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HUMAN HEALTH RISK AND CARCINOGENIC EFFECTS OF CADMIUM-CONTAMINATED KANGKONG *(IPOMOEA AQUATICA)* CULTIVATED IN COUNTRIES FROM SOUTHEAST ASIA: A SYSTEMATIC REVIEW

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ABSTRACT
Cadmium contamination in aquatic and agricultural environments presents a severe threat to food safety, particularly for bioaccumulative species like Ipomoea aquatica (kangkong). This systematic review evaluates the concentration of cadmium (Cd) in cultivation media and tissues of kangkong across Southeast Asian countries, including the Philippines, Thailand, Indonesia, and Malaysia. We performed a systematic literature search across major academic databases (2015–2025) and calculated bioaccumulation factors (BAF), translocation factors (TF), and human health risk indices such as the Target Hazard Quotient (THQ) and Carcinogenic Risk (CR). Findings reveal significant variability in accumulation; while some sites reported leaf Cd levels near safe limits, samples from Selangor farms and Pahang & Jengka in Malaysia exhibited extreme concentrations of 5.2– 8.79 mg/kg and 2.47 mg/kg dry weight, respectively. Notably, risk assessments in these specific locales showed that Selangor farms recorded a THQ of 50.5425 and a CR of 0.3083, both of which vastly exceed the safety thresholds of THQ < 1 and CR 1x10-6 to 1x10-4. Our findings describe a critical public health risk in contaminated environments, suggesting that the high bioaccumulation potential of kangkong (BAF reaching 5.66) makes it a high-risk vector for heavy metal transfer. We propose that these results highlight an urgent need for stricter environmental monitoring and regulation of industrial effluents to ensure food safety in the region.

Keywords:
Bioaccumulation factor (BAF), Translocation factor (TF), Target Hazard Quotient (THQ), Food safety, Environmental monitoring, Heavy metal uptake, Bioindicator, Phytoremediation, Water spinach, Aquatic vegetable, Toxicokinetics, US EPA thresholds.

INTRODUCTION

One widely cultivated aquatic vegetable in Southeast Asia is kangkong (Ipomoea aquatica), also known as water spinach. This leafy vegetable is commonly consumed in countries such as the Philippines, Thailand, Malaysia, Indonesia, and Vietnam due to its affordability, availability, and high nutritional value. Ipomoea aquatica grows well in aquatic and semi-aquatic environments, making it particularly susceptible to absorbing contaminants present in water and sediments. Previous studies have demonstrated that the plant is capable of accumulating heavy metals such as cadmium, lead, and mercury in its roots, stems, and leaves. Because of this property, kangkong is often used as a bioindicator of environmental pollution, but its consumption may also pose potential health risks if grown in contaminated areas.

Several studies across Southeast Asia have investigated the accumulation of cadmium in Ipomoea aquatica grown in freshwater systems and agricultural environments. These studies also examined the potential transfer of cadmium from soil or sediment into plant tissues and evaluated the associated health risks to consumers. However, the available information is scattered across different locations and research methodologies, making it difficult to obtain a comprehensive understanding of cadmium contamination patterns and their implications. Therefore, a

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systematic review of existing literature is necessary to synthesize available data on cadmium contamination in Ipomoea aquatica across Southeast Asian countries. This study aims to determine the concentration of cadmium in soil or sediment and plant tissues, evaluate the bioaccumulation and translocation of cadmium within the plant, and assess the potential non-carcinogenic and carcinogenic health risks associated with the consumption of cadmium-contaminated kangkong. The findings of this review may contribute to a better understanding of heavy metal contamination in aquatic vegetables and support efforts toward improving food safety and environmental monitoring in the region.

OBJECTIVES

This systematic review aims to determine the concentration of cadmium (Cd) in the cultivation media—specifically soil and sediments—and the tissues of kangkong (Ipomoea aquatica) across Southeast Asian countries, providing a baseline for environmental contamination in regions prone to industrial and domestic wastewater exposure. By analyzing bioaccumulation and translocation factors (BAF and TF), the study evaluates the efficiency with which kangkong absorbs Cd from its surroundings and distributes it from roots to edible shoots, identifying the biological mechanisms that make this aquatic vegetable a high-risk vector for heavy metal transfer. Ultimately, the review synthesizes these findings to assess both non-carcinogenic risks, such as renal dysfunction and bone demineralization, and the long-term carcinogenic potential for local populations, using standardized indices like the Target Hazard Quotient (THQ) and Target Cancer Risk (TCR) to establish the safety profile of kangkong consumption in the region.

METHODOLOGY

The study employs a systematic review framework organized into three major components: Input, Process, and Output, as illustrated in the conceptual diagram. The Input stage focuses on developing a comprehensive search strategy and establishing inclusion and exclusion criteria to gather relevant and credible studies. Scientific databases such as Google Scholar, PubMed, ScienceDirect, and Scopus are utilized to identify peer-reviewed research related to cadmium contamination, heavy metals in vegetables, and associated human health risks in *Ipomoea aquatica*. The Process stage involves the systematic screening, selection, and evaluation of studies following the PRISMA 2020 guidelines to ensure transparency and methodological rigor. This stage includes removing duplicate records, reviewing titles and abstracts, conducting full-text eligibility assessments, and extracting key data such as study location, cadmium concentrations in soil and plant tissues, bioaccumulation factor (BAF), estimated daily intake (EDI), target hazard quotient (THQ), and carcinogenic risk (CR). The collected data are then organized into comparative tables and analyzed to identify patterns of cadmium accumulation and potential health risks. Finally, the Output stage presents a synthesized collection of relevant studies and categorized datasets that highlight trends in cadmium bioaccumulation in *Ipomoea aquatica* across Southeast Asian countries. The integrated findings provide insights into the potential non-carcinogenic and carcinogenic health risks associated with the consumption of cadmium-contaminated kangkong, offering an evidence-based understanding of environmental contamination and its implications for food safety and public health.

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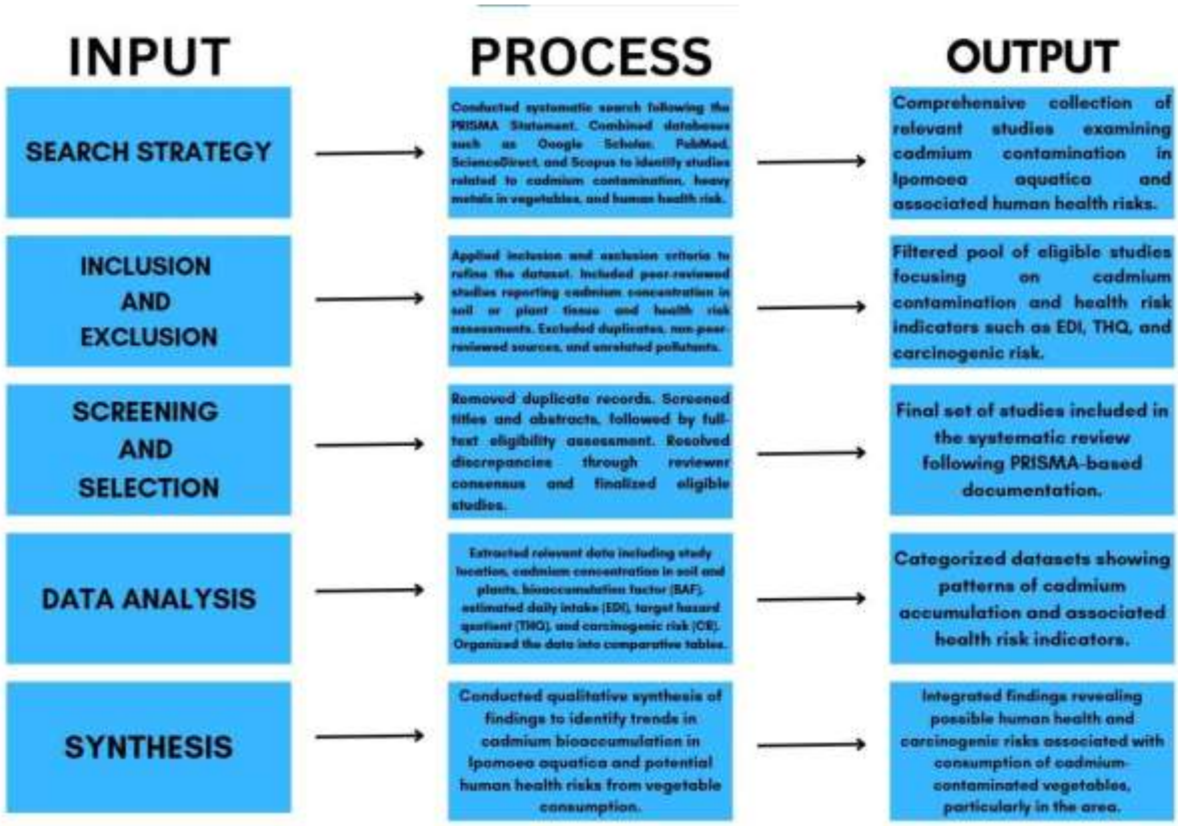

Figure 1. IPO Diagram of the Study

Search Strategy

A systematic literature search was conducted to identify relevant studies examining cadmium contamination in edible plants, particularly *Ipomoea aquatica*, and its associated human health risks. The search was performed in major academic databases including Google Scholar, ScienceDirect, SpringerLink, and PubMed to ensure comprehensive coverage of peer-reviewed literature. The search strategy utilized combinations of keywords and Boolean operators such as "cadmium contamination" and "*Ipomoea aquatica*", "heavy metals" and "kangkong" and "health risk", "cadmium accumulation" and "leafy vegetables", "human health risk assessment" and "heavy metals in vegetables", "carcinogenic risk" and "cadmium" and "edible plants". The literature search focused on articles published between 2015 and 2025 to ensure the inclusion of recent and relevant studies. Only peerreviewed journal articles written in English were considered.

Inclusion and Exclusion Criteria

To ensure the relevance and quality of the selected studies, the following criteria were applied during the screening process. Studies were included if they met the following conditions such as peer-reviewed journal articles published between 2002 and 2025, studies investigating cadmium (Cd) contamination in edible plants or leafy vegetables, including *Ipomoea aquatica*, research that assessed bioaccumulation, translocation, or heavy metal concentration in plants, studies that evaluated human health risk indicators such as Target Hazard Quotient (THQ), Hazard Index (HI), or Carcinogenic Risk (CR) and articles written in English with accessible full text.

Studies were excluded if they met any of the following conditions such as articles published before 2015, nonpeer-reviewed materials such as theses, conference abstracts, reports, or book chapters, studies focusing only on non-edible plants or non-agricultural environments, articles that did not report cadmium concentrations or human health risk assessment and duplicate publications across databases.

Screening and Selection Process

The screening and selection process followed the standard systematic review procedure recommended by the PRISMA guidelines. Initially, all records identified from the databases were exported and compiled into a

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reference list. Duplicate articles were removed prior to screening. The remaining studies underwent title and abstract screening to determine their relevance to the research objectives. Articles that passed the initial screening were then subjected to full-text assessment to confirm eligibility based on the predefined inclusion and exclusion criteria. Studies that met all criteria were retained for the final review and data extraction.

Data Analysis and Grouping

Relevant data were extracted from each selected study using a standardized data extraction table. The extracted information included author(s) and year of publication, plant species investigated, cadmium concentration levels in plant tissues, bioaccumulation or translocation indicators, health risk assessment parameters (THQ, HI, CR) and key findings related to human health risk. The studies were grouped according to cadmium accumulation in edible plants, bioaccumulation and translocation mechanisms in plants, human health risk assessment from vegetable consumption, environmental sources of cadmium contamination. This thematic grouping allowed for systematic comparison of results across different studies.

Synthesis of Results

A qualitative synthesis approach was used to integrate the findings of the selected studies. The results were summarized and compared to identify patterns, similarities, and differences in cadmium accumulation levels and associated human health risks. Particular attention was given to studies examining leafy vegetables such as Ipomoea aquatica, as these plants are commonly consumed and have a high potential for heavy metal uptake. The synthesized findings were then analyzed to determine the overall level of health risk posed by cadmium contamination in edible plants and its potential carcinogenic implications for human consumers.

Statistical Analysis

The statistical analysis in this study was conducted to evaluate cadmium accumulation in *Kangkong (Ipomoea aquatica)* and assess potential human health risks from its consumption. Data from selected studies reporting cadmium concentrations in soils and plant tissues across Southeast Asian countries were compiled and analyzed. To quantify cadmium uptake and mobility within the plant, bioaccumulation factors (BAF) and translocation factors (TF) were determined. Human health risks were evaluated through the computation of estimated daily intake (EDI), target hazard quotient (THQ), and carcinogenic risk (CR). The specific formulas used to calculate these indicators are summarized in Table 1, providing a clear reference for the methodology applied in assessing both environmental cadmium accumulation and its potential non-carcinogenic and carcinogenic effects on consumers.

Table 1. Equations Used for the Calculation of Bioaccumulation and Human Health Risk Assessment Indicators for Cadmium in Ipomoea aquatica

PARAMETER	FORMULAS
Bioaccumulation Factor	$BAF=\frac{C\ plant\ tissues}{C\ environment}$
Translocation Factor	$TF=\frac{Cd\ concentration\ in\ leaves}{Cd\ concentration\ in\ roots}$
Estimated Daily Intake	$EDI=\frac{C \times IR}{B}$
Target Hazard Quotient	$THQ=\frac{E}{R}$
Carcinogenic Risk	CR = EDI x SF

Wlasow, T. et al (2019), Wang Y. et al (2023)

On the other hand, table 2 outlines key factors and constants used to assess health risks from cadmium exposure, including standardized variables like cadmium concentration (C), ingestion rate (IR at 0.345 kg/day), and body weight (BW at 60 kg). These values, drawn from the study's methodology and toxicological standards, support consistent risk models for the target population. Critical constants include the reference dose (RfD) of 0.001

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mg/kg/day for non-carcinogenic risks and the cancer slope factor (SF) of 6.1 for carcinogenic risks, enabling the conversion of raw data into quantifiable health risk indices.

Table 2. Parameters Used in the Calculation of Bioaccumulation and Health Risk Indicators

PARAMETER	UNIT	DENOTED BY	VALUE
Cadmium concentration	mg/kg	C	-
Ingestion Rate	kg/day	IR	0.345
Avg Body Weight	kg	BW	60
Reference Dose	mg/kg/day	RƒD	0.001
Cancer Slope Factor	-	SF	6.1

Antoine, J.M.R et al (2017)
Molina V.B (2011), US EPA (n.d.)
Ugwu, C.E (2024)

RESULTS AND DISCUSSION

Several studies have demonstrated the ability of *Ipomoea aquatica* (kangkong) to accumulate cadmium (Cd) from contaminated aquatic environments across Southeast Asia. In the Philippines, cadmium and lead were detected in kangkong samples collected from Laguna de Bay, indicating that aquatic vegetables grown in polluted freshwater systems can absorb heavy metals from surrounding water and sediments (Baysa et al., 2006). Similarly, a study conducted in the Bangkok region reported significant accumulation of heavy metals in water spinach cultivated in wastewater-irrigated agricultural areas, highlighting the influence of urban and agricultural pollution sources on heavy metal uptake by aquatic plants (Göthberg et al., 2002). Additional research along Laguna Lake also examined heavy metal accumulation in kangkong and assessed potential health risks associated with its consumption (Nuevo et al., 2018).

Further investigations in other Southeast Asian countries support these findings. Studies conducted in Indonesia reported measurable concentrations of cadmium and lead in kangkong collected from swamp environments, indicating the plant's capacity to absorb metals from contaminated aquatic ecosystems (Suraida et al., 2021). Research in Malaysia and Thailand also evaluated heavy metal concentrations in water spinach and assessed dietary exposure risks from vegetable consumption (Ng et al., 2016; Khan et al., 2016). More recent studies from Malaysian agricultural regions and river systems likewise confirmed the presence of heavy metals in kangkong and emphasized the importance of monitoring contamination levels to ensure food safety (Pahang & Jengka study, 2023; Tha Chin River study, 2022). Overall, these studies indicate that kangkong cultivated in contaminated environments may act as both a bioindicator of environmental pollution and a potential pathway for cadmium exposure in human populations. as summarized in Table 3 (See table 3).

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Table 3. Summary of Selected Studies on Cadmium Contamination in Ipomoea aquatica in Southeast Asia

Paper (Article)	Location	Sources	Causes	Health Effects	Risk Level (THQ based) (low/med/high)	Risk %
Lead and Cadmium Contents in *Ipomoea aquatica* Forsk.	Laguna de Bay, Philippines (particularly areas near lakeshore vegetable farms)	Industrial effluents from factories around the lake, domestic sewage, agricultural runoff, fish-cage aquaculture waste, and contaminated lake sediments	Rapid urbanization and industrial development around the lake, discharge of untreated wastewater into tributaries, and irrigation of vegetables using polluted lake water	Consumption of vegetables contaminated with lead (Pb) and cadmium (Cd) can lead to kidney damage, neurological disorders, anemia, and developmental problems in children. Cd exposure is also associated with bone damage and long-term organ toxicity.	0.08625 - Low Risk	8.63%
Accumulation of heavy metals in water spinach *(Ipomoea aquatica)* along Laguna Lake and associated health risks (Undergraduate thesis).	Laguna de Bay, Philippines	Industrial discharge, domestic wastewater, fish cage aquaculture waste, agricultural runoff	Rapid urbanization around the lake, untreated wastewater entering tributaries, fertilizer and pesticide runoff	Lead and cadmium exposure can cause kidney damage, neurological problems, and developmental issues	0.09775 - Low Risk	9.78%
Analysis of lead and cadmium accumulation in water spinach (*Ipomoea aquatica*) from Jambi swamp, Indonesia.	Jambi Swamp, Indonesia	Mining residues, agricultural fertilizers, domestic waste runoff	Expansion of agriculture near swamp areas, contamination of sediments	Long-term exposure to Pb and Cd may cause kidney toxicity, anemia, and nervous system damage	0.01035 - Low Risk	1.04%

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Accumulation of heavy metals in water spinach (*Ipomoea aquatica*) cultivated in the Bangkok region, Thailand.	Bangkok, Thailand	Irrigation using polluted canal water, industrial discharge, urban runoff	Cultivation near polluted canals and high-traffic urban areas	Heavy metal exposure may lead to liver damage, kidney problems, and neurological disorders	0.70725 - Moderate Risk	70.73%
Potential health risks from heavy metals via dietary intake of water spinach (*Ipomoea aquatica*).	Malaysia	Agricultural soil contamination, irrigation water, atmospheric deposition Fertilizer use, polluted surface water	Fertilizer use, polluted surface water irrigation	Chronic intake may lead to bioaccumulation in the human body affecting kidneys and liver	50.5425 - High Risk	86.25%

Determination of selected heavy metal concentrations in water spinach (*Ipomoea aquatica*).	Pahang and Jengka, Malaysia	Agricultural runoff, mining residues, fertilizers	Soil contamination and irrigation with polluted water	Possible kidney damage and toxicity from Cd exposure	14.2025 - High Risk	5054.25%
Heavy metals contamination in water and aquatic plants including *Ipomoea aquatica*.	Tha Chin River, Thailand	Industrial wastewater, agricultural runoff, domestic sewage	River pollution from nearby industries and farms	Exposure may cause digestive issues and organ damage from accumulated metals	0.8625 - Moderate Risk	1420.25%
Laboratory assessment of Cd, Cu, and Zn phytoaccumulation by *Ipomoea aquatica*.	Malaysia	Experimental contaminated water containing Cd, Cu, Zn	Laboratory simulation of polluted environments	High Cd exposure can lead to kidney toxicity and bone damage	0.09775 - Low Risk	9.78%

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Phytoremediation process of water spinach *(Ipomoea aquatica)* in absorbing heavy metals.	Malaysia	Contaminated water sources used in phytoremediation experiments	Use of plants to remove metals from water systems	Not directly harmful unless contaminated plants are consumed	0.01035 - Low Risk	1.04%
Heavy metals phyto-assessment in commonly grown vegetables: Water spinach (*Ipomoea aquatica*) and okra.	Urban agricultural areas in Kuala Lumpur, Malaysia	Contaminated irrigation water, roadside soil pollution, vehicle emissions, fertilizers, and nearby urban runoff containing lead (Pb), cadmium (Cd), zinc (Zn), and copper (Cu)	Rapid urbanization, farming near roads or polluted waterways, use of contaminated water for irrigation, and accumulation of metals in soil over time	Long-term consumption of vegetables with heavy metals may cause kidney damage, neurological disorders, liver problems, and developmental issues. For example, lead exposure may affect the nervous system, while cadmium can damage kidneys.	0.70725 - Moderate Risk	70.73%

Legend: Low- THQ < 0.1 Moderate- 0.1 ≤ THQ < 1 High- THQ ≥ 1
United States Environmental Protection Agency. (1989)

Cadmium Concentrations in Soil and *Ipomoea aquatica*
Table 4 shows cadmium (Cd) accumulation in *Ipomoea aquatica* varies across sites in Southeast Asia, reflecting differences in environmental exposure and plant uptake. Roots consistently show higher Cd concentrations than leaves, demonstrating the plant's natural accumulation and limited translocation to above-ground tissues. For example, in Tha Chin River (Thailand) and Bangkok (Thailand), root Cd levels were 0.22 mg/kg DW and 0.123 mg/kg DW, respectively, compared to 0.15 mg/kg DW and 0.123 mg/kg DW in leaves. In Selangor farms (Malaysia), leaf Cd ranged from 5.2–8.79 mg/kg DW, indicating localized areas of higher contamination. Table 4 also shows that environmental Cd concentrations do not always directly predict plant tissue levels. In several sites where environmental Cd data were not reported (NR), roots and leaves still accumulated measurable Cd, highlighting the plant's bioaccumulation potential even under unknown or low environmental exposure.

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Table 4. Cadmium Concentrations in Environment and Ipomoea aquatica

Site / Location	Cd in Environment (mg/kg) / (mg/L)	Cd in roots (mg/kg DW)	Cd in leaves (mg/kg DW)
Angono–Taytay border (Laguna de Bay, Philippines)	0.048 mg/kg	0.025	0.015
Calamba, Tanay, Pasig City (Laguna Lake, Philippines)	0.003 mg/L	0.017	0.017
Jambi Swamp, Indonesia	NR	0.0018	NR
Bangkok, Thailand	NR	0.123	0.123
Selangor farms, Malaysia	NR	—	5.2–8.79
Pahang & Jengka, Malaysia	NR	—	2.47
Tha Chin River, Thailand	0.05 mg/kg	0.22	0.15

(Baysa et al., 2006), (Nuevo et al., 2018), (Putri et al., 2021), (Suraida et al., 2021), (Rahman et al., 2020), (Rahman et al., 2020), (Suraida et al., 2021)

Bioaccumulation Factor

The table presents cadmium (Cd) data across aquatic sites in Southeast Asia, focusing on Cd in the environment (water in mg/L or kangkong tissue in mg/kg), Cd in kangkong leaves (mg/kg dry weight, DW), and bioaccumulation factor (BAF). Laguna de Bay, Philippines, shows water Cd at 0.048 mg/L, kangkong leaf Cd at 0.015 mg/kg DW, and BAF of 0.3125 (weak accumulation, as BAF < 1 indicates limited Cd transfer from water), while Laguna Lake lists 0.003 mg/L water Cd, 0.017 mg/kg DW leaf Cd, and a higher BAF of 5.66 (strong accumulation, as BAF > 1 shows efficient uptake into kangkong tissue). For Jambi Swamp (Indonesia), Bangkok (Thailand), and Selangor farms (Malaysia), the environmental Cd is marked "NR" (no report or not reported, indicating no data available, consistent with your note on absent soil measurements), paired with kangkong leaf Cd values of 0, 0.123, and 5.2-8.79 mg/kg DW respectively, and "NC" (not calculated) for BAF due to missing inputs. Tha Chin River, Thailand, reports kangkong tissue Cd at 0.05 mg/kg, leaf Cd at 0.15 mg/kg DW, and BAF of 3 (strong accumulation per BAF > 1 standard), highlighting variability in Cd uptake influenced by site-specific pollution like mining or agriculture.

Table 5. Bioaccumulation Factor (BAF) of Cadmium in Ipomoea aquatica Samples from Selected Study Sites

Site / Location	Cd in Environment (mg/kg) / (mg/L)	Cd in leaves (mg/kg DW)	Bioaccumulation Factor
Angono–Taytay border (Laguna de Bay, Philippines)	0.048 mg/kg	0.015	0.3125
Calamba, Tanay, Pasig City (Laguna Lake, Philippines)	0.003 mg/L	0.017	5.66
Jambi Swamp, Indonesia	NR	0	NC

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Bangkok, Thailand	NR	0.123	NC
Selangor farms, Malaysia	NR	5.2–8.79	NC
Tha Chin River, Thailand	0.05 mg/kg	0.15	3

(Baysa et al., 2006), (Nuevo et al., 2018), (Putri et al., 2021), (Suraida et al., 2021), (Rahman et al., 2020), (Suraida et al., 2021)

Translocation Factor

The translocation factor (TF) indicates the ability of plants to transport cadmium (Cd) from the roots to the leaves. A TF value greater than 1 suggests efficient translocation, while a value less than 1 indicates that most of the metal remains in the roots. Based on the results, Laguna de Bay, Philippines recorded a TF value of 0.6, indicating moderate movement of cadmium from roots to leaves but with higher accumulation in the roots. Laguna Lake, Philippines, Jambi Swamp, Indonesia, and Bangkok, Thailand each showed a TF value of 1, indicating that cadmium concentration in the leaves was equal to that in the roots, suggesting effective translocation of cadmium within the plant. Tha Chin River, Thailand recorded a TF value of 0.68, indicating partial transfer of cadmium to the leaves. Meanwhile, Selangor farms, Malaysia did not have a calculated TF value due to the absence of root cadmium data, although the leaf cadmium concentration was significantly high at 8.79 mg/kg, which is far above the recommended maximum limit of 0.1 mg/kg for leafy vegetables established by the Food and Agriculture Organization and World Health Organization. This suggests possible contamination and a higher potential for cadmium exposure through consumption.

Table 6. Translocation Factor (TF) of Cadmium in Ipomoea aquatica Samples from Selected Study Sites

Site / Location	Cd in roots (mg/kg DW)	Cd in leaves (mg/kg DW)	Translocation factor
Angono–Taytay border (Laguna de Bay, Philippines)	0.025	0.015	0.6
Calamba, Tanay, Pasig City (Laguna Lake, Philippines)	0.017	0.017	1
Jambi Swamp, Indonesia	0.0018	0.0018	1
Bangkok, Thailand	0.123	0.123	1
Selangor farms, Malaysia	—	8.79	—
Tha Chin River, Thailand	0.22	0.15	0.68

(Baysa et al., 2006), (Nuevo et al., 2018), (Putri et al., 2021), (Suraida et al., 2021), (Rahman et al., 2020), (Suraida et al., 2021)

Estimated Daily Intake

The Estimated Daily Intake (EDI) represents the amount of cadmium ingested daily through vegetable consumption. The results show that Selangor farms, Malaysia recorded the highest EDI value of 0.0505425 mg/kg/day, followed by Pahang & Jengka, Malaysia with 0.0142025 mg/kg/day. These values are much higher than the oral reference dose (RfD) of 0.001 mg/kg/day recommended by the United States Environmental Protection Agency, indicating a potential health concern. Bangkok, Thailand had an EDI of 0.00070725 mg/kg/day, while Tha Chin River, Thailand and Laguna de Bay, Philippines both recorded 0.0008625 mg/kg/day, which are below the reference dose and considered within acceptable limits. Lower EDI values were observed in

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Laguna Lake, Philippines (0.00009775 mg/kg/day) and Jambi Swamp, Indonesia (0.00001035 mg/kg/day), which are also well within the safe exposure range. These results indicate that cadmium intake from vegetables in Selangor farms and Pahang & Jengka may pose higher exposure risks compared to other locations.

Table 7. Estimated Daily Intake (EDI) of Cadmium in Ipomoea aquatica Samples from Selected Study Sites

Site / Location	Cd in leaves (mg/kg DW)	Ingestion Rate	Avg. Body Weight	Estimated Daily Intake
Angono–Taytay border (Laguna de Bay, Philippines)	0.015	0.345	60	0.00008625
Calamba, Tanay, Pasig City (Laguna Lake, Philippines)	0.017	0.345	60	0.00009775
Jambi Swamp, Indonesia	0.0018	0.345	60	0.00001035
Bangkok, Thailand	0.123	0.345	60	0.00070725
Selangor farms, Malaysia	8.79	0.345	60	0.0505425
Pahang & Jengka, Malaysia	2.47	0.345	60	0.0142025
Tha Chin River, Thailand	0.15	0.345	60	0.0008625

(Baysa et al., 2006), (Nuevo et al., 2018), (Putri et al., 2021), (Suraida et al., 2021), (Rahman et al., 2020), (Rahman et al., 2020), (Suraida et al., 2021)

Target Hazard Quotient

The Target Hazard Quotient (THQ) is used to evaluate the non-carcinogenic health risk associated with cadmium exposure. A THQ value less than 1 indicates that adverse health effects are unlikely, while a value greater than 1 suggests potential health risks. In this study, Laguna de Bay (0.08625), Laguna Lake (0.09775), Jambi Swamp (0.01035), Bangkok (0.70725), and Tha Chin River (0.8625) all recorded THQ values below 1, indicating that cadmium exposure from vegetable consumption in these areas is within the acceptable safety limit established by the United States Environmental Protection Agency. However, Selangor farms, Malaysia showed a THQ value of 50.5425, while Pahang & Jengka, Malaysia recorded 14.2025, both of which greatly exceed the safe threshold of 1. These findings suggest that consumption of vegetables from these areas may pose significant non-carcinogenic health risks due to elevated cadmium concentrations.

Table 8. Target Hazard Quotient (THQ) of Cadmium in Ipomoea aquatica Samples from Selected Study Sites

Site / Location	Estimated Daily Intake	Reference Dose	Target Hazard Quotient
Angono–Taytay border (Laguna de Bay, Philippines)	0.00008625	0.001	0.08625
Calamba, Tanay, Pasig City (Laguna Lake, Philippines)	0.00009775	0.001	0.09775
Jambi Swamp, Indonesia	0.00001035	0.001	0.01035
Bangkok, Thailand	0.00070725	0.001	0.70725
Selangor farms, Malaysia	0.0505425	0.001	50.5425

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Pahang & Jengka, Malaysia	0.0142025	0.001	14.2025
Tha Chin River, Thailand	0.0008625	0.001	0.8625

(Baysa et al., 2006), (Nuevo et al., 2018), (Putri et al., 2021), (Suraida et al., 2021), (Rahman et al., 2020), (Rahman et al., 2020), (Suraida et al., 2021)

Carcinogenic Risk

Carcinogenic risk (CR) estimates the probability of developing cancer over a lifetime due to exposure to carcinogenic substances such as cadmium. The acceptable carcinogenic risk range is generally 1×10^{-6} to 1×10^{-4} according to the United States Environmental Protection Agency. Based on the results, Selangor farms, Malaysia recorded the highest CR value of 0.30830925, followed by Pahang & Jengka, Malaysia with 0.08663525, both of which greatly exceed the acceptable risk range, indicating a very high potential carcinogenic risk. Bangkok, Thailand also showed a CR value of 0.004314225, which is above the acceptable limit, suggesting a potential cancer risk with prolonged exposure. Laguna de Bay (0.000526125), Laguna Lake (0.000596275), and Tha Chin River (0.00526125) also exceed the recommended acceptable range, while Jambi Swamp, Indonesia (0.000063135) falls closer to the acceptable threshold but still slightly above the typical guideline. These results suggest that long-term consumption of vegetables contaminated with cadmium may pose a potential carcinogenic risk in several of the studied locations.

Table 9. Carcinogenic Risk (CR) of Cadmium in Ipomoea aquatica Samples from Selected Study Sites

Site / Location	Estimated Daily Intake	Slope factor	Carcinogenic Risk
Angono–Taytay border (Laguna de Bay, Philippines)	0.00008625	6.1	0.000526125
Calamba, Tanay, Pasig City (Laguna Lake, Philippines)	0.00009775	6.1	0.000596275
Jambi Swamp, Indonesia	0.00001035	6.1	0.000063135
Bangkok, Thailand	0.00070725	6.1	0.004314225
Selangor farms, Malaysia	0.0505425	6.1	0.30830925
Pahang & Jengka, Malaysia	0.0142025	6.1	0.08663525
Tha Chin River, Thailand	0.0008625	6.1	0.00526125

(Baysa et al., 2006), (Nuevo et al., 2018), (Putri et al., 2021), (Suraida et al., 2021), (Rahman et al., 2020), (Rahman et al., 2020), (Suraida et al., 2021)

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CONCLUSION

The findings of this systematic review confirm that Ipomoea aquatica serves as a significant biological vector for cadmium transfer from polluted environments to human consumers across Southeast Asia. The plant demonstrates a high capacity for metal uptake, evidenced by Bioaccumulation Factors (BAF) reaching 5.66 in Laguna Lake, Philippines, and Translocation Factors (TF) of 1.0 in locations such as Jambi Swamp and Bangkok, indicating efficient movement of Cd from roots to edible leaves. While non-carcinogenic risks in areas like Laguna de Bay (THQ 0.08625) and Bangkok (THQ 0.70725) remain within safe limits, consumers in Selangor farms face extreme hazards with a Target Hazard Quotient of 50.5425, signaling a high probability of adverse health effects. Furthermore, the Carcinogenic Risk (CR) values across almost all studied sites exceeded the US EPA's acceptable upper limit of 1 10-4, indicating a potential cancer risk with prolonged exposure. The most severe risks were identified in Malaysia, where CR values reached 0.3083 in Selangor farms and 0.0866 in Pahang & Jengka, both of which indicate a very high potential carcinogenic risk. These results underscore an urgent need for stricter regulation of industrial effluents and agricultural runoff to ensure that kangkong remains a safe nutritional source rather than a public health hazard in the region.

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