REVIEW ARTICLE

EVALUATION OF MOLLUSC AS SENSITIVE INDICATIOR OF HEAVY METAL POLLUTION IN AQUATIC SYSTEM: A REVIEW
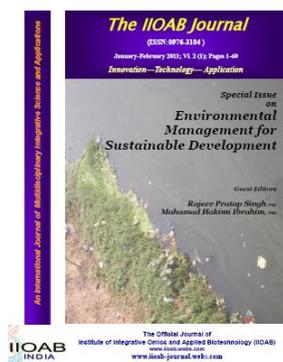
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ABSTRACT

A The potential ecological effects of rising levels of heavy metals concentrations in the environment are of great concern due to their highly bioaccumulative nature, persistent behavior and higher toxicity. These chemicals biomagnify in the food chain and impose various toxic effects in aquatic organisms. Molluscs reflect the higher degree of environmental contamination by heavy metals and are the most useful bioindicator tools. Several studies and research work have been cited to establish and evaluate the relationship between metal contents of water column, sediment fractions, suspended matter and mollusc tissue concentrations. The metals body burden in molluscs may reflect the concentrations of metals in surrounding water and sediment, and may thus be an indication of quality of the surrounding environment. The objectives of this work are to gather more information on the use of different species of molluscs as cosmopolitan bioindicators for heavy metal pollution in aquatic ecosystems.

Keywords: *bioaccumulation; biomonitoring; mollusk; heavy metals*

[I] INTRODUCTION

In the last few decades increasing attention has been paid to the relationship between the conformation of heavy metals and their impact on aquatic organisms. It is widely accepted that anthropogenic activity makes a significant contribution to the total aquatic burden of toxic metals by both point source and non point source contamination can occur. Non point source contamination usually arises from agricultural, industrial, and urban effluents that reach the coast by way of waterways, surface runoff, and precipitation. Both benthic and pelagic species may thus become contaminated by direct uptake and or through biomagnifications. Nevertheless, a permanent control of water quality is indispensable. To reveal the presence of pollutants and to measure their toxic effect biological indicators can be used, which are suitable for prediction of the expectable toxic influence of known or unknown substances.

Metals such as arsenic (As), mercury (Hg), cadmium (Cd), copper (Cu), chromium (Cr), lead (Pb), iron (Fe), manganese (Mn), zinc (Zn) etc. do not degrade in general; therefore, they accumulate throughout the trophic chain. Accumulation in living organisms leads to concentrations several orders of magnitude higher than those of the surrounding water [14]. Despite this the relationship between the concentration of a metal in the aqueous phase and in an organism is far from straight forward as the accumulation ratio depends on many factors; some of them have an environmental origin (temperature, pH, salinity, etc.), whereas others are related to biological factors like age, sex, sexual maturity stage, etc.[40]. Heavy metal toxicity in aquatic organisms, in association with the long residence time within food chains and the potential risk of human exposure, makes it necessary to monitor the levels of these contaminants in marine organisms [28]. In biological indication passive and active monitoring are accepted as a general approach, at different levels of organization. In passive monitoring degradation of the

ecosystem, elimination of sensitive species and reduction of biodiversity can be revealed as adverse consequences of pollution at the level of populations, while at the level of individuals accumulation of toxic substances in specimen, in organs and tissues indicative of pollution in the environment can be traced. In active monitoring the response of artificial or modified populations, behavioral patterns of specimen, specific function of organs like movement, feeding, respiration, reproduction and the neural regulation as well as cellular and sub cellular events are studied under the effect of toxic substances [57]. To achieve a better estimate of bioavailable metal exposure, it is recommended that the tissues of the organisms be analysed for trace metals [38]. Many benthic organisms accumulate trace metals to the levels reflecting those in the environment. Tissue metal concentrations can reflect contamination, and molluscs in particular may therefore be sensitive biomonitors of anthropogenic metal inputs [32].

[II] HEAVY METALS POLLUTION IN AQUATIC ECOSYSTEM

Aquatic ecosystems are under permanent pressure of anthropogenic pollutants originating from various sources located at the catchment areas, or at distant places. Many of the pollutants are toxic to aquatic organisms causing their lethal or sub lethal deterioration. The toxic effect depends mainly on the type of the pollutant and on its concentration. In most of the cases the concentrations of the pollutants are low, causing only sub-lethal or chronic disease nevertheless, acute massive pollution resulting fish-kill or death of various organisms, may also occur in rivers or lakes. Contamination of aquatic ecosystems (e.g. lakes, rivers, stream, lagoons, oceans etc) with metals has been receiving increased worldwide attention [20, 22, 54].

Heavy metals are a special group of contaminants of water reservoirs. Metals are introduced into the aquatic system as a result of weathering of soil and rocks, volcanic eruptions and from a variety of human activities involving mining, processing and use of metals and/or substances containing metal contaminants [36]. The natural levels of heavy metals in the environment had never been a threat to health but in the recent years increased industrial activities leading to air born emissions, auto exhausts, effluents from industries as well as solid waste dumping have become the sources of large quantities of heavy metals into the environment [39]. Trace metals, when entering into natural water become part of the water-sediment system and their distribution processes are controlled by a dynamic set of physical-chemical interactions and equilibrium. River sediments are basic components of the environment as it provides nutrients for living organisms and serves as sink for deleterious chemical species, reflect the history of the river pollution [55]. Sediments act as both carriers and sinks for contaminants in aquatic environments. Heavy metals are among the most common environmental pollutants and their occurrence in waters and biota indicate the presence of natural or anthropogenic sources. Numerous studies have demonstrated that the concentrations of

heavy metals in suspended and bed sediments can be sensitive indicators of contaminants in hydrological systems [20, 33, 35]. The presence of heavy metals in sediments is affected by the particle size, composition of the sediments and other organic substances. The heavy metals can be either adsorbed onto sediments or accumulated in benthic organism, sometimes to toxic levels. Therefore, the mobility, bioavailability and subsequent toxicity of metals have been a major research area [27]. Heavy metals are mainly distributed between the aqueous phase and the suspended sediments during their transport. Riverine suspended load and sediments have important function of buffering heavy metal concentrations particularly by adsorption or precipitation. More than 97% of the mass transport of heavy metals to the oceans is associated with river sediments [34]. Elevated concentrations of trace metals in aquatic bodies as a result of human activities have been recorded since ancient times. However, excessive releases of toxic trace metals into the urban environment and the associated health implications only became apparent in the 1960s when anthropogenic metal contamination of the environment was denoted. Physical mixing of fluvial and marine particulates leads to a continuous decrease in the trace metal content of the suspended matter with increasing salinity. From an environmental and health perspective, this profound geographical development will have a critical influence on our immediate environment and its quality for human health. On a daily basis, numerous human activities including municipal, industrial, commercial and agricultural operations release a variety of toxic and potentially toxic pollutants into the environment [16].

Table: 1. Global emissions of trace metals into the atmosphere, water and soil (in 1000 metric tones yr^{-1}) [44].

(1) Metals	(2) Air	(3) Water	(4) Soil
(5) Arsenic	(6) 18.8	(7) 41	(8) 82
(9) Cadmium	(10) 7.6	(11) 9.4	(12) 22
(13) Chromium	(14) 30	(15) 142	(16) 896
(17) Copper	(18) 35	(19) 112	(20) 954
(21) Mercury	(22) 3.6	(23) 4.6	(24) 8.3
(25) Indium	(26) 0.02	(27) -	(28) -
(29) Manganese	(30) 38	(31) 262	(32) 1670
(33) Molybdenum	(34) 3.3	(35) 11	(36) 88
(37) Nickel	(38) 56	(39) 113	(40) 325
(41) Lead	(42) 332	(43) 138	(44) 796
(45) Antimony	(46) 3.5	(47) 18	(48) 26
(49) Selenium	(50) 3.8	(51) 41	(52) 41
(53) Tin	(54) 6.4	(55) -	(56) -
(57) Thallium	(58) 5.1	(59) -	(60) -
(61) Vanadium	(62) 86	(63) 12	(64) 132
(65) Zinc	(66) 132	(67) 226	(68) 1372

During recent years, the pollution of reverine system by heavy metals has attracted a lot of attention of the scientific community. Unlike organic pollutants, natural processes of decomposition do not remove heavy metals. On the contrary, they may be enriched by organisms and can be converted to organic complexes, which may be even more toxic. The metal solubility is principally controlled by pH, concentration and type of ligands and chelating agents, oxidation-state of the mineral components and the redox environment of the system. Since each form may have different bioavailability and toxicity, the environmentalists are rightly concerned about the exact forms of metal present in the aquatic environment. The toxicity and fate of the water borne metal is dependent on its chemical form and therefore quantification of the different forms of metal is more meaningful than the estimation of its total metal concentrations. Critical assessment of the endpoints of determination for potentially and actually available and accessible metal fractions in the environmental matrices of water, soil, and sediment become the basis for a need-specific monitoring strategy [45]. Several studies has been conducted to reveal the heavy metals concentrations in river water and sediments throughout the world. Heavy metal concentrations in sediment are many times greater than the same metals in the water column. Sediments can act as a scavenger agent for heavy metal and an adsorptive sink in aquatic environment. It is therefore considered to be an appropriate indicator of heavy metal pollution [33]. River water and sediment were assessed for metal and nutrient concentrations from the cities in the Pearl River Delta, South China and observed that sediments were seriously contaminated with Cd, Pb, and Zn in accordance with the classification by Hong Kong Environmental Protection Department [16]. The magnitude and ecological relevance of metal pollution of the middle Po river deriving from the River Lambro tributary was investigated for the partitioning patterns of target heavy metals (Cd, Cu, Ni, Pb, Zn) as well as by investigations of Total metal concentrations in the surface sediments revealed significant pollution inputs on the whole river stretch investigated, with a distinct peak at the inlet of the River Lambro [22]. Different statistical techniques are also being applied for the detailed evaluation of spatial and temporal variations in water quality and different heavy metals. River Gomti monitored at eight different sites in relatively low, moderate and high pollution regions, regularly over a period of 5 years (1994–1998) for 24 parameters [54], Karoon river for Ni, Cr, Cu and results revealed that the minimal and maximal concentrations of these metals in winter were 69.3–110.7, 1.7–118.3, and 5.5–70.3 g/l, for Ni, Cr, and Cu, respectively. The minimal and maximal concentrations of these metals in spring were 41.0–60.7, 0.7–19.8, and 0.5–28.7 g/l, for Ni, Cr, and Cu, respectively [20]. The measurement of total metal may not be able to provide information about the exact dimension of pollution in riverine systems, thus the determination of different fractions assumes great importance. Several researchers studied the distribution of several trace metals in surface water and sediments by leaching, extraction and ion exchange speciation processes as well as fractionation of metal ions on bed sediments of river [35, 55].

[III] NEED OF BIOMONITORING OF AQUATIC ENVIRONMENT

Chemical analysis of the environment matrix such as water, sediment is the most direct approach to reveal the heavy metal pollution status in the environment, while it cannot afford the powerful evidence on the integrated influence and possible toxicity of such pollution on the organisms and ecosystem. Biomonitoring is a scientific technique for assessing environment including human exposures to natural and synthetic chemicals, based on sampling and analysis of an individual organism's tissues and fluids. The results of these measurements provide information about the amounts of natural and manmade chemicals that have entered and remained in the organisms and the corresponding effects induced. Due to consistency between the selected organisms and the corresponding living space, biomonitoring can directly offer the data on the potential effects and actual integrated toxicities of pollutants, reflecting the corresponding deleterious degree in the environment [65].

An important approach to assessment of risk from environmental and occupational exposures is biomonitoring which provides an estimate of the total dose absorbed and gives indirect access to determination of target site concentrations. To reveal the presence of pollutants and to measure their toxic effect biological indicators can be used. Active and passive monitoring are two general approaches to assess the pollutants and their toxic effects at different levels from species to community level of any ecosystem. In passive monitoring degradation of the ecosystem, elimination of sensitive species and reduction of biodiversity can be revealed as adverse consequences of pollution at the level of populations, while at the level of individual's accumulation of toxic substances in specimen, in organs and tissues indicative of pollution in the environment can be traced. In active monitoring the response of artificial or modified populations, behavioral patterns of specimen, specific function of organs like movement, feeding, respiration, reproduction and the neural regulation, as well as cellular and subcellular events are studied under the effect of toxic substances.
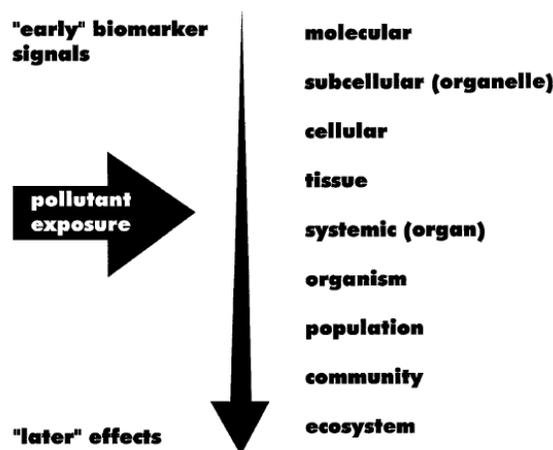

Fig: 1. Schematic representation of the sequential order of responses to pollutant stress within a biological system [51].

It is stated that an organism is a product of its environment and hence has an indicator value. A bioindicator is defined as a plant or an animal which reveals the presence of a substance in its vicinity by showing some typical symptoms which can be distinguished from the effects of other natural or anthropogenic stresses [39]. A good bioindicator is one which shows the earliest responses to the pollutants enabling to indicate the presence and predict the consequences of undesirable anthropogenic effects [52]. In biomonitoring surveys, the toxic elements arsenic, cadmium, chromium, cobalt, lead and nickel etc are used as examples to illustrate the disturbing factors in the interpretation of biomonitoring results [17]. The accumulation of trace elements in aquatic consumers is of interest to environmental scientists concerned with the fate and effect of contaminants, as well as to ecologists interested in food web dynamics and trace metal biogeochemical cycles to assess the toxic impact or distribution of contaminants [43]. It is necessary to understand how elements move through aquatic food webs. Understanding the means by which aquatic organisms accumulate trace metals from their environment is complicated by the existence of both soluble and dietary sources. For many aquatic invertebrates, trophic transfer accounts for a major portion of total trace element accumulation [1]. In the field, the ecotoxicological approach is very difficult for evaluation of the impact of heavy metals in an aquatic environment, due to the complexity of interrelationships between organisms and the ecosystem. However, field studies can enable assessment of the long-term effect on organisms of heavy metals. The underlying regulator of metal concentrations accumulated by animals in tissue is the balance between accumulation and elimination (both of which vary according to the organism's accumulation strategy and diluting body growth) [18, 56].

Trace metal exposure may induce specific metal-binding ligands. Other ligands such as sulfide are important for Ag biokinetic changes in bivalves. Metals also interact strongly in their accumulation by aquatic animals. Generally, dissolved Hg uptake is reduced following exposure to other metals such as Ag, Cd, Cu, and Zn in mollusks and invertebrates. The tissue body burden and the detoxificatory fate of metals in animals seem to be more important in affecting metal accumulation than the nature of the exposure routes (aqueous vs. dietary) or of the exposure regimes. Trace metal accumulation may also be variable in different natural populations of bivalves as a result of different physicochemical environments and histories of exposure [34].

Assessing bioaccumulation is also a component of international efforts to identify and control chemicals of environmental concern. It is now generally accepted that substances, which are persistent, bioaccumulative, and toxic and are subject to long range transport are of particular concern. There is a need to establish reliable procedures for estimating bioaccumulation potential from knowledge of molecular structure or from readily measurable properties of the substance. There is a further inventive to adopt a tiered assessment system in order that those substances which are not bioaccumulative can be rejected from the assessment process at an early stage with minimal expense

and effort. Even toxic effects on ecosystems start with these chemical reactions in individuals. In past few years monitoring programs, conducted to evaluate water quality, usually include chemical and common biological parameters, the use of biochemical markers for surveys is less frequent, but recently more efforts have been given to propose these biomarkers of exposure and effect, in toxicity testing aiming an application in pollution monitoring [29].

[IV] FACTORS AFFECTING BIOACCUMULATION OF HEAVY METALS IN MOLLUSCS

Different environmental factors such as water current, water flow, renewal of water, pH, hardness, salinity etc greatly affects the distribution of heavy metals in the molluscs. The greater metabolic rate of small organisms may partially account for the higher concentration of the essential elements Cu and Zn. [64]. Body size and weight also play an important role in bioaccumulation of metals. Sex plays a significant role in metals accumulation in molluscs. Significantly lower concentrations of cadmium and zinc concentrations were found in males as compared to females in Perna perna species and high concentration of cadmium was reported in Pecten maximus [10, 50]. Metal concentration may differ according to the species. Uptake of metals and subsequent bioavailability are highly dependent on geochemical and biological factors. Among biological factors, there are major differences in bioaccumulation between bivalve species. Within a single species accumulation can be a function of age, size, sex, genotype, phenotype, feeding activity and reproductive state [8].
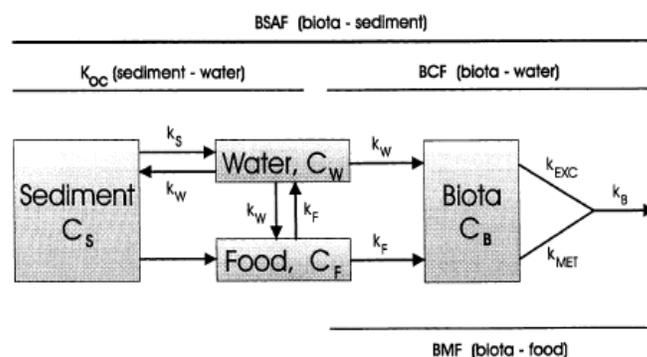

Fig: 3. Bioaccumulation model for aquatic organisms. KOC: sorption coefficient; BCF: bioconcentration factor; BSAF: biota-sediment accumulation factor; BMF: biomagnification factor. C refers to a concentration and k to a rate constant. The subscripts S, W, F, B, EXC and MET refer to sediment, water, food, biota, excretion and metabolism, respectively. The digestible sediment fraction is considered to be part of the food [62].

Geochemical factors that influence bioaccumulation are organic carbon, water hardness, temperature, pH, dissolved oxygen, sediment grain size, and hydrologic features of the system [21]. Salinity influences availability of contaminants whereas

temperature changes can alter bivalve spawning, which will affect the soft tissue mass and lipid composition of the mollusc [6]. Uptake and accumulation in deposit feeders would be expected to correlate to metal concentrations in sediments, whereas accumulation in filter feeders would most likely reflect metal concentrations in water [42]. Various workers noticed that in oysters, blood amoebocytes have been reported to present membrane-limited/membrane-bound vesicles, which can trap copper and zinc [26, 59]. In bivalves, metallothioneins may be trapped in whole soft tissues. Induction of metallothioneins binding cadmium in various soft tissues, gills, labial pulps, digestive gland as well as in remaining tissues, have been studied by several researchers [5,6]. High environmental phosphate concentration facilitates the uptake of cadmium by organisms [50]. Antagonism between zinc and cadmium has been reported on many organisms. However, the concentration of metal in the molluscs depends not only on the level of the element in the environment but also on other factors such as size, age, speed of growth, sex and reproductive conditions of the molluscs, season, salinity, chemical species and interaction with other pollutants.

[V] SIGNIFICANCE OF MOLLUSCS OVER OTHER AQUATIC INVERTIBRATES

The use of aquatic organisms as bioindicators for trace metal pollution is very common these days. Molluscs are among the organisms most used for this purposes. It is widely observed that various species of molluscs are the effective sentinel organisms and can achieve high concentrations of metals and metalloids relative to concentrations gradient of these substances in the surrounding environment [47]. Biomagnification in molluscs and most of the other aquatic animals involves the uptake of chemical from the water and sediments. Bioaccumulation is the process, which causes an increased chemical concentration in aquatic organisms compared to that in water, due to uptake by all exposure routes including dietary absorption, transport across respiratory surfaces and dermal absorption. Bioaccumulation can thus be viewed as a combination of bioconcentration and food uptake. Biomagnification can be regarded as a special case of bioaccumulation in which the chemical concentration in the organism exceeds that in the organism's diet due to dietary absorption. The extent of bioaccumulation thus can play key role in determining water and sediment quality criteria. The assessment of the levels of heavy metals pollution in aquatic molluscs which are used as bioaccumulation indicators, has become an important task in preventing risks to public health. It is to be pointed out that for a living species to be used as bioaccumulator some essential characteristics are necessary (i) It must be typical of the ecosystem studied (eg non-migratory), ubiquitous and abundant, (ii) Its size, biotype and behavior must be such as to make sapling easy. (iii) It must bioaccentrate xenobiotics substances to a level sufficient to perform a direct analysis without pre-concentrations. (iv) It must be able to stand high concentrations of different toxic substances so as to survive the pollutant studied. (v) It lives in a sessile style, thus definitely representing the local pollution. (vi) Its life long enough for the comparisons between various ages. (vii) It occupies the important position in food chain. (viii) Dose effect relationship can be observed in it [46, 65].

Among aquatic organisms, gastropods and bivalves molluscs have been recognized as a useful tool for monitoring of the environment they live in because of their ability to accumulate chemical elements and/or compounds in their tissues proportionally to their bioavailability and thus can be used as indicators of aquatic metallic pollution. They are filter feeders, herbivores or carnivores and have the potential to bioaccentrate contaminants, which would normally be present in the water or within sediments at concentrations too low for detection by routine monitoring techniques. They are also ideal species for environmental monitoring, because their sedentary nature does not require consideration of complex migratory factors in the interpretation of the bioaccumulation data. They are sedentary organisms filtrating large amounts of water allowing them to accumulate the substances from the environment. They also satisfy the other conditions to be bioindicators hence very appropriate for monitoring because of their abundance and wide geo- graphical distribution, relative longer life span, suitable dimensions, size, weight, easy identification and collection, abundance in an ecosystem and accumulate the elements to a degree suitable to measure for hazard and risk assessment [15]. Molluscs are also sturdy enough to survive in laboratory and field studies and tolerant to environmental alterations, and various contaminants [65].

[VI] BIOMONITORING OF HEAVY METAL POLLUTION USING GASTROPODS AND BIVALVES

Benthic molluscs play an important role as bioindicators for trace metal pollution and appear more and more often in global monitoring programs [47]. Among aquatic organisms suitable for biological monitoring molluscs occupy a prominent place and they are often used both for passive and active biomonitoring and in hazard and risk assessment [52]. In recent years, researchers have focused their attention on the identification of other possible bioindicators for trace metal pollution, such as the gastropod molluscs. Several biomonitoring studies for the heavy metals pollution in aquatic ecosystem, have been carried out in past two decades using different mollusk species like, gastropod mollusc Bembicium nanum [25], Donax trunculus and Chamelea gallina [61], bivalve: Pyganodon grandis [9], Crassostrea angulata, Scrobicularia plana, Palameon longirostris, Uca tangeri, Melicertus kerathurus [7], Crassostrea virginica [3], Radix ovata and Viviparus spp. [31], Rapana venosa and Neverita didyma [37]. This is because it is necessary to identify a wider range of bioindicators and thus expand current understanding of different bioaccumulation strategies for trace metals.

Both essential and non-essential trace elements are known to be highly accumulated by invertebrates, in particular by a variety of molluscs species. Aquatic molluscs seem to reflect ambient metal contamination and are therefore widely used as bioindicator organisms. Undoubtedly, aquatic molluscs are amongst the most thoroughly investigated bioindicator organisms. The translocation of sentinel species, mainly mussels from a reference site to the study areas has been demonstrated as a useful strategy for the assessment of water quality in coastal and estuarine environments, either through bioaccumulation or biomarkers analysis [41, 19, 31]. Body size, condition index and tidal height also affects the concentrations of As, Cd, Co, Cr, Cu, Fe, Mn, Ni, Pb and Zn in Mytilus edulis and findings suggested that the body weight was inversely related to metal concentrations and for Cd, Mn, Pb and Zn the regression was affected by tidal height. Except for As, Fe and Mn metal concentrations were inversely related to physiological status though no differences between essential and non-essential metals were recorded. Thus it is recommended that stringent measures during sampling for biomonitoring or metal concentrations at each location must be normalized to a common body size, condition index and tidal height [40]. As even closely related species may exhibit different accumulation strategies for trace elements, there is a need to identify widespread cosmopolitan biomonitors to allow intra-specific comparison of accumulated metals concentrations over large geographical areas [47]. Considering that bioaccumulation of heavy metals is highly site dependent, it was of general interest to test the suitability of molluscs as metal bioaccumulators in the moderately polluted waters. Different feeding habits in mollusc may influence metal bioaccumulation for example the prosobranch grazer Viviparus species is both a deposit-feeder and facultative suspension-feeder. In this species, the hypobranchial gland beneath the gill coats the filtered particles with mucus, food particles are then transported towards the mouth and ingested [31].

Various metal accumulating bivalve and gastropod species show a high presence and abundance in marine and freshwater reverine ecosystems therefore they are suitable for different monitoring projects for example Cd, Cr, Zn in Perumytilus purpuratus, Semelle solida and Tagellus dombeii [30]. Mussels can accumulate and integrate concentrations of several metals in seawater for relatively long intervals. They also assimilate trace metals from their food and from the ingestion of inorganic particulate material [46]. Moreover, bivalves such as Mytilus galloprovincialis [24]; Perna perna [23] and oysters eg Crassostrea angulata [24]; Crassostrea virginica [56] are widely employed in laboratory as well as field studies where the uptake, loss or the biological effects of heavy metals such as arsenic (As), Lead (Pb), Cromium (Cr), Manganese (Mn), Copper (Cu), Zinc (Zn) on the east coast of the middle Adriatic Sea [33], Black sea [49]; Monodonta turbinata and Patella caerulea in Mediterranean area [12], Mytilus edulis, Crassostrea talienwhanensis and Ruditapes philippinarum along the Chinese Bohai Sea [37] and results showed that Crassostrea talienwhanensis possessed a much greater ability for bioaccumulation of Cu and Zn than other species Rapana venosa manifested the high bioaccumulation capacity of Cd. Among the five species, the Ruditapes

philippinarum possessed the highest content of Ni. Furthermore, Cd, Cu and Zn contents in some gastropods and oysters samples exceeded the maximum permissible levels established by WHO. Another species Mytilus trossulus and the Barnacle balanus are also being used for such type of metals biomonitoring [47]. The digestive gland of bivalves is a target organ for the accumulation of metals, furthermore, the lysosomes of the digestive cells are generally considered as target organelles. While the gills have also been shown to accumulate various heavy metals either in the field or in the laboratory. A preliminary investigation conducted to assess the pollution in the northern part of Vietnam with focus on trace elements including heavy metals in a freshwater bivalve Pletholophus swinhoei used for human consumption. Significant site-specific differences were reported for As, Ba, Be, Br, Cr, Fe, Mn, Ni, P and Sr [63]. Freshwater mussel Dreissena polymorpha also used to assess trace metal pollution in the lower river Po, Italy and results showed that the Cd and Pb concentrations were increased from 1.23 to 3.22 and 3.40 to 5.93 pg/g dry weight respectively at one site and the same trend was observed at the second site, indicating that these metals accumulated. Cu and Zn concentrations in mussel tissues did not change relative to time zero concentrations. The highest Cr and Ni levels were found after 15 days at both stations (10 and 27 pg/g dry weight respectively). Low and relatively constant Hg concentrations (<0.10 pg/g dry weight were found in transplanted and native molluscs (D. polymorpha and Unio elongatulus). Concentration factors calculated for all trace elements assayed, ranged from 103 (Pb) to 104 (Zn) [13].

Environmental pollutants such as metals pose serious risks to many aquatic organisms. Accordingly, a great deal of previous research that has characterized physiological mechanisms of toxicity in animals exposed to contaminants. Relationships between ambient geochemistry, watershed land-use and trace metal (Cu, Zn, and Pb) concentrations in three types of invertebrate aquatic molluscs, odonates, and composite were established [48]. The results suggest that despite the high variation in ambient metal concentrations within each land-use category, macro invertebrates in ponds were accumulated higher levels of Cu and Zn but the levels of Cu, Zn, and Pb in invertebrates from all ponds were less than dietary concentrations considered toxic to fish. Relationship of Cd, Pb, Zn, Cu, Ni, Co, Cr, Mn and Fe in the soft tissue of Turbo coronatus, Acanthopleura haddoni, Ostrea cucullata and Pitar sp., as well as in associated surface sediments (bulk and bioavailable metal concentrations) from the Gulf of Aden, Yemen were showed the significant spatial differences in metal concentrations in the molluscs and associated sediments. A slope of the linear regression was noted significantly higher than unity for Fe (9.91) and Cd (3.45) in A. haddoni and for Ni (4.15) in T. coronatus, suggesting that the bioavailability of these metals is disproportionally increased with a degree of enrichment of the sediments in Fe, Cd and Ni, respectively. A slope constant approximating to unity (1.14) for Cu in A. haddoni relative to its concentration in sediment extract implies that bioavailability of this metal proportionally increased with growing concentrations of its labile forms in the associated sediment [58].

Metallothioneins are cysteine rich, low molecular weight, heat stable proteins that bind to metals such as Cd, Cu and Zn [53]. Metallothioneins in aquatic invertebrates play an important role in the homeostasis of essential metals like Cu and Zn and detoxification of excess amount of essential and non essential metals such as Cd, therefore extensively used as as biomarkers [2, 47]. Moreover, MT levels are also known to be related to the fitness status and health of organisms [11]. The literature on metallothioneins (MT) and metallothionein-like proteins (MTLP) in aquatic invertebrates is large and increasing. Metallothionein like proteins appear to play an important role in mediating metal uptake and hence accumulation, therefore metallothionein has been assayed in a range of aquatic animal tissues as an indicator of metal exposure [4, 2]. MTs can be induced by the essential metals Cu and Zn and the non-essential metals Cd, Ag and Hg in both vertebrates and invertebrates, but their induction is variable [60]. Against this background of variability MTs do appear to play roles both in the routine metabolic handling of essential Cu and Zn, but also in the detoxification of excess amounts intra-cellularly of these metals and of non-essential Cd, Ag and Hg. Different isoforms of MT play different physiological roles, and the dependence on MT in detoxification processes varies environmentally and between zoological groups.

[VII] CONCLUSION

Various species of gastropods and bivalves molluscs have been recognized as a useful tool for monitoring of heavy metals pollution. These organisms accumulate comparatively higher concentrations of metals because of their sedentary nature, both from water and sediment. The extent of bioaccumulation thus can play key role in determining water and sediment quality criteria. Molluscs occupy the important position in food chain and are ubiquitous and abundant, live in a sessile style thus represents the pollution level of habitat. Several studies have been carried out on its different life stages including embryonic stages. They also satisfy the other conditions to be bioindicators like their abundance and wide geo- graphical distribution, relative longer life span, suitable dimensions, size, weight, easy identification and collection. There are suitable to measure for hazard and risk assessment. Molluscs are also sturdy enough to survive in laboratory and field studies and tolerant to environmental alterations, and various contaminants.

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