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論文題目	Risk assessment of heavy metal contamination concerning residents living in the vicinity of the Cho Dien lead/zinc mine, Vietnam (ベトナム、チョディエン鉛／亜鉛鉱山近傍居住者に関する重金属汚染のリスクアセスメント)		
（論文内容の要旨） Chapter 1 provides the rational, structure of the thesis and the objectives to be achieved, and how to get the expectation results. Since mining activities has posed a potential public health risk and environmental concern from previous studies and based on current information on mining activities, environmental status and health situation of residents in the mining site, Cho Dien mine in Vietnam was selected as a target area of the research. Main objectives of this study were: (1) to investigate occurrence situation and identify the sources of As and heavy metals; (2) to determine the accumulation of metals (Pb, Cd, Ca, Zn) in the residents’ hair and to examine how ages, environmental factors, sex, and life style influenced metals exposure; (3) to develop the environmental transport model (ETM) and physiologically based pharmacokinetic model (PBPK) to estimate the pollution level of Pb in the environment and risk level of human health; and (4) to propose the mitigation options for reducing the risk of human health by Pb contamination. Chapter 2 provides literature review of Pb and Cd related to the contents of the thesis, including their properties, their regulation, effects on human body, occurrence in environment and human body. Chapter 3 investigates occurrence situation of Arsenic and heavy metals in environmental samples, and recognizes the sources of those elements. This chapter found that soil, drinking water, surface water and vegetables in Cho Dien mine were polluted by As and heavy metals, especially by Pb element. Lead content in drinking water and surface water exceeded the Vietnamese standards of 10 µg/L and 50 µg/L at 45% and 40% of sampling locations. The results also investigated the potential accumulation of As and heavy metals in soils of the mining sites. Major pollution sources derived from mining activities and tailings dam in the mining site. In addition, the results pointed out that residents living around the mining site are suffering a significant potential health risks by intake of Pb and Cd via consumption of vegetables. Chapter 4 determines the accumulation of metals (Pb, Cd, Ca, Zn) in the residents’ hair, examines how ages, environmental factors, sex, and life style influenced metals exposure, and identifies determinant factors in lead exposure of residents’ hair at the mining site. The results of this chapter showed that Pb content in hair was very high and influenced by factors such as gender, age and environmental pollution. Lead in soil had strong relationship with lead in hair ($r = 0.81$) and was the most determinantly influenced on lead in hair of inhabitants. The results also found that lead in hair of children in Cho Dien mine was much higher than previous studies, exceeded 6.61 times the Recommended Maximum Level (30 µg/g) at 2-6 years old. In addition, 66% of the total samples had hair lead levels higher than recommended value and 14.6% higher than dangerous level (110 µg/g). The results showed that the residents living in and around lead/zinc mine may be exposed by Pb contamination. Health of residents in Cho Dien mine might be threaten by lead contamination from mining operations. Chapter 5 develops the environmental transport model in order to estimate the pollution levels of Pb in environmental media and assesses the health risk of individuals residing around the Cho Dien mine,. In this chapter the mass balance was developed with the first was described how lead transfer in the			

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environment in the period 1990-2030 and then applied to calculate daily intake of human due to vegetable ingestion. The results figured that with using streams water for irrigation contained lead from mining operations, the inhabitants living in the mining sites will suffer health effects from 2020 through vegetable consumption. Lead concentrations in soil and vegetables increased significantly in the period from 1990-2030 when emissions from mining activities into soil was 1.148 tons/year. The modeled results also indicated that Pb concentrations in soil exceeded the environmental standards 6.2, 9.0 and 11.9 times in 2010, 2020 and 2030, respectively. On the other hand, the daily intake of Pb from the different pathways: from drinking water, soil and vegetable ingestion were investigated, showing that, due to the impact of mining activities, lead levels in vegetables has increased significantly by years. Hazard quotient of Pb by three pathways exposure was higher than 1 from 2020. As a consequence, the impact of Pb contamination has seriously affected on human health in the mining sites. Chapter 6 evaluates the kinetic behavior of lead within human body based on exposure pathway routes, and estimates the internal dose of lead in human body at the mining site. The model estimated blood lead levels (BLLs) of two subjects: an adult with a body weight of 55.6 kg and a 2 years old child with that of 9.5 kg. BLLs were estimated through 20 years exposure to lead for adult and 10 years exposure for children through oral intake: vegetables, drinking water, and soil ingestion. The results showed that the highest contribution to BLLs in children and adult was via daily consumption of local vegetables (accounting 84.5% and 85.1%), then drinking water ingestion (12.4% and 7.86%), and soil ingestion (3.1% and 6.97%) respectively. BLLs calculated through drinking water and soil ingestion below the control level (10µg/dl) set by WHO. Vegetable consumption had a dominant contribution in increasing BLLs, higher than control level 5.13 times after 20 years exposure for adults and 4.25 times for children after 10 years exposure. In order to reach reduction target for BLLs of residents living in the mining site at 10 µg/dl, four scenarios have been considered for both adult and children. The modelled results showed that, the best way for keeping BLLs of residents by the control level at 2020 is that the people should avoid eating vegetables grown in lead contaminated areas. Chapter 7 is for conclusion and recommendation. This research archived its main objectives: (1) investigating occurrence situation and identifying the sources of As and heavy metals; (2) determining metals accumulation in the residents' hair and examining how ages, environmental factors, sex, and life style influenced metals exposure; (3) estimating the pollution level of Pb in the environment and risk level of human health; and (4) proposing the mitigation options for reducing the risk of human health by Pb contamination. In addition, the findings will help the government carrying out the appropriate policies in order to mitigate the effects to human health in the studied sites. Moreover, the results will provide very good data for future directions. Besides, the appropriate recommendations have been made to local governments and residents at the mining areas.			

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(論文審査の結果の要旨)

本論文は、ベトナムの Cho Dien 鉛／亜鉛鉱山の影響を受けている地域を対象として、各種重金属などの環境動態と、体内動態モデルを用いてそこに住む住民の将来におけるリスク評価を行う手法を確立したものであり、さらにその手法を利用して対象となる住民らの健康リスクを低減するための政策を決定する方法を提供するものである。得られた主な成果は以下のとおりである。

1. 環境調査により、精錬所や鉱滓ダムに近いほど、土壌、水、野菜などが鉛などの重金属で汚染されていること、そして付近住民らの髪の毛中の重金属濃度がその汚染度に対応していることを示した。その結果、特に鉛とカドミウムの曝露量の指標として、髪の毛中重金属濃度が有効であることを示した。

2. 重金属の環境中移行モデル(ETM)、住民の生活モデル、そして人体中移行モデル(PBPKモデル)を連立して解くことにより、環境への重金属のインプットや蓄積から年齢や性別の違いも考慮して人体の標的器官中濃度をシミュレートする手法を開発した。その結果、Cho Dien 鉛／亜鉛鉱山からの重金属汚染の影響による付近住民の年齢別生体汚染状況を再現することに成功し、その汚染状況が土壌の汚染状況に大きく影響を受け、汚染野菜の摂取が最大の曝露経路であることを明らかにした。

3. 本研究で確立した手法を用いて、この地域の住民の血中鉛濃度を大人と子供それぞれについて、基準値以下に維持するための政策について検討した。その結果、汚染地域の野菜を摂取しないなどの規制を行うことにより、大人も子供も含めたこの付近住民の血中鉛濃度を WHO の基準以下に保つことができることを示した。

以上のように本論文は、重金属の地域規模での移動から人体中の組織レベルの移動までを総合してモデル化する方法を提案するものであり、人体への健康影響を指標とした重金属環境汚染のリスク評価手法確立に大きく貢献するものであって、学術上、実際上寄与するところが少なくない。よって、本論文は博士(工学)の学位論文として価値あるものと認める。また、平成24年8月23日、論文内容とそれに関連した事項について試問を行って、申請者が博士後期課程学位取得基準を満たしていることを確認し、合格と認めた。