The Bioavailability and Evolution of Trace Metals in Environment: A Brief Review

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Abstract: As a kind of important pollutants, trace metals and the pollution have been become a concerned worldwide environmental problem. Despite the fact that the bioavailability of trace metals indicated by their speciation has been an indispensible parameter in the assessment and treatment of trace metal pollution, many studies suggest that the bioavailability of trace metals may change according to environmental conditions, and they can also transform between some speciation fractions. These transformations are related with factors such as the compositions, microorganism, time, and other physical-chemical conditions of the system. So, it is necessary to systematically understand and investigate for the factors to affect the transformation aside from analysis at certain time-place. The results of these understanding and investigations can be used for reasonably determining the allocation of financial and technical resources in natural and engineered processes with bringing about inspirations from the evolution of the speciation of the trace metals on environmental impacts.

Keywords: Trace metals, speciation, transformation.

1. INTRODUCTION

With the fast development of economy worldwide trace metals from large-scale industrial production and human life had been and are adding to ecosystems. The pollution of trace metals from rapid development has become one of the challenges to have to be faced by human today [1, 2]. In the study of trace metal pollution, either in natural or engineering systems, the speciation is a key parameter for assessment and treatment of the pollution [3-8].

Currently, the speciation data obtained at certain time-place conditions are used to assess the environmental impact for the trace metal pollution, especially used in soil and water sediment pollution research and engineering treatment. But the emphases of real effects of the transformation for the speciation of trace metals in environment seem relatively weak, and the significance of this transform in real environmental impacts are not well valued in practices. Although the research on the speciation of trace metals has been a basic work in the study of pollution problems, with understanding of this pollutant going deep and the analysis technique being advanced, the evolution that may affect metal's real bioavailability in inorganic systems and life entities should be taken into consideration to develop a counter plan for the pollution research and treatment [9-13].

Because of its serious impact on the biotoxicity, speciation of trace metals as a significant topic in the research of trace metal pollution has become an indispensable subject in metal pollution problems. The speciation of trace metals from certain analysis procedure is considered as a key parameter in the assessment of trace metal bioavailability and, accordingly, the prevention and remediation plan for the pollution is generally formed based on the level of this speciation parameter from the analysis [14, 15]. This has been viewed as an irreplaceable measurement for pollution assessment by not only scholars but also public and policymakers. However, as more and more facts show that the speciation of the trace metals is in evolution in environment, except the significance of the data on the speciation at certain time-space condition, it is paying attention to that the speciation is in variation with the physical and chemical condition change in the system [15-19].

2. OVERVIEW ON CASES OF THE SPECIATION EVOLUTION

2.1. The Cases on Water Sediment

It has been demonstrated by a lot of work in recent years that the speciation of trace metals changes with the changes of conditions of environment. The work from Laing *et al*. on the sediment of the Scheldt River, Europe showed that the speciation of the metals varied with conditions such as hydrological regime, organic matter, salinity etc. [20, 21]. The same facts from aqueous systems were demonstrated too by recent work from UK etc. [22-25]. Furthermore, studies relative to aqueous systems by García-Delgado *et al*.

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on cadmium in sewage sludge from Salamanca province, Spanish in 2007 [26], Wang *et al*. on metals in the sediment from rivers in 2012 [27], Scheckel *et al*. on silver and zinc by aqueous environmental experiments in 2010 [28], and Prica *et al*. on lead, cadmium etc. on some aqueous environmental media in 2010 [29] all suggested that the speciation change with environmental conditions and it is not always constant. The work from Masson *et al*. on Arsenic from the Garonne and Dordogne rives, France in 2007, Verschoor *et al*. on experimental research for copper, nickel, and Zinc in 2011 and Duman Fatih *et al*. on metals in Sapanca lake, Turkey in 2006 suggested that temperature may be a factor to affect metal speciation change in the system [30-32]. Also, reported by Catalano *et al*. respectively in 2010 and 2012, conditions such as pH value, plant feature in the aqueous environment may be factors to affect the variation of the speciation of trace metals [33].

2.2. The Case on Soil

A very interesting discussion about the bioavailability of trace metals was from Dr. Alexander in a review for Environmental Science and Technology in 2000 on crisis assessment of soil system, and the bioavailability of metals in metal environmental problems, and its variation nature in environment media were raised in his presentation, based on a lot of important discussions together with organic pollutants. And, in this review, it was first pointed out that pollutant bioavailability may be varied under different conditions in environment and the general understanding of pollutant bioavailability from instant analysis seems to be exaggerated compared with its real impacts in the ecosystem, thus causing a huge waste in treatment of the pollution [34]. The facts of metal availability change in soil system had also been demonstrated by the work on repeated phytoextraction test recently completed by Zhu *et al*. and the work on coastal soil completed by Zheng *et al*. in 2016 [35, 36].

2.3. The Factors in the Speciation Evolution of Trace Metals

The speciation change of trace metals with the condition varyinged in environment has been revealed from work on water and sediments from Asia [37-40]. Components of the system, the concentration of the trace metals in the system, the time of the trace metal reacting with other matters in the system, and other physical-chemical conditions such as the value of pH, Eh etc. may all be factors to affect speciation change in the system of soil, water, and other media such as fly ash of coal [41-43]. Some researchers have found that the sulfate can significantly affect the release of metals such as Ag, Cu etc. in the systems, especially under water-flooding conditions [44-47]. The speciation of the Zn in sediment may be very in different under different features of porewater and overlying water of the sediment [48]. The change of the speciation of trace metals (Cr, Cu, Pb, Zn, and Cd) can be induced to occur from the variation of the physical-chemical parameters of the system such as adding chlorinating agent or drying, revealed by some engineering treatment for sewage sludge and refuse landfill [49-51, 31]. It can be different in different kinds of soils for the speciation of the trace metals to change under same environmental conditions [52, 53].

Excepting these research findings, there are work to suggest to assess the bioavailability of trace metals using the feature of rare earth elements (REE) fractionation, the variation of soil enzyme activities (IR/reduced partition index), and delayed geochemical hazard model (DGH), based respectively on the differences in ionic radius, oxidation statuse and bonding of the rare earth elements (REE) drive fractionation of these elements in natural systems and the closed relationship between metal release and the soil enzyme activities or mechanism of chain reaction (Hg) [54-57].

Recently, the work on the sediment of the Dianshan lake, Shanghai showed the change and transform of the trace metal speciation within fractions of the speciation of the metals, and it was found by the Pollutant Behavior Chemistry Group, Shanghai Jiaotong University that the transformations of the speciation of metals defined and analyzed with BCR sequential extraction procedure might occur respectively between water and acid soluble fraction and reducible fraction, oxidisable fraction and residual fraction, and oxidisable fraction and reducible fraction etc. (Figure **1**).

The studies mentioned above suggested that the variation of speciation of trace metals requires to be understood and be considered in not only researches but also treatment. Although it has been concerned by many scholars, much more work on this field should be done since it has become a current cutting-edge problem in trace metal pollution research and treatment. Because of the importance of the speciation and the speciation transformation of trace metals in metal environmental problems, based on the facts

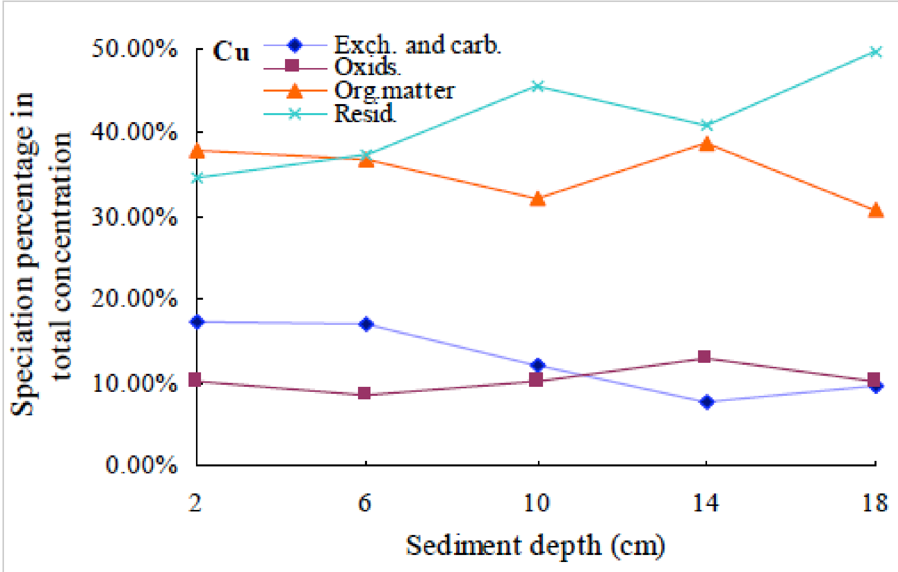

Figure 1: The relationship of the trace metal speciation in the sediment of the Dianshan Lake, Shanghai.

reviewed here if only the data of speciation of trace metals from instant sample were used to evaluate the pollution, it will cause unreasonable disposition for resources and funds, by ignoring the speciation transformation nature in systems.

3. SUMMARY

In general, the issue of speciation of trace metals, the understanding of speciation and its transformation is very important to offer significant references more objectively for comprehending and assessing the real impact of trace metal pollution in environment. The condition and effects of the speciation transformation of trace metals in environment should be emphasized to understand, assess, and treat impersonally and effectively as well as speciation data on the samples from certain time or site should be valued. Now, the issue on metal speciation and bioavailability is being paid more and more attention by scientists, and hope it will be made a point of doing this by policymakers too.

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