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Conceptual Background of Bioaccumulation in Environmental Science

Abdullateef Abdullahi Ibrahim [1,*], Ali Gambo Yusuf [2], Gambo Ismail [3], Muhammad Abdullahi Ibrahim [1], Abdulhamid Ruwa Musa [4] and Mustapha Said Sulaiman [5]

[1] *Department of Biological Sciences, Faculty of Sciences, University of Maiduguri, P.M.B. 1069, Maiduguri, Borno State, Nigeria*
[2] *Department of Biochemistry, Faculty of Sciences, University of Maiduguri, P.M.B. 1069, Maiduguri, Borno State, Nigeria*
[3] *Northeast Zonal Biotechnology Centre, University of Maiduguri, P.M.B. 1069, Maiduguri, Borno State, Nigeria*
[4] *Department of Microbiology, Faculty of Sciences, University of Maiduguri, P.M.B. 1069, Maiduguri, Borno State, Nigeria*
[5] *Department of Biological Sciences, Faculty of Life Sciences, Bayero University, Kano, P.M.B. 3011, Kano State, Nigeria.*

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Abstract

Environmental metal pollution is one of the serious global problems with severe health effects due to its persistence and accumulation in living organisms, these require biological strategies such as bioaccumulation for remediation, the main environmental contaminants are associated to water, soil, and air. Meanwhile, Bioaccumulation is the accumulation of pollutants in living organisms which enable to assess the risk related to their presence in the ecosystems. In other words; Bioaccumulation is the net result of all uptake and loss processes, such as respiratory and dietary uptake, and loss by egestion, metabolism, passive diffusion, transfer to offspring and growth. Hence, this paper provides the conceptual background of bioaccumulation factors, effect of heavy metals on the ecosystems, and the organisms involved in the processes as well as some fishes and plants responsible for bioaccumulation.

Keywords: Ecosystems; Environment; Heavy Metals; Contaminants; Accumulation.

1. Introduction

Bioaccumulation is a term commonly used for metal toxicity [1]. The knowledge on bioaccumulation enables to assess the risk related with the presence of different chemicals in the food, environment, and at workplace and to present quantitative ability to control the use and the emissions of the chemicals [2]. Accumulation of toxic heavy metals in edible food crops is a potential threat to animal and human health [3]. Therefore, Bioaccumulation refers to the uptake of contaminant concentrations from the ambient environmental medium in aquatic organisms [4]. Meanwhile, the detailed mechanism of bioaccumulation remains unclear [5].

Anthropogenic involvement has made a significant contribution to soil contamination which may exert possible human health risk [6]. Pollution of the biosphere by the toxic metals is a global threat that has accelerated dramatically since the beginning of industrial revolution [7]. Unwarranted release of heavy metals from anthropogenic activities especially industrial discharge has threatened sustainable agricultural practices and limited the overall yield of diverse plants species [8].

Despite of low bioavailability of heavy metals in benthic organisms; accumulation is often observed [9]. This accumulation of toxicants or other chemicals in the soil expands both the potential targets (e.g., invertebrates, bacteria)

* Corresponding author: Abdullateef Abdullahi Ibrahim; Phone: +2347083333163; E-mail: abdullateefgaya@gmail.com
Department of Biological Sciences, Faculty of Sciences, University of Maiduguri, P.M.B. 1069, Maiduguri, Borno State, Nigeria.

of exposure and its availability for entrance into the food chain/web [10]. The impact of soil contamination on the food chain presents a challenge for many investigations [11].

2. Bioaccumulation Factor (BAF)

BAF is the assessment of the risks caused by contaminants in relation to the safety of animals and human in the occurrence of exposure to the chemicals present in the ecosystems [12]. The BAF is also used to evaluate the potential ability of the plant to accumulate elements from water. The BAF can be computed as follows: [13].

BAF = C plant ÷ C water

Bio-concentration Factor (BCF) in animals can only be measured in laboratory experiments, where uptake from food can be restricted, whereas BAF is the ratios measured in field. Bioaccumulation factors are usually used in assessment models, as they present a pollution-scale of independent parameter [14].

BCF refers as the ratio between the concentrations of chemical in organism to the respective concentration in water whereas BMF is the ratio between the concentration toxic in predator (C-predator) to concentration in prey (C-prey):

BCF = C organism ÷ C water

BMF = C predator ÷ C prey

Both, BMF and BCF are usually determined in laboratory tests according to Organization of Economic Co-operation and Development, OECD, test 305 [15].

3. Effect of Heavy Metals on the Ecosystems

Ecosystem is degrading gradually due to heavy industrialisation [16]. Contamination by heavy metals in soil is one of the key environmental problems in many countries and these contaminants are from various sources such as vehicular sources and other industrial activities [17]. Heavy metal contaminations is a serious problem not only from the human health viewpoint but also from broader environmental perspective because of its non-biodegradability, hazardous and toxic properties [18].

Hence, heavy metals are elements having atomic weights between 63.55 - 200.59 and a specific gravity greater than > 4.0. Meanwhile, living organisms require trace amounts of some heavy metals which include; Cu, Co, Fe, Mo, Mn, V, Zn and Sr [19]. Heavy metals are well-known environmental contaminants due to their toxicity; bio-accumulative nature and persistence in the environment. Pollution of terrestrial and aquatic ecosystems with toxic heavy metals is an environmental issue of public health concern [20]. The presence of heavy metals in the ecosystems can increase their risk of transfer to the food chain and food web [21]. Heavy metals are transferred from the abiotic components to living organisms, accumulated at different trophic levels, and hence contaminate the food chains [22].

Health risks associated with heavy metals such as skeletal deformation, hepatic failure and renal failure have been linked to their non-decomposable and persistence nature in the splanchnic organ-parts of humans [23].

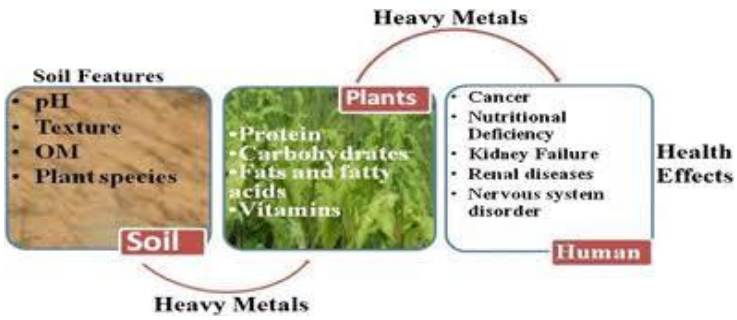

Figure 1 The diagrammatic presentation of heavy metal sources, plant uptake, and health effects; adopted from Khan *et al.,* [24].

4. Bioaccumulation in Organisms

The most important bacterial species that are used in bioaccumulation processes are as follows; *Staphylcoccus, Bacillus, Corynebacterium, Escherichia, Enterobacter, Aeromonas, Klebsiella, Pseudomonas, Arthrobacter, Vibrio, Erwinia, Brevibacterium, Micrococcus, Deinococcus, Sarratia, Nocardia, Zoogloea* and *Thiobacillus* [25].

Table 1 Some Organisms Responsible for Bioaccumulation

Element(s)	Potential organism(s)	Reference
Cu, Zn, Fe, Mn	*Bacillus megaterium*	Stefanescu [26]
Cd, As, Pb	*Alcaligenes* sp., *Bacillus cereus*	Ansari *et al.,* [17]
Zn, Cu	*Pseudomonas,* *Bacillus* *Staphylococcus*	Ahemad & Malik [27]
Cr, Ni, Ca, S, Zn, Sr, V, Zn, Cu, Hg, Cd	*Stolephorus indicus*	Malik [28]
Hg, Pb, Zn, Cu, Co, Cr	*Staphylocaccus* sp., *Bacillus* sp., *Pseudomonas* sp., *Streptococcus* sp., *Moraxella* sp., *Escherichia coli, Proteus* sp., *Klebsiella* sp., and *Salmonella* sp.	Olukoya *et al.,* [29]
Cr, Ni, Cu, Cd	*Pseudomonas* spp.	Hussein *et al.,* [30]
Ni	*Escherichia coli*	Krishnaswamy & Wilson [31]
Cr, Pb, Cd	*Gemella sp., Micrococcus* sp. and *Hafnia* sp.	Marzan [32]
Cu, Cr	*Pseudomonas* sp.	Singh *et al.,* [33]
As, Hg, Co, Cd, Pb, Se	*Bacillus arsenicus, Bacillus pumilus, B. arsenicus, Bacillus indicus, Bacillus clausii, Planococcus maritimus, Staphylococcus pasteuri*	Nithya *et al.,* [34]
Zn, Cd	*Streptomyces zinciresistens*	Lin *et al.,* [35]
Al, Pb, Cd, Ag, Cu, Sn	*Alcaligenes faecalis*	Abo-Amer *et al.,* [36]
Hg, Cd, Ni	*Macrophthalmus depressus*	Saadati *et al.,* [21]
Cd, Pb, Cu, Zn	*Porcellionides pruinosus*	Ghemari *et al.,* [37]
Cd, Zn, Cu, Pb	*Metaphire californica,* *Amynthas homochaetus,* *Amynthas pecteniferus,* *Amynthas heterochaetus*	Wang *et al.,* [38]
Cu, Zn, Pb, Cd	*Eisenia fetida*	Li *et al.,* [39]

5. Bioaccumulation in Aquatic Organisms

According to a recent research conducted by Rubalingeswari *et al.,* [40] Bioaccumulation factor (BAF) revealed that the concentration of heavy metals viz. Ni, Cr, Cu, Pb, Co, Mn, Fe and Zn in different tissues of fishes was several times higher than their concentrations in water.

In another development, metals accumulated in fish organs as per the order of Zn > Cu > Pb; It was also noted that metals in the fish organ accumulated as per the order of digestive gland > gill > muscle [41].

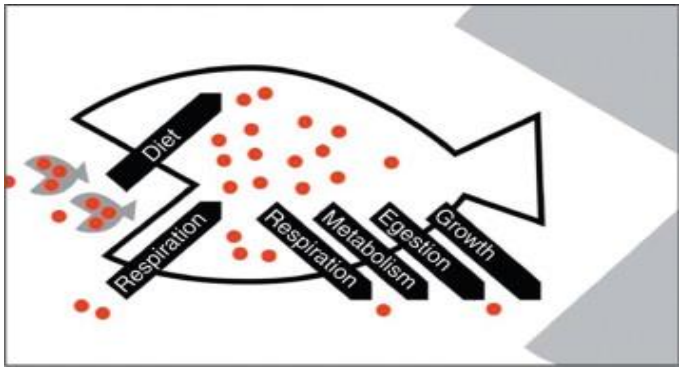

Figure 2 Bioaccumulation of pollutants (dots) to an organism (fish) as a net result of uptake and loss processes (arrows); adopted from Borgå [42].

Table 2 Fish Responsible for Bioaccumulation

Contaminants	Characterised Fish	Reference
Cd, Cu, Pb, Zn	*Procambarus clarkia*	Goretti *et al.,* [43]
Zn, As, Pb, Cu, Sn	*Rasbora elegans, Trichogaster trichopterus, Oxyeleotris marmorata Macrobrachium resenbergii, Mastacembelus armatus, Rasbora eleganss*	Ashraf *et al.,* [44]
Cr, Cd, Cu	*Odontesthes bonariensis*	Blanco *et al.,* [5]
Ni, Zn, Cr, Cu, Pb, Co, Mn, Fe	*Arius parkii*, *Gerres oyena*	Rubalingeswari *et al*., [40]

6. Bioaccumulation in Plants

The accumulation of heavy metals by crops irrigated with wastewater has been considered as a severe environmental issue in many developing countries [45]. The use of sewage water for irrigation has engrossed the arid and semi-arid countries where the availability of freshwater is poor [46].

Table 3 Plants Responsible for Bioaccumulation

Contaminants	Potential Plant(s)	Reference
Cr, Cd	*Lepidium sativum*	Diaconu *et al.,* [47]
Fe, Pb, Mn	*Bassia indica, Solanum nigrum, Pluchea dioscoridis, Amaranthus viridis, Bassia indica, Portulaca oleracea*	Eid & Shaltout [48]
Cd, Cu, Ni, Pb	*Spinacia oleracea, Rumex acetosa*	Balabanova *et al.,* [11]
Zn, Cu, Ni.	*Sulla coronaria*	Chiboub *et al.,* [49]
Cd, Pb, Zn, Fe, Mn	*Vaccinium myrtillus, Vaccinium vitis-idaea*	Kandziora-Ciupa *et al.,* [50]

7. Conclusion

In conclusion, Bioaccumulation is one of significant strategies that are used by organisms in bioremediation. Biological remediation of heavy metals involves the use of organisms such as microorganisms and plants, Hence, their products or derivatives are essential as placid environmental friendly mechanisms for decontamination.

Compliance with ethical standards

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Disclosure of conflict of interest

All authors do not have any conflict of interest.

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