Evaluation of Mercury Accumulation in Sediments and Benthic Invertebrate Masses from Sanandaj Gheshlagh Reservoir

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Introduction

Mercury (Hg) is a toxic compound that is produced in the environment by anthropogenic activities and physico-chemical interactions in the earth crust. Therefore, mercury (Hg) pollution is considered as an environmental problem in global scale. Among heavy metals, mercury is a unique element which exists in different organic and inorganic forms in the nature. This metal readily biomagnifies in the aquatic food chain, because it is almost completely absorbed and transported throughout the body, particularly the body of lower trophic levels members in natural aquatic ecosystems. The high concentration of mercury will restraint the natural growth of living creatures, disturb material exchange and transform in natural ecosystems, and cause disorders in body functions. Inorganic mercury (Hg) can be converted to methylmercury (M-Hg, the most toxic from of mercury) basically by anaerobic microorganisms existing in aquatic ecosystems substrates. The obvious characteristic of this compound is its stability in environment and long biological half-life. Previous studies showed that the level of total mercury (THg) in Sanandaj Gheshlagh Reservoir (SGR) water is higher than those limits established by WHO and Iran (i.e., 1 μg/L). Sediments and benthic invertebrates (benthos) are assumed as the indicators of the level of mercury concentration in aquatic ecosystems.

The stability of mercury in sediments plays an important role in mercury cycle in natural ecosystems. On the other hand, the level of accumulated total Mercury (T-Hg) in benthos biomass is subordinated to the level of accumulated T-Hg in sediments with living organisms on them. Microorganisms inhabiting aquatic ecosystems substrates convert inorganic mercury to methylmercury during the process of bio-methylation, which is the most hazardous mercury form. Methylmercury is eliminated from live tissues much later than inorganic mercury. Field observations verified that SGR pollution was occurred by natural processes because intensive agricultural activities and other pollutant sources such as industrial activities were not observed within the SGR watershed and it's upstream. In addition, previous geological and pedological studies proved considerable levels of mercury in the SGR geological structures. The most favorite and consumed fish in the region is common carp (*Cyprinus carpio*) due to its high abundance and relatively low price. Common carp is a benthivorous fish and its staple food diet is benthic invertebrates. Therefore, the present study aimed to evaluate the level of total mercury in sediments and benthos masses of Sanandaj Gheshlagh Reservoir, in order to evaluate the capability of benthic invertebrates to accumulate mercury and their ability to transfer the mercury up to the higher trophic levels during July to December 2009.

Materials and Methods

Sanandaj Gheshlagh Reservoir (35° 26' 58" N and 46° 59' 10" E) is located in Northeast of Sanandaj city, west of Iran. This Reservoir covers an area of approximately 8.5 km^2 and its actual water capacity is about 224 million m^3. Meanwhile, Gheshlagh Reservoir is the focal resource of drinkable water for the people whom dwelled in Sanandaj region and is the main source of fisheries activities and products in this region.

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Sediment and benthos samples were obtained using Ekman grab (20 by 20 cm in size) in three different sites with different depths and at least three replicates, during July to December 2009. Two sites with the depth of lower than 17 m were situated at the end of the two main river basins feeding the dam lake (i.e., Gheshlagh and Chehelgazi Rivers) and the third site was located in the main water body of the dam lake with variable depths of about 30 m. Sediment samples were preserved in mercury-free screw cap bottles and were stored in the temperature of 4ºC. Obtained benthos and sediment samples were passed through 250μ sieve. Benthic organisms were isolated from sediments using stereomicroscope with optical zoom of 20 and kept in 4% buffered formalin. Although this study aimed only to measure T-Hg in benthic invertebrate benthos masses, they have been identified in family and genus levels as well.

As methylmercury is a volatile compound, to prevent methylmercury volatilization, sediment and benthos samples were dried out for 24 hours in -54ºC by a Freeze drier (Operon, FDCF-12012). Fifty mg of each sample was grinded and the level of the total accumulated mercury in sediments and benthic samples was measured by Advanced Mercury Analyzer (Model; Leco 254 AMA) according to ASTM, D-6722 standard and on the ngg^{-1} dry weight basis.

Biota-Sediment Accumulation Factor (BSAF) was calculated based on the suggested equation by Szefer his colleagues (i.e., BSAF= Hg in benthos/Hg in associated sediment) in 1996. SPSS 16 software (*SPSS Inc., 2002*), SAS software (*Version 9.1 ref.*) and Excel (*Microsoft office 2007*) were used for statistical analysis as well as drawing relative graphs. Kolmogorov-Smirnov and Shapiro-wilk tests were considered to check data normality, which later was proved to be unnecessary. Randomizes Complete Block Design (RCBD) was used to compare the level of accumulated T-Hg in sediments and benthos biomass between different months and sites. Duncan test was used to compare the mean values with significant statistical difference. Paired T-test was used to compare the level of concentrated T-Hg in sediments and benthos. Pearson correlation was also used to show the correlation between T-Hg in sediments and benthos.

Results

The most abundant macrozoobenthos observed in the reservoir were mostly members of Oligochaeta sub-class and Tubificidae family. In summer, few numbers of Chironomidae family and Chironomus genus were also identified. Mean total mercury (± S.E.) concentration in benthos and sediment samples were 94.3±5.02 and 117.66±9.72 ngg^{-1}, respectively. The highest monthly mean concentration of accumulated mercury (171.7±28.82 ngg^{-1}) and the lowest monthly mean concentration of accumulated mercury in the sediment samples (91.93±13.3 $ng\ g^{-1}$) were detected in July and November, respectively. The highest monthly mean concentration of accumulated mercury (115.89±12.83 ngg^{-1}) and the lowest monthly mean concentration of accumulated mercury (79.11±6.22 ngg^{-1}) in benthos biomass were measured in August and October, respectively. Mean total mercury in benthos masses was not significantly different among sampling efforts ($F_{5,10}$=2.16, P=0.14), whereas the levels of total mercury in sediments were significantly different ($F_{5,10}$=4.88, P=0.02) amongst the sites. The mean values of accumulated mercury concentration in benthos biomass samples ($F_{2,10}$=5.37, P=0.03) and sediments ($F_{2,10}$=7.88, P=0.008) demonstrated significant differences among sampling sites. The highest mercury concentration in benthos biomass (110.69±11.83 ngg^{-1}) and in sediment (147.04±19.86 ngg^{-1}) was observed in the deeper site. Monthly mean values of the obtained benthos biomass were significantly different ($F_{5,10}$=4.55, P=0.02) among different months as well as different sites ($F_{2,10}$ = 4.55, P=0.01). Duncan test showed that the benthos biomass in November was significantly greater than that of other months. There were similar conditions for Chehelgazi River site. Wong, et al., (1996) method was followed to determine the potential transferable Hg from benthos trophic level to higher trophic level (i.e., Fish). Hg pools (ngm^{-2} dry weight) were estimated by multiplying Hg concentration (ngg^{-1} dry weight) and the mean benthic invertebrate biomass (gm^{-2} dry weight). Mean Hg pools with 95% confidence interval (in parentheses) for benthic invertebrate was 114.1 (79.61, 148.77) on the ngm^{-2} dry weight basis. The correlation between T-

Hg in benthos and associated sediments was significant (r = 0.528, P = 0.026). In general, T-Hg was higher in sediment samples compared with benthos samples based on the paired T-test (T=2.83, P=0.0116). All calculated BSAF in this study were lower than one.

Discussion of Result

Gheshlagh watershed runoffs carry soil from the watershed and add it to the SGR substrates. In freshwater ecosystems sediments are the main source of mercury pollution. Therefore, those organisms which live in sediments are subject to being polluted by this hazardous heavy metal. Benthic invertebrates are associated to the sediments via dietary needs or their habitat requirements. Oligochaetas members have been used frequently to indicate water quality and test sediment toxicity. A majority of oligochaetes members fed by ingesting sediment, extract nutrition from the organic matter particularly the bacteria. Organisms fed directly by sediments typically have higher overall mercury levels in comparison with those fed by the above sediment–water interface. Since benthos and sediments are appropriate indicators for measuring mercury pollution of SGR, the results of this study showed that the mean accumulated T-Hg in sediments and benthos biomass from SGR varies between summer and autumn months (P<0.05). High concentrations of the accumulated T-Hg in the sediment and benthos biomass samples in summer months could be due to the dissolved oxygen reduction in water column, reduction in water volume, physical, chemical and biological changes, increasing material deposition and higher water temperatures in summer. It has been proven that the rate of methylation process will be elevated during summer times in lenthic aquatic ecosystems. Results showed that the amounts of the accumulated T-Hg in the sediment and benthos biomass samples were higher in deeper sites in comparison with the shallower ones. This could be due to the dissolved oxygen reduction, decreasing the sun light absorption in the deep water, increasing the rate of anaerobic bacteria (sulfate-reducing bacteria) activities and increasing the bioavailability of mercury along with increasing the water depth. Similar results have been reported by other researchers. Despite the lower T-Hg accumulated in benthos samples collected in autumn, benthic invertebrate Hg pools were higher in autumn as a result of higher benthos biomass. Therefore it seems that benthivorous fish such as common carps, receive higher amounts of mercury in autumn which is the open season for fisheries activities in the region. Correlation between T-Hg in sediments and benthos was significant (P<0.05); which means that benthic mercury intakes are associated with the amount of mercury in sediments.

The calculated amount of BSAF in the present study was lower than one. This means that the capacity of benthos collected from SGR to accumulate mercury from sediments is not an important fact with respect to the accumulated T-Hg in their body. It has been assumed that the incapability of SGR benthic invertebrates in mercury bioaccumulation is related to the SGR substrates composition and texture, and the stage of benthos life cycle during this study as well as some specific physico-chemical characteristics of SGR that reduce the bioavailability of mercury for benthic invertebrate.

Conclusion

This study proved mercury contamination in benthic invertebrates and associated sediments in SGR. T-Hg in benthos and sediment in the summer months were higher than that in the autumn months. However, due to the higher benthos biomass in autumn, the rate of mercury transformations could be higher in this season (open season for fisheries). In this study all calculated BSAF values were lower than one. However, due to the mercury methylation by benthos and its biomagnifications capability, strong considerations have to be taken into account with respect to the consumption of SGR benthivorous fish. Thus, it needs more investigations.

Key words

Mercury, Bioaccumulation, Sediments, Benthic invertebrate, Sanandaj Gheshlagh Reservoir.