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Assessment of Risks Related to Health and Industrial Effluents: Study of Physical and Occupational Risks within Jamuna Fertilizer Company Limited

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Abstract

Industrial effluents discharge into the rivers severely degrade water quality by introducing heavy metals, organic pollutants, and excess nutrients, leading to toxicity of aquatic life and severe health risk for humans. This research aimed to explore occupational health risks and assess the discharge of effluents from a canal connected to the Jamuna River. An in-depth interview was conducted among employees of the Jamuna Fertilizer Company Limited (JFCL) to know the occupational health condition of that industry from January to June 2023. These employees reported various health problems, including eye, respiratory, and abdominal disorders, due to poor management and a lack of awareness. The Jamuna River was negatively affected by untreated waste discharged by JFCL. Water samples were collected at the discharge points of effluents from the Jamuna fertilizer plants to investigate the river's physicochemical parameters. The results revealed that the water quality of the Jamuna River is compromised by these discharges, posing a threat to aquatic life. The average dissolved oxygen (DO) concentration measured was 4.06 ppm, below the WHO-recommended standard of 5 ppm. Although the average pH is 8.32 and the average total dissolved solids (TDDS) content is 172.33 ppm, both of these parameters are within acceptable limits, the electrical conductivity (EC) exceeds acceptable thresholds. Furthermore, concentrations of heavy metals such as lead (Pb) and cadmium (Cd) exceeded safety thresholds, threatening aquatic organisms. Low levels of dissolved oxygen (DO) were particularly detrimental to aquatic habitats in the region. During the study, pre-monsoon water temperatures remained within acceptable limits, but they exceeded these thresholds during the monsoon season. Overall, the study revealed that the water quality of the canal, which is connected to the Jamuna River, has deteriorated significantly due to untreated discharges, affecting not only aquatic life but also the entire ecosystem and local communities.

Keywords: Effluents, Heavy metals, Occupational health, Risks, Pollution.

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Introduction

The rapid industrialization of Bangladesh, particularly in sectors such as textiles, shipbreaking, and chemicals, has led to significant occupational health problems. Workers in these industries are exposed to a range of health risks related to inadequate safety measures, exposure to hazardous substances, and poor working conditions. In the garment industry, employees frequently suffer from respiratory problems, skin diseases, and musculoskeletal disorders due to exposure to chemicals, poor ergonomics, and insufficient safety protocols (Azad et al. 2022). Similarly, Islam et al. (2022) assessed occupational safety practices among metalworkers and found a high rate of workplace accidents associated with inadequate safety training and equipment. Fertilizer and chemical plants present significant occupational and environmental hazards due to exposure to ammonia, acids, and other chemicals used in manufacturing processes. Furthermore, small, unregulated industrial groups and small and medium-sized enterprises (SMEs) frequently discharge untreated effluents, exposing workers to mixed chemical hazards due to poor waste management and the lack of engineering controls in Bangladesh.

Approximately 11% of Bangladesh's rivers are contaminated by industrial waste. A government study reveals that the rivers around Dhaka, including the Buriganga, Shitalakshya, Turag, Balu, Bangshi, and Dhaleswary, are particularly affected by severe pollution. The main sources of this pollution are industrial waste (60%) and municipal and urban wastewater, including sewage (30%) (Rahman 2005). Most of the country's rivers are affected by a combination of industrial effluents, agricultural runoff, municipal waste, sewage, and household waste. Pollution is a global problem that poses a significant threat to human existence (Trivedi 1992). Bangladesh is among the most polluted countries in the world: 1,176 industries discharge approximately 0.4 million cubic meters of untreated wastewater into its waterways every day (JICA 1999). Water quality is a serious concern: the country's surface waters are heavily exposed to untreated industrial effluents, municipal wastewater, and runoff pollution from chemical fertilizers and agrochemicals (DHV 1998). River water is primarily contaminated with heavy metals, toxic substances, minerals, nutrients, and organic pollutants. Furthermore, nearly half of the population in developing countries lacks access to safe drinking water, and 75% lack adequate sanitation. Consequently, some of this waste contaminates drinking water supplies, leading to serious health problems. Waterborne diseases are also a source of considerable economic losses (Manson 1996).

The Jamuna River is one of the largest rivers in Bangladesh. This waterway plays a significant role in geology and other socio-economic factors, particularly for the riparian lives of human and animal populations. The Jamuna Fertilizer Company Limited (JFCL) is located in Tarakandi, Jamalpur District, Bangladesh. It lies on the banks of the Jamuna River, approximately 1.5 kilometers from the production site. This proximity to the river raises environmental concerns, as untreated effluent from the plant is discharged into the Jamuna, polluting waterways and impacting the surrounding ecosystem. Despite the recognized importance of occupational health and environmental protection, limited integrated studies have been conducted in Bangladesh that simultaneously address worker health risks and the environmental impacts of industrial effluents. Most existing studies focus either on occupational safety or on water pollution, without considering their interconnections. The main objectives of this study are to assess current safety measures and the health status of workers, and to analyze the physicochemical properties of the effluent discharged from the JFCL site.

Materials and Methods

Study area

The study area is located in Tarakandi, Sarishabari, in the Jamalpur district, on the banks of the Jamuna River. This location is of major economic importance, as it provides access to the north of the country, particularly Dhaka, and is essential to the livelihoods of the surrounding populations. The study area (Fig. 1) is located at 24°39' north latitude and 89°50' south longitude. The Jamuna Fertilizer Company Limited plant is located 37 km from Jamalpur, on the banks of the Jamuna River, approximately 1.5 km from its main site (Banglapedia 2015).

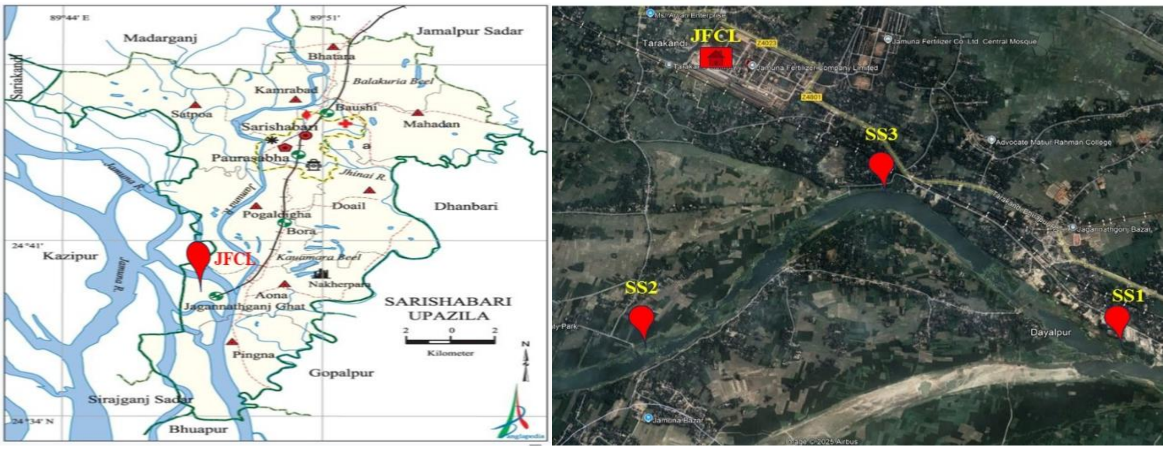

Fig. 1: Location of the study area and sampling stations in the Sarishabari Upazila, Jamalpur district.

Data collection

This research relies on primary and secondary data. Various data collection methods were used, including in-depth interviews with factory occupants and focus groups, to determine the occupational risk and health condition of the workers. An industry should maintain some standard of industrial and occupational health and safety measures according to ISO (International Organization for Standardization) 45001. This standard framework is a systematic process for organizations to manage risks, prevent work-related injuries and illnesses, and adopt a safe and healthy working environment. So, first, it is necessary to identify risks and injuries of industrial workers of the respective industry and the working environment of that industry. In-depth interviews, experiences, and perceptions were considered to assess current safety measures and the health status of workers.

The sample size of employees and workers was determined by random sampling to assess occupational health risks in the factory.

Sample size (n) = $z^2.p.q.N/e^2(N-1) + z^2.p.q$ (Kothari 1990).

Where:

i) The desired precision/error (e) is set at 10%.

ii) The desired confidence level (z) is 90%.

iii) The z value associated with this confidence level is 1.29.

iv) In the absence of information on the proportion of the target population (p), I assumed it to be 50%, i.e., p = 0.50.

v) The total number of employees is 4,500.

Based on these parameters, the calculated sample size is 41.

Water samples were collected at the discharge points of effluents from the Jamuna fertilizer plants, which were discharged into the canal and subsequently mixed with the Jamuna River, to assess the river's physicochemical parameters. The total area was divided into three sampling stations: S1, S2, and S3. The average distance between each station was 1,000 m. The industrial effluent discharge area from the Jamuna fertilizer plants was selected as sampling station 1 (S1), 2 (S2), and 3 (S3). Sampling station 2 (S2) was located 1,000 m from S1. Similarly, at sampling station S3, water samples were collected at each point using 500 ml plastic bottles. These bottles were washed with tap water, then with distilled water. Before sampling, they were rinsed 3 to 4 times with the water to be sampled. After sampling, the bottles were screwed shut and labeled with their identification number. Sampling and analysis of all samples were carried out during both the dry and rainy seasons. Secondary data were obtained from a variety of books, journals, periodicals, theses, and newspapers.

Sample analysis

Color, odor, temperature, pH, dissolved oxygen (DO), electrical conductivity (EC), and total dissolved solids (TDDS) were measured in situ during water sampling. Temperature, pH, and DO were measured using a digital thermometer, pH meter, and pulse oximeter, respectively (Hannah, Woonsocket, RI, USA), while EC and TDDS were analyzed using a conductivity meter and a peak conductivity meter, respectively (HM digital, Redondo Beach, CA, USA). All digital measuring devices used were calibrated with demineralized water and a buffer solution before analysis. Total hardness (TH) was determined by titration. Heavy metals (Pb, Cd) were analyzed by atomic absorption spectrometry (AAS) (Model: AA-7000, Shimadzu, Japan) at the laboratory of the Institute of Nuclear Science and Technology, Atomic Energy Research Center, Savar, Dhaka.

Results and Discussion

Health problems of respondents

The study reveals that approximately 39.5% of respondents suffered from weakness and headaches due to a heavy workload. In addition, 17% reported weakness and sleep disturbances, 13% suffered from hypertension, and 10% experienced stress and muscle pain. The remaining respondents reported no health problems.

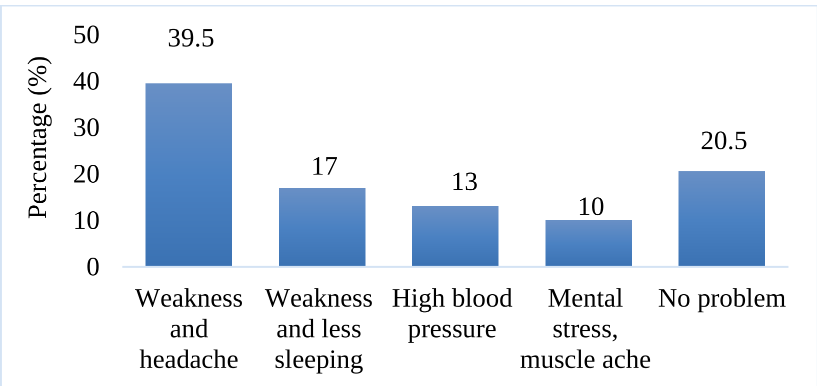

Fig. 2: Health problems of respondents.

Problems related to machine operation

The JFCL employees interviewed were required to operate machinery and equipment in their respective departments. Welders, fabricators, and skilled technicians, for example, were required to use various types of machines: shears, grinders, drills, strapping machines, rolling machines, welding machines, angle welding machines, gas cutting machines, gas heating machines, etc. Operating these machines caused them various problems, such as skin burns, eye irritation, and the penetration of fine particles into their eyes or nose.

Direct *effects of handling chemicals*

The respondents experienced direct effects related to handling chemicals in their work. The most frequently handled chemicals were aluminum sulfate, sodium carbonate, sulfuric acid, caustic soda, and potassium carbonate. The results show that the respondents experienced health problems following their exposure to these chemicals. Among them, 33% reported eye irritation and respiratory problems, 18.5% skin irritation, 10.5% respiratory problems, 10% respiratory problems, and 9% both skin irritation and respiratory problems. The remaining respondents reported no health problems.

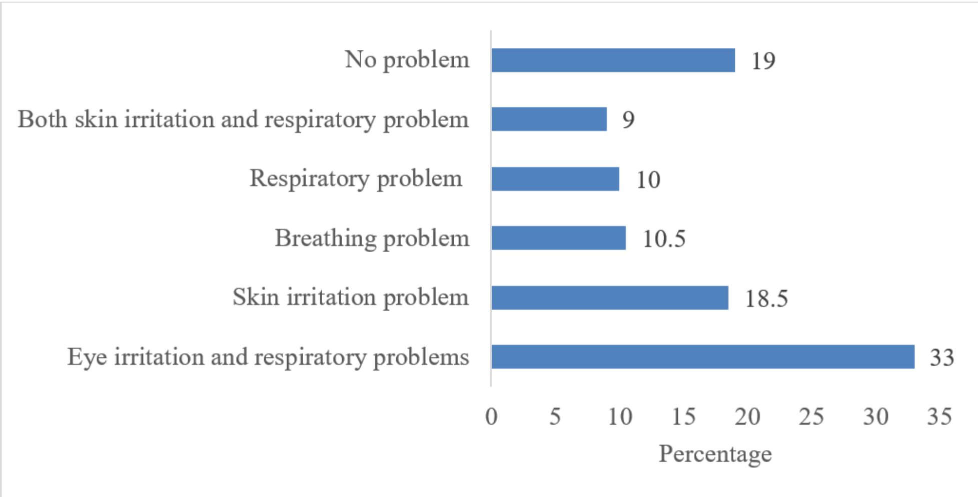

Fig. 3: Direct effect during the handling of chemicals.

Eye problems

Eye problems are common among industrial workers. Those interviewed in the study area reported experiencing eye problems related to the chemicals they were exposed to, ammonia in the atmosphere, and the use of arc and TIG welding machines. The study shows that approximately 30% of those interviewed experienced decreased visual acuity, and 25% presented with redness, watering, and other vision disturbances. These problems primarily affected welders and the elderly. Only 15% of those interviewed experienced redness and eye pain. Occupational exposure to UV radiation, particularly during arc welding, primarily affects the eyes and causes severe conjunctivitis (Park, 2007). Symptoms include redness and eye pain. Gordon et al. (2005) conducted a survey of workers at a fertilizer plant and found that 22.6% of them complained of eye problems.

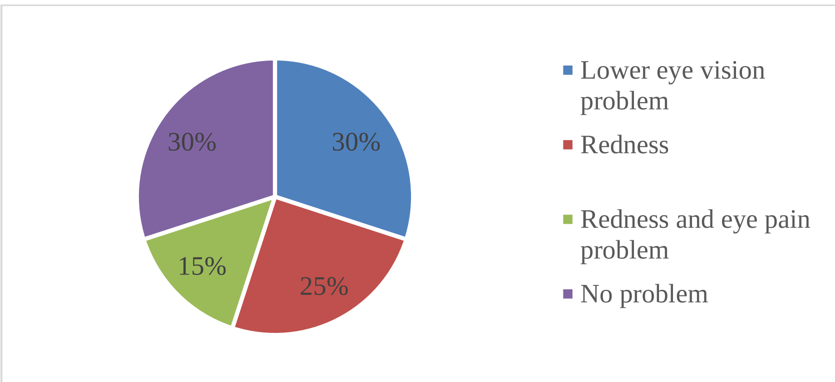

Fig. 4: Interviewees suffering from various eye problems.

Respiratory problems

Respondents were required to come into contact with or inhale chemicals such as aluminum sulfate, sodium carbonate, sulfuric acid, caustic soda, and potassium carbonate, among others, which resulted in respiratory problems. The study shows that 20% of respondents suffered from asthma and 7.5% experienced respiratory distress. Only 2% of respondents reported coughing and phlegm production, and 3% experienced chest pain. The remainder had no respiratory problems. Workers exposed to ammonia at a fertilizer plant had a higher prevalence of coughing, phlegm production, wheezing, bronchial asthma, chronic bronchitis, and chronic obstructive pulmonary disease (COPD) than other workers. Exposure levels ranged from 2 to 130.4 mg/m^3 (Ballal et al. 1998). In addition, Holness et al. (1989) reported that workers exposed to ammonia had an increased prevalence of coughing, wheezing, nasal problems, eye irritation, and sore throat compared to control workers, who had lower average ammonia exposure levels.

Abdominal problems among participants

The workers were exposed daily to an ammonia concentration of approximately 25 to 30 ppm in the factory atmosphere. Following continuous exposure to this concentration, they developed digestive problems (Rosenbaum et al. 1998). The study shows that 55% of participants suffered from gastric disturbances, 10% from diarrhea, 3.5% from abdominal pain, and 2% from vomiting. The remaining participants did not experience any of these health problems.

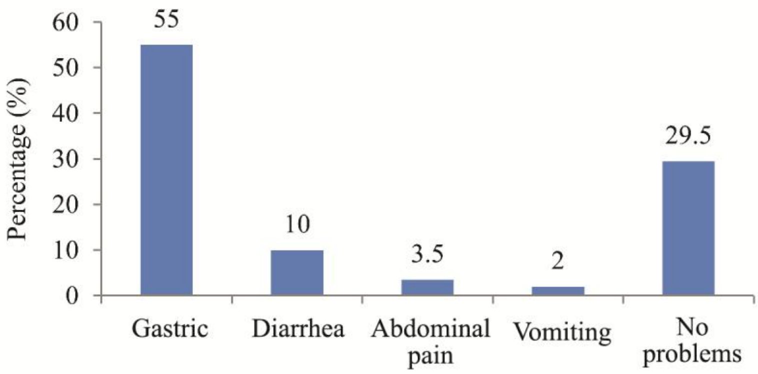

Fig. 5: Workers suffer from various abdominal problems.

Hearing problems among respondents

The noise level inside the plant during production was extremely high. The continuous operation of high-speed turbomachinery, vibrations from piping and structures, the transport of high-pressure gases, and sudden releases of high-pressure gases all generated noise hazards within the plant during production. The urea plant is a large facility that produces noise levels ranging from 80 dB to approximately 98 dB. This level exceeds the noise standard for an industrial area, which is 75 dB (Dara 2007). Occupants had to work daily in this noisy environment. The study shows that 60% of respondents suffered from partial hearing loss and that 40% reported no hearing problems at JFCL to date.

Main body pains of respondents

The workers reported various muscle pains due to operating different types of heavy machinery and the nature of their tasks. The survey revealed that 55% of respondents suffered from back, neck, or knee pain. Among them, 10% reported knee pain related to prolonged standing, 2.5% neck pain, and 3.5% back pain. The remainder reported no problems.

Skin problems among respondents

Skin problems were common in the factory. Workers were exposed daily to various chemicals, such as sodium carbonate, alum, sulfuric acid, caustic soda, and potassium carbonate. These chemicals have dermatological effects upon contact with the skin. The study shows that 20% of respondents suffered from allergic dermatitis, 6% from skin irritations, 6% from frostbite (due to a nitrogen leak), and 68% had no skin problems.

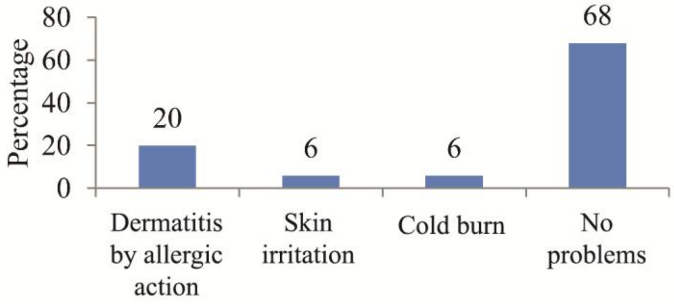

Fig. 6: Skin problems of respondents.

Mechanical hazards

The respondents were required to operate heavy machinery in their respective departments. They were exposed to mechanical hazards or accidents while operating this machinery. The study shows that 15% of respondents working in welding suffered skin burns, 12.5% fractures, and 15.5% eye injuries caused by the welding arc, steam, and metal shavings. The remaining respondents experienced no problems.

Psychochemical parameters of the water

Color and Odor

Initially, the water's color and odor were observed visually. The water appeared clear, but the inlet water was cloudy. However, the presence of phytoplankton with dark blue-green, red, or brown hues can be beneficial to fish (Das 1997). Therefore, this water is unsuitable for aquaculture, as well as for any domestic, industrial, or agricultural use. Odor is an important physical parameter for assessing water quality, and the analysis revealed an unpleasant odor of organic or inorganic origin.

pH

The pH levels measured during this study ranged from 7.95 to 8.50. The lowest value was recorded at station 1, while the highest was recorded at station 3. The average pH across all stations was 8.32. In accordance with standards established by Bangladesh, the Food and Agriculture Organization of the United Nations (FAO), and the Environmental Conservation Regulations (ECR) of 1997, the acceptable pH for irrigation water is between 6.5 and 8.5. A pH that is too high can harm aquatic life, including fish, plants, and microorganisms. Fortunately, all values recorded in this study were within the permitted range of 6.5 to 8.5 (ECR 1997, DoE 2003).

Electrical conductivity (EC)

EC is a measure of water salinity and is related to its concentration of dissolved ions. It is of particular importance because significant variations in EC indicate potential disturbance of river water, which can lead to pollution. During the study, the EC values recorded at stations 1, 2, and 3 were 205 µS/cm, 309 µS/cm, and 408 µS/cm, respectively. The average EC value was 307.33 µS/cm, which is higher than the standard value of 300 µS/cm for inland waters, public wastewater, and irrigated land (WHO 2011).

Total dissolved solids (TDSS)

It is well established that electrical conductivity (EC) and TDSS are positively correlated in any water body (Islam et al., 2013). TDSS alters the mineral composition of water, which is essential for the survival of many aquatic species. The study reveals that TDSS values recorded at three sampling stations range from 160 to 190 ppm. The average TDSS value is 172.33 ppm, below the standard value of 500 ppm (WHO 2011). Total dissolved solids include inorganic salts and organic matter. Common dissolved salts, such as mineral salts, are known to affect taste, hardness, corrosion, and scale formation. Dissolved inorganic substances can have adverse effects on aquatic organisms. According to the study, the TDSS concentration in the study area is within an acceptable range.

TDS indicates the presence of various minerals, including ammonia, nitrate, phosphate, alkalis, certain acids, sulfates, and metal ions, which are both colloidal solids and dissolved in water (Kabir et al. 2002).

Temperature

The average temperature was 29.93°C, which falls within the standard range of 20–30°C for inland waters, sewage systems, and irrigated land (ECR 1997). The highest temperature, 31°C, was observed at S3, and the lowest, 29°C, at S1. This low temperature is detrimental to fish production and also harmful to aquatic organisms. The high river temperature indicates water pollution. Fish metabolic activity increases by 10% for every 10°C increase in water temperature; therefore, fish require 10% more oxygen for every 10°C increase, making their survival critical (Swingle 1967). Colder water contains more oxygen. The temperature observed before the monsoon in the study area was below the permitted limit, while the water temperature during the monsoon exceeded it.

Table 1. Water quality parameters and reference values for the different sampling sites in the JFCL industrial zone.

Parameters	S1	S2	S3	Average	Standard
pH	7.95	8.5	8.5	8.32	6.5 - 8.5 (EQS, ECR 1997, Das 1997)
EC (μs/cm)	205	309	408	307.33	300 (μs/cm) (WHO 2011)
TDS (ppm)	160	190	167	172.33	500 (ppm) (WHO 2011)
Temperature (°C)	29	29.8	31	29.93	20 to 30°C (ECR 1997)
DO (ppm)	3.9	4.1	4.2	4.06	5 ppm (WHO 2011)
Lead (Pb) (ppm)	7.54	6.2	5.35	6.36	0.1-1.0 (ECR 1997)
Cadmium (Cd) (ppm)	1.5	2.9	2.5	2.3	0.05-0.5 (ECR 1997)
Hardness (ppm)	22.5	38.33	43	34.61	40 (ECR 1997), 123 ppm (Huq and Alam 2005)

Dissolved oxygen (DO)

According to the study, the DO concentration ranged from 3.9 ppm (S1) to 4.2 ppm (S3). The average concentration was 4.06 ppm, below the standard value of 5 ppm (WHO 2011). High DO values indicate a productive aquatic environment, while low values indicate a degraded one. Determining the DO concentration is crucial for water quality analysis, as oxygen influences all chemical and biological processes in the aquatic environment. In a typical river, the DO content should be between 4.27 and 11.20 ppm (Jhinngran and Pathak 1987). The optimal DO value for good water quality is 4 to 6 ppm, but the value measured in this study was low. These low DO values in the study area indicate a high microbial load and pollution. Furthermore, an OD level of 2.45 ppm was measured in 2012 in Ashulia, during the pre-monsoon period (Megla et al. 2013).

Lead (Pb)

The lead concentration measured at three sampling stations ranged from 5.35 (S3) to 7.54 (S1) ppm, a level harmful to aquatic organisms. The average concentration was 6.36 ppm, exceeding the limit values of 0.1 to 1.0 ppm (ECR 1996). Lead (Pb) accumulates in organs, particularly the kidneys and brain, and disrupts their function, as well as that of the gastrointestinal and central nervous systems. The concentration considered protective for aquatic life, for a water hardness of 100 mg/L, is less than 0.003 mg/L. Ahmed (1998) reported lead concentrations of 61.66 and 10.96 mg/kg, respectively, in sediments from the Sundarbans Forest Reserve.

Cadmium (Cd)

According to the study, the cadmium concentration at the three sampling stations ranged from 1.5 to 2.9 ppm. The average concentration was 2.3 ppm, exceeding the standard of 0.05 to 0.5 ppm (ECR 1997). Cadmium is highly toxic and responsible for several cases of food poisoning. Ahmed et al. (2009) studied the concentration of heavy metals in sediments from the Shitalakhya River in Bangladesh and found that the Cd concentration was 1.71 to 2.17 μg/L (dry weight). Khan et al. (1998) found a Cd concentration between 0.001 and 0.107 μg/L in the Ganges-Brahmaputra-Meghna (GBM) estuary.

Hardness

Measurements revealed that water hardness at the three sampling stations ranged from 22.50 (S1) to 43 (S3) ppm. The average value was 34.61 ppm, below the standard of 40 ppm (ECR 1997). Islam et al. (2002) reported high water hardness in the Hazaribag region on the Buriganga River, ranging from 50 to 65 mg/L during the rainy season. Excessive soap use, scale buildup, corrosion, and aquaculture are the main problems associated with water hardness. Hardness can significantly influence pH (Talukder 2003).

Potential sources of river pollution

Table 2 presents a detailed Pearson correlation matrix for the physicochemical parameters of effluent samples collected from Jamuna Fertilizer Company Limited. The results of the correlation analysis reveal significant interdependencies between several parameters. This highlights the combined influence of industrial discharges, physicochemical interactions, and organic pollution on the overall quality of the effluents.

Table 2: Pearson correlation matrix of heavy metals with other physico-chemical properties of sampling sites in the JFCL industrial zone.

Physio-chemical properties	pH	EC	TDS	Temp.	DO	Lead	Cadmium	Hardness
pH	1							
EC	0.873	1						
TDS	0.681	0.237	1					
Temperature	0.803	0.992	0.110	1				
DO	0.945	0.985	0.403	0.954	1			
Lead	-0.923	-0.993	-0.346	-0.971	-0.998*	1		
Cadmium	0.961	0.704	0.857	0.606	0.817	-0.780	1	
Hardness	0.976	0.958	0.505	0.913	0.993	-0.985	0.878	1

*The correlation is significant at the level of 0.05 (two-sided).

Numerous parameters have demonstrated positive correlations, including between pH and dissolved oxygen (DO), pH and cadmium, pH and hardness, temperature and electrical conductivity (EC), EC and DO, and EC and hardness ($r > 0.9$). These relationships indicate a strong interdependence between ionic strength, DO, and the organic load of wastewater (Ajibade and Ayodele 2008). Such correlations are frequently observed in industrial wastewater containing nitrogen and phosphate compounds (Adam et al. 2022). Furthermore, the correlations between temperature, DO, and hardness suggest that elevated effluent temperatures stimulate microbial activity, leading to increased oxygen demand and alterations in carbonate equilibria (Bhuyan et al. 2019, Ustaoglu et al. 2020).

Furthermore, the positive correlations observed between TDS, EC, cadmium (Cd), and hardness indicate that metal ions and dissolved matter likely originate from well-known sources, including effluent discharges, leaching from corroded pipes, and fertilizer residues (Dey et al. 2021). Moreover, these relationships suggest that Cd^{2+} ions coexist with dissolved salts, thereby increasing both conductivity and the total dissolved solids concentration (Adamu et al. 2015).

Lead (Pb) exhibits strong negative correlations with most key parameters, including pH ($r < -0.9$), electrical conductivity (EC), temperature, dissolved oxygen (DO), and hardness. This suggests that Pb concentrations are likely to increase in acidic environments characterized by low oxygen levels and high organic matter content (Perpetual et al. 2022). This inverse relationship could result from the precipitation or complexation of Pb^{2+} ions in alkaline, oxygen-rich environments, leading to decreased Pb solubility when EC, DO, and hardness are high (Lorenzo et al. 2021). Therefore, Pb accumulation in effluents is likely attributable to industrial corrosion, catalyst residues, or leaks during fertilizer production and handling processes (Ur Rahman et al. 2024).

The observed correlations suggest that the composition of Jamuna Fertilizer Company Limited's effluents is influenced by interactions between organic matter, dissolved ions, and heavy metals, reflecting both natural geochemical processes and human activities. Strong correlations between electrical conductivity (EC), dissolved oxygen (DO), and hardness highlight a significant presence of organic and inorganic pollution. Furthermore, negative correlations with lead (Pb) indicate specific heavy metal contamination risks that could have serious consequences for occupational health and the environment in the surrounding area.

Conclusion

Workers' health is influenced by several factors, including occupational hazards that can lead to various health problems such as cancer, accidents, musculoskeletal disorders, respiratory illnesses, hearing loss, circulatory diseases, stress-related disorders, communicable diseases, and more. This study examines the occupational health conditions of employees across the entire company and assesses the effluents discharged by the fertilizer plant. Health effects, such as respiratory infections and skin problems, have been associated with exposure to high concentrations of air pollutants, including ammonia and other chemicals released into the air. Water is an essential natural resource. The study revealed that industrial discharges have a minimal impact on the water quality of the Jamuna River, primarily due to good flow during the rainy season. However, in some cases, the values of certain water quality parameters fell below permitted levels. The continued discharge of these effluents into the river could lead to a significant accumulation of contaminants. If the authorities do not implement regulations to govern waste treatment, this could have detrimental consequences for the lives of those living along the river.

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Author’s contribution: Authors of the article designed the study including data collection method, data analysis and interpretation, draft of the manuscript, supervised the study, and finally corrected the manuscript.

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Data availability: Data generated in the study are reported in the manuscript, and unprocessed data is with the corresponding author and available upon request.

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