学 位 論 文 内 容 の 要 旨

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学 位 論 文 題 名

Phytofiltration of arsenic and cadmium from the water environment using *Micranthemum umbrosum*

（*Micranthemum umbrosum* を用いた水圏環境よりのヒ素及びカドミウムの浄化）

Heavy metals pollution in aquatic environment due to natural sources and anthropogenic activities, is posing a dreadful threat to the human health. Among different heavy metals, arsenic (As) and cadmium (Cd) are the two most toxic and carcinogenic agent that extensively contaminates the water bodies. More than 300 µg As L-1 and 30 µg Cd L-1 has already been detected in water whereas World Health Organization and United States Environmental Protection Agency have settled 10 µg As L^{-1} and 3 µg Cd L^{-1} of water as a drinking water standard, that is 30 and 10 times higher As and Cd than that of recommendation limit already exist in aquatic environment and thus remediation of these contaminants is an important global issue.

There are some physical and chemical remediation methods that have some limitations like high production technology, costly, destruction of native micro flora and fauna, and creation of secondary pollutions. In contrast, phytofiltration is a novel, cost effective, environmental friendly, aesthetic and solar-driven technology, using aquatic plants to remove As and Cd from contaminated water without causing any or little secondary pollution. A small number of aquatic plants were identified to uptake contaminants from aquatic environment. Among them very few could accumulate more than one pollutant in their bodies. *Micranthemum umbrosum* (J.F. Gmel) S.F. Blake, commonly known as Water fern, Baby's tears, or Pearl grass, belongs to the family Linderniaceae, is one of them, that can significantly absorbed both As and Cd from contaminated water.

After culturing *M. umbrosum* for 7 days in a hydroponic experiment, the accumulation of about 1,220 µg As g^{-1} and 800 µg Cd g^{-1} were observed in the leaves, from 1,000 µg As L^{-1} and 1,000 µg Cd L^{-1} of water, respectively and it can removed 79.3–89.5% As and 60-73.1% Cd from 200 to 1,000 µg As L^{-1} and 300 to 3,000 µg Cd L^{-1} solutions, respectively. Plant and water samples were analyzed for assessing the As and Cd accumulations, translocations, phytotoxic effects, uptake mechanisms and kinetics, and for evaluating the potential of *M. umbrosum* as As and Cd phytofiltrator.

For As treatment, root to stem and stem to leaf translocation factors greater than 1.0 indicated that accumulation of As in leaves was large compared to that in stem and roots but there are little differences in accumulation of Cd in roots, leaves and stem. It is easy to clean up aquatic environment rather than soil due

to most of the soil phytoremediators accumulated contaminants in their root parts which is sometimes very difficult to harvest and removal from the contaminated soil environment. However, the absorption pattern of As and Cd within *M. umbrosum* was leaf > stem > root. Bio-concentration factors (2,350 for As and 3,027 for Cd) for *M. umbrosum* were higher than for other As and Cd phytoremediators, indicates its hyperaccumulation of As and Cd from contaminated water environment. The analysis of different photosynthetic pigments and macro micro-nutrient concentration within plant body indicated that the plant showed more resistance to internal and external As concentrations than to that of Cd.

Absorption uptake kinetics within *M. umbrosum* was studied by using Michaelis Menten equation from different As species like arsenite, monomethylarsinic acid (MMAA), dimethylarsinic acid (DMAA) and Cd. The uptake of inorganic As species was much greater than that of organic As and was found at above the substrate concentration. Concentration dependent arsenite and Cd uptake influx were linear up to 500 μg L^{-1} and after that decreased, probably due to the toxicological inhibition. However, Cd showed similar uptake pattern to that of inorganic As species, and the data was better fitted to a non-linear than a linear model. Higher V_{max} and lower K_m value indicated that this plant has high affinity to uptake inorganic arsenite than Cd, organic MMAA and DMAA; and the uptake order was inorganic arsenite > Cd > MMAA > DMAA.

As and Cd uptake mechanism within *M. umbrosum* was investigated by using Gel chromatography column made from Sephadex G-50 (fractionation range is about 1,500-30,000 MW) and Sephadex G-15 (fractionation range is about 700-1,500 MW) beads. After analysis of As, Cd, protein and thiol contents in each 2 mL fractionation collected from gel filtration column, we concluded that As within plants appeared to involve an induction of thiol synthesis or binding with low molecular weight substances that have thiol group(s) whereas Cd showed a different mechanism to that of As. Amino acid profile studied also showed that Cd uptaking mechanism and binding substances in *M. umbrosum* is different from algae and other plants which is not phytochelatin or thiol complex formation.

M. umbrosum showed good As phytofiltration capabilities without any phytotoxic effects, but it was found to be a moderate accumulator of Cd with some phytotoxic effect and it can lower the As toxicity to a level (about 25 μg As L^{-1}) close to the limit recommended by the World Health Organization (10 μg As L^{-1}) but below the limit recommended by Bangladesh and China Government (50 μg As L^{-1}). So *M. umbrosum* has the high As and Cd phytofiltration potency at low level (500 μg L^{-1}) As and Cd contaminated water and it can be used as ornamentation for room in addition to As and Cd accumulation from water, as it is popular as a green aquarium plant, from the aesthetic point of view of phytoremediation.