REVIEW ARTICLE

https://doi.org/10.3329/jmcwh.v21i2.83606

INDUSTRIAL TOXICANTS IN BANGLADESH: SOURCES, EXPOSURE AND PUBLIC HEALTH IMPACTS – A SYSTEMATIC REVIEW

Lamiya Tasnim Niloy[1], Irin Hossain[2*], Md Golam Abbas[2], Shahria Sattar[2], Afsana Naznnen[2], Mst. Foyzunnahar[3], Hazzaz Bin Mujib[2], Aurpa Tabassum[2], Nusrat-E-Alam[2], Sanzidah Yeasmin[2], Anjum Ara Sifat[2], Nelema Jahan[2], Md. Raihan Parvez[2], Srabone Dutta Tama[2], Romana Sultana Puspo[2]

ABSTRACT

Background: Bangladesh's rapid industrialization has significantly contributed to economic growth but has also resulted in widespread environmental contamination. Industries such as tanneries, textile dyeing, battery recycling, and metal processing discharge effluents containing hazardous toxicants, particularly heavy metals like lead (Pb), cadmium (Cd), arsenic (As), chromium (Cr), and mercury (Hg). These substances have been found across environmental media -including air, water, soil, and food-posing serious health risks, especially for children, pregnant women, and industrial workers. **Materials and Method:** This systematic review was conducted following PRISMA guidelines. A total of 35 peer-reviewed studies published between 2009 and 2024 were selected from electronic databases. Studies were included if they assessed heavy metal concentrations, exposure pathways, health effects, or ecological impacts in industrial areas of Bangladesh. Data extraction included study location, sample type, toxicant concentration, health endpoints, and risk metrics such as Hazard Index (HI) and Target Carcinogenic Risk (TCR). Geographic coverage spanned major industrial hubs including Dhaka, Gazipur, Narayanganj, Savar, Hazaribagh, Kushtia, Tangail, and Sylhet. **Results:** The review revealed heavy metal contamination in street dust, vegetables, rice, water, and biological samples. Blood lead levels among battery workers averaged 65.25 μg/dL, far exceeding safe limits. Arsenic in drinking water reached up to 0.146 mg/L, over 14 times the World Health Organization (WHO) guideline. Children near industrial zones had elevated urinary metal levels associated with neurodevelopmental issues. Environmental impacts included degraded soil fertility, disrupted aquatic ecosystems, contaminated groundwater, and food chain bioaccumulation. **Conclusion:** Industrial toxicants pose a critical and often underestimated public health and ecological threat in Bangladesh. Urgent, coordinated policy action is needed to strengthen pollution control, enforce effluent treatment, enhance occupational safety, and expand environmental surveillance and public health education.

Keywords: Industrial pollution, Heavy metals, Environmental health, Bangladesh, Chemical exposure

Cite this article: Niloy LT,Hossain I,Abbas MG,Sattar S, Naznnen A, Foyzunnahar M,Mujib HB,Tabassum A,Alam NE,Yeasmin S, Sifat AA,Jahan N,Parvez MR,Tama SD,Puspo RS. Industrial Toxicants in Bangladesh: Sources, Exposure and Public Health Impacts – A Systematic Review.J Med Coll Women Hosp.2025;21(2):175-191.

INTRODUCTION

Bangladesh's rapid economic growth over the past few decades has been closely tied to a surge in industrialization across several sectors, including textiles, leather processing, pharmaceuticals, metalworking, battery recycling, plastic production, and dyeing[1-3].

While this industrial expansion has played a vital role in boosting national GDP, employment, and exports, it has also brought significant environmental and public health challenges[1,4,5].

1. National Institute of Preventive and Social Medicine, Dhaka, Bangladesh.

2*. Department of Occupational and Environmental Health, National Institute of Preventive and Social Medicine, Dhaka, Bangladesh
Email: irin.hossain@gmail.com , https://orcid.org/000-0003-1068-674X [**Address of Correspondence**]

2. Department of Occupational and Environmental Health, National Institute of Preventive and Social Medicine, Dhaka, Bangladesh.

3. Department of Public Health Emergency, National Institute of Preventive and Social Medicine, Dhaka, Bangladesh.

Among these, pollution from industrial toxicants- particularly heavy metals- has emerged as a critical concern. Inadequate waste management practices, coupled with weak enforcement of environmental regulations, have allowed persistent toxic chemicals to contaminate Bangladesh's air, water, soil, and food systems[2,4,6,7,8].

Heavy metals such as lead (Pb), cadmium (Cd), arsenic (As), chromium (Cr), and mercury (Hg) are among the most frequently identified pollutants in environmental samples collected near industrial areas[7,9,10]. These substances are non-biodegradable, tend to accumulate in ecosystems, and pose a variety of health risks- ranging from neurodevelopmental disorders and organ damage to cancer and reproductive toxicity[11-13]. Vulnerable populations, especially children, pregnant women, and workers directly involved in industrial processes, are disproportionately affected[14-17]. The problem is compounded by the fact that these toxicants often enter the food chain through contaminated crops, water, poultry, and fish, exposing not only residents of industrial areas but also consumers in distant regions[18-24].

Numerous studies from industrial hotspots such as Dhaka, Gazipur, Narayanganj, Savar, Hazaribagh, Kushtia, Sylhet, and Tangail have reported pollutant levels in effluents, soil, and agricultural produce that far exceed WHO and national safety guidelines[1,2,6, 10,25,26,27,28,29,30,31,32,33]. Wastewater from tanneries, textile mills, dyeing plants, and battery recycling units is often discharged directly into rivers and canals without any treatment, carrying carcinogenic and neurotoxic substances like hexavalent chromium (Cr VI), lead, and cadmium[5,7,25,26,34,35]. These contaminated water sources are subsequently used for irrigation, spreading the toxicants to rice fields and vegetable plots and further embedding them in the national food supply[36,37].

The public health implications of these exposures are profound. Elevated blood lead levels in battery workers, high arsenic concentrations in drinking water, and dangerous levels of cadmium in vegetables and fish are well-documented[17,18,34]. Yet, in the absence of a centralized environmental surveillance system or unified industrial monitoring framework, the true extent of toxicant exposure remains difficult to quantify[1,15,25]. Individual studies remain the primary means of identifying and understanding the scale of contamination and its consequences.

This review was motivated by the growing recognition that the disease burden attributable to environmental chemicals is both substantial and underreported. Many of these chemical exposures can be significantly reduced or even eliminated through appropriate environmental and occupational health policies. However, the issue has yet to receive adequate attention from policymakers, health professionals, and the broader research community. To address this gap, the current systematic review synthesizes existing literature on industrial toxicants in Bangladesh, with an emphasis on their sources, human exposure pathways, associated health outcomes, and potential mitigation strategies.

By consolidating findings from diverse studies conducted over the past 15 years, this review seeks to inform national policymakers and promote multi-sectoral actions that can reduce human exposure to industrial chemicals, improve environmental quality, and protect public health.

MATERIALS AND METHOD

This systematic review was based on a qualitative synthesis of the literature and was conducted according to the guidelines established by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA)[38]. The objective was to develop a robust and comprehensive understanding of industrial toxicants, their sources, exposure pathways, concentrations, hazard indices (HI), target carcinogenic risk (TCR), and associated health and environmental effects in Bangladesh.

Literature Search and Selection Strategy

A rigorous literature search was performed using reputable databases such as PubMed, Scopus, and Web of Science. Pertinent keywords and search terms were selected after an initial scoping review. These included "industrial toxicants," "heavy metals," "exposure pathways," "hazard indices," and "public health impacts." The search was limited to complete papers composed in English and published between 2009 and 2024. These criteria were chosen to ensure that the review included only recent and relevant evidence, capturing the latest developments and findings in the field.

Inclusion and Exclusion Criteria

Studies were included if met the following criteria:

- They were observational, cross-sectional, environmental monitoring, or case-control studies.
- They reported data on toxicants (e.g., heavy metals such as Pb, Cd, As, Cr, Hg), exposure pathways (inhalation, ingestion, dermal contact, and occupational), and included measures of concentration, hazard indices (HI), and target carcinogenic risk (TCR).
- They examined health outcomes (e.g., neurodevelopmental disorders, organ damage, cancer, respiratory, and cardiovascular issues) or environmental effects (e.g., soil degradation, groundwater contamination, ecosystem disruption).

Studies were excluded if:

- Were not published in English.
- Did not provide primary data on environmental or health risk assessments.
- Focused on chemical exposures not linked to industrial processes (e.g., active smoking or radioactive substances) or were not relevant to the target industrial zones in Bangladesh.
- Were review articles, editorials, or commentaries lacking original data.

Data Extraction and Quality Assessment

The quality of the studies was assessed according to pre-established criteria based on study design, sample size, exposure assessment methods, and the reliability of risk metrics reported. This rigorous evaluation was essential to establish a comprehensive and reliable basis for examining the link between industrial toxicants and associated health and ecological impacts. Studies demonstrating robust methodologies and clear risk estimation were given higher weight in the synthesis.

A qualitative synthesis of the extracted data was conducted to summarize the evidence across studies. The synthesis focused on identifying patterns in the types of toxicants present in various industrial zones, their pathways of human exposure, the magnitude of the measured concentrations, and the calculated hazard indices and target carcinogenic risks. Moreover, the synthesis included an evaluation of the reported health effects among different population groups and an assessment of environmental impacts, such as soil degradation and water contamination.

The integration of data from 26 studiesprovided an extensive overview of the subject (Figure-1). By comparing results across different geographical areas and industrial processes, the review aimed to delineate the overall public health burden attributable to industrial toxicant exposure in Bangladesh and to highlight priority areas for intervention.

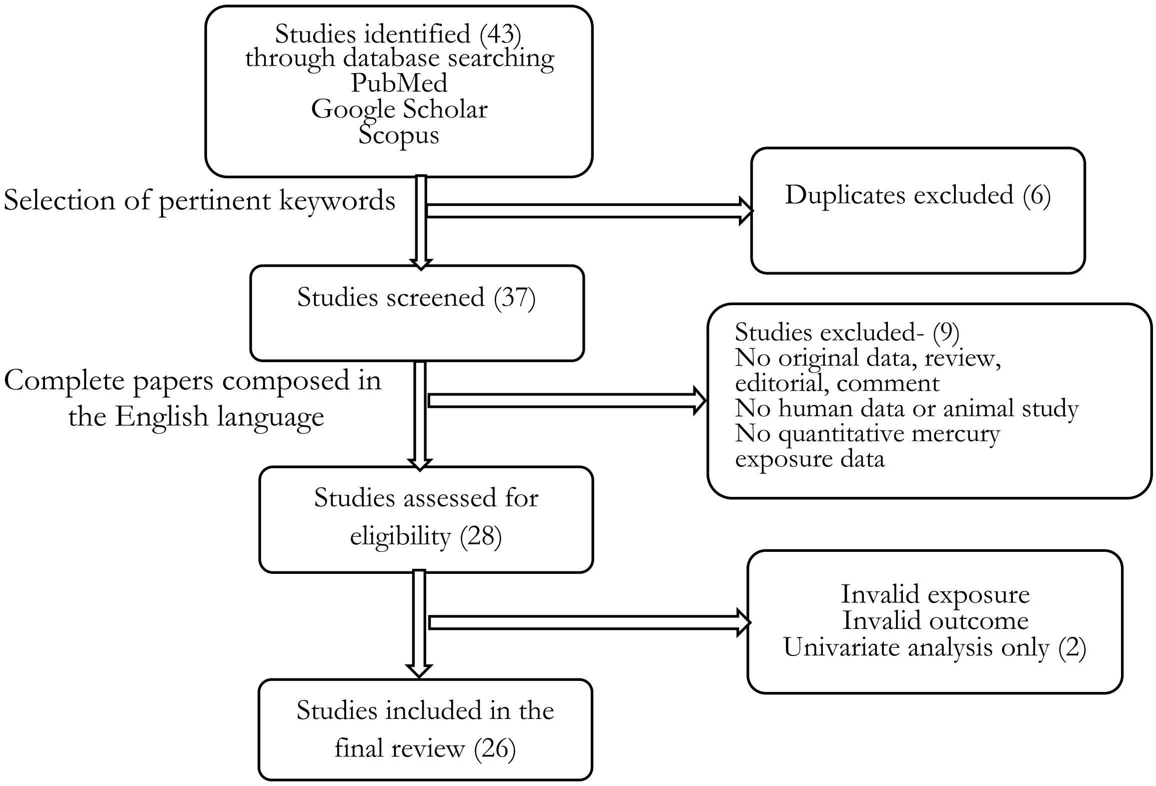

Figure 1: Search and selection of articles for systematic review on Industrial Toxicants in Bangladesh

RESULTS AND DISCUSSION

Sources and Environmental Pathways

The environmental dissemination of industrial toxicants in Bangladesh is primarily driven by direct discharges of untreated effluents from factories, poor waste management practices, and a lack of regulatory enforcement. Among the most notorious sources are tanneries, particularly in the Hazaribagh area, where leather processing activities have historically discharged large volumes of chromium-rich wastewater into nearby canals and drainage systems[29]. Textile dyeing and printing industries, particularly concentrated in Narayanganj and Savar, also contribute significantly by releasing dyes and wash waters that contain heavy metals such as cadmium (Cd), lead (Pb), and copper (Cu)[30,31].

Battery recycling operations serve as another potent source of environmental lead contamination. The improper dismantling of batteries and open dumping of residues result in the leaching of lead into soils and water bodies[19]. Multi-industry clusters, where several manufacturing units coexist without unified waste treatment infrastructure, further intensify this problem. In regions like Gazipur and Narayanganj, studies have identified high cumulative levels of arsenic (As), Cu, nickel (Ni), and zinc (Zn) in surface water, groundwater, and agricultural soils[16].

Transmission of these toxicants occurs through several interconnected environmental pathways. Untreated industrial wastewater is frequently discharged into local rivers, canals, and agricultural lands, leading to contamination of both surface water and shallow aquifers. The use of polluted water for irrigation facilitates the deposition of heavy metals into agricultural soils, which not only degrades soil fertility but also enhances the uptake of contaminants by food crops[17,18,34].

Airborne transmission plays a major role in the dispersion of industrial pollutants. Emissions from chimneys and the open burning of industrial waste release particulate matter (PM) into the atmosphere. These particles often contain embedded heavy metals that settle as street dust or remain airborne, posing inhalation risks. In areas with strong wind activity, metal-laden dust can be transported over considerable distances, causing secondary contamination of non-industrial zones[39,40].

Furthermore, heavy rainfall during the monsoon season accelerates surface runoff, mobilizing deposited metals from industrial soils and roadways into nearby water bodies. This runoff exacerbates aquatic pollution and alters oxygen availability in freshwater ecosystems, thereby increasing toxicity. These processes perpetuate the environmental cycling of industrial toxicants and ensure their long-term persistence in ecosystems and food webs[41].

Human Exposure to Industrial Toxicants

Exposure to industrial toxicants in Bangladesh is both widespread and multifaceted, affecting occupationally exposed workers as well as the general population. The primary toxicants of concern - Pb, Cd, As, Cr, Hg, and other heavy metals- originate from various industries, including tanneries, textile dyeing units, metal smelting plants, battery recycling operations, and plastic manufacturing facilities. These hazardous substances enter the environment through untreated or poorly managed industrial effluents and emissions and subsequently accumulate in ambient air, surface and groundwater, soils, and the food chain[40,41].
Vulnerable populations, particularly children and pregnant women, face elevated risks. Elevated urinary concentrations of Mn, Cr, Cu, and Pb have been observed in children residing near industrial zones[18]. These biomarkers are linked to behavioral abnormalities and cognitive deficits[1]. Prenatal exposure through maternal ingestion of contaminated food and water may result in fetal toxicant uptake, exacerbating developmental risks.

Pathways of Exposure

Human exposure to industrial toxicants in Bangladesh occurs through multiple environmental and occupational routes, including inhalation, ingestion, dermal contact, and maternal transfer. Each route presents substantial health risks, particularly in heavily industrialized zones such as Savar, Narayanganj, and Gazipur.

Inhalation is one of the most direct and hazardous exposure pathways. Industrial processes release fine particulate matter (PM) into the air, which contains high levels of metals. Street dust samples from Savar, Narayanganj, and Gazipur show elevated levels of Pb, Zn, and Cd, posing respiratory risks to children and adults via airborne particles[12]. Occupational inhalation exposure is especially acute among battery recycling and plastic manufacturing workers, where metal-laden dust and fumes are common. The absence of personal protective equipment (PPE) and inadequate ventilation systems heightens these risks[42,43].
Ingestion of contaminated food and water is another significant pathway of chronic exposure. Crops irrigated with untreated industrial wastewater—particularly from textile and tannery operations - accumulate heavy metals such as Cr, Pb, Cd, and Ni at levels often exceeding WHO safety limits[23,33]. Poultry and eggs from areas near effluent discharge points like the Dhaka-Narayanganj-Demra (DND) embankment also show high levels of Zn, Cu, and Pb[14], making food a major exposure source.

Drinking water contamination persists in areas like Kushtia and Sylhet. Arsenic levels in tube wells have reached 0.146 mg/L- more than 14 times the WHO guideline of 0.01 mg/L[3]. Prolonged ingestion of this water is linked to increased risks of cancer, cardiovascular disease, and skin lesions.

Dermal contact is another relevant route, particularly in communities near industrial sludge deposits. In Hazaribagh, residents and workers come into daily contact with soil and sludge heavily contaminated with Cr and Pb, increasing the risk of transdermal absorption [27].

To visually represent the findings of this review, Figure 2 presents a conceptual framework outlining the sources of industrial toxicants in Bangladesh and the key pathways through which these toxicants reach human populations.

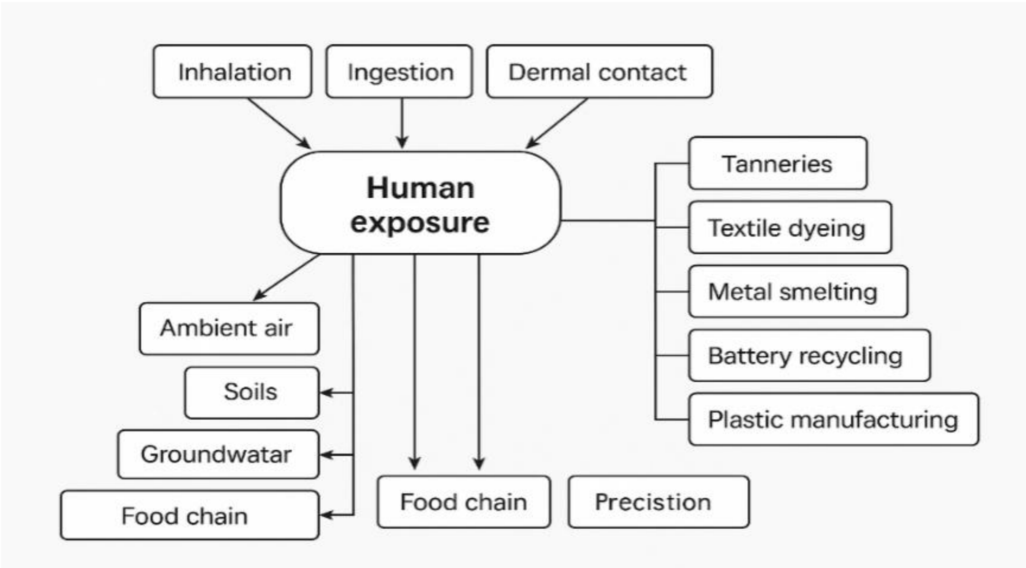

Figure 2: Framework of Human Exposure to Industrial Toxicants in Bangladesh

Exposure Patterns and Bioaccumulation

A particularly alarming dimension of toxicant exposure in Bangladesh is the systemic integration of heavy metals into the food chain. Wastewater irrigation and the contamination of staple foods such as rice have resulted in widespread dietary exposure across both urban and rural populations. Studies confirm that crops grown near industrial areas—including leafy vegetables, brinjals, beans, and rice-consistently contain heavy metal concentrations that surpass established Maximum Residue Limits (MRLs). Poultry and eggs are also affected due to animals consuming contaminated water and feed[14-16]. Continuous exposure through food sources contributes to the accumulation of toxicants across generations, elevating the risk of chronic illnesses and subclinical health impairments.

Occupational exposure is equally concerning due to its intensity and persistence. Workers in battery recycling facilities face the highest exposure levels. Ahmad et al.[18] reported average blood lead levels of 65.25 µg/dL among workers-over 13 times the reference value of 5 µg/dL accepted by the Centres for Disease Control and Prevention (CDC).Some roles, such as acidification and plate-making, had blood lead levels exceeding 80 µg/dL. These elevated levels were linked to symptoms such as anemia, gastrointestinal distress, and hypertension. Workers with pre-existing conditions like anemia or high blood pressure demonstrated even higher metal absorption, suggesting that toxicant burden may interact synergistically with existing health vulnerabilities[18].

Table 1: Consolidates studies focusing on environmental contamination, toxicant sources, and exposure pathways across industrial zones in Bangladesh.

Table 1 Summary Table of Studies on Industrial Toxicants in Bangladesh				
Study & Year	**Location**	**Key Metals**	**Risk Metrics**	**Major Findings**
Shammi et al., 2021[1]	Dhamrai Upazila, Dhaka	Fe, Mn, Cr, Cu, Ni, Co, Zn, Pb, Cd	Not specified	Exposure associated with neurodevelopmental issues, impaired growth, liver and kidney damage, gastrointestinal and respiratory disorders, and cancer; environmental impacts include soil contamination and ecosystem disruption.
Kormoker et al., 2021 [2]	Konabari Industrial Area, Gazipur	Fe (350.38 ppm), Zn (1.42 ppm), Pb (0.46 ppm), Cu (0.40 ppm), Cd (0.03 ppm)	Not specified	Soil contamination poses risks for food chain entry and reduced agricultural productivity.
Bhuiyan et al., 2010[3]	Meghna Ghat Industrial Area	Cr, Cd, Pb	Water pollution indices (WQI, DC, HEI, HPI)	Contaminated water associated with organ damage, cancer, and developmental/neurological disorders; groundwater contamination threatens ecosystems.
Syed Hafizur Rahman et al., 2012 [4]	DEPZ, Savar,	As, Pb	HQ < 1; HI < 1; CR for As: 1.43E-05 (adult male), 1.54E-05 (adult female), 6.97E-07 (children); CR for Pb: ~4.54E-07	Soil near industrial zones shows low acute risk but poses potential long-term neurotoxicity, cancer, and kidney damage.
Hasan et al., 2022[5]	(Industrial areas, Gazipur region, Bangladesh)	Pb	Concentration-based	Rice cultivated in contaminated areas shows high lead accumulation, posing potential health risks via dietary exposure.
Hossain et al., 2014 [7]	Dhaka,	Pb	Mean Blood Lead Level (BLL): 65.25 ± 26.66 µg/dL	Elevated BLLs among LAB workers indicate significant risks for neurological, gastrointestinal, hematological, and cardiovascular disorders.

Table 1 Summary Table of Studies on Industrial Toxicants in Bangladesh				
Study & Year	**Location**	**Key Metals**	**Risk Metrics**	**Major Findings**
Islam et al., 2012 [9]	Kutubdia channel, Moheskhali, Cox's Bazar	Cu, Zn, Mn, Cr, Pb, Cd	THQ > 1 for non-carcinogenic risk	Contaminated water from industrial discharges (including near a coal thermal power plant) poses non-carcinogenic risks.
Rana et al., 2024[11]	Savar, Fulbaria, Katlapur & Dhaka	Pb, Cd, Cr, Co	EDI, THQ, HI, TCR (all exceed safe limits)	Consuming vegetables grown in contaminated environments presents unacceptable lifetime cancer and non-carcinogenic risks.
Saha et al., 2017 [12]	Tangail	As, Cd, Cr, Cu, Ni, Pb	THQ > 1; HI > 1; Target Carcinogenic Risk (TR) exceeds safe limits	Consumption of contaminated food contributes to significant risks of kidney, liver, cardiovascular, and cancer-related effects.
Hasan et al al., 2019 [14]	Gazipur (near multi-industry zone)	Cr, Cu, Zn, As, Cd, Pb	Concentration-based	Industrial discharges result in significant heavy metal contamination, affecting the food chain and human health.
Ahmed et al., 2019 [15]	Dhaka	Cr, Cu, Zn, As, Cd, Pb	Concentration-based	Wastewater discharges from diverse industries cause severe contamination in agricultural products, raising health concerns.
Ahmed et al., 2020[16]	Dhaka,	Pb, Cd, Ni, Zn	Concentration-based	Workers in plastic manufacturing exhibit elevated heavy metal burdens, indicating noteworthy occupational risks.
Hossain et al., 2014 (Rice Field Study)[17]	Gazipur, Dhaka	Not individually enumerated	HQ > 1; HI ranging from 6.51 to 29.30; CR > 1×10^{-5}	Rice consumption in contaminated areas presents significant carcinogenic and non-carcinogenic health risks.
Ahmad et al., 2014 [18]	Dhaka	Pb, Cd, Ni, Zn	Concentration-based measurements	Workers exposed in industrial settings show raised heavy metal levels, underscoring occupational hazards.
Tanvir et al., 2021[19]	Dhaka,	Various metals/metalloids	HQ and HI above safe thresholds	High environmental exposure in industrialized areas correlates with adverse neurodevelopmental and cardiovascular outcomes in

Table 1 Summary Table of Studies on Industrial Toxicants in Bangladesh				
Study & Year	**Location**	**Key Metals**	**Risk Metrics**	**Major Findings**
				children.
Proshad et al., 2020[21]	DEPZ, Savar	Cr, Pb	HQ for Cr and Pb were >1	Long-term exposure may result in neurotoxicity, cancer, and kidney damage.
Islam et al., 2018 [22]	Hazaribagh Tannery area, Dhaka,	Cr	Concentration-based; Cr measured at 23,149 mg/kg (29× EU limit)	Exceptionally high Cr levels indicate severe ecological and human health threats, including potential carcinogenesis and ecosystem disruption.
Islam et al., 2022[24]	Hazaribagh Leather Industries, Dhaka, Bangladesh	As, Cr, Cd, Co, Pb, Cu, Ni, Zn, Sb, Hg	Concentration-based	Very high Cr levels (workers: 21.85–483 mg/kg; residents: 6.01–296.16 mg/kg) suggest increased risks for chromium-related diseases and potential bioaccumulation in nearby populations.
Amin et al., 2020[25]	DEPZ, Savar,	As, Cr, Cu, Pb, Mn, Ni, Cd, Zn	HI > 1 for surface water; TCR for As > 1×10^{-4} in river water; Groundwater within safe limits	Surface water ingestion poses high cancer risk, while groundwater remains relatively safe; overall non-carcinogenic risks are elevated.
Jiku et al., 2021[27]	Industrial areas of Gazipur and Savar	Cu, Cd, Mn, Cr, Zn, Pb	SAR (Sodium Absorption Ratio: 0.72–6.05)	Industrial wastewater from textile, dyeing, tannery, and metal processing industries links to kidney damage, bone fractures, cancer, and neurological disorders.
Das et al., 2011 [29]	Narayanganj	Pb, Cd, Zn, Cu (and several anions: Cl^-, NO_2^-, NO_3^-, SO_4^{2-}, PO_4^{3-})	Not specified	Textile dyeing effluents cause drastically altered water quality leading to potential gastrointestinal and dermal health effects.
Sultana et al., 2009[30]	Araihazar, Narayanganj,	Cd, Pb, Cu, Cr	Not specified	Textile dyeing effluents resulted in polluted surface water with elevated heavy metal and anion levels, posing risks for waterborne diseases.
Hasan. and Miah M., 2014 [31]	Narayanganj, Dhaka	Pb	Not provided; concentrations compared	Widespread lead contamination observed across multiple media; bioaccumulation in eggs

Table 1 Summary Table of Studies on Industrial Toxicants in Bangladesh

Study & Year	Location	Key Metals	Risk Metrics	Major Findings
			to safety limits	highlights serious long-term health risks.
Uddin et al., 2023 [36]	Kumarkhali Upazila, Kushtia District	Likely Cu, Zn, Pb, Cr	Not specified	Exposure to hand-loom dyeing effluents correlates with self-reported symptoms (e.g., itchiness, pain); indicative of environmental degradation in soil and water.
Huda et al., 2024[37]	Gazipur, Hazaribagh, and Narsingdi	Mn, Cr, Cu, Pb	Spearman's correlation & Quantile Regression estimates	Strong correlations between drinking water and urinary metal levels; children in industrial areas show elevated metal exposure, indicating widespread environmental contamination.
Rahman et al., 2022[41]	Jhenaidah and Kushtia	Cr, Ni, Cu, As, Cd, Pb	HQ, HI, and CR calculated	Groundwater and food chain contamination lead to significant carcinogenic and non-carcinogenic health risks as well as ecological impacts.

***HI = Hazard Index; TCR = Target Carcinogenic Risk; BLL = Blood Lead Level; MRL = Maximum Residue Limit.

Health Impacts

Neurodevelopmental and Behavioral Disorders

Children residing near industrial zones in Bangladesh face increased risks of neurodevelopmental impairments. Huda et al. reported significantly elevated urinary concentrations of manganese (Mn), chromium (Cr), copper (Cu), and lead (Pb) among children living in industrial regions, correlated with contaminated drinking water. These exposures were associated with behavioral abnormalities, attention deficits, and learning difficulties[37]. In Dhamrai, Shammi et al. observed signs of neurotoxicity and impaired physical development among children exposed to contaminated soil, crops, and air particles[1]. Rana et al. found excessive lead concentrations in street dust from Dhaka and Savar, linked to cognitive deficits, decreased IQ, and behavioral disorders in children[11].

Renal, Hepatic, and Gastrointestinal Effects

Elevated levels of Cr were documented in the hair and nails of tannery workers and residents of Hazaribagh, associated with symptoms such as skin irritation, liver dysfunction, and gastrointestinal disturbances[10]. Bhuiyan et al. observed similar health effects near the Buriganga River due to exposure to Cr, Pb, and Cd from industrial sources[28]. Jiku et al. found that 92% of water samples from Gazipur and Savar exceeded permissible limits for Cu and all exceeded limits for Cd, linking these exposures to kidney damage, bone demineralization, and metabolic disorders[27].

Cancer Risk

Long-term exposure to arsenic, cadmium, and lead poses significant cancer risks. Saha et al. reported a Target Carcinogenic Risk (TCR) value of 3.1E+01 for arsenic in children in Tangail—more than 100,000 times above the WHO safe limit[9]. Amin et al. found TCR values greater than 10^{-4} for arsenic in water near the Dhaka Export Processing Zone[7]. Juel et al. also reported Hazard Quotients greater than 1 for Pb, Cd, Cr, and Fe in water from Tongi and the Shitalakkhya River, indicating high non-cancer and cancer risks[13].

Cardiovascular, Respiratory, and Reproductive Effects

Heavy metal exposure has been associated with systemic effects including elevated blood pressure, respiratory symptoms, and reproductive issues. Lead contamination in water, soil, and poultry eggs was linked to symptoms such as wheezing, irregular heartbeat, and fertility problems in studies by Hasan et al. and Hossain et al.[14,17]. Ahmad et al. found blood lead levels averaging 65.25 µg/dL among lead-acid battery workers - more than 13 times the CDC's reference limit - with some workers exceeding 80 µg/dL. Individuals with anemia and hypertension had significantly higher BLLs, indicating compounding physiological risks[18].

Dietary Exposure Risks

Dietary exposure to heavy metals remains one of the most significant chronic exposure routes in industrial regions of Bangladesh. Multiple studies have documented hazardous concentrations of toxic metals in commonly consumed food items. For example, vegetables and rice cultivated near industrial zones in Gazipur and Dhaka were found to consistently exceed the WHO/FAO permissible limits for lead (Pb), cadmium (Cd), and chromium (Cr), as reported by Hasan et al. and Ahmed et al.[14,15]. Furthermore, a study by Hasan, Das, and Satter revealed alarmingly high levels of Pb in rice samples collected from industrial agricultural fields, raising serious concerns about bioaccumulation and long-term dietary toxicity through the food chain[5].

Table 2: Presents a summary of key studies that link industrial toxicant exposure to specific health outcomes across various regions of Bangladesh.

Table 2: Health Effects by Heavy Metal				
Metal	**Major Sources**	**Exposure Pathways**	**Health Effects**	**Key Studies**
Lead (Pb)	Battery recycling, plastic industry, contaminated soil, poultry feed, street dust, vegetables	Inhalation, ingestion (food/water), occupational contact, maternal-fetal transfer	Neurodevelopmental disorders in children (e.g., low IQ, behavioral problems), anemia, hypertension, kidney damage, reproductive toxicity, cardiovascular effects	Hasan et al. (2022)[5],Islam et al. (2022)[10], Rana et al. (2024)[11], Hossain et al. (2014)[17], Ahmad et al. (2014)[18], Huda et al. (2024)[37]
Cadmium (Cd)	Textile and dyeing industries, contaminated vegetables, irrigation water	Inhalation, ingestion (vegetables, water), dermal contact	Kidney damage, bone demineralization, metabolic disruption, liver dysfunction, gastrointestinal symptoms, cancer	Hasan et al. (2019)[14], Ahmed et al. (2019)[15], Jiku et al. (2021)[27], Das et al. (2011)[29], Rahman et al. (2020)[41]

Table 2: Continued

Table 2: Health Effects by Heavy Metal				
Metal	**Major Sources**	**Exposure Pathways**	**Health Effects**	**Key Studies**
Arsenic (As)7	Groundwater (tube wells), multi-industry clusters, contaminated soil	Ingestion (drinking water, rice), maternal-fetal exposure	Skin lesions, cancer (e.g., skin, lung), cardiovascular disease, developmental toxicity	Rahman et al. (2020)[6], Saha et al. (2017)[12], Amin et al. (2020)[25]
Chromium (Cr)	Tanneries, metal industry, industrial effluents, vegetables, irrigation water	Inhalation, ingestion (food/water), dermal contact	Skin irritation, liver dysfunction, neurotoxicity, gastrointestinal distress, carcinogenicity	Shammi et al. (2021)[1], Islam et al. (2022)[10], Bhuiyan et al. (2010)[28], Huda et al. (2024)[37]
Manganese (Mn)	Industrial air emissions, drinking water near industrial zones	Inhalation, ingestion (water), maternal-child transfer	Neurodevelopmental delays, behavioral abnormalities, motor dysfunction	Shammi et al. (2021)[1] ,Huda et al. (2024)[37]
Copper (Cu)	Wastewater from textile and dyeing industries, vegetables, poultry feed	Ingestion (vegetables, meat), inhalation	Gastrointestinal symptoms, liver toxicity, kidney damage	Islam et al. (2022)[10], Ahmed et al. (2019)[15], Jiku et al. (2021)[27]
Nickel (Ni)	Multi-industry clusters, water pollution, vegetable crops	Ingestion (vegetables, water)	Allergic dermatitis, respiratory effects, possible carcinogenic effects	Hasan et al. (2019)[14] ,Ahmed et al. (2019)[15]
Zinc (Zn)	Poultry feed, contaminated vegetables, metal industries	Ingestion (eggs, vegetables), inhalation	Gastrointestinal issues, vomiting, interference with copper metabolism	Islam et al. (2022)[10], Rana et al. (2024)[11]
Mercury (Hg)	Industrial effluents (limited reporting), atmospheric emissions	Inhalation, ingestion (fish, possibly water)	Neurotoxicity, developmental disorders, renal effects	Huda et al. (2024)[37]

Ecological and Environmental Impacts

Industrial toxicants have not only impacted public health but also inflicted extensive environmental degradation in Bangladesh. These impacts include soil infertility, aquatic toxicity, groundwater contamination, and the bioaccumulation of heavy metals in food chains.

Soil Degradation and Loss of Fertility

Heavy metals such as As, Pb, and Cr accumulate in the soil through direct industrial effluent discharge and atmospheric fallout. Islam et al. and Kormoker et al. reported hazardous levels of these metals in soils from Konabari and DEPZ industrial zones, leading to reduced microbial activity, inhibited root development, and impaired soil fertility[2,9]. Long-term exposure alters soil composition, rendering it unsuitable for agricultural use.

Aquatic Ecosystem Disruption

Aquatic ecosystems near industrial sites are under severe threat. Das et al. observed elevated Biological Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) in water from the DND channel, which reduced oxygen availability and led to fish mortality[29]. Similar findings were reported by Sultana et al. in Narayanganj, where aquatic life was compromised by heavy metal contamination[21]. Bhuiyan et al. and Rahman et al. documented Cr concentrations up to 293.08 μg/L and Cd levels of 2.37 μg/L in Buriganga and Karnatoli rivers, threatening biodiversity and local livelihoods[6,28].

Bioaccumulation in the Food Chain

Toxic metals are now present across the food chain. Hossain et al. found lead levels in poultry eggs from industrial areas exceeding food safety limits[23]. Ahmed et al. and Hasan et al. confirmed the accumulation of Pb, Cd, and Cr in vegetables irrigated with wastewater, establishing a direct exposure pathway to humans through dietary intake[14,15].

Groundwater Contamination

Groundwater contamination is prevalent in multiple industrial zones. Arsenic levels exceeding 0.14 mg/L were reported by Rahman et al. and Kormoker et al., surpassing WHO's permissible limit of 0.01 mg/L[2,6]. In communities lacking piped water, residents rely on tube wells and are unknowingly exposed to unsafe levels of toxicants, leading to chronic disease risk.

General Environmental Degradation

Widespread degradation of environmental quality was observed in areas near industrial activity. Jiku et al. and Shammi et al. reported increased turbidity, chemical odor, color changes in water, and high Sodium Adsorption Ratio (SAR), which make these waters unfit for agriculture[1,27]. During the monsoon season, surface runoff transports heavy metals across ecosystems, further extending contamination beyond original source zones.

CONCLUSION

This systematic review confirms the widespread and hazardous presence of industrial toxicants in Bangladesh's environment, highlighting significant health and ecological consequences. The accumulation of heavy metals such as lead (Pb), cadmium (Cd), arsenic (As), chromium (Cr), and mercury (Hg) across air, water, soil, and food systems poses both acute and chronic health risks. These toxicants originate from a range of industries- including tanneries, dyeing and textile manufacturing, battery recycling, and metal processing- and are transmitted through multiple environmental and occupational pathways.

Children and industrial workers emerge as the most vulnerable groups. Among children, elevated urinary concentrations of heavy metals have been linked to neurodevelopmental impairments, behavioural disorders, and cognitive deficits. In occupational settings, especially among battery and tannery workers, blood lead levels have far exceeded international safety thresholds, resulting in a range of health issues including anemia, kidney and liver damage, and reproductive dysfunction. Additionally, the ingestion of contaminated rice, vegetables, poultry, and drinking water presents a significant route of chronic exposure for the general population.

Beyond human health, the review highlights severe ecological degradation due to the persistent release of untreated industrial effluents. Soil fertility loss, groundwater contamination, aquatic toxicity, and bioaccumulation in food chains collectively demonstrate that industrial pollution is not only a public health emergency but also an environmental crisis.

Despite its magnitude, the burden of disease linked to chemical exposures in Bangladesh is likely underestimated. This under-recognition undermines efforts to prioritize chemical safety in health and environmental policies. The findings of this review emphasize the urgent need for an integrated national strategy. Key recommendations include the strict enforcement of environmental regulations, mandatory treatment of industrial effluents, implementation of occupational health standards, and investment in public health surveillance systems. In addition, public awareness campaigns and environmental education programs should be expanded to encourage safer industrial practices and community-level engagement.

RECOMMENDATIONS

- Strengthen regulatory enforcement of effluent discharge standards.
- Expand biomonitoring in industrial zones.
- Mandate effluent treatment plants (ETPs) in all factories.
- Launch public awareness campaigns on environmental health risks.
- Promote cleaner production and eco-friendly technologies.

ACKNOWLEDGMENTS

The authors gratefully acknowledge the National Institute of Preventive and Social Medicine (NIPSOM) for providing institutional support and guidance throughout the course of this systematic review. We are especially thankful to the Department of Occupational and Environmental Health (OEH) at NIPSOM for their academic mentorship, access to resources, and encouragement during each stage of this work.

CONFLICT OF INTEREST

There is no conflict of interest.

REFERENCES

1. Shammi SA, Salam A, Khan MAH. Assessment of heavy metal pollution in the agricultural soils, plants, and in the atmospheric particulate matter of a suburban industrial region in Dhaka, Bangladesh. Environ Monit Assess. 2021;193(2):104. doi: 10.1007/s10661-021-08848-y.

2. Kormoker T, Proshad R, Islam S, Ahmed S, Chandra K, Uddin M, et al. Toxic metals in agricultural soils near the industrial areas of Bangladesh: ecological and human health risk assessment. Toxin Rev. 2021;40(4):1135–54. doi:10.1080/15569543.2019.1650777

3. Bhuyan MS, Islam MS. Status and impacts of industrial pollution on the Karnafully River in Bangladesh: a review.Int J Marine Sci.2017;7(16):141-160. doi: 10.5376/ijms.2017.07.0016

4. Rahman SH, Khanam D, Adyel TM, Islam MS, Ahsan MA, Akbor MA. Assessment of heavy metal contamination of agricultural soil around Dhaka Export Processing Zone (DEPZ), Bangladesh: implication of seasonal variation and indices. Appl Sci. 2012;2(3):584–601.doi:10.3390/app2030584

5. Hasan GMMA, Das AK, Satter MA. Accumulation of Heavy Metals in Rice (*Oryza sativa*. L) Grains Cultivated in Three Major Industrial Areas of Bangladesh. J Environ Public Health. 2022;2022:1836597. doi: 10.1155/2022/1836597. 17

6. Rahman MATMT, Paul M, Bhoumik N, Hassan M, Alam MK, Aktar Z. Heavy metal pollution assessment in the groundwater of the Meghna Ghat industrial area, Bangladesh, by using water pollution indices approach. Appl Water Sci. 2020;10(8):1–15.doi:10.1007/s13201-020-01266-4.

7. Hossain MS, Ahmed MK, Liyana E, Hossain MS, Jolly YN, Kabir MJ, et al. A case study on metal contamination in water and sediment near a coal

thermal power plant on the eastern coast of Bangladesh. Environments. 2021;8(10):108.doi:10.3390/environments8100108 .

8. Ruba UB, Chakma K, Senthi JY, Rahman S. Impact of industrial waste on natural resources: a review in the context of Bangladesh. 2021;16(2).doi: http://dx.doi.org/10.12944/CWE.16.2.03.

9. Islam SM, Tusher TR, Mustafa M, Mamun SA. Investigation of soil quality and heavy metal concentrations from a waste dumping site of Konabari industrial area at Gazipur in Bangladesh. IOSR J Environ Sci Toxicol Food Technol. 2012;2(1):1–7.

10. Islam S, Rahman A, Nahar K, Chowdhury SR, Ahmed I, Mohiuddin KM. Heavy metal pollution through hand loom-dyeing effluents and its effect on the community health. Environ Sci Pollut Res Int. 2022;29(44):66490-66506. doi: 10.1007/s11356-022-20425-5.

11. Rana M, Wang Q, Wang W, Ebere E, Islam M, Isobe Y, et al. Sources, distribution, and health implications of heavy metals in street dust across industrial, capital city, and peri-urban areas of Bangladesh. Atmosphere. 2024;15:1088.doi:10.3390/atmos15091088.

12. Saha N, Rahman MS, Ahmed MB, Zhou JL, Ngo HH, Guo W. Industrial metal pollution in water and probabilistic assessment of human health risk. J Environ Manage. 2017;185:70–8. doi: 10.5696/2156-9614-10.27.200905.

13. Juel MAI, Chowdhury ZUM, Mizan A, Alam MS. Toxicity and environmental impact assessment of heavy metals contaminated soil of Hazaribagh tannery area. In: Proc 3rd Int Conf Adv Civil Eng (CUET). Chittagong, Bangladesh; 2016. p. 94–9.Available from: https://www.researchgate.net/publication/311886924_TOXICITY_AND_ENVIRONMENTAL_IMPACT_ASSESSMENT_OF_HEAVY_METALS_CONTAMINATED_SOIL_OF_HAZARIBAGH_TANNERY_AREA [(Accessed on 4 June 2025)]

14. Hasan MM, Hosain S, Poddar P, Chowdhury AA, Katengeza EW, Roy UK. Heavy metal toxicity from the leather industry in Bangladesh: a case study of human exposure in Dhaka industrial area. Environ Monit Assess. 2019;191(9):530. doi: 10.1007/s10661-019-7650-6.

15. Ahmed M, Matsumoto M, Ozaki A, Thinh NV, Kurosawa K. Heavy metal contamination of irrigation water, soil, and vegetables and the difference between dry and wet seasons near a multi-industry zone in Bangladesh. *Water*. 2019;11(3):583.doi:10.3390/w11030583.

16. Ahmed MS, Yesmin M, Jeba F, Hoque MS, Jamee AR, Salam A. Risk assessment and evaluation of heavy metals concentrations in blood samples of plastic industry workers in Dhaka, Bangladesh. Toxicol Rep. 2020; 7:1373-1380. doi: 10.1016/j.toxrep.2020.10.003.

17. Hossain MA, Mostofa M, Alam MN, Sultana MR, Rahman MM. Assessment of lead contamination in different samples around the industrial vicinity in selected areas of Bangladesh. Bangladesh J Vet Med. 2014;12(1):83–9.doi:https://doi.org/10.3329/bjvm.v12i1.20468.

18. Ahmad SA, Khan MH, Khandker S, Sarwar AF, Yasmin N, Faruquee MH, et al. Blood lead levels and health problems of lead acid battery workers

in Bangladesh. ScientificWorldJournal. 2014;2014:974104. doi: 10.1155/2014/974104.

19. Tanvir EM, Mahmood S, Islam MN, Khatun M, Afroz R, Islam SS, et al. Environmental exposure to metals and metalloids in primary school-aged children living in industrialised areas of eastern South Asian Megacity Dhaka, Bangladesh. Expo Health. 2021;13:1–14. doi: 10.1007/s12403-021-

20. Rahman MS, Barua BS, Karim MR, Kamal M. Investigation of heavy metals and radionuclide's impact on environment due to the waste products of different iron processing industries in Chittagong, Bangladesh. 2017.doi:10.4236/jep.2017.89061.

21. Proshad R, Islam MS, Kormoker T, Bhuyan MS, Hanif MA, Hossain N, et al. Trace metals in vegetables and associated health risks in industrial areas of Savar, Bangladesh. Environ Health Prev Med. 2020;25(1):52.doi:10.1186/s12199-020-00885-0.

22. Islam MS, Tusher TR, Mustafa M, Mahmud S. Effects of solid waste and industrial effluents on water quality of Turag River at Konabari industrial area, Gazipur, Bangladesh.2013; *5*(2):213–218. https://doi.org/10.3329/jesnr.v5i2.14817 .

23. Mia R, Selim MD, Shamim AM, Chowdhury M, Sultana S, Armin M, et al. Review on various types of pollution problem in textile dyeing & printing industries of Bangladesh and recommendation for mitigation. J Text Eng Fashion Technol. 2019;5(4):220–6. doi: 10.15406/jteft.2019.05.00205.

24. Islam S, Islam S, Islam SA, Eaton DW. Total and dissolved metals in the industrial wastewater: A case study from Dhaka Metropolitan, Bangladesh. Environ Nanotechnol Monit Manag. 2016;5:74–80. doi: 10.1016/j.enmm.2016.04.001.

25. Amin MA, Rahman ME, Hossain S, Rahman M, Rahman MM, Jakariya M, et al. Trace metals in vegetables and associated health risks in industrial areas of Savar, Bangladesh. *J Health Pollut.* 2020;10(27):200905. doi: 10.5696/2156-9614-10.27.200905

26. Islam MS, Proshad R, Haque MA, Hoque MF, Hossin MS, Sarker MNI. Assessment of heavy metals in foods around the industrial areas: health hazard inference in Bangladesh. Geocarto Int. 2020;35(3):280–95. doi: 10.1080/10106049.2018.1516246 10

27. Jiku MAS, Singha A, Faruquee M, Rahaman MA, Alam MA, Ehsanullah M. Toxic wastewater status for irrigation usage at Gazipur and Savar industrial vicinity of Bangladesh. Acta Ecol Sin. 2021;41(4):358–64. doi: 10.1016/j.chnaes.2021.07.001

28. Bhuiyan MA, Suruvi NI, Dampare SB, Islam MA, Quraishi SB, Ganyaglo S, et al. Investigation of the possible sources of heavy metal contamination in lagoon and canal water in the tannery industrial area in Dhaka, Bangladesh. Environ Monit Assess. 2011;175(1-4):633-49. doi: 10.1007/s10661-010-1557-6.

29. Das M, Ahmed MK, Islam MS, Islam MM, Akter MS. Heavy metals in industrial effluents (tannery and textile) and adjacent rivers of Dhaka city, Bangladesh. Terr Aquat Environ Toxicol. 2011;5(1):8–13.

30. Sultana MS, Islam MS, Saha R, Al-Mansur MA. Impact of the effluents of textile dyeing industries on the surface water quality inside DND embankment, Narayanganj. *Bangladesh J Sci Ind Res.* 2009;44(1):65–80.doi:10.3329/bjsir.v44i1.2715.

31. Hasan K, Miah M. Impacts of textile dyeing industries effluents on surface water quality: a study on Araihazar thana in Narayanganj district of Bangladesh. J Environ Human. 2014;1(3):8–22. doi: 10.15764/EH.2014.03002.

32. Akhtar P, Ahmed Y, Islam F, Alam K, Mary M, Islam MZ, et al. Efficiency of Effluent Treatment Plants and Threat to Human Health and Aquatic Environment in Bangladesh. Asian J Chem. 2016;28(1).doi:10.14233/ajchem.2016.19230.

33. Karim MR, Manshoven S, Islam MR, Gascon JA, Ibarra M, Diels L, et al. Assessment of an urban contaminated site from tannery industries in Dhaka city, Bangladesh. J Hazard Toxic Radioact Waste. 2013;17(1):52–61. doi: 10.1061/(ASCE)HZ.2153-5515.0000139.

34. Hossain L, Sarker SK, Khan MS. Evaluation of present and future wastewater impacts of textile dyeing industries in Bangladesh. Environ Dev. 2018;26:23–33. doi: 10.1016/j.envdev.2018.03.005.

35. Sultana MS. Toxic Metal Contamination on the River near Industrial Area of Dhaka. Univ J Environ Res Technol. 2012;2(2):56-64.Available from:www.environmentaljournal.org.[(Accessed on 6th August 2025)].

36. Uddin M, Alam FB. Health risk assessment of the heavy metals at wastewater discharge points of textile industries in Tongi, Shitalakkhya, and Dhaleshwari, Bangladesh. J Water Health. 2023;21(5):586-600. doi: 10.2166/wh.2023.284.

37. Huda MN, Harun-Ur-Rashid M, Hosen A, Akter M, Islam MM, Emon SZ, et al. A potential toxicological risk assessment of heavy metals and pesticides in irrigated rice cultivars near industrial areas of Dhaka, Bangladesh. Environ Monit Assess. 2024 ;196(9):794. doi: 10.1007/s10661-024-12927-1.

38. Page MJ, McKenzie JE, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021;372:n71. doi: 10.1136/bmj.n71.

39. Rahman M, Rahman MM. Study of the dyeing industry pollution after mandatory installation of ETP in Madhabdi municipality, Bangladesh. Water Sci. 2024;38(1):158–71. doi: 10.1080/23570008.2024.2313874

40. Sarker A, Kim JE, Islam ARMT, Bilal M, Rakib MRJ, Nandi R, Rahman MM, Islam T. Heavy metals contamination and associated health risks in food webs-a review focuses on food safety and environmental sustainability in Bangladesh. Environ Sci Pollut Res Int. 2022 Jan;29(3):3230-3245. doi: 10.1007/s11356-021-17153-7.

41. Rahman MS, Ahmed Z, Seefat SM, Alam R, Islam ARMT, Choudhury TR, Begum BA, Idris AM. Assessment of heavy metal contamination in sediment at the newly established tannery industrial Estate in Bangladesh: A case study.2022.doi:10.1016/j.enceco.2021.10.001.

42. Matei E, Râpă M, Mateş IM, Popescu AF, Bădiceanu A, Balint AI, et al. Heavy Metals in Particulate Matter-Trends and Impacts on Environment. Molecules. 2025; 30(7):1455. doi: 10.3390/molecules30071455.

43. Ahmad R, Akhter QS, Haque M. Occupational Cement Dust Exposure and Inflammatory Nemesis: Bangladesh Relevance. J Inflamm Res. 2021;14:2425-2444. doi: 10.2147/JIR.S312960.