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A Review on Effects of Selenium in Aquatic Environment

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Abstract: In summary, selenium is an trace element that has great physiological and ecotoxicological significance because it is a basic micronutrient for aquatic organisms. At the same time, selenium is toxic in high concentrations. In recent years, selenium and its effects have been discussed in aquatic environment. This review presents the effects of selenium in aquatic environment. Consequently, the approach of using selenium as a parameter in water quality monitoring studies is strongly recommended in aquatic environment.

Keywords: Aquatic Environment, Ecotoxicology, Effect, Selenium

1. Introduction

Selenium is an essential trace element that is very important for water, soil, plants and animals. Selenium was identified in Sweden by Jons Jacob Berzelius in 1817. The name originates from Greek word "Selene" meaning "Moon". It can exist in two forms as a silvery metal or a red powder. Selenium is known as an essential element which means it is essential for life in some species, including humans. Selenium is relatively rare but occurs in trace amounts in pyrites. It is mostly extracted from anode mud formed during the electrolytic refining of copper. Plants take up selenium from soil and propagate it through the food chain. Selenium is found in water supplies as selenite and selenate. Because of their high solubility, these forms are more available for plants and are potentially toxic to aquatic organisms [1, 2]. Selenium in aquatic environment is of concern due to its propensity to accumulate through the food chain and its potential to impair fish reproduction. It is a non metal element widely distributed throughout the environment and is found in most ground and surface waters at concentrations between 0.1 and 0.4 µg/L. Once released into aquatic environment selenium can be removed from water column and deposited into sediments by adsorption, complexation, and coprecipitation processes, as well as, absorption by aquatic organisms. Selenium can be mobilized from sediments into the food chain by mechanisms present in most aquatic ecosystems [3-5]. Primary producers are important contributors to the selenium accumulation and its subsequent transfer to higher trophic levels in aquatic ecosystems. A major concern regarding elevated levels of selenium in aquatic environment is its ability to accumulate through the food chain and potentially impact the sustainability of fish populations [3, 6, 7]. In aquatic environment, selenium can rapidly attain levels that are toxic to fish and wildlife because of its bioaccumulation in food chains and the resulting dietary exposure [2, 8]. The number of studies that examine the effects of selenium in aquatic environment is very limited. In recent years, selenium and its effects have been discussed in aquatic environment. This review reveals the effects of selenium in aquatic environment.

2. Biological Importance of Selenium

The reason for determination of selenium in biomaterials is that it is both a necessary and a toxic element. There is a narrow nerve between selenium deficiency and levels of toxic effects [9]. When selenium is taken in small quantities for cells and tissues are free radical It is a very important antioxidant that protects against damage. However, when taken in larger quantities, it is a trace element that can be toxic. The prominence of selenium is due to the presence of glutation peroxidase in structure of enzyme and the fact that this enzyme is an essential element for its activity. Glutation peroxidase converts the oxidising peroxides of unsaturated fatty acids to water, destroys free radicals, which disrupt cell structure and damage cell membranes. This is a powerful antioxidant that neutralizes hydroperoxides and lipoperoxides by preventing the degradation of polyunsaturated fatty acids by oxidative action [10-12]. Another feature of selenium is that it destroys the effects of toxic heavy metals. In seafood, mercury and mercury are found together with methyl esters of selenium. Although its mechanism is not known precisely, it has been found that it prevents the toxic effect of cadmium and mercury [9, 11, 13].

Uptake of selenium by biota can be from water or diet. Uptake of selenium dissolved in water by fish can be either by mouth, gills, gut and skin [14]. Selenium bioaccumulated in aquatic food chains and caused severe tissue pathology and reproductive impairment in resident fish community [15]. High levels of selenium in aquaculture show toxic effects in fish. These effects include growth retardation, malnutrition and increased mortality. In the most of commercial fish feed used in aquaculture are available at a sufficient level of selenium. However, selenium levels may be inadequate in case of illness and stress. With selenium deficient in fish, anorexia, muscle structure disorders, deceleration at growth and mortality are observed. Symptoms of selenium deficiency are often exacerbated by addition of vitamin E. Nevertheless, the effect of vitamin E depends on degree of selenium deficiency. In advanced selenium deficiency, it has been found that digestive enzymes are reduced in activation, resulting in a decrease in digestibility of many nutrients, including vitamins and minerals in fat and oil.

3. Ecotoxicological Properties of Selenium

Selenium is a naturally occurring trace element which is toxic at high concentrations, but it is also an essential element for many organisms [6]. It has three levels of biological activity: 1- Trace concentrations are required for normal growth and development; 2- Moderate concentrations can be stored and homeostatic functions maintained; and 3- Elevated concentrations can result in toxic effects. Selenium is a potential toxic element to natural ecosystems due to its bioaccumulation potential. Agricultural and industrial activities accelerate the release of selenium from geological sources and make it available to wild animals and fish in terrestrial and aquatic ecosystems. Agricultural drain water, sewage sludge, fly ash from coal fired power plants, oil refineries, and mining of phosphates and metal ores are all sources of selenium contamination of aquatic environment [14]. Inorganic selenium is rapidly and efficiently assimilated by primary producers and transformed into organic selenium types in aquatic environment. These organic selenium types are transferred throughout the food web via the diet to primary and secondary consumers. Toxicity results from dietary exposure to organic selenium compounds, predominantly selenomethionine, and subsequent production of reactive oxidized species [16].

In aquatic environment, selenium poses its particular threat to wildlife. Bioaccumulation and biomagnification increase the threat that toxic forms of selenium pose to wildlife. Accordingly, selenium concentrations in tissues of lower invertebrates or fish can reach concentrations up to 2000 times the selenium water concentration [17, 18]. It has been shown that adverse effects on fish can arise at a waterborne selenium concentration of 5 μg/L, but do not necessarily occur at higher concentrations [14, 18, 19]. Selenium laden water is a problem for most ecological wildlife particularly for aquatic dependent, egg laying vertebrates where most sensitive ecotoxicity is found as embryo mortality of water fowls and larva deformities of fishes [16, 20, 21]. Physical deformities, mutations, reproduction failures and even death were observed after exposure to toxic levels of selenium concentrations, particularly for aquatic life.

4. Determination of Selenium

Selenium content in aquatic food and water can be determining by analytical techniques such as Graphite Furnace Atomic Absorption Spectrometry (GFAAS), Hydride Generation Atomic Absorption Spectrometry (HGAAS) and Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES) for environmental samples.

5. Effects of Selenium on Aquatic Environment

At the global scale, selenium is constantly recycled in environment via the atmospheric, terrestrial, marine and freshwater systems. Estimates of selenium flux indicate that anthropogenic activity is a major source of selenium release in the cycle, whereas the marine system constitutes the main natural pathway. Selenium cycling through the atmosphere is significant because of rapidity of transport, but the terrestrial system is most important in terms of animal and human health because of direct links with agricultural activities and the food chain [22]. Selenium pollution has a wide environmental impact range in humans, ecosystems and even agricultural processes. Because environmental contamination by selenium typically occurs at low concentrations, importance in remediating selenium containing environments has been deemed less important. However, selenium is found in soil and water and can be mobilized to enter the food chain through the roots of plants or aquatic organisms, thus causing concern of possible long term environmental impacts [21, 23, 24].

Selenium a natural constituent of the earth's crust, is widespread over all the earth compartments, in rocks, soil, air, water, vegetation and food. The amount of selenium in water is affected by many factors which include the leaching of this element from rocks, contaminants, the geochemical environment and pH. The largest amount of this micronutrient can orginate from underground and groundwater that flows through rocks rich in selenium containing minerals. Groundwater also contains selenium leached from waste disposal sites; such waste primarily includes ash produced by coal combustion. The world mean content of selenium in freshwater is 0.02 µg/L, while in sea and ocean water it is less than 0.08 µg/L. Groundwater generally contains higher selenium levels than surface waters, due to the contact with rocks. Oceans, via seafood, and drinking-water play an important role in human selenium exposure [25, 26]. World Health Organization provisional guideline for selenium was set at 40 µg/L in drinking water [27]. Selenium limit in drinkingwater is 10 µg/L in European Union [28]. Various countries have adopted an upper limit of 50 µg/L for drinking water and 5 µg/L for selenium effluent discharge [21, 25, 29].

The biogeochemical cycle of selenium moves from rocks, sediments and soils to waters, where it enters plants, animals or humans via the food chain. Thus, the selenium distribution in environment is affected by a variety of physicochemical and biological processes [21]. Environmental pollution by selenium may occur due to natural and anthropogenic sources. Natural sources include the weathering of selenium containing rocks and soils and volcanic eruptions. Selenium is mainly a by product in metal (i.e. copper, nickel) refinery and processing plants. Selenium is found in aqueous discharge from electric power plants, coal ash leakages, coal combustion, oil refinery effluents, mining activities, industrial wastewater, photocells, glass manufacture, insecticide production as well as agricultural drainage water from irrigation. The addition of selenium to feed stuffs and soil fertilizers is common practice. Part of the selenium added to feed is used by animals and part is spilled or secreted and finds its way into the environment. Selenium pollution is a worldwide problem and there is a huge demand for cleanup of selenium contaminated water [6, 8, 30, 31]. There is a possibility that selenium issues will grow in coming years due to exploitation of lower grade coal, fossil fuels, and mineral ores by the mining industry and irrigation in semi arid regions [18, 21]. In aquatic environment, selenium is an ecologically important trace element due to its effect on reproduction in birds and fishes.

In aquatic ecosystems, algae serve as the primary source of energy assimilation and as the base of aquatic food chain. Algae have been shown to incorporate selenite in to amino acids and proteins and, thus probably serve as the major vector for uptake of organic selenium compounds by consumer organisms. Invertebrates are a key link in the aquatic food chain, making energy assimilated by primary producers availiable to higher trophic levels. As such, they play a key role in accumulation of selenium by secondary consumers. Surprisingly, there are relatively few studies examining selenium bioaccumulation in aquatic invertebrates. Fish are the most economiccally impotant organisms in most aquatic ecosystems. They are the most sensitive taxa in aquatic ecosystems. Fish reproduction is apparently one of the most selenium sensitive biological processes and bioaccumulation of selenium has been suggested as the reason for reproductive problems in ecosystems examined thus far. A considerable number of studies have investigated bioconsentration of selenium in fish [32]. This processes and bioaccumulation occurs rapidly in lentic ecosystems.

6. Conclusion

The health of aquatic environments is crucial to health of the world as a whole. Aquatic environments of the world are all precious repositories of biodiversity. They face a host of serious threats, all of which are caused primarily by human activity. One of the most serious threats to aquatic environments is the selenium. Nowadays, negative effects of waste from selenium to aquatic environment are increasingly in aquatic environment. Human activities are increasing which increase the concentrations of selenium and provide favorable conditions for bioaccumulation. Selenium has been identified as a hazardous substance due to its toxicity. The prevalent risk of selenium threats is now more than ever in aquatic environment. The selenium toxicity is primarily to the reproductive system, causing organisms to die in the egg or to have weak and deformed offspring. The levels of selenium at which toxicity occurs in aquatic organisms are highly dependent upon specific physicochemical and biological attributes of an aquatic environment. The absence of selenium in the measured parameters list of water quality monitoring studies is a major error. For this reason, selenium should be used as a parameter in water quality monitoring studies. This is very important for the conservation of aquatic environment.

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