% of global evaporation originates from the sea (NASA 2023). In many African countries, marine environments are important sources of revenue via tourism (FAO 2017). The rapid expansion of coastal cities such as Lagos, Cairo, and Cape Town and an increase in seaports, coastal fisheries, industries, and agriculture contributes around 56% to the West African gross domestic product (GDP) (FAO 2017).

Metals with a relatively high density in comparison to water (H_2O) are referred to as heavy metals. They are able to induce toxicity even at low exposure. Due to their use for several purposes, such as agricultural, domestic, and industrial applications, heavy metals have become threats to human health (Tchounwou *et al.* 2012; Aransiola *et al.* 2021). Heavy metals are reported to originate from different geogenic and anthropogenic sources (Adewumi *et al.* 2022; Ogundele *et al.* 2023; Aransiola *et al.* 2013). Industrial, agricultural, pharmaceutical, and home effluents, as well as other metal-based industrial operations, are examples of anthropogenic sources (Tchounwou *et al.* 2012). It has also been claimed that natural events like weathering and volcanic activity contribute immensely to heavy metal contamination (Adewumi *et al.* 2022).

19.2 GEOLOGY OF AFRICA'S MARINE ENVIRONMENT

The coastal environments of Africa are characterized by diverse geology due to the continent's varied topography, tectonic history, and climate. In the north, the Mediterranean coast is marked by rugged mountains, and the Red Sea coast is a narrow plain bordered by steep cliffs (Stern & Johnson 2019). The East African coast is home to low-lying sandy beaches, coral reefs, and mangrove swamps (Stern & Johnson 2019). The geology of these environments is largely shaped by plate tectonics (Stern & Johnson 2019). The East African Rift System, a geological feature that runs from Ethiopia to Mozambique, has uplifted large parts of the East African coast, creating steep cliffs and rocky headlands. The rift system has also caused extensive volcanic activity, resulting in the formation of offshore islands such as Zanzibar and Pemba. The West African coast is dominated by ancient Precambrian rocks, which have been subjected to extensive erosion and

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deposition over millions of years (Dillon & Sougy 1974). The Niger and Congo Rivers have deposited vast amounts of sediment into the Atlantic Ocean, creating large deltas and estuaries (Bonne 2014). The coastal plain is characterized by sandy beaches, lagoons, and mangrove swamps. The Mediterranean coast is marked by rugged mountains, including the Atlas Mountains in Morocco and the Aures Mountains in Algeria (van Vleck 1936). These mountains form a barrier between the coast and the Sahara Desert, which has resulted in a semi-arid climate along the coast. Overall, the coastal environments of Africa are characterized by diverse geology shaped by plate tectonics, erosion, and climate. These environments are important ecosystems, providing habitat for a wide range of marine and terrestrial species and supporting the livelihoods of millions of people.

19.3 HEAVY METAL CONTAMINATION OF MARINE ENVIRONMENTS IN AFRICA

Heavy metal contamination of the marine environment is a major issue of serious concern across the globe (Appiah-Opong *et al.* 2021; Ridwan & Ethadal 2022). Heavy metals affect both the biotic and abiotic components of the marine environment. In Africa, heavy metals affect the water, sediments, animals, and plants within the marine environment. Recent studies revealed that marine water in Egypt (Nour & El-Sorogy 2020), Ghana (Appiah-Opong *et al.* 2021), Ivory Coast (Tuo *et al.* 2012), Libya (Saleh *et al.* 2017), Mauritania (Yedih *et al.* 2022), Morocco (Jounaid *et al.* 2022), Nigeria (Yahaya *et al.* 2022), Senegal (Diop *et al.* 2014), and South Africa (Sparks *et al.* 2019) has high concentrations of heavy metals such as As, Cd, Co, Cr, Cu, Ni, Pb, and Zn that are above the world surface water standard (Table 19.1). The concentration of Cr in oceanic sediments of Africa is between 4.56 mg/kg (Senegal) and 1102.36 mg/kg (Ghana), with the amount in DR Congo and Ghana above the average crustal value (ACV). The amount of Cu in marine sediments of Africa is between 1.90 mg/kg (South Africa) and 120.14 mg/kg (Cameroun), with its concentration in those of Cameroun, Ghana, Egypt, and Sudan above the ACV. Nickel in the marine sediments of Africa is between 2.15 mg/kg (Mauritania) and 319.67 mg/kg (Ghana), with its concentration in those of Cameroon, Ghana, and Sudan also above the ACV. Lead in oceanic sediments of Africa is between 1.61 mg/kg (Senegal) and 404.15 mg/kg (Ivory Coast), with its amount in those from Angola, Benin Republic, Ghana, Ivory Coast, South Africa, Tanzania, Kenya, Egypt, and Sudan above the ACV. Zinc in marine sediments of Africa is between 1.30 mg/kg (South Africa) and 480.52 mg/kg (DR Congo), with those in Cameroun, DR Congo, Ghana, Ivory Coast, Tunisia, Kenya, Egypt, and Sudan above the ACV. Fish in the sea bioaccumulate more heavy metals in the coastal areas across the world (Bosch *et al.* 2016; Jezierska & Witeska 2006). Bosch *et al.* (2016) reported high amounts of potentially toxic metals in shells collected around the African oceanic waters.

19.4 MARINE GREENS IN AFRICA

Marine greens are abundant in coastal environments across the world. In Africa, marine greens are abundant in the coastal areas around the continent. A study by Hain *et al.* (2022) in coastal areas of Benin Republic revealed that *Amphora coffaeformis*, *Chroococcus* sp., *Oscillatoria subulatum*, *Planktothrix compressa*, *Spirogyra* sp., *Tetrastrum triangulare*, *Trachelomonas intermedia*, *Trachelomonas* sp., *Ulothrix* sp., *Anabaena piscinale*, *Anabaneopsis elenkinii*, *Bacillaria paxillifer*, *Campilodiscus baleanicus*, *Campilodiscus clypens*, *Chaetoceros muelleri*, *Closterium aciculare*, *Closterium kuetzingii*, *Coscinodiscus rudolfii*, *Cyclotella kuetzingi*, *Diatoma vulgare*, *Gomphonemaoli vaceum*, *Gyrosigma accuminatum*, *Komvopheron constrictum*, *Mastogloia braunii*, *Melosira granulata*, *Microcystis aeruginosa*, *Nostoc piscinal*, *Staureneis* sp., *Surirella capronii*, *Synechocystis aeruginosus*, and *Synechocystis aqualis* are common marine greens available in the environment. In the coastal areas of Cameroon, Fonge *et al.* (2013) reported that about 125 species of Chlorophyta, Cyanophyta, Bacillariophyta, Euglenophyta, Dinophyta, Chrysophyta, and

TABLE 19.1
Average Distribution of Heavy Metals in Oceanic Water and Sediments in Africa

	As (mg/l)	Cd (mg/l)	Co (mg/l)	Cr (mg/l)	Cu (mg/l)	Ni (mg/l)	Pb (mg/l)	Zn (mg/l)	Author
Marine water									
Egypt		**0.09**			**0.43**	**0.01**	**0.51**	**0.23**	Nour and El-Sorogy 2020
Ghana	**0.0033**				**0.012**		**0.047**	**0.015**	Appiah-Opong *et al.* 2021
Ivory Coast		**0.04**				**0.26**	**0.67**	**13.22**	Tuo *et al.* 2012
Libya				**0.0022**	**0.0264**	**0.007**		**0.461**	Saleh *et al.* 2017
Mauritania			0.02			**0.02**			Yedih *et al.* 2022
Morocco		**0.065**			**0.05**		**0.086**	0.001	Jounaid *et al.* 2022
Nigeria		**0.061**		**0.087**	**2.17**	**0.76**	**1.41**		Yahaya *et al.* 2022
Senegal		**0.23**	0.12	**0.45**	**1.93**	**1.28**	**0.48**	**21.29**	Diop *et al.* 2014
South Africa					**0.01**		**0.01**	**0.16**	Sparks *et al.* 2019
World Surface Water Standard	0.0026	0.0001		0.0002	0.0009	0.006	0.00003	0.005	Saleh *et al.* 2017
Marine sediments									
	As (mg/kg)	**Cd (mg/kg)**	**Co (mg/kg)**	**Cr (mg/kg)**	**Cu (mg/kg)**	**Ni (mg/kg)**	**Pb (mg/kg)**	**Zn (mg/kg)**	**Author**
Angola	**7.55**		8.92		12.15	4.36	**30.12**	29.47	Dinis *et al.* 2020
Benin Republic		14.81					**23.40**	52.42	Yehouenou *et al.* 2013
Cameroun		0.08	130.64	79.36	**120.14**	**229.60**		**110.00**	Ekoa-Bessa *et al.* 2020
DR Congo	**15.76**	0.13	16.46	**166.53**	17.36	27.39		**480.52**	Suami *et al.* 2020
Ghana	**182.03**		554.13	**1102.36**	**91.27**	**319.67**	**62.70**	**212.34**	Kuranchie-Mensah *et al.* 2013
Ivory Coast		2.85				45.63	**404.15**	**208.77**	Tuo *et al.* 2013
Libya		0.83	5.59		17.3	22.65	11.69	26.55	Nour and El-Sorogy 2017
Mauritania	1.01	0.16	0.49	13.03	5.55	2.15	5.08	19.02	Yehdhih *et al.* 2020
Morocco	**8.50**	0.16	3.57	26.60	6.60	16.50	6.13	51.70	Tnounmi *et al.* 2020
Nigeria	**5.00**		6.44	14.22	6.43	6.69	4.49	26.44	Adeyemi *et al.* 2019
Senegal		0.24	0.30	4.56	7.29	3.06	1.61	46.74	Diop *et al.* 2014
South Africa		1.70			1.90		**251.00**	1.30	Okoro *et al.* 2014
Tunisia	**4.17**	81.40		77.22	37.00	11.08	10.71	**104.90**	Naifor *et al.* 2018
Mozambique	**3.00**	0.11		6.50	3.70	5.60	9.70	14.00	Boitsov *et al.* 2021

(*Continued*)

TABLE 19.1 (CONTINUED)
Average Distribution of Heavy Metals in Oceanic Water and Sediments in Africa

Tanzania	0.00048	3.60	4.70	21.60	13.50	15.50	**35.40**	58.40	Muzuka 2008
Algeria	**7.50**		2.70	33.50	7.20	10.30	8.40	31.80	Ahmed *et al.* 2018
Kenya					28.03		**230.00**	**332.50**	Mwatsahu *et al.* 2020
Egypt		1.80			**110.00**	60.00	**20.00**	**110.00**	Ridwan and Ethadal 2022
Sudan					**68.80**	**102.00**	**17.10**	**83.00**	Idris *et al.* 2007
Average Crustal Value	1.80			100	55	75	12.5	70	

Note: Metal values above the limit are represented in bold.

Haptophyta existed. In the coastal area of Gabon, Zongo *et al.* (2022) reported that there were seven species of marine green that existed in the marine environment. These are *Bryopsis plumose*, *Bryopsis pennata*, *Caulerpa sertularioides*, *Caulerpa taxifolia*, *Chaetomorpha linum*, *Cladophora prolifera*, and *Ulva flexuosa*. In Cote D'Ivoire, the coastal areas are dominated by phytoplankton such as *Aphanizomenon* sp., *Aphanizomenon* sp., *Anabaena planctonica*, *Oscillatoria princeps*, *Oscillatoria tenuis*, *Pseudanabaena limnetica*, *Lyngbya* sp., *Aulacoseira granulata*, *Anabaena constricta*, *Phormidium, uncinatum*, *Phormidium* sp., *Merismopedia glauca*, *Merismopedia elegans*, *Oscillatoria limosa*, *Aphanothece castagnei*, *Microcystis wesenbergii*, *Lyngbya martensiana*, *Microcystis aeruginosa*, *Anabaena* sp., and the Chlorophyte *Pediastrum duplex* var. *gracillimum* (Seu-Anoï *et al.* 2011). In the coastal area of Morocco, some of the major marine greens available are *Coscinodiscus* sp., *Hemidiscus* sp., *Leptocylindrus danicus*, *Melosira nummuloides*, *Detonula* sp., *Lauderia annulata*, *Lauderia borealis*, *Chaetoceros decipiens*, *Gymnodinium* sp., and *Protoperidinium* sp. (Natij *et al.* 2014). In the coastal area of Nigeria, Akanmu and Onyeama (2020) described 86 phytoplankton species. Examples of the major phytoplankton species described include *Chaetoceros*, *Coscinodiscus*, *Melosira*, *Odontella*, *Thalassiosira*, *Bacillaria*, *Fragillaria*, *Nitzschia*, *Thalassionema*, *Oscillatoria*, *Trichodesmium*, *Noctiluca*, *Ceratium*, *Peridinium*, and *Protoperidinium*. In this region, diatoms are the most common marine greens reported. In the coastal area of South Africa, Gama *et al.* (2005) reported the presence of *Ulva* sp., *Micromonas* sp., *Pyramimonas* sp., *Nitzschia closterium*, *Melosira nummuloides*, *Diatoma* sp., *Peridinium* sp., *Gymnodinium* sp., and *Katodinium* sp. In the marine environment of Togo, 795 species of microalgae, which include *Bacillariophyceae*, *Cyanophyceae*, *Chorophyceae*, *Conjugatophyceae*, and *Euglenophyceae*were reported by Issifou *et al.* (2014). In the coastal environments of Tunisia, Rekik *et al.* (2016) showed that some of the abundant marine greens include *Amphora* sp., *Coscinodiscus* sp., *Grammatophora* sp., *Navicula* sp., *Alexandrium* sp., *Peridinium* sp., *Prorocentrum lima*, *Prorocentrum triestinium*, *Protoperidinium* sp., and *Euglena ascusformis*. Along the Algerian coastline, Boudjenah *et al.* (2019) reported 296 species of marine green, which include *Navicula* sp.,*Gymnodium* sp., *Prorocentrum mecans*, *Peridinium* sp., *Chaetoceros* sp., *Melosira* sp., and *Chaetoceros* sp. Nihal *et al.* (2014) reported more than 207 marine greens along the Egyptian Mediterranean coastal waters, which include *Carteria* sp., *Chlorella vulgaris*, *Asterionella glacialis*, *Cylindrotheca closterium*, *Melosira granulata*, *Navicula cryptocephala*, *Pseudo-Nitzschia palea*, *Pseudo-Nitzschia sigma*, *Pseudo-Nitzschia delicatissima*, *Skeletonema costatum*, and *Gonyaulax* spp. Along the Tanzanian coastal waters, some of the marine greens observed by Sekadende *et al.* (2021) in the area include *Amphiprora alata*, *Chaetoceros decipiens*, *Coscinodiscus nodulifera*, *Guinardia striata*, *Leptocylindrus danicus*, *Rhizosolenia alata*, *Thalassiothrix* sp., and *Protoperidinium steinii*.

19.5 SOURCES OF HEAVY METALS IN MARINE GREENS IN AFRICA

In marine settings, heavy metal concentrations are low, usually in nanograms or milligrams per kilogram. Studies across the world have confirmed that oceanic waters are now mostly contaminated by toxic metals (Singh *et al.* 2022), and this has continually increased the fear of environmental degradation. There are many factors that have led to a surge in ocean pollution by heavy metals. Some of these factors include the exponential increase in human population (Halpern *et al.* 2019), increase in urban expansion (Singh *et al.* 2022), more industrial growth (Cordes *et al.* 2016), search for and use of natural resources (Grigalunas & Opaluch 1988; Aranssiola *et al.*), modern agricultural practices (Cordes *et al.* 2016), and uncontrolled wastewater discharge into the sea (Potter *et al.* 2004). In Africa, the rate of population expansion is higher than in any other continent of the world (Kröner *et al.* 2023). The increase in population has contributed greatly to the contamination of the marine environment in Africa. For example, the population of Accra, a coastal city in Ghana, increased from 1,668,000 in the year 2000 to 2,660,000 in the year 2023, with an annual percentage increase of between about 1.50% and 3.00% (Macrotrends 2023a). Dakar, a city located along the coast of Senegal, had a surge in population growth of 1,862,000 in the year 2000 and 3,430,000 in the year 2023, with a yearly percentage of between 2.99% and 3.13%, respectively (Macrotrends 2023b). The population of Lagos, a cosmopolitan megacity on the coast of Nigeria, in the years 2000 and 2023 was 7,281,000 and 15,946,000, respectively. This represents an annual increase of between 3% and 4% each (Macrotrends 2023c). For the coastal city of Abidjan in Cote D'Ivoire, the population in the years 2000 and 2023 was 3,007,000 and 5,686,000, respectively, with a percentage growth of 2.77% and 3.08% each (Macrotrends 2023d). Also, the population of Alexandria city in Egypt, which borders the Mediterranean Sea, in the years 2000 and 2010 was 3,546,000 and 5,588,000, respectively, with a percentage growth of 2.04% and 1.09% per annum. The United Nations has projected that the population of Africa will increase exponentially from 819 million in the year 2000 to 2.5 billion in the year 2050 (Statista 2023). The observed increase in the population of these cities has led to an increase in waste generation. In Nigeria, Lagos alone generates about 13,000 metric tonnes of municipal waste per day (Theconversion 2021). In Accra, Ghana, the amount of waste generated per capita is 0.70 kg (AMA 2020), while the city of Cape Town, a coastal city in South Africa, generates about 1.7 million tonnes of municipal waste yearly and amasses approximately 0.6 million tonnes of commercial and industrial wastes and about 0.07 million tonnes of agricultural waste per annum (GreenCape 2020). The wastes generated from these expanding cities host heavy metals, which are finally mobilized into the ocean, thereby increasing their potential threat to both living and non-living things in the environment.

Increased industrialization has also played a major role in the release of heavy metals into the marine environment of Africa. For example, Lagos, Nigeria is an industrial hub that hosts industries such as maritime, steel, baking, manufacturing, engineering, textile, cement, quarry, welding, and paint companies. Also in the free zone city of Alexandria, Egypt, which accounts for over 40% of the nation's industries, there exist companies such as chemicals, petrochemicals, oil refinement, iron production, steel production, and agro-allied industries. Through the release of poisonous exhausts, waste waters, and waste products, these companies contribute significantly to the release of toxic metals into the oceanic and adjoining environment.

19.6 HEAVY METAL UPTAKE BY MARINE GREENS IN AFRICA

The sea is very important to the socio-economic development of the African continent. However, pollution of the ocean by heavy metals and other forms of pollutants is posing a great threat to the ecosystem. Within this ecosystem, marine greens are among the major oceanic plants that are affected by the release of organic and inorganic pollutants, especially potentially toxic metals. Plants have the ability to take up and accumulate potentially toxic metals in their bodies (Adewumi & Lawal 2023). This process is referred to as "bioaccumulation" For plants to bioaccumulate heavy metals in their bodies, the concentration must be high in their ambient environment, such as the water, soils, and sediments on which they grow (Tshithukhe *et al.* 2021). The main part of the plant that aids bioaccumulation of heavy metals is the root (Collin *et al.* 2022). Some bottom-dwelling marine greens, such as seaweeds or marine algae, because of their non-flowering nature, use a hold-fast to absorb metals from their immediate environment (Agarwal *et al.* 2022). The rate of uptake of heavy metals by marine greens along the coastal areas of Africa is generally high (Tshithukhe *et al.* 2021; Addico & deGraft-Johnson 2016). In the coastal areas of Cape Town, South Africa, a study by Tshithukhe *et al.* (2021) revealed that marine greens such as *Pontederia crassipes* and *Salvinia molesta* bioaccumulate heavy metals. The highest concentrations of As, Cd, Cr, Cu, Fe, Hg, Pb, and Zn in these marine greens were 2.35 mg/kg, 2.67 mg/kg, 0.82 mg/kg, 7.10 mg/kg, 2.37 mg/kg, 4.19 mg/kg, 0.24 mg/kg, and 8.34 mg/kg, respectively. A report by Vlachos *et al.* (1998) showed that the range of concentrations of As, Co, Cr, Cu, Ni, and Pb in KwaZulu-Natal beaches in South Africa was 24–1428mg/kg, 10–498mg/kg, 9–168 mg/kg, 2–87mg/kg, 9–107mg/kg, and 10–75 mg/kg, respectively. Ferletta *et al.* (1996) assessed the amount of heavy metals in marine macroalgae from the Zanzibar area of Dar es Salaam, Tanzania. The study showed that in marine greens in this area, the range of concentrations of Cd, Cr, Cu, Fe, Mn, Ni, Pband Zn was 0.14–5.62 mg/kg, 2.88–33.64 mg/kg, 2.62–17.42 mg/kg, 78.76–3619.77 mg/kg, 9.76–111.78 mg/kg, 9.76–111.78 mg/kg, 3.62–22.93 mg/kg, 6.13–53.19 mg/kg and 5.59–104.58 mg/kg respectively. On the western coast of Ghana, Addico and deGraft-Johnson (2016) reported that the range of concentrations of Cu, Zn, Fe, Pb, Cd, and As in marine greens was 24–36 mg/kg, 16–100 mg/kg, 1209–5910 mg/kg, 86–335 mg/kg, 95–119 mg/kg and1–2mg/kg, respectively. Aly *et al.* (2006) determined the content of toxic metals in marine greens from the Egyptian Red Sea coast. The study showed that on the coast of Suez, the range of the amount of Cd, Cu, Ni, Pb, Mn, Co, Cr and Zn in marine greens was 2.10–10.40 mg/kg, 2.30–17.30 mg/kg, 6.30–17.10 mg/kg, 19.40–50.50 mg/kg, 8.30–66.80 mg/kg, 2.70–16.60 mg/kg, 0.60–13.40 mg/kg and 23.40–90.40 mg/kg respectively, while for those from the Mars Alam coast, the range of concentrations was 0.40–2.40 mg/kg, 0.60–4.30 mg/kg, 1.00–7.10 mg/kg, 3.10–19.20 mg/kg, 3.50–22.20 mg/kg, 1.80–9.60 mg/kg, 0.10–6.80 mg/kg and 2.00–22.10 mg/kg respectively.

19.7 POSSIBLE HEALTH RISKS OF HEAVY METALS IN MARINE GREENS

Heavy metals are dangerous not only to the environment but also to human health (Adewumi *et al.* 2020). In some parts of the world, marine greens such as seaweeds are consumed for health benefits. It is believed that marine greens are sources of dietary fiber, calcium, iron, folate, and iodine (MacArtain *et al.* 2007). According to Adewumi *et al.* (2020), oral intake of heavy metals from plants can lead to both carcinogenic and non-carcinogenic health risks.

Arsenic is a toxic element that can cause serious health problems if ingested into the human body. Consumption of As from marine greens may lead to several health risks, including cancer. Chronic exposure to As may lead to skin, lung, bladder, liver, and kidney cancers (Adewumi *et al.* 2020). It could also lead to skin lesions such as hyperkeratosis and hyperpigmentation (Hong *et al.* 2014). Also, bioaccumulation of As in the human body has been linked to an increased risk of cardiovascular disease, including hypertension and atherosclerosis (Hong *et al.* 2014). Intake of As can cause respiratory problems such as coughing and shortness of breath (Adewumi *et al.* 2020). Excessive intake of As may also lead to neurological problems, such as numbness, tingling, and peripheral neuropathy (Hong *et al.* 2014). For married couples, excessive oral ingestion of As from marine greens may cause infertility and miscarriage (Hong *et al.* 2014). It could also lead to digestive problems such as vomiting, diarrhea, and abdominal pain (Hong *et al.* 2014).

Cadmium is also a toxic heavy metal that can cause serious health problems if ingested into the human body (Genchi *et al.* 2020). Exposure to cadmium has been linked to several health risks, such as kidney damage, which can cause kidney failure (Genchi *et al.* 2020). It can also cause lung damage including chronic bronchitis and a condition known as “cadmium pneumonitis,” which can be fatal (Adewumi *et al.* 2020). Cadmium is also carcinogenic, causing lung, prostate, and bladder cancer. Exposure to cadmium can cause reproductive dysfunction, including reduced fertility and birth defects (Adewumi *et al.* 2020). It could also lead to hypertension or high blood pressure, which can cause heart disease and stroke (Adewumi *et al.* 2020). Anemia has been linked with excessive intake of Cd (Genchi *et al.* 2020). Anemia is a condition in which there are not enough red blood cells to carry oxygen to the body’s tissues (Genchi *et al.* 2020). Another health issue associated with exposure to Cd is osteoporosis, which is a condition that weakens bones and makes them more susceptible to fractures (Genchi *et al.* 2020).

Zinc is another major dietary metal necessary for the proper functioning of human health (Plum *et al.* 2010). Consuming too much zinc from marine greens can lead to health issues like vomiting, stomach cramps, and diarrhea (Plum *et al.* 2010). Excessive intake of Zn can lead to the suppression of the immune system, making it difficult for the body to fight off infections (Adewumi *et al.* 2020). Also, consuming too much zinc can lead to an unpleasant metallic taste in the mouth and can also cause bad breath (Plum *et al.* 2010).

Lead is a highly toxic metal that can cause significant harm to various organs and systems in the body (Adewumi *et al.* 2020). Lead in the body system can cause neurological damage.

It is highly toxic to the nervous system (Ara & Usmani 2015). Even low doses of lead can lead to behavioral problems, learning disabilities, and cognitive impairment, especially in children (Adewumi *et al*. 2020). The presence of lead in the human body can also cause interference with the production of red blood cells, leading to anemia (Ara & Usmani 2015). Lead can also damage the kidneys, leading to kidney failure (Ara & Usmani 2015). This toxic metal can also have a negative impact on the reproductive system in both males and females, leading to infertility or other problems. Another major health challenge caused by Pb is cardiovascular disease, which has been linked to an increased risk of high blood pressure in many adults. Prenatal exposure of pregnant women to lead can cause developmental delays and intellectual disability in children (Ara & Usmani 2015). Exposure to lead can also lead to stunted growth in children. Lead can accumulate in the body over time, so even low levels of exposure can be harmful (Adewumi *et al*. 2020).

19.8 CONCLUSIONS

Heavy metals in marine greens originate from wastes generated from coastal cities around the continent. Other sources include exponential population growth, exploitation of natural resources, unabated industrialization, runoff from agricultural activities, and geological processes. Marine greens have high amounts of heavy metals, which are above internationally accepted limits. Over a period of time, they bioaccumulate these toxic metals into their bodies and subsequently release them into the marine environment after their death and decay. Marine greens are basically food for fish and other organisms in the sea. However, when humans eat fish, heavy metals in them stored in the body and may cause several carcinogenic and non-carcinogenic health problems that may eventually lead to death. It is important that the government put forward policies that will promote a healthy environment.

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