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CADMIUM CONTAMINATION IN SOIL AND WATER AND ITS IMPACT ON HUMAN HEALTH IN SOUTHEAST ASIA: A SYSTEMATIC REVIEW

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ABSTRACT
This Cadmium (Cd) is a highly toxic heavy metal that poses serious threats to environmental and human health, especially in Southeast Asia, where industrial, mining, and agricultural activities are rapidly increasing. Chronic exposure to cadmium can lead to kidney damage, bone disorders, reproductive issues, and cancer, especially in areas relying on local water and food sources. This study employed a systematic literature review method, analyzing relevant studies published from databases including PubMed, Scopus, Google Scholar, and ScienceDirect. Keywords used included "cadmium contamination", "soil pollution", "water pollution", and "Southeast Asia". Inclusion criteria focused on studies reporting cadmium levels in soil or water and their health impacts in Southeast Asia. Cadmium contamination was reported in multiple countries, particularly in Thailand, Indonesia, and Vietnam. The primary sources of pollution include mining, fertilizer use, and industrial discharge. In many cases, cadmium levels in soil and water exceeded safety limits set by WHO and national standards and Health impacts. Cadmium contamination in Southeast Asia is a critical environmental and public health issue. Consistent findings across studies highlight the need for better waste management, stricter regulations, and regular monitoring. Public awareness and targeted interventions are essential to mitigate exposure and protect vulnerable populations.

Keywords: cadmium exposure; environmental health; heavy metals; soil and water pollution; southeast asia

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INTRODUCTION

The Cadmium (Cd) is a toxic non-essential metal that is harmful to humans and animals even in low concentrations. In addition to being easily accumulated in biological tissues, cadmium can persist in soil and water for many years. As a result, the use of fertilizers and sewage sludge containing cadmium on agricultural land can contaminate the soil and increase the uptake of cadmium by crops and vegetables grown for human consumption (Huang et al., 2022). Mining, smelting, and refining of inc produce cadmium, a hazardous heavy metal. Coal combustion residues, mine tailings, municipal waste, smelting slag, and waste are deposite into the soil through atmospheric emissions (Annar., 2022). Concerns about food safety and potential health hazards have made cadmium (Cd) contamination in agricultural soils a global issue (Suhani et al., 2021).

In addition to its environmental impact, chronic exposure to cadmium can cause kidney damage, bone disorders (osteomalacia), reproductive system disorders, cardiovascular disease, and lung cancer (Kuna et al., 2024). In the long term, the health burden resulting from cadmium exposure can become a serious issue, particulary in areas reliant on local agriculture and groundwater as primary sources of food and drinking water. The International Agency For Research on Cancer (IARC) has classified cadmium as a Group 1 carcinogen, meaning it is proven to cause cancer in human (Zhao et at., 2023).

The two main sources of Cd in soil are natural occurrences originating from parent materials and human activities. Various human activities, such as minning, waste disposal, vehicle exhaust, and phosphate fertilizer application, have resulted in significant releases of Cd into the environment (Briffa et al, 2020).

Southeast Asia is a particular concern in this regard because the region is experiencing rapid industrial development, agricultural intensification, and urbanization, but also has suboptimal waste management and environmental monitoring systems. Countries such as Thailand, Indonesia, and Vietnam have reported significant cadmium contamination in both soil and agricultural water (Saengwilai et al., 2021). The main goal of this research is to investigate the sources, prevalence, and health risks associated with cadmium (Cd) contamination in agricultural soils, particularly in Southeast Asia. This study aims to highlight the significant health burden caused by chronic exposure to cadmium, a Group 1 carcinogen, and emphasize the urgent need for effective environmental monitoring and waste management strategies to mitigate this global issue, especially in regions experiencing rapid industrial and agricultural growth.

METHOD

This study applied a literature review method to systematically examine previous research related to cadmium (Cd) contamination in soil and water and its impact on human health in Southeast Asia. Literature was gathered through database searches using Google Scholar, PubMed, Scopus, and ScienceDirect. The keywords used included “cadmium contamination”, “soil pollution”, “water pollution”, “human health”, and “Southeast Asia”, along with the names of relevant countries such as Indonesia, Malaysia, Singapore, Thailand, Cambodia, Myanmar, Vietnam, Laos, Brunei, and the Philippines. The literature search was conducted from April to May 2025, and publications were limited to the period from 2000 to 2025. The inclusion criteria for selected articles were: (1) studies focusing on cadmium contamination in soil or water in Southeast Asian countries, (2) studies discussing the relationship between cadmium exposure and human health effects, and (3) articles available in full text in either English or Indonesian. The analysis was conducted using a qualitative, thematic, and comparative approach, focusing on geographic distribution, environmental media (soil or water), measured cadmium levels (mg/kg or mg/L), sources of contamination (such as agriculture, industry, and mining), and reported health impacts, including increased cadmium concentration in urine, kidney damage, and chronic exposure symptoms.

RESULT

In this literature review, a number of studies discussing cadmium contamination levels in soil and water, as well as their relationship to human health impacts in Southeast Asia, were analyzed. This review was conducted by selecting scientific literature from various databases based on research location, cadmium levels in soil and water, exposure data, and effects on human health, as explained in the following table:

Table 1. Literature Review Result

Article	Method and Population	Outcome and Conclusion
Assesing the level of Heavy Metal Cd, Cr, and Pb in the naturally occuring red seaweed Gracilariopsis heteroclada in iloilo Province, Piliphine, for potential mass cultivation	Sample Analysis Population: red seaweed Gracilariopsis heteroclada in iloilo Province, Piliphine,	1. Elevated levels of Pb and Cr in samples, exceeding safety standards, while Cd remained within permissible limits. 2. These high heavy metal concentrations pose health risks, making the sites currently unsuitable for large-scale cultivation and consumption.
Cadmium Contamination in Farmland Soil and Water Near Zinc Minning Site	Sample Analysis Population: samples of farmers’ residence soil and water, farmland soil, and farmland water.	1. Cadmium concentrations in farmland soil and water were higher than those at farmers' residences 2. Farmers' working environments had higher cadmium exposure than their living environments, likely due to nearby industrial activities, especially zinc mining.

Heavy Metal Contamination and Human Health Implication in The Chan Thnal Reservoir, Cambodia	Sample Analysis Population: water and sediment sampling methods from 6 different locations in Chan Thnal Reservoir, Cambodia.	1. The levels of cadmium (Cd) found in water samples ranged from 1.15 to 1.79 µg/L, all of which are below the established standard limits. 2. Analysis shows that the main sources of pollution come from human activities such as household waste, agriculture (pesticides, fertilizers), and municipal waste.
Heavy Metal in Soil of Placer Small-Scale Gold Minning sites in Myanmar	Sample Analysis The method used was to collect soil samples from three stages of gold processing, screening, screening, and amalgamation at three different mining sites.	1. The highest concentration of cadmium (Cd) was found during the amalgamation process, reaching 3,070 mg/kg, indicating a significant level of pollution. 2. In general, the levels of heavy metals in the soil exceed international safety limits, indicating environmental pollution due to small-scale gold mining activities.
Chromium, Cadmium, Lead, and Arsenic Concentrations in Water, Vegetables, and Seafood Consumed in a Coastal Area in Northern Vietnam	Sampel Analysis Researchers took 54 surface water samples, 222 well water samples, vegetables, and seafood samples from areas near 6 industrial sites. The samples were analyzed using Atomic Absorption Spectrophotometry (AAS) to measure heavy metal content.	1. The Cd level in surface water was found to be 0.02 mg/L, exceeding Vietnam's national safety limit (0.01 mg/L), while the Cd level in well water reached 0.03 mg/L, or 10 times the WHO safety limit (0.003 mg/L). Most of the water samples, both surface and well, exceeded the threshold, making them unsafe for consumption. 2. Demonstrating the dangers of eating tainted food; this was the first thorough study carried out in Northern Vietnam.
Risk Assessment and Fractionation of Cadmium Contamination in Sediment of Seguling Lake in West Java, Indonesia	Sediment Sampling: A portable Global Positioning System (GPS) was utilized to identify the sampling locations, and surface sediment samples were collected from 12 sampling points in Lake Saguling. - Laboratory Analysis: Techniques like atomic absorption spectrometry (AAS) and mass spectrometry (ICP-MS) are used to evaluate sediment samples and ascertain the cadmium levels. In order to ascertain the type and availability of cadmium in the sediment, sediment fractionation is carried out.	1. According to this study, Saguling Lake's surface sediments contain more cadmium (Cd) during the rainy season than during the dry one. The average concentration of Cd is 11.12 mg/kg during the dry season and 14.82 mg/kg during the wet season. This Cd level is higher than what ANZECC has established. 2. Since the majority of the cadmium in Lake Saguling's surface sediments is in a non-reactive form (resistant fraction), there is little chance of environmental harm. To lower the risk of cadmium pollution in Lake Saguling, appropriate monitoring and management are required, as the cadmium content still beyond the set limits.
Urinary and Blood Cadmium Levels in Relation to Types of Food and Water Intake and Smoking Status in a Thai Population Residing in Cadmium-Contaminated Areas in Mae Sot	The research was conducted in Mae Sot District, Tak Province, Thailand, specifically in 11 villages known to have been contaminated with cadmium. This study examined the relationship between cadmium levels in blood and urine with food consumption habits, types of drinking water, in people living in areas exposed to cadmium.	1. Of the 7,697 residents, 45.6, 4.9 and 2.3% had urinary Cd levels of <2, 5-10 and >10 µg/g creatinine, respectively. Cd concentrations in 69% of river sediment samples passing through the area were found to exceed the maximum permissible Cd level of 3.0 mg/kg 2. Cadmium (Cd) exposure in Mae Sot, Thailand, is closely related to environmental conditions, especially soil and water quality in the area. Cadmium can contaminate agricultural soil through industrial activities or waste, then absorbed by food crops such as vegetables, rice, and tubers which are then consumed by residents. In addition, cadmium is also found in shallow well water and deep groundwater that are most commonly used.
Spatial Distribution and Contamination Status of Arsenic, Cadmium, and Lead in Several Coastal	This research was conducted in four coastal shrimp farming zones in Vietnam: Vunh Tau, Nha Trang, Da Nang, and Hue.	1. From 0 to 2708 µg kg^{-1}, the Cd content in the sludge from 20 ponds varies significantly. Vunh Tau had the greatest content of Cd, with a maximum value of 2708 µg kg^{-1}.

Shrimp Ponds (Macrobrachium rosenbergii) in Vietnam	Sediment samples were taken from twenty randomly selected shrimp ponds and analyzed using an atomic absorption spectrophotometer to determine cadmium (Cd) content.	2. Compared to the typical range of metals for soil, up to 60% of the ponds under study had Cd contamination. According to the study, the cadmium amount in soil varies from 9.7 to 35 mg/kg, while it can reach 28 to 35 mg/kg in canal sediment. 3. Health problems like kidney disease and reproductive difficulties are linked to cadmium exposure.
Status of metal levels and their potential sources of contamination in Southeast Asian rivers	River water sampling in the dry season and the rainy season. The study was conducted on four major rivers in Southeast Asia, namely: the Tonle Sap–Bassac River in Cambodia, the Citarum River in Indonesia, the Chao Phraya River in and the Saigon River in Vietnam	1. Cadmium (Cd) was found as one of the heavy metals that pollutes large rivers in Southeast Asia. Of the four rivers studied, the Saigon River in Vietnam showed the highest level of cadmium pollution reaching 245 µg/L. 2. Meanwhile, in the Citarum River (Indonesia) and Chao Phraya (Thailand), Cd levels were recorded at 1 µg/L, and were not detected in Tonle Sap–Bassac (Cambodia). The high levels of Cd in the Saigon River are thought to originate from human activities, especially industry and household waste that enters the river without adequate treatment.
Heavy Metal Contamination Status in the Soil-Water-rice System Near Coal-Fired Power Plants in Cilacap, Indonesia	Sample Analysis The research methods used include taking samples of soil, water, rice, and rice bran around the Cilacap PLTU location.	1. The cadmium levels found in this study were below the maximum limits set by international standards such as SNI, Codex, and FAO/WHO. Specifically, the cadmium levels in rice and other environmental compartments did not exceed the established safe limits.
Assessing Cadmium and Chromium Concentrations in Drinking Water to Predict Health Risk in Malaysia	Researchers collected water samples at four stages of the supply chain river water, water from a treatment plant, household tap water, and household filtered water. A survey was conducted on 402 households to determine drinking water consumption patterns.	1. Cadmium (Cd) levels found in water sources ranged from 0.42 × 10^−3 mg/L, with maximum values at the Hentian Kajang II location of 0.75 × 10^−3 mg/L and at UKM III of 0.73 × 10^−3 mg/L. This value is still below the drinking water quality standard limit set by WHO and MOH of 0.003 mg/L, so that in general the Cd levels can be categorized as safe and do not have the potential to cause direct health risks. However, the presence of Cd below the standard limit still needs to be monitored due to long-term accumulation and other factors that affect water quality.
Risk Assessment of Lead and Cadmium in Drinking Water for School use in Nakhon Si Thammarat Province, Thailand	This cross-sectional study was conducted between September 1, 2018 and January 31, 2019 in public elementary schools located in four districts, Drinking water samples were collected from drinking water sources and in elementary schools including 48 bottled drinking water, 44 tap water, 30 filtered water and 24 raw water.	1. The results showed Packaged drinking water (0.0013 mg/L). tap water (0.0042 mg/L). filtered tap water (0.0021 mg/L), raw water (0.0049 mg/L). The highest Cd levels were found in raw water, up to 0.0049 mg/L, which slightly exceeds the WHO safe limit for drinking water (0.003 mg/L). 2. However, most samples were still below the safe limit, especially for packaged drinking water and filtered water.
Heavy Metals in Paddy Soils of Brunei Darussalam and Their Relationship with Selected Soil Properties	The study was conducted in four agricultural development areas (Wasan, Limau Manis (LM), Selapon and Lot Senkuang (LS)). Wasan and Limau Manis (LM) are located in Brunei-Muara District; Selapon is in Temburong District and Lot Senkuang (LS) is in Belait District. 26 surface samples were taken to a depth of 20 cm	1. The Limau Manis and Selapon locations showed very high cadmium (Cd) content in the soil, at 11.0 mg/kg and 10.2 mg/kg, respectively. This amount is quite large and indicates a significant source of heavy metal contamination in the area. 2. The high Cd content in the Limau Manis and Selapon soils most likely comes from the use of TSP fertilizer and interaction with manganese oxide in the soil.

	at each location.	
Cadmium, Nickel, and Lead Consentration of Municipal Dumpsite in Western Samar, Philippines	Sample Analysis Soil samples were taken from three sampling locations: shoulder slope, main dump site, and toe slope.	1. Cadmium increased with depth, from 0.0084 to 0.0137 mg/kg 2. Cd levels were almost 4 times higher in the lower layer (30–60 cm) than in the upper layer (0–30 cm). 3. This supports the theory that Cd easily moves downward with rainwater (leaching). 4. All levels are still considered low and safe according to WHO
Enviromental Cadmium Exsposure Induces Kidney Tubular and Glomerular Dysfunction in Myanmar	The study was conducted from December 2018 to September 2019. In this study, participants who appeared healthy, aged 18-40 years Researchers collected urine samples using the provided beakers to analyze cadmium levels in urine.	1. The cadmium level found at 0.96 μg/g creatinine in the exposed group indicates low-level cadmium exposure, but it is enough to cause impaired kidney function, especially in the tubules (small channels in the kidneys) and glomeruli (blood filters in the kidneys). 2. The main source of cadmium exposure is likely to come from food, especially rice and fish from polluted areas. Although the levels are still relatively low, the impact on kidney health is already visible.
Heavy Metal Accumulation in Water, Soil, and Plants of Municipal Solid Waste Landfill in Vientiane, Laos	Sample Analysis Surface water: Collected from three flow points from upstream to downstream in the wetland area of the landfill. Groundwater: Collected from two wells, one inside and one outside the landfill (approximately 70 m from the site). Soil: Collected from a depth of 0–25 cm inside and outside the landfill, using a composite method of 6 subsamples per point. Plants: Ipomoea aquatica (water spinach), Pennisetum purpureum (elephant grass)	1. Cadmium was not detected in water (surface or soil), indicating very low levels or below the detection limit of the device. 2. Soil in and around the landfill was contaminated with cadmium, with levels reaching 3.76 mg/kg—exceeding the safe threshold of 0.8 mg/kg according to Dutch standards. 3. Plants such as kale and elephant grass contain high levels of cadmium, even up to 8.24 mg/kg in the roots, far above the WHO safe limit of 0.02 mg/kg, thus posing a health risk.
Human health risk assessment of cadmium exposure through rice consumption in cadmium-contaminated areas of the Mae Tao sub-district, Tak, Thailand	Method: analysis of a total of 159 rice samples Consumption survey of 91 residents Location: Mae Tao Sub-district, Mae Sot District, Tak Province, an agricultural area that has been contaminated with cadmium (Cd) for more than 20 years.	1. Most of the rice in Mae Tao area is contaminated with cadmium (Cd), both local rice and rice from the market. About 19% of samples exceeded the safe limit (0.4 mg/kg), and local rice contained higher Cd than market rice. 2. The highest cadmium exposure occurred in the consumption of sticky rice and a combination of rice, with an average Hazard Quotient (HQ) value exceeding 1, indicating a health risk. While consuming only white rice is relatively safer, some still have risks.
The Low Presence of Potentially Toxic Elements in Singapore's Urban Garden Soil	Exploratory survey with comprehensive soil sampling in various urban areas. The survey was conducted from May to June 2018, with a total of 10 sampling points representing three types of land use: forest areas, public parks, and community gardens. Each soil sample was taken as much as 300 grams, then analyzed to measure the concentration of various PTE elements.	1. Based on the survey results, Cd (cadmium) elements were rarely found in soil samples. Very few samples had levels above the Cd detection limit of 1.6 mg/kg. While one sample from the forest had a higher level of 6.4 mg/kg, three samples from community gardens had levels between 1.7 and 3.2 mg/kg. Garden soil did not contain Cd. 2. The results of the total assessment of Cd, Cu, Pb, and Zn indicate that the health risks associated with urban agriculture in Singapore are quite low. Although the calculations are rough, the intake levels of these elements are

		still far below the maximum limits estimated by the guidelines.
Identification of Lead and Cadmium Levels in white Cabbage (Brasica rapa L.) Soil, and water irrigation in the Pjilippines	The research was conducted in Las Piñas and Parañaque, Metro Manila, Philippines from October 2001 to May 2002. Samples of white cabbage, soil, and irrigation water were taken from two. For each location, white cabbage and soil samples of 2.0 kg and 1.5 kg per sample, respectively, were taken from each section and replicated three times.	1. Cadmium (Cd) concentrations in white cabbage differed significantly between two urban farming locations, namely Parañaque (0.42 µg/g) and Las Piñas (0.18 µg/g). Despite the differences, Cd levels in both locations were still below the safe limit (1.5 µg/g), so white cabbage from both areas was relatively safe for consumption. 2. The content of heavy metals (Cd and Pb) in water, soil, and white cabbage was generally still below the safety standard for human consumption.
Study of Heavy Metal Cadmium (Cd) Levels in Water Plants in the Buntung River, Sidoarjo	From August to December 2020, aquatic plants (Ipomea aquatica and Eichhornia crassipes) and river water were sampled at three separate locations using an observational methodology	1. The highest concentration of Cd in water is 0.028% up to 0.000000 parts per million (Eichhornia crassipes stage III). According to PP RI No.82 of 2001, the Cd content in water is 0.002 ± 0.000 ppm, or below the quality standard of 0.01 ppm. Compared to river water, the Cd content in plants is higher. 2. Buntung River is safe and has good water quality because the levels of cadmium metal in water and aquatic plants are still below acceptable limits.
Analysis of Heavy Metals (Pb and Cd) in Indonesian Soil Layers: Spatial Distribution, Potential Sources, and Their Impact on Groundwater	Spearman correlation was used for statistical analysis, and SPSS and Microsoft Excel were used for data processing. identifying possible sources of heavy metals using environmental and distribution data.	1. Pb and Cd concentrations in soil in a few regions are lower than usual, especially in industrial areas like Majalaya. 2. The highest concentration of lead, 398.489 ppm, indicates a significant increase in industrial pollution. 3. Spasial distribution indicates that this pencemaran is not fair and is impacted by industrial activities and heavy machinery use.
Bioavailable Cadmium in Water, Sediment, and Fish, in a Highly Contaminated Area on the Thai-Myanmay Border	Sample Analysis Samples: Surface water, riverbed sediment, 6 species of fish (including swamp eel, walking catfish, climbing perch, etc.), and 1 type of shellfish (pond snail).	1. Surface water: Cadmium levels are higher during the rainy season due to runoff from agricultural and mining activities; however, they are still below the Thai standard (5 µg/L). 2. River sediment: Cd concentrations are much higher than water, with some points exceeding the UK standard (2 mg/kg) but still below the Thai standard (37 mg/kg). 3. Fish and shellfish: Swamp eel had the highest Cd levels (0.27 mg/kg), exceeding the FAO/WHO safety limit (0.2 mg/kg).

Cadmium impacts on reproduction health

Exposure to heavy metals such as lead (Pb), cadmium (Cd), and arsenic (As) has been shown to have adverse effects on the human reproductive system. Lead disrupts reproductive hormones and reduces sperm quality, including motility and morphology (Ilieva et al., 2020). In women, Pb can cross the placenta and affect the fetus and hormonal processes (Tasin et al., 2022). Cadmium has a high affinity for testicular and ovarian tissue, causing oxidative stress, damage to Leydig/Sertoli cells, and hormonal disturbances leading to infertility (Putra et al., 2021; Pogrmic-Majkic et al., 2021; Zhao et al., 2020).

Cadmium impacts on the nervous system

Cadmium can harm the nervous system, including causing neurotoxicity, which impairs cognitive and neurobehavioral function. Cadmium exposure can also increase oxidative stress and inflammation in the brain, leading to neuronal damage, impaired memory and learning, and leading to neurodegenerative diseases such as Alzheimer's (Syeda, 2021). Even at lower concentrations, cadmium can disrupt nervous system function in children, causing neuropathy, learning disabilities, behavioral problems, and decreased memory, attention, and psychomotor skills (Charkiewicz et al., 2023). Cadmium can also cause cognitive and behavioral decline, especially in people who are significantly exposed (Ruczaj, 2021).

Cadmium Impacts on the skeletal system

Chronic exposure to cadmium (Cd) has been shown to have significant adverse effects on the human skeletal system. Cadmium disrupts the metabolism of important minerals such as calcium, magnesium, iron, zinc, and copper. This imbalance leads to bone demineralization, resulting in conditions such as osteomalacia (softening of the bones) and osteoporosis (brittle bones). These disorders typically affect large bones such as the pelvis, femur, shoulder blades, and spine, and are characterized by chronic bone pain and an increased risk of fractures. One of the most well-known cases is Itai-Itai disease, first identified in Toyama, Japan, due to the consumption of rice irrigated with cadmium-contaminated water. Patients experience bone deformities, abnormal gait, and complex fractures (Charkiewicz et al., 2023; Purushottam & Reddy, 2024).

Epidemiological studies show that increased cadmium levels in urine correlate with reduced bone mineral density (BMD) and an increased risk of fractures, particularly in postmenopausal women. Yang et al. (2023) added that cadmium also triggers oxidative stress in bone tissue, increasing the production of reactive oxygen species (ROS), which disrupts the balance between bone formation and resorption.

Bouida et al. (2022) found that cadmium has a high affinity for calcium ions in bone and can replace them in hydroxyapatite, leading to structural instability and increased fracture risk. Ahmad et al. (2023) added that populations living in areas with cadmium-contaminated soil and water exhibit higher rates of bone pain and spontaneous fractures, indicating that even low-level environmental exposure can be osteotoxic.

Cadmium impacts on the kidneys

The kidneys are one of the main targets of Cd toxicity, where Cd accumulates and causes damage to the renal tubule epithelial cells, which can lead to renal dysfunction and ultimately renal failure. Chronic exposure to Cd has been associated with an increased risk of chronic kidney disease, proteinuria, and renal cancer. Cadmium exposure can cause urinary tract stones. Kidney stones exposed to cadmium show focal calcification on the basal membrane of proximal tubular epithelial cells, which is indicated as the cause of stone formation (Yunxi Yang, et al., 2025)

Cadmium impacts on human respiratory system

The effects of Cadmium poisoning on the respiratory system include: Irritation of the upper respiratory tract and nasal mucosa, which interferes with the perception of odor, pulmonary edema, Smell disorders, including complete loss are a consequence of chronic bronchitis, Expectoration after dry cough, Shortness of breath on exertion with decreased efficiency of the entire lung and reduced exercise tolerance. In the respiratory system, cadmium can irritate the upper respiratory tract and nasal mucosa, interfering with the perception of perception. Respiratory changes can be identified through a variety of examinations, including chest X-rays, spirometry, and laryngological assessments (Georgakopulou, et al., 2025). Spirometry and radiological tests can detect these symptoms, which often appear within 24 hours. Inhaled CD is readily absorbed by the respiratory system, which contributes significantly to its systemic bioaccumulation.

The harmful effects of Cd on the human body are found to be lung damage. Symptoms of respiratory tract irritation, such as dry throat, pain, runny nose, dry cough, chest tightness, difficulty breathing, dizziness, fatigue, and joint pain, can appear within 4 to 10 hours after inhaling large amounts of Cd vapor (Charkiewicz et al., 2023). These symptoms are similar to influenza. In severe cases, individuals can experience pulmonary edema bronchopneumonia (alveolar distension, hypertrophy of the alveolar walls), as well as filling of swollen alveoli. In addition, bronchial mucosal epithelial cells can experience degeneration, necrosis, and loss, accompanied by pulmonary capillary dilation, congestion, and high interstitial water content in the lungs, which can ultimately lead to death (Peana et al., 2022).

Cadmium Impacts of Blood

Acute exposure to cadmium (Cd) has several significant effects on the blood and circulatory system, especially on the parts of the white blood cells (leukocytes). A significant increase in the number of leukocytes indicates inflammation of the system due to cadmium exposure. blood clotting. Increases the risk of thromboembolism (blood clots that block blood vessels). Acute cadmium does not directly affect the production or presence of red blood cells in the context of this study. The effects of cadmium on the blood are mainly seen effect, this is very dangerous because it can cause cerebral thrombosis, kidney damage, and liver damage due to blood vessel dysfunction and systemic inflammation.

Carcinogenic Effects of Cadmium

The International Agency for Research on Cancer (IARC) has classified cadmium (Cd), a cytotoxic heavy metal, as a group I carcinogen. This means that it can cause cancer in humans, especially if inhaled. To date, there is no strong evidence that oral consumption of Cd can cause cancer. However, several studies have shown that environmental and occupational exposure to Cd is associated with a greater risk of several types of cancer, including lung, breast, prostate, pancreatic, bladder, and nasopharyngeal cancers (Charkiewicz et al, 2023).

Even low to moderate exposure to cadmium has been linked to a variety of health problems, including kidney disease, bone disease, and cardiovascular problems. Hypertension, diabetes, atherosclerosis, peripheral artery disease, chronic kidney disease, heart attack, stroke, and heart failure are some of the health problems that can be caused by cadmium exposure (Purushottam, 2024).

DISCUSSION

This study, as a systematic literature review, has several inherent limitations. First, the study did not generate primary data or conduct direct experiments. The complete reliance on findings from previous publications means that the quality and comprehensiveness of this review are intrinsically limited by the availability and methodology of data present in the literature analyzed. Furthermore, literature reviews are susceptible to publication bias, where studies with significant results may be more frequently published and included, potentially overlooking studies with inconsistent findings. Although this study identifies trends in cadmium contamination and health risks across Southeast Asian countries, the reliance on secondary data may hinder capturing the specific nuances of local population and environmental conditions in each region. Finally, the limitation of the publication years of the collected literature (2000–2025) may exclude relevant studies published before that period.

The findings of this study highlight the urgent need for strengthened environmental policies and public health strategies to address cadmium contamination in Southeast Asia. Governments should enhance monitoring systems for soil and water quality, particularly in industrial and agricultural regions, to detect and control elevated cadmium levels before they pose serious health risks. Implementing stricter regulations on activities such as mining, waste disposal, and the use of contaminated fertilizers is crucial to reduce the entry of cadmium into the environment. Additionally, public awareness campaigns should be promoted to educate communities about the sources and health effects of cadmium exposure, encouraging safer agricultural practices and consumption habits. Furthermore, policymakers should prioritize developing remediation technologies and intervention programs aimed at reducing existing contamination. Regular health screenings and biomonitoring in high-risk populations can facilitate early detection of cadmium-related health issues, such as kidney and bone disorders. By integrating scientific research findings into policy frameworks, Southeast Asian countries can establish more effective standards and strategies to prevent further environmental pollution and protect community health, ensuring sustainable development and environmental justice in the region.

CONCLUSION

Widespread cadmium exposure in Southeast Asia is a significant environmental problem and has the potential to threaten public health at large. Based on studies analyzed, it was found that cadmium contamination mainly originates from mining, industrial, and agricultural activities. Several regions showed cadmium levels in soil, water, and food that exceeded safe thresholds, increasing the risk of kidney disease, reproductive disorders, nervous and bone disorders, and cancer. Countries such as Thailand, Indonesia, and Vietnam are areas with high exposure and significant health impacts. Therefore, integrated mitigation measures are needed through strengthening regulations, public education, and improving environmental monitoring systems. This study also provides an important basis for public policy making and further research in order to protect public health from the dangers of cadmium heavy metals.

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