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学位論文名	パキスタン・イスラム共和国の都市農村部住民の鉛とヒ素曝露
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論文内容の要旨

1　研究目的

Lead (Pb) and arsenic (As) are among the top ten (10) chemicals of major public health concern worldwide which accrue death and disabilities. Pb causes 0.6% of global burden of disease leading to 143,000 deaths and 600,000 intellectual disabilities, mainly among young children of low- and middle-income countries. Pb is a man-made hazard pervasively present in the environment. Gasoline is the primary source of Pb. The control of Pb in primary source has increased the importance of secondary sources of Pb exposure globally including food, house dust and soil.

While As occurs naturally in earth crust (a natural hazard) and most of the exposure to population occurs through drinking groundwater. An estimated 140 million people are exposed to As above 10 ppb globally. The long-term exposure to As lead to development of cancers of liver, lung and bladder. The As is also associated with hypertension, diabetes, cognitive disabilities among children and adverse pregnancy outcomes such as abortion and premature births. The most frequent and typical adverse effects of arsenic appear as pigmentation of unexposed areas of the skin and the symmetrical hardening (hyperkeratosis) of palms of soles. The adverse health effects of As is still evolving and it may affect all organ and systems of the body.

Although Pb has been controlled in gasoline (primary source) in Pakistan since 2001, there has been consistent reports of exposure to Pb and high blood lead levels among vulnerable population (pregnant women, newborn and children), particularly urban population in Pakistan. One of the recent studies conducted in 2008 in the heart of the city of Karachi (megacity) reported that about 90% of newborn's cord blood had levels of Pb above 5 μg/dl. In scenarios where primary sources of exposure are controlled, the secondary sources such as food, dust and soil becomes more important source of exposure for several decades. Thus, there was a need to investigate the secondary sources of Pb exposure among the urban

population of Pakistan.

Similarly, several studies have reported presence of As in groundwater along Indus river in Pakistan. Previous studies had shown low prevalence of arsenic skin lesions among population exposed to As. However, the policy makers were not convinced about the health burden of As in Pakistan. Therefore, I carried out an investigation of health burden of As in high exposed areas along River Indus to estimate the As associated health burden among these population.

I, therefore, conducted a health exposure assessment of Pb and As in urban and rural areas among the vulnerable population of Pakistan. In this respect, I present three linked studies.

2　研究方法

The first study was carried out to identify the main sources of exposure to Pb among pregnant women, newborn and young children in an urban area (Karachi), Pakistan. The study assessed the Pb intake of pregnant women, newborn and one-to- three-year-old children from secondary sources including food, water, house dust, respirable dust, and soil around the house. We collected three-days food duplicates for the pregnant women and 1-3-year-old child from the same households. The exposure of Pb through cooking utensils were also tested. The house dust was collected using vacuum cleaners and the respirable dust. The inductive coupled plasma mass spectrometry (ICP-MS) was conducted to determine the Pb levels in food, water and blood samples. Energy dispersive x-ray fluorescence (EDXRF) method was used to determine Pb in house dust and respirable dust. We also conducted fingerprinting of the Pb isotopic ratios (LIR) of gasoline and secondary sources including food, house-dust, respirable dust, soil, surma (eye cosmetics) of exposure in the blood of pregnant women, newborns (cord blood), and children.

The eye cosmetics (surma) was considered a major source of exposure to Pb among the women and children in Pakistan. The second study determined the Pb levels in nails of rural women and possible contamination from external sources.

Previous studies have reported the presence of As in groundwater and associated health effects. However, these studies were not able to convince policy makers regarding the health burden of As among the population. One of the reason was that the study showed low prevalence of arsenic skin lesions, as the areas surveyed were both affected and non-affected by As. Therefore, the third study was conducted to determine the adverse health effects (typical arsenic skin lesions – pigmentation in unexposed areas and symmetrical hardening of palms and soles) among a population highly exposed (in villages within 18 km of the river as identified by previous study) to As through groundwater in rural areas along river Indus in Pakistan.

3　研究成果

The first study found that the main sources of exposure to Pb for children were food and house-dust, and those for pregnant women were　respirable dust and food. The LIR results suggests the same that food, house-dust, respirable dust are the main sources of exposure for blood lead levels. However, the LIR of surma and also gasoline was distinct from blood and have little contribution to blood lead levels.

The second study identified that surma was a potential external source of contamination for a commonly used biomarker of Pb i.e. nails. Of the 84 nail samples, 13 had Pb levels above which survival of human were not possible. The LIR of these nails showed that it had similarity to LIR of surma. Therefore, nails may not be suitable a biomarker in environments such as Pakistan where surma use is common.

The third study found higher prevalence of skin lesions among population exposed to high levels of As in the villages along river Indus. About 90% population in these villages were drinking water above 100ppb. The prevalence of skin lesions among population exposed to As 100ppb and above were between 12 to 14%.

5　考察

Overall, findings of my studies suggested that urban women and children are exposed to high levels of Pb through secondary sources including food, house-dust and respirable dust. Also, the use of eye cosmetics makes nail biomarker ineffective in determining exposure levels in such scenarios as they may also be externally contaminated. The rural population living along river Indus are exposed to naturally occurring As through groundwater and have high prevalence of adverse arsenic skin health effects.

5　結論

Therefore, regular monitoring of Pb in secondary sources is required. The simple measures of regular wet-mopping of living rooms may reduce the exposure to Pb. Furthermore, the food production, processing, and packaging needs to be monitored to identify the sources of exposure of Pb. Arsenic (As) in groundwater along river Indus require strategies such as switching of wells. The groundwater handpumps along River Indus have safe and unsafe wells lying usually close to each other. Population need to be made aware about the hazards of As and safe handpumps need to identified for safe use of drinking water. About 13 to 15 million people live along the length of River Indus within the high risk zones where As in groundwater is above 100 ppb. Thus, immediate measures need to be undertaken to protect these populations from hazards of As.

論文審査の結果の要旨

パキスタンにおける人（1〜3 歳の小児と妊婦）への鉛曝露を幾つかの手法を用い、研究した。血液、臍帯血、食物、飲料水、ハウスダスト、空気中の埃、土、ガソリン、スルマ（surma、化粧品である）の鉛濃度を測定した。この研究の新規性として Lead Isotope Ratio (LIR：LIR207/206 と LIR 208/207 を測定)を各検体で測定し、生体から検出される鉛、生体外の試料から検出される鉛の関係性について検討している。結果として、食物、ハウスダストは小児への鉛曝露に関係し、食物、空気中の埃、ハウスダストは妊婦への鉛曝露に関係していることを明らかにした。湿ったモップで床掃除することで曝露を防ぐことが可能と推測している。

また、鉛を含有するスルマを使用する女性の爪の分析により、生体への鉛曝露を推測できるかを検討したが、爪は鉛曝露を調べるための試料としては不適という結論を得た。

更なる研究として、ヒ素中毒の研究を行った。インダス川流域では自然由来のヒ素が検出される。流域の 707 カ所の井戸水のヒ素濃度、住民のヒ素中毒による皮膚病変を調査した。534 人の住民のうち 490 人（91.8%）は 100 ppb 以上のヒ素を含有する水を飲料水としていた。この結果は国の政策にはまだ反映されていないものの、重要な提言となる可能性がある。

提出された論文には幾つかの修正が必要であった。指摘後に適切に修正がなされた。

本論文は、パキスタンにおける鉛、ヒ素の曝露に関して、複数の視点から調査、研究されたものである。学術的、社会的にも重要な知見を示している。合格と判断する。

試問の結果の要旨

パキスタンにおける人（1〜3 歳の小児と妊婦）への鉛曝露を幾つかの手法を用い、研究した。血液、臍帯血、食物、飲料水、ハウスダスト、空気中の埃、土、ガソリン、スルマ（surma、化粧品）の鉛濃度を測定した。この研究の新規性として Lead Isotope Ratio (LIR： LIR207/206 と LIR 208/207 を測定)を各検体で測定し、生体から検出される鉛、生体外の試料から検出される鉛の関係性について検討している。結果として、食物、ハウスダストは小児への鉛曝露に関係し、食物、空気中の埃、ハウスダストは妊婦への鉛曝露に関係していることを明らかにした。湿ったモップで床掃除することで曝露を防ぐことが可能と推測している。

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過去の論文では飲料水が鉛暴露の原因と報告されているが、今回の研究では飲料水は有意な暴露原因ではなかった。それは何故か聞いたところ、既報の論文の研究手法に関係するのではということであった。

上記より試問は合格と判断する。尚、提出された論文には幾つかの修正が必要であったが、適切に修正がなされた。