

論文の内容の要旨

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論文題目

Studies on the accumulation of trace metals in tropical anguillid eels from Vietnam (ベトナムにおける熱帯ウナギの微量金属蓄積に関する研究)

Vietnam is an agricultural based country which has a very strategic position at the center of the Southeast Asian region. The usage of chemicals for agriculture was extensive in the past and has remained until very recently. In the last decade, furthermore, the rapid domestic growth and industrialization since the introduction of the renovation policy in 1986 have caused serious environmental pollution as the results of increase in industrial and municipal waste. The discharge of wastewater from human activities inputted to rivers and coastal areas have severely impacted on aquatic systems in many places for recent years. Among pollutants, trace metals are great concern because of their toxicity, persistence and prevalence. Although environmental monitoring systems to assess the water system quality in Vietnam have been done since 1990s, the systems are still under development and merely monitor the water systems along the coastal areas. A lack of advanced studies examines the effects of contamination by toxic chemicals to aquatic organisms, especially fish species. As a consequence, pollutants discharged in the aquatic environment are likely to accumulate in fish and represent a potential risk not only to the fish, but also to other fish consumers, particularly humans.

Catadromous eels, widely distributes throughout the world, are one of the top predator in freshwater ecosystems and they are abundant in Vietnam. The anguillid eels are also commercial fishes for both

local consumption and international trade in Vietnam. Due to the long-life cycle and the specific biological and ecological features of anguillid eels, they are vulnerable to adverse impacts from nature and human activities. Therefore, the eel populations have declined dramatically in recent years and the causes are attributed to over-fishing, construction, climate change, other environmental factors, especially environmental pollution. Otherwise, a little information available for using tropical eels as bio-indicator in Asian countries including Vietnam though anguillid eels are abundant in aquatic system of the countries.

Therefore, in the present study, trace metal accumulation in tropical anguillid eels are examined, which is important first step to understand the mechanism of trace metal accumulations in the tropical anguillid eels and to determine whether anguillid eels can be used as bioindicator or biomonitor in aquatic system in Vietnam as well.

Firstly, the study investigated the accumulation of trace metals in sediment of the rivers from central part of Vietnam in order to assess environmental quality. The concentrations of 10 trace metals in surface sediments of the Ba River and Thach Han River were examined. The Mn levels were the most abundant metal in the sediment, followed by Zn, V, Cr, Sr, Pb, Cu and Co. The lowest levels were found to be Cd and Hg. While the concentrations of trace metals in the sediment did not vary among sites in the Ba River, excepted for Sr, the metal levels in the sediment, however, differed among sites in Thach Han River. The high levels of V, Cr, Cu, Cd Pb and Co observed in upper part of the Thach Han River might result from anthropogenic sources. In contrast, trace metal levels in the Ba River might originate from the natural environment. Although the mean levels of Cd, Cu, Zn and Pb in Thach Han River were higher than those in Ba River, the level of V, Cr, Mn, Co and Sr in the Thach Han River were slightly lower than those in the Ba River. The metal concentrations in sediment from both rivers were comparable with the Environmental Protection Agency (EPA) criteria and background concentration, except for Mn, Zn and Pb in sediment, these trace metal levels, however, do not show the probable effect levels to aquatic environment.

Secondly, the study investigated the distribution of trace metal accumulation in various organs of

the maturing eel *Anguilla marmorata* from the Ba River to understand the target organs for metal accumulation and metabolism. The results indicated that the liver and kidney were dominant organs for almost all trace metals, whereas muscle tended to highly accumulate Hg and approximately 87.4-100% of Hg was methylmercury. Interestingly, a strict link of metal accumulations between liver and gonad related to the Zn levels in these organs and the elevated Cd burden in gonad suggest that hepatic trace metals, both essential and nonessential, can transfer to gonad during gonadal maturation. Though almost none of the metal concentrations in the muscle exceeded the reference doses (RfDo) of the U.S.EPA (2008), approximately 80% of the eels from the river contained mercury exceeding the recommended levels (0.30 µg/g) of the U.S.EPA, and might present a risk for human consumption.

Thirdly, in order to understand the present status of trace metal contamination and the risk associated with human consumption, commercial freshwater eels in Vietnam were examined. The concentration of ten elements (V, Cr, Mn, Co, Cu, Zn, Sr, Cd, Pb, and Hg) was determined in muscle and liver tissues of tropical eel *Anguilla marmorata* collected from four provinces, Quang Tri (QT), Quang Ngai (QN), Binh Dinh (BD), and Phu Yen (PY), in the central part of Vietnam. The results indicated that both muscle and liver tissues reflected the higher potential metal pollution in QT when compared to other sites. Hg levels in muscle significantly correlated to body size. None or negative relationships between other trace metal levels in muscle and body sizes existed, which likely related to somatic growth dilution. Additionally, the maximum metal levels in the muscle of the yellow eel were found to be far below RfDo guideline values of U.S.EPA for human consumption. Thus, the muscle tissue of yellow eel from the central part of Vietnam may not currently cause any serious health risk for human consumption.

Fourthly, whether metal accumulations relates to the maturity stages of tropical anguillid eels, *Anguilla marmorata* and *A. bicolor pacifica*, was examined. The level of nine trace metals in liver and muscle were determined in both yellow and silver stages of the eels. The results indicated that the elevated levels of essential metal of Zn in tissues of both species related to the maturation of anguillid eels. The levels of other essential metals such as Cr, Co, Mn and Cu accumulated in silver eels were

higher than those in yellow eels but the differences were depended on the organ tissues and the species. Nonessential metals such as Cd and Pb in tissues exposed no significant difference between maturity stages of eels. Although two species resided in the same river, the Hg levels in *A. marmorata* found to be higher than that in *A. bicolor*. The difference seems to be caused by the difference in the food items between the two species rather than ambient environment.

Finally, in order to understand whether the metal concentrations in eels are related to migratory types using Japanese eel *Anguilla japonica* as a substitute for tropical eel. Nine elements were analyzed in the livers of three migratory types of the eels collected from Tokushima Prefecture (south Japan). Japanese eels were collected from two sites of the Katsuura River; the upper reach and the estuary 1-2 km from the river mouth. The eels (silver stage) were also collected from Kii Channel. Three migratory types of silver eels were classified by examining the Sr:Ca ratio in otoliths. All types were found 'sea eels', 'estuarine eels', and 'river eels' from the channel, whereas only 'river eels' in the two sites of the river. The results showed that there were significant differences in V, Cr, Cd, and Pb concentrations among the migratory types. Maturing silver sea-eels show a higher risk of metal accumulation than other types of eels, and the concentrations of Mn, Cu, and Zn in maturing eels were significantly higher than those in immature eels. Furthermore, finding of correlations between metal accumulations and otolith Sr:Ca ratios suggested that the sea eels seem to be higher potential risk of metal pollution than other migratory types of eels. Therefore, the study suggests that migratory types of anguillid eels can be considered as a useful tool to aid the interpretation of metal pollution in fresh, brackish and coastal waters.

Hence, the findings in this study provide the useful information on trace metal accumulations in anguillid eels, which are considered to be good indicators to assess water system quality in Vietnam and other tropical countries where the eel distributes as well.