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REVIEW

The significant impacts of trace elements on marine life: a review

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Abstract Trace elements constitute a substantial factor in the course of life processes. Trace elements can be found consistently in the environment. Trace elements, despite being present in exceedingly low concentrations, are vital for life in the oceans. A multitude of definitions for the term "trace elements" have been attributed by various scientists. However, it was termed because of their levels of concentrations contributed to our lives and environment; a small increase or reduction in their levels of concentration may prove toxic to the flora and fauna of the Earth, which could be due to extensive productivity and human intervention. The main aim of the review is therefore to highlight the main concern of the effects these trace elements carry on marine life, producing a disturbance in the biota that not only affects productivity, and their nutrient cycle but also contributes to the marine environment. Hence, the overarching objective of this review is to underscore the fact that trace elements continue to be contaminants of significance that necessitate scientific scrutiny. Therefore, finding a better alternative to monitor the contamination is an absolute necessity, considering their toxicity levels.

Keywords Biodiversity . Health . Pollution . Toxic chemicals

Introduction

Environmental pollution has now become the foremost concern in the world. Conversely, scientific community is in pursuit of an explanation for pollution and its primary cause. It's because it's impossible to utilize 100% of a process. Neither fuel burning nor the other process, natural or artificial, shows 100% efficiency to place resources into great innovation, which aggravates the waste and contamination delivered. Trace elements are one of the pollutants we will naturally find in the environment, but their priority rises when their level increases. Due to the use of most metals in agricultural products, industries, and auto emissions, the concentration of trace elements has increased to a concerning level, which involves not only human activities but also natural activities. This rise in trace element concentration will consequently affect the food chain, may eventually enter the human body, and can prove to be toxic once it reaches harmful levels in our body. The commonly found trace elements within the environment are Copper (Cu), Lead (Pb), Nickel (Ni), Zinc (Zn), Mercury (Hg), Chromium (Cr), Cadmium (Cd) and Arsenic (As) (He et al. 2005). Although these trace elements carry out vital contributions to nutrient cycling within the sea, their rise or drop by a small factor can impart disbalance within the aquatic biota (Renforth and Henderson 2017).

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The Bay of Bengal, though, quite large is, however, moderately a shallow embayment of the North eastern Indian Ocean, which covers a neighbourhood of about 839,000 sq. miles. It is situated between latitudes 5ºN and 22ºN at longitudes 80ºE and 90ºE. To the west, it is bordered by Sri Lanka and India, Bangladesh to the North and Myanmar and therefore the northern part of the Malay Peninsula to the east. The bay is about 1000 miles wide with a normal depth of 8,500 ft (Morgan et al. 2009).

The Sundarbans (Fig.1) is a huge tract of mangrove forest and saltwater swamps in the world and a crucial part of it has been declared as UNESCO world heritage site (Uddin 2011). The tract broadens roughly 160 miles west-east along the Bay of Bengal (Pletcher 2013). The Sundarbans is quite a place for mangroves. The Sundarban estuary was found with more trace metal contamination than any other estuaries (Asha et al. 2020). A number of studies have found an increased amount of zinc, copper, and lead within the body of shellfish species as referred to as Indian white shrimp within the waters of sundarban and these species of shrimp are important to carry out the livelihoods of millions of people living within the forest (Islam et al. 2017). According to Mitra (2019) "The low salinity and intense industrialization within the Hooghly estuarine stretch is liable for the high concentration of heavy metals within the shrimp muscle sampled from stations in and round the western side of Sundarbans". Further scientific investigation must be carried on in response to exposure of pollution due to domestic sewage and various industrial effluents which eventually leads to serious impacts on our biota.

The intention of the review is to discuss about the trace element concentrations in marine biota and its effects.

Trace elements

Trace elements can be defined in many ways as it was defined by a chemist as any elements which in a given sample have an average concentration of less than 100 ppm when counted on an atomic basis or less than 100µg/g. Contrastingly, a biochemist defined trace elements which are required in very small amounts to maintain physiological and biochemical balance of an organism (Koller and Saleh 2018). In humans, deficiency, which means less than the human requirement will lead to disorders and also may prove fatal. These trace elements are however classified into metals and non-metals. Elements belonging to metals are:

Fig. 1 The Sundarbans has been accorded the status of 'Wetland of International Importance' under the Ramsar Convention. A part of the Sundarban delta, which lies in Bangladesh, was accorded the status of a Ramsar site in 1992.

copper, iron, zinc, chromium, cobalt, iodine, molybdenum and selenium while the non-metals include: arsenic and iodine (Prashanth et al. 2015). Trace elements are furthermore classified into Essential Trace Elements and Non-essential Trace Elements.

Essential trace elements regarded by World Health organisation are: iron, zinc, copper, chromium, iodide, cobalt, molybdenum and, selenium. Non-essential trace elements are recognised to be arsenic, boron, lead, silicon and, nickel. The absence of these elements has not shown any indication to interrupt the life cycle nor any physiological or biochemical functions (Nielsen 2017). Depending on the concentration and chemical form, non-essential trace elements such as cadmium, mercury, lead, arsenic may be quite harmful even if it is in small quantity. Although essential trace elements are very much demanding but it can be deficient if the quantity is too small and even toxic when high concentrations are absorbed (Vázquez et al. 2015; Richir and Gobert 2016). The term 'trace element' varies from organism to organism and species to species. If a certain element of certain concentration is required in a certain organism it doesn't necessarily indicate that the same element of exact concentration is responsible for a certain phase in another organism (Navrátil and Minařík 2002) (Fig. 2).

Sources of trace element in the sea

Trace metals are already present in the seawater but in very small amounts. But the involvement of Humans has increased the concentrations of Trace elements in the seawater and also the freshwater (Islam et al. 2014). Trace elements are often carried to the ocean by the dust carrying by the wind from banal regions, also from other sources such as rivers. These trace elements enter the sea through riverine influx, due to erosion of rocks, deposition of dust particles, mine drainage, offshore oil, gas exploration, agricultural run-off, acid rain, etc, volcanic eruptions are a major source and of course anthropogenic activities (Fig. 2). These elements acquainted with the marine condition eventually settle on the seabed. Another rising concern is the disposal of plastics in oceans (Table 1). Certain metals like cadmium and lead are major constituents in manufacturing plastics and plastic disposal in water have an impact on the marine life. These metals are not only a concern for the organisms mainly those living in the intertidal zones but also it affects the humans

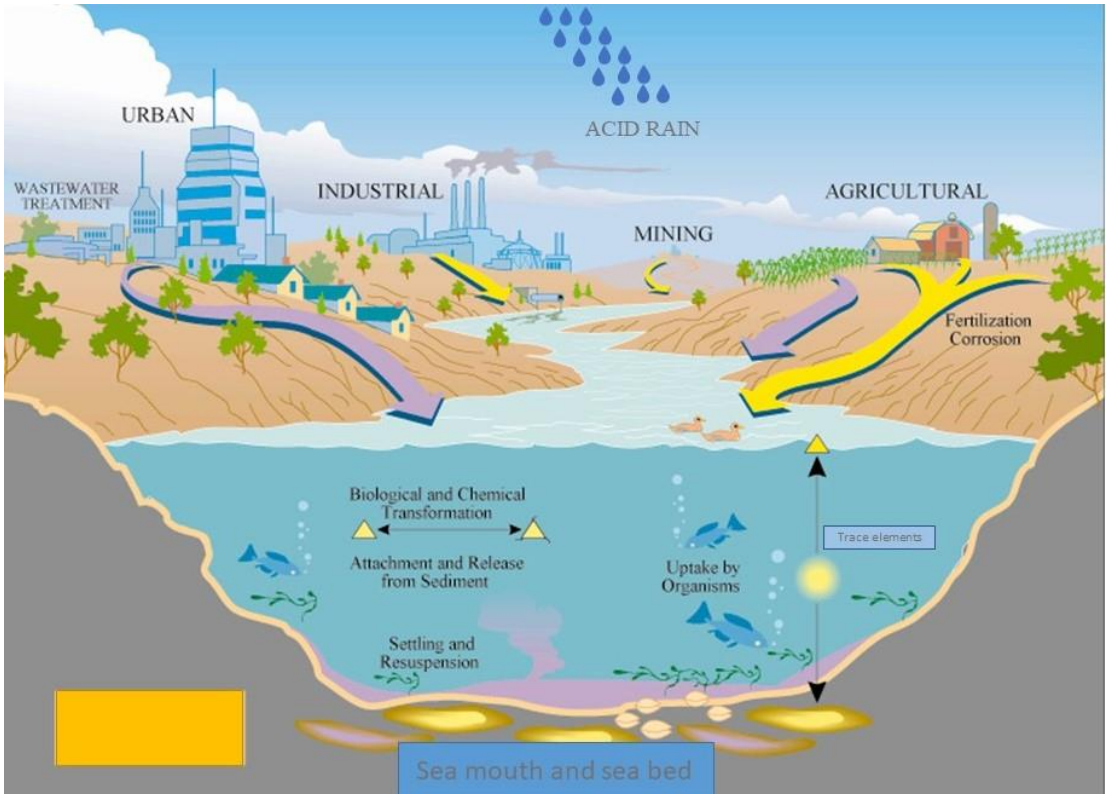

Fig. 2 The various ways of trace elements entering water and then finally to marine life

(Beurteaux 2018). In seawater, the dissolvable metal cations are hastened by the anions, for example, sulphate, chloride, fluoride, carbonates or bicarbonates (Ansari et al. 2004). The value of trace element concentration in the river Ganga along with some major rivers is very unengaging as being reported by some researcher (Mitra 2019) (Table 2).

Trace elements affecting the environment

Trace elements can naturally be found in our environment. Our environment consists of the land, water and the atmosphere of earth (Masindi and Muedi 2018). Impacts of trace elements, simultaneously affects the hydrosphere, lithosphere, biosphere, and the atmosphere and so contamination by these trace elements is a major issue of concern around the globe. Fossil combustion is a major source of accumulation of trace elements in the environment such as Cd, Pb and As. And trace elements such as Cr, Zn, Cd and Pb are involved in vehicle emissions. The common sources of Cr are textile industries, tanneries, fertilizers, etc. Coal combustion is one of the major sources for the generation of Cd, also chemical fertilizers. Some sources of Pb includes acid batteries, combustion of leaded gasoline, etc (Ali et al. 2019) (Table 3).

Effects of trace elements on soil is pretty severe as well. The availability of trace elements to the plants essentially depends on their solubility, and sometimes the measure of trace elements dissolvable in the typical extraction arrangements for the most part surpass the sums required by plants by a significant edge. A phytoremediation study in the Sunderbans have put forwarded that the endangered *Heritiera formes* leaves can accumulate 80% of Cd from the soil, according to the study it is highest compared to any other mangroves. This study also reveals that the threatened date palm *Phoenix paludosa* leaves can accumulate 74% and 73% of Cu and Fe from the soil. However, the Screening Quick Reference table (SQuiRT) showed that Cu and Cd may exert a possible toxic effect on the sediment dwelling biota. Many plants are used as indicators for trace element deficient and toxic areas due to the difference in the requirements and tolerance of trace elements by different plant species (Kader and

Table 1 Concentrations of certain dissolved trace elements in surface and deep waters of the North-Atlantic Ocean

Trace elements	Concentration of dissolved trace elements in surface waters of North-Atlantic Ocean	Concentration of trace elements in deep waters of North-Atlantic Ocean
Pb	21-31 ng/l	4 ng/l
Zn	6.5-13 ng/l	105 ng/l
Cu	64-83 ng/l	127 ng/l
Hg	0.2-1.4 ng/l	0.2 ng/l
Cd	0.1-1.1 ng/l	39.3 ng/l
As	1.5 µg/l	1.5 ng/l
Mn	55-165 ng/l	14-27 ng/l
Fe	3-56 ng/l	34-56 ng/l
Cr	182 ng/l	234 ng/l
Ni	117 ng/l	352 ng/l

Table 2 Trace metal concentration in various rivers of India

Trace elements	Trace element concentration (in µg/l)
Cr	Ganga 0.00-366.91> Yamuna 3.245-290> Kali 3.00-200> Ramganga 0.00-108.7> Gomati 105-68.8
Cu	Ganga 10.00-140.64> Ramganga 57.15-99.10> Yamuna 00.871-84.88> Kali 1.3-4.3
Cd	Yamuna 00.018-330> Kali 2.00-80> Ganga 0.6-36> Gomati 0.1-0.5
Pb	Kali 22-340> Yamuna 0.067-254> Ganga 4.7-86.9> Ramganga 10.1-48.92> Gomati 15.8-27.6

Table 3 Average content of twenty trace elements (in ppm) in Earth's crust (FAO soils bulletin)

Trace elements	Conc. (ppm)	Trace elements	Conc. (ppm)	Trace elements	Conc. (ppm)	Trace elements	Conc. (ppm)
Mn	1000	Cr	200	Cu	70	As	5
P	800	Sr	150	Sn	40	Cs	32
S	520	V	150	Co	40	Mo	2.3
Cl	480	Ni	100	Pb	16	I	0.3
Ba	430	Zn	80	B	10	Se	0.09

Narayan Sinha 2018).

The participation of trace elements in the air has shaped the air pollution we are facing today. The cause of this intense air pollution is mainly due to dust and fine Particulate Matters (PMs). Both natural and anthropogenic processess are involved. Discharged particulate matters into air incorporates rock weathering, soil erosion, storms, volcanic eruptions industrial activities and much more. These particulate matters must be given priority as they can cause severe problems like heart diseases, skin and eye irritation, respiratory septicaemia also is a major cause of unnatural deaths. These are also responsible for corrosions, acid rains, infrastructural detoriation etc (Masindi and Muedi 2018) (Table 4).

Toxicity of trace elements in aquatic species

Contamination by trace elements affects the marine organism at a cellular level and can damage the ecological balance. There are generally three ways for trace elements to enter any aquatic species, which are either by ingesting food, or through body surface, or through gills while breathing (Baby et al. 2010). These trace elements become toxic only when these gets accumulated in the soft tissues and not metabolized by the body. From previous studies, it is seen that the trace elements content is found more in gills, livers and kidneys. Fishes can also accumulate trace elements in their tissues (Rajeshkumar and Li 2018). In a recent study, it is being stated that Pb, Cu and Zn of all trace elements are the most toxic elements which imposes threat to several other organisms and Pb surely being the most toxic among these three. In this study, three local river fishes were taken into account and monitored the concentration of Pb, Cu and Zn in *Cyprinus carpio, Ctenopharyngalon idella, Liza abu* (Huseen and Mohammed 2019). The observation made from the study is the concentration of Pb, Cu and Zn varied among gills, liver, muscles of fishes seasonally (Table 5). The data reveals that the highest concentration of these mentioned trace elements are much higher than the acceptable limit according to the standards of FAO/WHO. For instance, the standarized limit for Pb is 1 mm/kg; for Cu it is 2 mm/kg and for Zn it is 3 mm/kg.

In a study, (Denton et al. 1980), have reported that some marine mammals have high Cd levels even when their diet doesn't consist of any direct Cd contaminated food. In *Balaenoptera acutorostra,* which is found in Greenland has a higher mercury concentration than *Balaenoptera bonaerensis* which are found in the Antarctic region. Authors predicted that it could be due to their dietary habits as *Balaenoptera acutorostra* feeds on fishes and *Balaenoptera bonaerensis* feeds on krills (Hansen et al. 1990). Hence, the higher concentration of Cd in *Balaenoptera acutorostra* is due to its higher trophic position as the food web of Antartic compared to Greenland is much more simple and small (Das et al. 2002).

Also, studies on three *Leptonychotes weddelli* (Weddell seals) of the Antarctica and the distribution of

Table 4 Important data for key Hazardous Trace Elements (HTEs), of prime environmental concern, in Chinese coals, 2019

Elements	Stimulated mean concentration (ppm)	Emissions from coal use in China in 2007 (t)
Cr	30.37	8217.8
Ni	17.44	2308.4
Cd	0.61	245.4
Pb	23.04	12547.0
Hg	0.20	305.9
As	5.78	2205.5
Se	3.66	2353.0
Sb	2.01	546.7

Table 5 The highest conc. and lowest conc. of the trace elements Pb, Zn, and Cu found in fishes

Fish species	Highest concentration (in mg/kg)			Lowest concentration (in mg/kg)		
	Pb	Zn	Cu	Pb	Zn	Cu
Cyprinus carpio	9	26	9.78	0.04	0.208	0.01
Location	Gills	Gills	Gills	Muscle	Muscle	Muscle
Season	Autumn	Summer	Autumn	Winter	Winter	Winter
Ctenopharyngdon idella	5.47	5.7	5.264	0.06	0.01	0.13
Location	Liver	Gills	Gills	Muscle	Liver	Muscle & Liver Winter
Season	Autumn	Summer	Autumn	Spring	Spring	
Liza abu	10.8	6.05	3.630	0.002	0.02	0.10
Location	Muscle	Liver	Muscle	Liver	Liver	Liver
Season	Autumn	Autumn	Autumn	Spring	Spring	Spring

heavy metals and its concentration among various organs has been carried out to analyze the concentration of the elements of the whole body weight of the adult Weddell seals and observed that Zn is mostly found in muscles and bones, Hg in liver and muscles, Cu in muscles and liver as well, Cd in liver and kidney. However, the skin of the marine mammal had low Hg concentration (Yamamoto et al. 1987; Das et al. 2002).

Monitoring the marine ecosystem

A number of species helps in monitoring the trace element contamination in water (Pröfrock et al. 2012). In the coasts of Gulf of Mannar, India, Venkateswara Rao et al. (2009) have studied the use of marine sponge (*Haliclona tenuiramosa)* in monitoring the contamination imposed by trace elements. Sponges are considered good biomonitors in detecting the state a marine ecosystem is in. In the following study, analysis of the bio-concentration factor (BCF) of the trace elements in the offshore and inshore sponges has been done and represented the conc. of trace elements is higher in the inshore sponges than in the offshore sponges hence, stating that the toxicity of nearshore is much more than the offshore (Table 6).

Fishes also have been an amazing bio-indicator (Authman et al. 2015). Fishes are highly exposed to all the trace elements present in the water and so we can observe the accumulation of trace elements in the fishes. Although the accumulation of toxic trace elements in the tissues of the fishes are dependent on various factors. Primarily, the concentration of these elements in water is a main source but it also depends on the diet of the fishes, the entrance-exit ratio. For instance, if the concentration of trace elements entering the

Table 6 Bio-concentration factor (BCF) of trace elements in nearshore and offshore environment in the coasts of Gulf of Mannar, India

Trace elements	Bio-Concentration Factor (BCF) In tissues of *Haliclona tenuiramosa* (in µg/g)	
	Nearshore	Offshore
As	3.25	2.02
Cd	1.59	1.30
Co	1.03	1.47
Cu	2.19	1.80
Mn	4.03	2.22
Ni	2.99	1.71
Fe	15.30	6.23

BCF = Conc. of trace element accumulated in tissue (µg/g) ÷ Conc. of trace elements in water (µg/l)

Table 7 Average value of trace element conc. in bivalve samples of Mediterranean sea and the Red sea

Trace elements	Average value (wet weight in (µg/g)	
	Mediterranean sea	Red sea
Cd	0.34 ± 0.18	0.70 ± 0.17
Co	1.51 ± 0.39	2.18 ±0.95
Cu	8.83 ± 4.91	5.95 ± 1.57
Mn	7.95 ± 2.79	4.815 ± 1.36
Zn	14.14 ± 2.58	17.39 ± 3.98
Pb	0.90 ± 0.17	1.46 ± 0.14
Ni	2.85 ± 0.83	3.33 ± 1.36

Table 8 Trace element conc. (in mg/kg) in samples of water hyacinth plant

Location	Organ	Fe	Zn	Cu	Co	Ni	Cd	Pb	Cr
Nile	Shoot	334	18.4	5.6	4.2	0.82	0.4	9.0	11.1
	Root	911	48.8	15.2	14.7	2.4	1.0	25.1	3.2
	ratio	0.37	0.38	0.37	0.29	0.34	0.4	0.36	0.35
Ismailia	Shoot	448	21.6	11.2	7.2	1.7	0.4	18.9	1.6
canal	Root ratio	1212	57.6	30.4	18.3	4.8	1.2	52.7	3.8
		0.37	0.38	0.37	0.39	0.35	0.33	0.36	0.42
Abo-zabel	Shoot	484	10.4	16.0	10.8	2.5	0.7	26.9	2.3
drain	Root	1554	93.6	48.8	32.1	7.3	2.1	74.7	6.8
	ratio	0.31	0.09	0.33	0.34	0.34	0.33	0.36	0.34

tissues of fishes are more than that being excreted then these trace elements will be toxic to the fishes until it is ingested by the humans. These fishes react to trace element contamination in various ways. In some, there might be observatory signs of illness, in some the productivity rate of fishes might get reduced and hence, following the risk of extinction.

In Mediterranean sea and Red sea, El-Sikailey et al., worked on trace elements Cd, Cu, Fe, Ni, Co, Pb, Mn and Zn and calculated its concentration (in wet wt.) in 13 locations on Bivalves which are great biomonitors in analyzing pollution in certain locations (El-Sikaily et al. 2004) (Table 7).

It has been seen from the analyzed bivalve samples that the concentration of trace elements are much higher in the Mediterranean sea than the Red sea and this could be due to the more involvement of industries surrounding the Mediterranean sea (Table 7).

Phytoremediation of trace elements

Not a long time ago, the estimation of metal aggregating plants for remediation been completely acknowledged bringing forth another innovation named phytoremediation (Black 1995; Cunningham et al. 1995; Zhu et al. 1999). Phytoremediation is an approach grounded in plants, wherein elemental pollutants are extracted and eliminated from soil or their bioavailability is reduced (Berti and Cunningham 2000). Ionic compounds present in the soil, even at low concentrations, can be absorbed by plants via their root systems. Water hyacinth *(Eichhornia crassipes)* is an aquatic floating plant which has higher capability of translocating trace elements from root to shoot and their uptake.

Water hyacinth, hence, greatly helps reducing the toxicity of water and while doing so it exhibits signs indicating its toxicity (Zhu et al. 1999). Water hyacinth accumulates trace elements in huge content mainly in roots such as Cd, Hg and Pb respectively (Abdel-Sabour 2010). These trace elements when accumulated in the tissues of water hyacinth can be recovered with the help of ashing the plant biomass. The study by Zhu et al. (1999) was revealed that water hyacinth can assemble a great concentration of Cr and Cd and average concentration of Cu and Se (Table 8).

Advantages and disadvantages of phytoremediation

Advantages

Natural resources are being used to control the pollution, so its less expensive. The plant biomass can later be used to remove the contaminants for various commercial uses. There is no involvement of technologies or any kind of materials or equipments for this operation. It can be carried out in both In-situ and Ex-situ. A number of contaminations can be treated at a time. This kind of treatments are periodic and doesnot have to be continuous. Phytoremediation are not only just accessible to aquatic environment but also to soil and the atmosphere (Farraji 2014).

Disadvantages

The accumulated plant biomass contains many hazardous pollutants. Some highly toxic contaminants are treated to some limiting phase. Hence, it cannot be completely treated. Some plant species can uptake only a very limited amount of trace elements. The uptake of the trace element concentration is mostly by the roots then it gets translocated to shoots and leaves and various other parts. Falling of these leaves may spread the contamination. If not managed properly, there is a possibility of these contaminants to enter the animal and human food chain (Farraji 2014).

Conclusion

Undoubtedly, trace elements play very important roles in maintaining the physiological, biochemical and cellular functions of all the species. Its contribution towards marine environment is also very promising but only to an extent. When it exceeds the standarized limit, it referred as toxic. Various human and natural activities are the main cause of the threat. A number of studies have been carried out examining the nutrient cycle in various species and the concentration of trace elements are found to be much higher in most spe-

cies. Biomonitoring is one of the most effiecient way to control the pollution and so it has to be prioritorized more. Hence, more scientific investigation in this field would lead us towards a less polluted environment.

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Author's contributions Sristi Bhattacharjee: Conceptualization, data curation, Tables and Fig. preparation and editing writing original manuscript draft. Ashutosh Srivastava: Draft editing, supervision. Sofia Priyadarsani Das: Overall supervision, conceptualization, final manuscript editing. All authors contributed to the article and approved the submitted version.

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