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Heavy Metals Toxicity Among Thai People

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Abstract:

Industrialization has brought about numerous societal benefits but also significant environmental challenges, including heavy metal contamination. Heavy metals, such as lead, mercury, cadmium, and arsenic, enter the environment through industrial activities, posing serious health risks. This article reviews the current situation of heavy metal exposure globally, with a focus on Thailand. It discusses the contamination of soils, rice, and grains with heavy metals, emphasizing their impact on human health. Additionally, the article highlights the health effects of heavy metal exposure, including organ toxicities, genetic alterations, and carcinogenesis. Gender-specific vulnerabilities and the effects on children and adults are explored. The article concludes by providing practical recommendations to avoid heavy metal contamination, such as safe drinking water practices, proper food handling, and minimizing exposure to environmental sources. Overall, addressing heavy metal contamination is crucial for safeguarding public health and the environment.

Keywords **—heavy metal, contamination, health impacts**

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Introduction

The advancement of industrialization has brought about numerous benefits to society, including technological progress, economic growth, and improved living standards. However, this progress has also led to various environmental challenges, including pollution and heavy metal contamination.[1]

Industrial processes often involve the burning of fossil fuels, such as coal, oil, and natural gas, for energy. These activities release pollutants like sulfur dioxide, nitrogen oxides, and particulate matter into the atmosphere. These pollutants can combine with water vapor to form acid rain, which can carry heavy metals from the atmosphere to the ground, further contaminating soil and water bodies. As industries produce goods, they generate waste materials, including hazardous wastes containing heavy metals. If not properly managed and disposed of, these wastes can seep into soil and groundwater, contaminating ecosystems and potentially entering the food chain.[2]

From past studies, it has been found that heavy metals have been deposited and contaminated in the environment. Industrial activities contribute to the release of various heavy metals into the environment, leading to contamination of air, soil, water, and ecosystems. Some of the heavy metals commonly found in the environment due to industrial activity include: Lead (Pb): Mercury (Hg): Cadmium (Cd): Arsenic (As):

Chromium (Cr): Nickel (Ni): Zinc (Zn): Copper (Cu): Antimony (Sb): Vanadium (V): Beryllium (Be) [3,4]

Heavy metal contamination in the environment can have serious adverse effects on human health, as these toxic elements can accumulate in the body over time. The extent of harm depends on the specific heavy metal, its concentration, the duration of exposure, and individual susceptibility. Heavy metal contamination can harm human health: Neurological Effects: Cancer, Kidney Damage, Cardiovascular Effects, Respiratory Issues, Gastrointestinal Problems,Developmental and Reproductive Effects, Immunotoxicity, Skin and Dermatological Issues, Endocrine Disruption, DNA Damage, Bone and Joint Issues, Hematological Effects [3,5,6,7]

This article assesses the present status of worldwide heavy metal exposure, specifically emphasizing Thailand, and underscores the health consequences associated with heavy metal exposure while offering actionable advice for preventing heavy metal pollution.

Current situation of heavy metals exposure in worldwide and in Thailand

Since there is an escalating trend of population expansion and demand for rice consumption, an increase in the number of using pesticides and chemical fertilizers for agriculture, coupled with human activities such as mining and smelting, may influence the level of heavy metals contamination in soils including cadmium (Cd), arsenic (As), and lead (Pb), which have been identified as the most widespread metals in rice cultivation [1].

In the United States (US), there were growing concentrations of toxic and essential elements in rice and other grains (barleys, beans, oats, wheat, and peas). The study in US showed that median concentrations (in mg/kg) for toxic elements in white rice from Thailand were 155 x 10^{-3}, 3.6 x 10^{-3}, and 8.4 x 10^{-3} for arsenic (As), lead (Pb), and cadmium (Cd), respectively, while white rice from the US showed median toxic elements concentrations (in mg/kg) of 131 x 10^{-3} (As), 2.8 x 10^{-3} (Pb), and 6.5 x 10^{-3} (Cd), which were lower than the white rice from Thailand. On the other hand, brown rice has a germ layer that retains greater amounts of inorganic As and contains an outer layer, which accumulates metals more easily, brown rice from the US showed median concentrations (in mg/kg) of 217 x 10^{-3} for As, 4.5 x 10^{-3} for Pb, and 17.4 x 10^{-3} for Cd, while Thailand grains showed median concentrations (in µg/kg) of 5.4 x 10^{-3}, 4.6 x 10^{-3}, and 6.7 x 10^{-3} for these elements, respectively [3].

Even though Pb and Cd concentrations did not exceed the codex standards, As concentrations in brown rice and one white rice from the US exceeded the codex standards [3]. Moreover, the study of 180 samples of polished and brown rice of three rice types, namely white, jasmine, and sticky, and 44 samples of rice bran from these three rice types, which were purchased in Thailand revealed that concentrations (expressed in nanograms per gram) of inorganic arsenic in polished white, jasmine, and sticky rice were 68.3 ± 17.6 (with a range of 45.0 to 106), 68.4 ± 15.6 (41.7 to 101), and 75.9 ± 24.8 (43.5 to 156), respectively, while those in the three brown rice samples were 124 ± 34.4 (74.5 to 193), 120 ± 31.6 (73.1 to 174), and 131 ± 35.6 (78.0 to 188), respectively. Inorganic arsenic concentrations (expressed in nanograms per gram) in rice bran produced from the three rice types were 633 ± 182 (375 to 919), 599 ± 112 (447 to 824), and 673 ± 195 (436 to 1,071), respectively. Rice bran contained concentrations of total and inorganic arsenic approximately seven and nine times higher, respectively than those found in the corresponding polished rice [4]. Non-ferrous metal mining and smelting are significant sources of heavy metal emissions and have led to environmental pollution ultimately threatening the health of local residents. Cadmium exposure was found to be related to the consumption of rice, especially the rice near the smelting areas, and provided a high risk to consumers [1,2]. The results of the study in China showed that rice and vegetable samples surrounding the Zhuzhou smelter in Hunan, China were significantly contaminated by Cd and Pb. The Cd concentrations in local rice ranged from 0.132–3.35 mg/kg, with an average of 0.913 mg/kg. The portions exceeding the national limit of Cd (0.2 mg/kg) were 97% (30/31) in local rice. The Pb concentrations in local rice ranged from 0.03–0.32 mg/kg, with an average of 0.10 mg/kg. The portions exceeding the national limit (0.2 mg/kg) were 23% (7/31) in local rice. Age and source of rice were essential factors for the enrichment of heavy metal concentrations in human hair. The results of ratios of Pb isotopes in human hair indicated that Pb in human hair mainly originated from food ingestion [2]. Since Cd enters the body primarily through inhalation and ingestion, individuals who get poisoned by Cd from consuming rice suffer leg and spinal pain and other diseases such as anemia, coughing, and kidney failure. Cd could also accumulate in immune cells, modulates the function of the immune system, triggers immunological responses, and leads to diverse health problems[1,7]. The studies that examined rice intake stratified by water concentrations of arsenic, found evidence of increasing trends in cardiovascular [8]. High level of Pb in rice grains could also negatively affects to human liver, reproductive, and endocrine system [1]. The presence of toxic elements in rice and grains, particularly arsenic, lead, and cadmium, underscores the importance of ongoing monitoring, stricter safety standards, and public awareness regarding the potential health risks associated with contaminated food sources. Efforts to reduce environmental pollution and implement measures to mitigate exposure to these toxic elements are crucial for protecting public health. Efforts to reduce environmental pollution and implement measures to mitigate exposure to these toxic elements are crucial for protecting public health.

Thailand is a developing country that faces high-volume e-waste issues due to a lack of appropriate technologies, facilities, and resources, as well as gaps in e-waste regulations causing the informal importation of e-waste for dismantling and recycling purposes [9,10]. The study in Nakhon Si Thammarat Province, Thailand showed that the e-waste workers' urinary mercury levels were 11.60±5.23 μg/g creatinine (range, 2.00 to 26.00 μg/g creatinine) and the mean airborne mercury levels were 17.00±0.50 μg/m3 (range, 3.00 to 29.00 μg/m3). The average urinary mercury (Hg) levels of the e-waste office workers who worked in office areas that were exposed to low levels of Hg (9.84±1.02 μg/g creatinine; range, 3.00 to 15.30 μg/g creatinine); were significantly different from e-waste workers who worked in e-waste processes areas that had high levels of exposure. It was also found that mean urinary mercury levels were significantly affected by characteristics such as hours worked per day, duration of work, smoking cigarettes, not using PPE, and not washing one's hands before lunch ($p<0.001$). The urinary and airborne mercury levels were significantly correlated ($r=0.552$, $p<0.001$). The prevalence of self-reported symptoms was 46.8% for insomnia, 36.7% for muscle atrophy, 24.1% for weakness, and 20.3% for headaches[10]. Moving to Guiyu, an e-waste recycling area in China has been described as "the world's most toxic place" and "junk town" since it accommodates millions of tons of e-waste from overseas and domestic sources each year and is infamous for its e-waste dismantling industry. Informal e-waste recycling activities have caused severe pollution to the local environment and are associated with severe health problems to the residents. Although blood Pb levels (BLLs) were of children in Guiyu have been reduced from around 15 µg/dL to 6.00 µg/dL from 2004-2014, the current BLLs of children are ≥5 µg/dl and still higher than Chendian(2004-2008) and Haojiang(2010-2014), indicating that children are more sensitive to e-waste exposure and thus have higher potential health effects compared with adults and Pb exposures from e-waste can affect children's health, such as a decrease in serum cortisol levels, inhibition of hemoglobin synthesis, impact on neurobehavioral development, affect physical development, etc. Pb exposure also has been associated with multi-system and long-term effects in neonates and children, covering cardiovascular, adaptive immune, chromosome, and DNA damage [6,11]. The study of exposure of 99 workers (23 women) to metals and flame retardants in the primary e-recycling sector in the province of Quebec (Canada). In most facilities, dust control was inadequate and personal protective equipment was improperly worn. In e-recycling, lead was detected in all air samples and in most blood samples, up to 48 µg/m3 and 136 µg/l, respectively. When handling cathode ray tube screens, workers were 4.9 times and 8.5 times more likely to be exposed to lead and yttrium, respectively, than workers who were not assigned to a specific type of electronics. The concentration of As was above the recommended Biological

Exposure Indices (BEIs®) of 35 µg/l in one urinary sample from one hundred samples of e-recycling workers' urinary, and Cd was above the recommended level of 5 µg/l in one blood sample of the one hundred sample. Overexposures to Cr have up to a third of urinary samples above the 0.7 µg/l BEI for Cr. Three e-recycling workers were above the 5 µg/l BEI for Ni [12].

Cadmium (Cd), arsenic (As), and lead (Pb) have become widespread contaminants in rice cultivation. Rice consumers have risks of intaking contaminated heavy metal, the adverse health effects associated with heavy metal exposure, particularly arsenic, lead, and cadmium, are a cause for concern.

Impact of Heavy Metals on Health

Heavy metals can have a profound impact on human health, leading to various organ toxicities, including neurotoxicity, nephrotoxicity, hepatotoxicity, skin toxicity, and cardiovascular toxicity. These toxicities can manifest in a range of complications, such as neurological issues, renal dysfunction, liver damage, skin disorders, and cardiovascular problems. For instance, exposure to heavy metals like arsenic can cause acute and chronic skin diseases, while hexavalent chromium can lead to lung and cardiovascular issues.

Furthermore, heavy metals are associated with genetic alterations, DNA damage, and carcinogenesis, contributing to cellular damage and cancer development. Hepatitis and liver cirrhosis can result from heavy metal exposure, especially lead and cadmium. In addition, heavy metals can disrupt hormone levels, impacting endometrial cancer incidence, fertility, and the risk of developmental disabilities in children. [5,13]

Gender also plays a role in heavy metal toxicity, with differences in retention and sensitivity between men and women. For instance, cadmium retention tends to be higher in women, who are more susceptible to the immunotoxic effects of lead, while men are more vulnerable to lead and methyl mercury's neurotoxic effects after early-life exposure. However, further research is needed to fully understand these gender-based differences. [14,15,16,17]

In children, heavy metal exposure can lead to a range of health issues, including developmental disabilities, growth problems, and learning difficulties. Excessive intake of metals like copper, iron, and cobalt can result in various symptoms and complications, including gastrointestinal distress and skin disorders. [18,19,20,21] Lead exposure, even in small amounts, can severely affect a child's development, leading to lower IQ, behavioral issues, and impaired growth. [22,23]

Moreover, heavy metal exposure during the neonatal and postnatal periods has been linked to conditions like autism spectrum disorder. Additionally, high levels of heavy metals like cadmium can lead to hearing loss in adolescents and young adults.[24]

In adults, heavy metal toxicity can cause a wide array of health problems. Excessive zinc intake can lead to cardiac dysfunction, while copper overload can affect cholesterol, blood pressure, and heart rhythm. Iron toxicity can result in caustic injury to the gastrointestinal mucosa, leading to symptoms like nausea and diarrhea. Cobalt exposure may cause lung disease, asthma, and skin issues, and chromium exposure can lead to respiratory tract problems, ulcers, and cancer. Lead exposure is associated with various health issues, including neurological, circulatory, and gastrointestinal problems. Arsenic exposure, often through contaminated water, has been linked to numerous health conditions, including cancer, heart disease, and diabetes. Mercury exposure can lead to a range of health problems, including neurological, respiratory, cardiovascular, renal, hepatic, and immune system issues. Cadmium exposure is associated with hypertension, kidney dysfunction, osteoporosis, lower lung function, and diabetes. [5,25]

In summary, heavy metals can have detrimental effects on human health, impacting various organ systems and contributing to a wide range of health conditions and diseases. The severity of these effects depends on factors such as the type of metal, exposure levels, and individual susceptibility. Public awareness and measures to reduce heavy metal exposure are crucial for protecting human health.

How to avoid heavy metal contamination

Avoiding heavy metal exposure to reduce health risks can be done through the following measures 1) Ensure your drinking water comes from a safe and reliable source. Use water filters that are certified to remove heavy metals if needed. [26] 2) When preparing and storing food, use safe cookware options such as stainless steel, glass, or cast iron instead of non-stick or aluminum cookware, as these may release metals into your food. Store food in glass or stainless steel containers instead of plastic containers, which can potentially contain heavy metal contaminants. [27,28] 3) Adopt safe eating habits, consume a balanced diet rich in fruits, vegetables, and whole grains. These foods can help your body naturally detoxify and eliminate some heavy metals.[27] 4) Choose a variety of protein sources, including lean meats, fish, poultry, and plant-based options. [29] 5) Limit consumption of high-mercury fish, such as shark, swordfish, king mackerel, and tilefish. [27,30,31] 6) Be mindful of where your food comes from. Avoid food products grown or produced in areas known for heavy metal contamination. 7) Avoiding Certain Foods and Practices: Reduce your intake of rice, particularly rice grown in regions with known heavy metal contamination. [32] 8) Avoid consuming large quantities of organ meats, as they can contain higher levels of heavy metals. [33] 9) Minimize or eliminate smoking and exposure to secondhand smoke, as tobacco can accumulate cadmium. 12) Safe E-Waste Disposal:Dispose of electronic waste (e-waste) properly by recycling it through authorized channels. Avoid informal recycling methods that can release heavy metals into the environment. [34] 13) Filtering and Purifying Air: Use air purifiers with HEPA filters to reduce indoor air pollution and minimize exposure to heavy metal-containing dust particles. [35]

Conclusion

Heavy metal toxicity poses a significant health concern for people, both globally and particularly in Thailand. The escalation of heavy metal contamination in soils, driven by factors such as population growth, agricultural practices, and industrial activities, has led to the widespread presence of cadmium (Cd), arsenic (As), and lead (Pb) in rice cultivation. This contamination not only impacts the safety of rice and grain consumption but also has serious health implications. Heavy metal exposure can result in various organ toxicities and complications, affecting the nervous system, kidneys, liver, skin, and cardiovascular health. Genetic alterations, DNA damage, and carcinogenesis are associated with heavy metal exposure, with potential long-term consequences. Gender differences in retention and sensitivity further complicate the health effects of heavy metals, requiring more research to understand fully. Children are particularly vulnerable, facing developmental disabilities, growth issues, and learning difficulties due to heavy metal exposure. Adults can experience a wide range of health problems, from cardiac dysfunction and gastrointestinal distress to respiratory issues and cancer, depending on the specific heavy metal involved. Preventing heavy metal contamination and minimizing health risks require proactive measures. Ensuring safe drinking water sources, using appropriate cookware, adopting healthy eating habits, and being mindful of food sources are essential steps. Avoiding high-mercury fish and reducing rice consumption from contaminated regions can also help mitigate exposure. Proper disposal of electronic waste (e-waste) and purifying indoor air further contribute to safeguarding health. Public awareness and individual efforts to reduce heavy metal exposure are crucial for protecting human health.

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