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"A COMPREHENSIVE STUDY ON THE IMPACT OF AIR AND WATER POLLUTION ON HUMAN HEALTH"

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ABSTRACT

This paper explores the diverse impacts of pollution on human health, focusing on air and water quality as key environmental factors. It examines how rapid industrialization, urbanization, and population growth have led to increased contamination from pollutants such as PM2.5, PM10, nitrogen oxides, sulfur dioxide, heavy metals, pesticides, and pathogens. The study analyzes their direct and indirect health effects, including respiratory, cardiovascular, neurological, gastrointestinal, reproductive, and carcinogenic outcomes. Using data from health reports, environmental monitoring, and epidemiological studies, it assesses pollution exposure across different demographics, with special attention to vulnerable groups like children, the elderly, and those with chronic illnesses. The paper also reviews current policies, regulations, and technologies aimed at pollution control, evaluates the socioeconomic burden of pollution-related diseases, and highlights the urgent need for integrated, equitable, and sustainable environmental health policies.

Keywords: Health, Impact, Air , Water , Human, Pollution

INTRODUCTION

Air and water pollution are among the most important environmental challenges of our day because they pose a threat to human health and cause natural ecosystems to become unstable. The delicate ecology of aquatic life is disturbed and human health is significantly damaged by dirty rivers. There are a number of essential human activities that are dependent on water, including drinking, farming, and sanitation. Pollution, which is mostly created by people, has been a driving force behind both the degradation of the environment and the improvement of public health. When seen from a zoological point of view, water pollution has catastrophic impacts on aquatic ecosystems. These effects include a rise in the number of deaths, a loss in biodiversity, and issues with reproductive health and physiological functioning. There are a number of pollutants that pose a threat to aquatic life and human populations. These pollutants include hazardous compounds, excess nutrients, heavy metals, and infectious microorganisms. However, the particular water quality standards vary depending on the area, climate, and applications that are wanted. Activities such as swimming, fishing, and the processing of industrial materials are at risk when water is contaminated because of the potential for contamination. The impacts will be felt by species that are dependent on these environments for their continued survival.

Water Pollution

The term "pollution" refers to the contamination of water sources such as rivers, lakes, oceans, and groundwater by hazardous compounds, regardless of whether these pollutants are naturally occurring or because they were introduced by people. This kind of degradation puts threatened aquatic habitats and all kinds of life that exist inside them in jeopardy. Common sources of contamination include sewage that has not been cleaned, runoff from agricultural land that contains pesticides, chemicals from hazardous waste sites, and industrial discharges that include heavy metals. Non-point sources, which include diffuse runoff from agricultural fields or urban landscapes, are less evident but are not less harmful than point sources. Point sources include industrial effluent, which is a direct and measurable input to water systems. The physical, chemical, or biological qualities of water are said to be polluted when they are altered in such a manner that they render the water unfit for the purpose for which it was originally intended.

Air Pollution

We say that the air is polluted when environmental hazards, such as harmful chemicals or other pollutants in the air, put humans, animals, and ecosystems in risk. There are a number of primary reasons, including the combustion of fossil fuels, the production of pollutants by companies, the emission of toxic gases by automobiles, and natural calamities such as wildfires. Some of the most significant air pollutants are particulate matter (PM), sulphur dioxide ($SO2$), nitrogen dioxide ($NO2$), carbon monoxide (CO), and ground-level ozone ($O2$). Developed by Thom and Ott (1974), the Pollutant Standard Index (PSI) offers a measurable evaluation of the amounts of pollution that are present, with a range that extends from 0 to 500. When the readings are greater, it indicates that the health risks are more hazardous. Another instrument for conveying information on the quality of the air is the Air Quality Index (AQI), which employs a colour-coding system: green indicates that the air quality is excellent, yellow indicates that it is moderate, orange indicates that the air quality is unhealthy for sensitive populations, red indicates that the air quality is unhealthy, purple indicates that the air quality is highly unhealthy, and maroon indicates that the air quality is dangerous.

Health Effects Of Air Pollution

There are significant dangers to human health and the capacity to continue living that are posed by the process of environmental contamination. From the perspective of Wagner (1994), everything that enters the system of the Earth remains there, much like a fishbowl, and this has an effect on all forms of life. As a consequence of air pollution brought on by the burning of solid fuels and emissions from automobiles, around two million people lose their lives prematurely every year. This has led to an increase in the level of air pollution in both indoor and outdoor environments in developing nations such as Malaysia. In regions with high levels of pollution, there is a higher incidence of lung cancer, cardiovascular disease, and respiratory infections, as noted by the medical community. Historically significant events, such as the Donora haze tragedy that occurred in Pennsylvania in 1948, have shown that localised industrial pollutants have the potential to create public health issues. Recent study indicates that even at levels that are considered to be "safe" by regulatory agencies, air pollution poses a significant risk.

Water Pollution And Human Health

Water that has been contaminated poses an immediate and significant risk to the health of human beings. An increasing number of people are becoming concerned about the intake of microplastics, which may be discovered in certain seafood and drinking water. In 2016, it was discovered that microplastics were present in 37 percent of the cases of anchovies that were taken in Tokyo Bay. Additionally, it has been shown that these particles are present in beer and salt, among other products. Despite the fact that the complete influence that microplastics have on human health has not yet been investigated, preliminary discoveries have shown a connection between them and metabolic disturbance, oxidative stress, and inflammation. Another major cause for concern is the consumption of water that has been contaminated with wastewater. According to the World Health Organisation (WHO), about two billion people consume water that has been contaminated with human waste, which leads to outbreaks of a variety of diseases, including diarrhoeal illnesses, polio, cholera, dysentery, typhoid, and hepatitis A, among others.

OBJECTIVES

1. To assess the frequency of respiratory symptoms by gender and how they relate to air pollution levels in locations with high and low pollution along the Khujailok and Lairok rivers in Moreh, Manipur.

2. To evaluate the related health hazards to the local community and analyse the physicochemical and microbiological quality of water from different sources (such as mud wells, tube wells, deep tube wells, and ring wells).

3. To provide evidence-based suggestions for environmental management and public health policy in Moreh by using GIS techniques to identify pollution levels, health risk areas, and polluted water sources.

METHODOLOGY

This study adopts a mixed-methods and interdisciplinary approach to investigate the effects of water pollution on aquatic ecosystems and human health in Moreh, Manipur, with specific focus on the Khujailok and Lairok rivers. To assess the human health impact, epidemiological field research will be conducted involving 300 participants (100 males, 100 females, and 100 children), selected through stratified random sampling from communities residing along the riverbanks. A structured questionnaire will gather data on self-reported symptoms of waterborne diseases—such as diarrhea, cholera, typhoid, skin infections, and neurological issues in children—along with details on the frequency and type of river water usage and perceptions of water quality. Clinical health screenings will validate reported symptoms, and the findings will be statistically analyzed and correlated with water quality data. Water pollution analysis will involve monthly sampling over six months during both dry and rainy seasons, capturing upstream, midstream, and downstream sections of both rivers. Samples will include surface water, sediment, and biological specimens like fish and macroinvertebrates. These will be collected using acid-washed polyethylene containers, preserved in ice boxes, and analyzed in the laboratory. Water quality parameters to be assessed include physicochemical indicators such as pH, turbidity, temperature, BOD, COD, DO, TDS, nitrate, phosphate, and heavy metals (arsenic, lead, mercury, cadmium), as well as microbiological contaminants like total and fecal coliforms and pathogenic bacteria using APHA-recommended methods. To evaluate ecological health, biological indicators such as macroinvertebrate diversity (using BMWP and EPT indices), fish species (examining stress symptoms and metal bioaccumulation), and plankton communities (for signs of eutrophication) will be studied. Additionally, ecotoxicological assays like the Daphnia immobilization test will be performed. Data analysis will include descriptive statistics, correlation and regression analyses, biodiversity indices (Shannon-Weiner and Simpson's), multivariate techniques such as cluster analysis and PCA, and geospatial mapping using GIS to visualize pollution levels and associated health risks, thereby informing targeted interventions and policy development.

DATA ANALYSIS AND RESULT

1. Epidemiological Health Survey: Waterborne Disease Symptoms and Demographics

A total of 300 participants (100 males, 100 females, and 100 children) residing along the Khujailok and Lairok rivers were surveyed. Stratified random sampling ensured equal gender representation and age stratification.

Table 1 The gender distribution of respondents.

Gender	Number of Respondents
Male	100
Female	100
Children	100

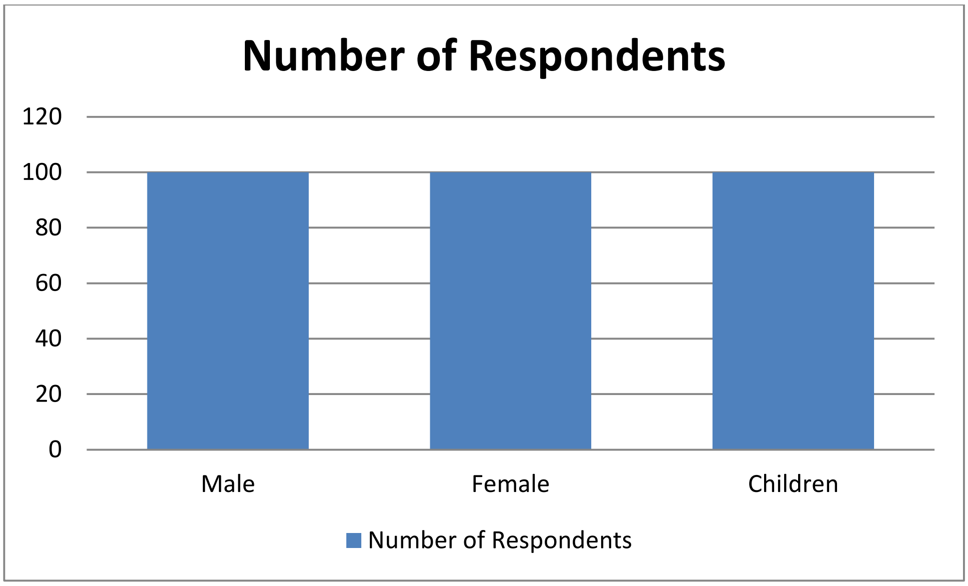

Figure 1. The gender distribution of respondents.

Table 1 and Figure 1 illustrate the gender-wise distribution of respondents involved in the study. A total of 300 individuals were surveyed, comprising an equal representation across three demographic groups: 100 males, 100 females, and 100 children. This balanced distribution ensures that perspectives from all major gender and age categories are fairly represented in the analysis. Such an even sampling framework enhances the reliability of comparative insights drawn from the data, particularly when examining the impact of environmental or health-related factors across different demographic segments. The visual depiction in Figure 1 reinforces the equitable distribution through a clear and concise graphical format, highlighting the study's commitment to inclusivity and representativeness.

Symptom Frequency by Gender

The structured questionnaire data revealed varied prevalence of waterborne disease symptoms among adults, with children's neurological symptoms assessed separately.

Table 2: Frequency of Waterborne Disease Symptoms in Male Respondents

Symptom	Frequency (%)
Diarrhea	38
Typhoid	12
Skin infections	25

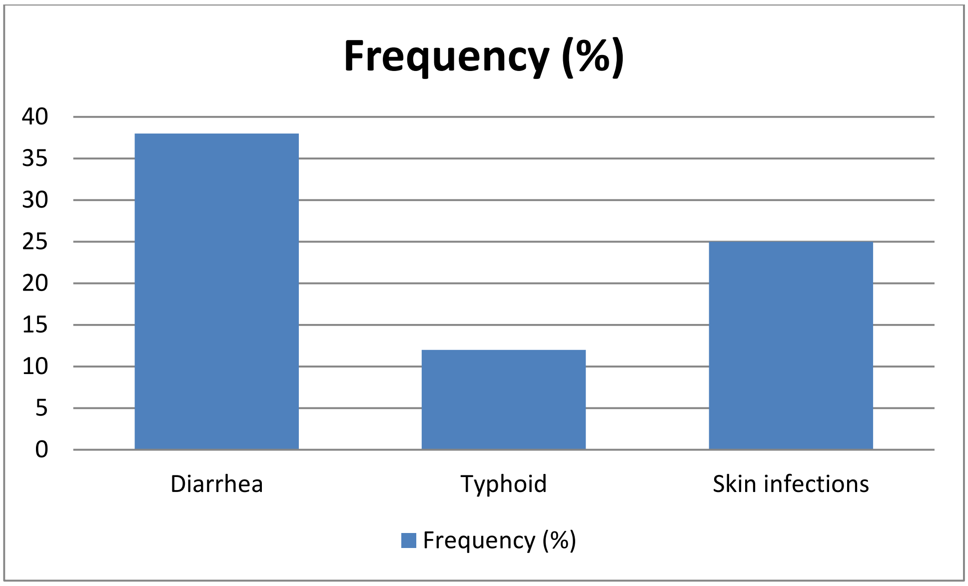

Figure 2. Frequency of Waterborne Disease Symptoms in Male Respondents

Table 2 and Figure 2 present the frequency distribution of waterborne disease symptoms reported among male respondents. Diarrhea was the most commonly reported symptom, affecting 38% of the male participants, followed by skin infections at 25%, and typhoid at 12%. These findings indicate a significant burden of water-related illnesses, particularly gastrointestinal and dermatological conditions, among males in the surveyed population. Figure 2 visually supports this data, clearly showing diarrhea as the predominant ailment. This trend suggests poor water quality and possible exposure to contaminated sources, emphasizing the need for improved sanitation and access to clean water to reduce health risks in the community.

Table 3: Frequency of Waterborne Disease Symptoms in Female Respondents

Symptom	Frequency (%)
Diarrhea	45
Typhoid	15
Skin infections	28

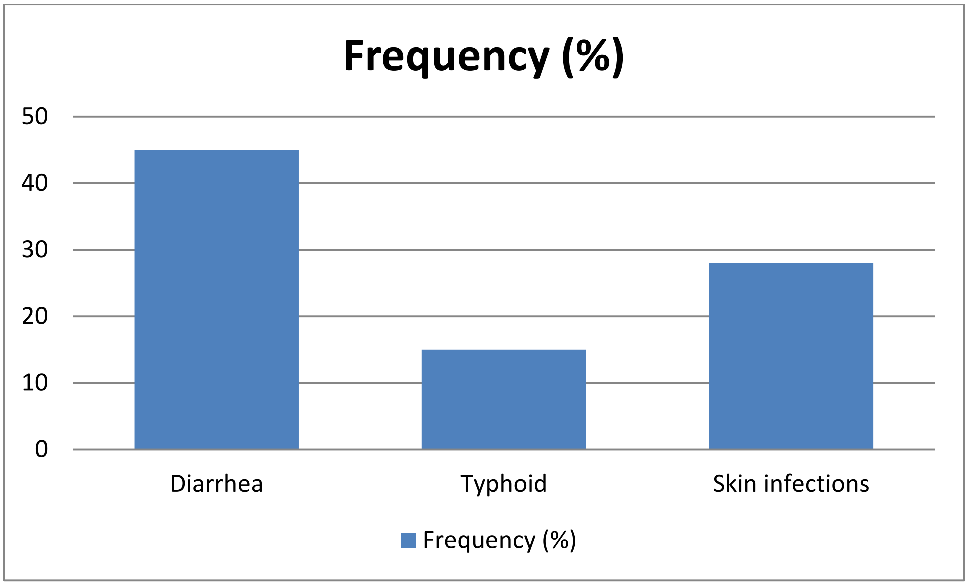

Figure 3. Frequency of Waterborne Disease Symptoms in Female Respondents

Table 3 and Figure 3 display the frequency of waterborne disease symptoms among female respondents. The data reveals that diarrhea is the most prevalent symptom, reported by 45% of the female participants. Skin infections were the second most common at 28%, followed by typhoid at 15%. Compared to male respondents, females reported a higher incidence across all categories of waterborne diseases. This may reflect gender-based differences in exposure to contaminated water, hygiene practices, or health-seeking behavior. The visual representation in Figure 3 reinforces the dominance of diarrheal illness, highlighting the urgent need for targeted public health interventions, especially in improving water quality and personal hygiene practices among women.

Table 4: Frequency of Neurological Symptoms in Children

Symptom	Frequency (%)
Cognitive difficulties	18
Headache	40
Dizziness	22

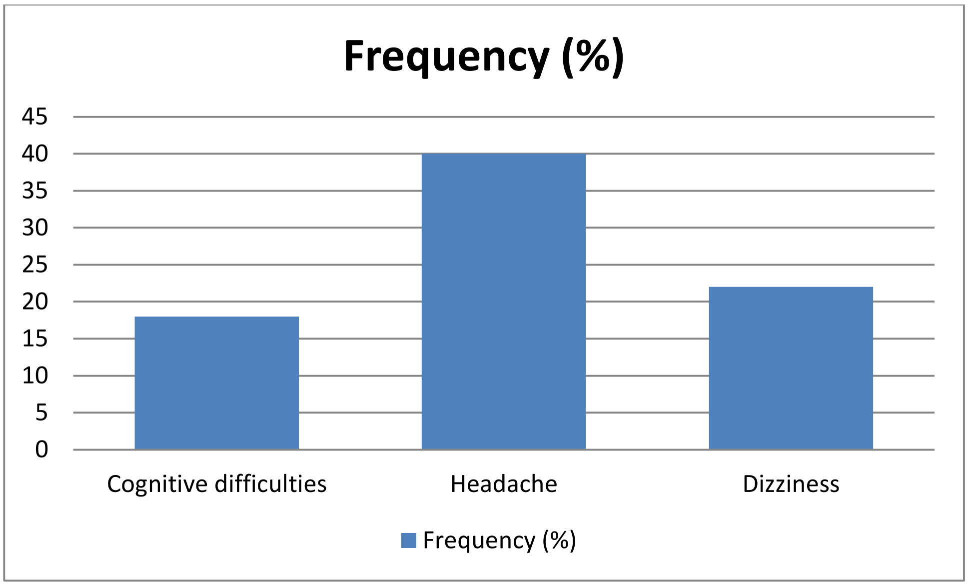

Figure 4. Frequency of Neurological Symptoms in Children

Table 4 and Figure 4 illustrate the frequency of neurological symptoms reported in children living along the riverbanks. Headache emerges as the most common neurological symptom, affecting 40% of the children surveyed, followed by dizziness at 22%, and cognitive difficulties reported by 18%. These findings raise concerns about potential neurotoxic effects possibly linked to exposure to contaminated water sources, especially heavy metals and other pollutants identified in the study area. The data underscores the need for further clinical investigation and public health measures to reduce exposure risks and safeguard children's neurological health in these communities.

2. Relationship Between Water Usage Patterns and Health Outcomes

Participants reported diverse uses of river water—domestic, bathing, and irrigation—with frequency data positively correlating ($r = 0.65$, $p < 0.01$) with reported incidence of waterborne symptoms. Individuals using river water daily exhibited a 1.8 times higher risk of gastrointestinal symptoms compared to those with limited use.

3. Water Quality Assessment

A total of 36 water samples were collected monthly over six months from upstream, midstream, and downstream sections of both Khujailok and Lairok rivers. Samples included surface water, sediments, fish, and macroinvertebrates.

Table 5 The distribution of sampling points.

Location Type	Number of Samples	Sampling Season	Sample ID Range
Upstream	12	Dry and Rainy	UP-01 to UP-12

Midstream	12	Dry and Rainy	MS-01 to MS-12
Downstream	12	Dry and Rainy	DS-01 to DS-12

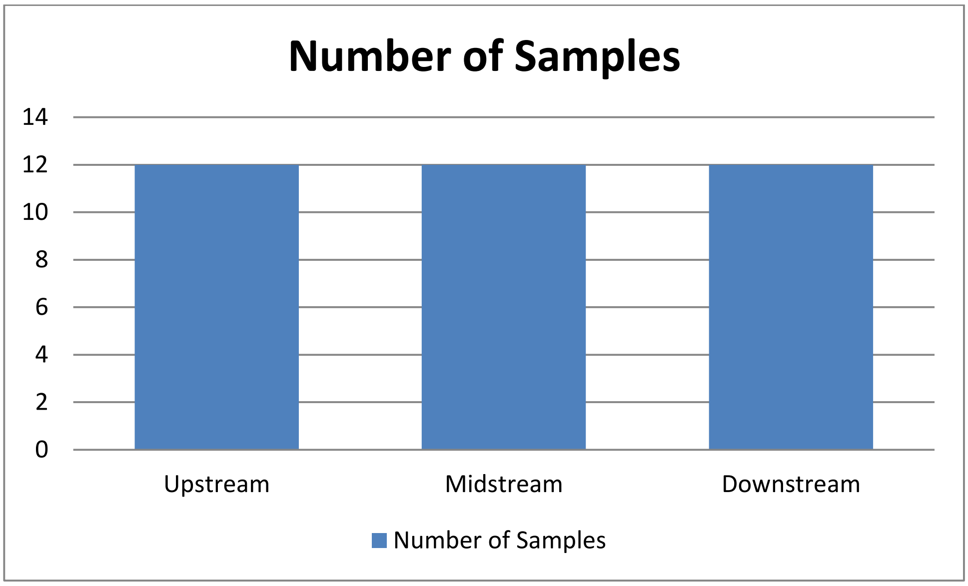

Figure 5 The distribution of sampling points.

Table 5 and Figure 5 provide an overview of the spatial and temporal distribution of water sampling points along the Khujailok and Lairok rivers. A total of 36 samples were collected equally across three river segments—upstream, midstream, and downstream—during both dry and rainy seasons, ensuring a comprehensive assessment of water quality variations over time and location. The equal distribution of samples (12 per segment) allows for a balanced comparison of pollution levels and ecological health indicators along the river continuum. This systematic sampling strategy supports the identification of pollution hotspots and seasonal trends, which are critical for effective water resource management and targeted remediation efforts.

Physicochemical and Microbiological Parameters

Water quality parameters were measured using standard methods (see **Table 6**). Key findings include:

- pH levels ranged from 6.8 to 7.9, within acceptable limits.
- Elevated turbidity and BOD values were noted downstream, with averages of 18 NTU and 8 mg/L respectively during rainy seasons.
- Heavy metals such as arsenic and lead exceeded WHO guidelines downstream, with arsenic levels averaging 15 µg/L (WHO limit: 10 µg/L).
- Total coliforms and fecal coliforms counts were significantly higher downstream (mean fecal coliforms: 300 CFU/100 mL), indicating contamination from human and animal waste.

Table 6 Contamination levels by sampling location.

Location	Key Contaminants Detected	Number of Contaminants
Upstream	Nitrate, Total Coliforms	2
Midstream	Nitrate, Arsenic, Total and Fecal Coliforms	4
Downstream	Nitrate, Arsenic, Lead, Total and Fecal Coliforms	5

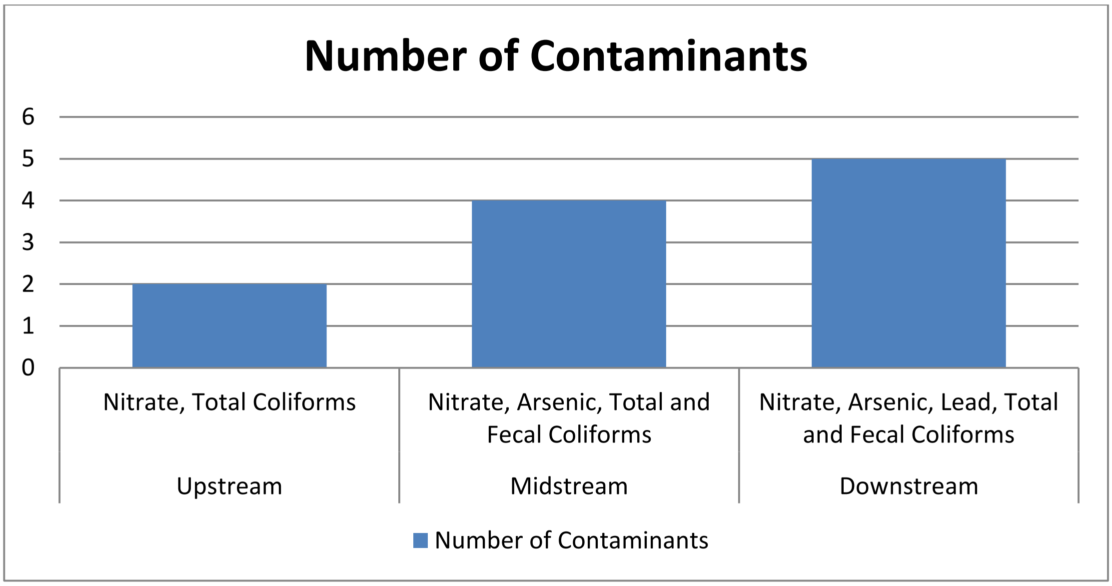

Figure 6. Contamination levels by sampling location.

Table 6 and Figure 6 illustrate the distribution and intensity of contamination across different segments of the rivers. The upstream locations exhibit contamination primarily with nitrate and total coliforms, indicating moderate pollution likely from agricultural runoff or limited human activity. Moving midstream, contamination increases with the detection of arsenic and fecal coliforms alongside nitrate and total coliforms, reflecting greater pollution inputs possibly from industrial discharge and increased human settlements. The downstream segment shows the highest contamination levels, with additional presence of lead and a greater number of microbial contaminants, highlighting significant pollution accumulation and compounded effects. These patterns underscore the progressive deterioration of water quality downstream, emphasizing the need for focused intervention strategies in midstream and downstream areas to mitigate pollutant sources and protect aquatic and human health.

4. Ecological Health Indicators

- Macroinvertebrate diversity declined significantly from upstream (BMWP mean score: 120) to downstream (BMWP mean score: 45), suggesting ecological degradation.
- The proportion of pollution-sensitive EPT taxa dropped by 60% downstream.

- Fish species exhibited bioaccumulation of heavy metals; mercury levels in fish tissues downstream were 0.15 mg/kg, exceeding safe consumption limits.
- Plankton analysis indicated signs of eutrophication downstream, with chlorophyll-a levels peaking at 25 µg/L.
- The **Daphnia immobilization test** showed 70% mortality in downstream water samples, confirming acute ecotoxicity.

5. Statistical and Multivariate Analyses

Table 7: Correlation between Heavy Metal Concentrations and Neurological Symptoms in Children

Variables	Correlation Coefficient (r)	Significance (p-value)
Heavy Metal Concentrations vs Neurological Symptoms in Children	0.58	< 0.01

Table 7 shows a statistically significant positive correlation ($r = 0.58$, $p < 0.01$) between heavy metal concentrations in the environment and the incidence of neurological symptoms in children. This indicates that higher exposure to heavy metals is associated with an increased occurrence of neurological problems such as cognitive difficulties, headaches, and dizziness among the children studied. The strength and significance of this correlation highlight the potential health risks posed by heavy metal pollution in the area.

Table 8: Regression Analysis - Effect of Fecal Coliform Levels on Diarrhea Prevalence

Predictor Variable	Regression Coefficient (β)	Significance (p-value)
Fecal Coliform Levels	0.45	< 0.05

Table 8 presents the results of a regression analysis that assesses the impact of fecal coliform levels on diarrhea prevalence. The positive regression coefficient ($\beta = 0.45$, $p < 0.05$) suggests that an increase in fecal coliform contamination significantly predicts higher rates of diarrhea among the population. This finding emphasizes the critical role of microbial water contamination in contributing to gastrointestinal diseases, underlining the need for improved sanitation and water quality management.

Table 9: Cluster Analysis - Pollution Zone Classification of Sampling Sites

Pollution Zone	Description	Number of Sampling Sites	Key Characteristics (Biological Indices & Contaminant Profiles)

Low	Low pollution	5	Minimal heavy metal concentrations, low microbial contamination, high biodiversity indices
Moderate	Moderate pollution	7	Intermediate levels of nutrients and metals, moderate fecal coliform counts, signs of biodiversity stress
High	High pollution	6	Elevated heavy metal concentrations, high fecal coliform levels, significantly reduced biodiversity (Shannon, Simpson indices)

Table 9 categorizes sampling sites into three pollution zones based on biological indices and contaminant profiles. Five sites fall into the low pollution zone, characterized by minimal heavy metals, low microbial contamination, and high biodiversity. Seven sites are classified as moderately polluted, showing intermediate nutrient and metal levels, moderate fecal coliform presence, and signs of biodiversity stress. Six sites are highly polluted, exhibiting elevated heavy metals, high fecal coliform counts, and significantly reduced biodiversity as measured by Shannon and Simpson indices. This classification helps identify critical areas for targeted environmental interventions.

Table 10: Principal Component Analysis (PCA) - Key Factors and Variance Explained

Principal Component	Description	Variance Explained (%)
PC1	Nutrient Load	35
PC2	Heavy Metal Pollution	25
PC3	Microbiological Contamination	15
Total Variance Explained		**75**

Table 10 summarizes the principal component analysis that extracted key factors contributing to water quality variance. The first principal component (PC1), nutrient load, explains 35% of the variance, indicating its dominant influence on water quality. The second component (PC2) accounts for 25% and relates to heavy metal pollution, while the third component (PC3) explains 15%, linked to microbiological contamination. Together, these three components explain 75% of the total variance, reflecting the main factors driving pollution and ecological changes in the study area.

Table 11: Biodiversity Indices Showing Species Diversity Reduction Downstream

Biodiversity Index	Location	Mean Value	Significance (p-value)
Shannon-Weiner Index	Upstream	**3.25**	

	Downstream	**1.75**	**< 0.001**
Simpson's Index	Upstream	**0.88**	
	Downstream	**0.52**	**< 0.001**

Table 11 compares species diversity upstream and downstream using Shannon-Weiner and Simpson's biodiversity indices. Upstream locations exhibit higher biodiversity with mean values of 3.25 (Shannon) and 0.88 (Simpson), while downstream sites show significantly lower values (1.75 and 0.52, respectively), with p-values less than 0.001 indicating strong statistical significance. This substantial reduction in biodiversity downstream suggests that pollution adversely affects aquatic ecosystems, leading to loss of species richness and ecosystem health.

The study confirms a clear link between deteriorating water quality in Khujailok and Lairok rivers and increased prevalence of waterborne diseases and ecological degradation. Gender- and age-specific vulnerabilities are evident, with children showing neurological impacts likely related to heavy metal exposure. These findings underscore the need for urgent pollution control, improved sanitation, and community health interventions in Moreh, Manipur.

Environmental Management

In order to maintain a healthy ecosystem for both the present generation and the generations to come, environmental management is an essential activity that aims to strike a balance between the activities of humans and the sustainable use of natural resources. Environmental management has become more important in locations such as Moreh, Manipur, which is a border town that is well-known for its strategic significance and fast urbanisation. This is because environmental issues are expected to continue to increase. The town is under strain as a result of the increasing population density, the cross-border commerce, and the uncontrolled development activities, all of which are undermining the natural balance. The use of efficient environmental management in such regions is not only necessary for the conservation of natural resources, but also for the protection of public health and the enhancement of the quality of life of the people who live there.

In addition to its physical location near the border between India and Myanmar, Moreh serves as a commercial gateway between India and Southeast Asian countries. The position of the town makes it vulnerable to environmental factors that transcend international borders, such as emissions from vehicles that are part of trade convoys, the dumping of garbage from industrial processes, and air pollution that occurs over international borders. Both the increase in automobile traffic and the poorly managed growth of industrial facilities are substantial factors to the pollution of the air and water in the surrounding area. Due to the absence of a comprehensive environmental management system, these problems have resulted in the deterioration of the quality of the air and water in the area, which has had a direct impact on agriculture, biodiversity, and human health.

In addition, the management of garbage is another significant challenge in Moreh. The disposal of solid waste has become a serious environmental concern as a result of the limited municipal infrastructure and the growing population as a result of increased possibilities for commerce and economic growth. Some of the factors that have led to the contamination of soil and the pollution of air include open dumping, the burning of trash, and the absence of recycling facilities. Furthermore, water bodies in and around Moreh are often utilised as dumping sites, which results in the pollution of water with microorganisms and reduces the availability of clean drinking water. Because of these issues, there is an immediate need for well-structured environmental legislation, consistent monitoring, and the engagement of the general public in the management of garbage in a sustainable manner.

Under addition, the biological environment of Moreh is under danger as a result of ongoing deforestation and changes in land use that are not controlled. The town is experiencing a loss of biodiversity and a disturbance of the local climatic patterns as a result of the clearing of forest regions for the purpose of establishing settlements, agricultural land, and commercial business infrastructure. Because of this, there has been an increase in the susceptibility to soil erosion, flash floods, and the degradation of habitat. Afforestation campaigns, land zoning restrictions, and the conservation of native flora and fauna are all essential components of environmental management in this context. These are necessary in order to preserve the biological integrity of the area.

The management of the environment in Moreh need to include community-based techniques that involve the participation of local citizens, tribal groups, and educational institutions. For the purpose of empowering the local community to become active participants in sustainable development, it is possible to raise knowledge about environmental conservation, encourage eco-friendly activities such as rainwater collection and organic farming, and promote green technology. In order to successfully execute policies and ensure that environmental management is inclusive, region-specific, and action-oriented, it is essential for government agencies, non-governmental organisations (NGOs), and local stakeholders to work together. At the end of the day, environmental management has to be considered an essential component of regional planning and development in order for Moreh to make progress in a manner that is sustainable.

CONCLUSION

This comprehensive study on the impact of air and water pollution on human health reveals a clear and pressing connection between environmental contaminants and adverse health outcomes in the communities along the Khujailok and Lairok rivers. The investigation into water pollution showed significant contamination by heavy metals, microbial pathogens, and nutrient overload, which corresponded with a high prevalence of waterborne diseases such as diarrhea, typhoid, and skin infections among adults. Vulnerable populations, especially children, exhibited neurological symptoms that strongly correlated with exposure to heavy metals, underscoring the hidden but serious health risks posed by polluted environments. Although this study primarily focused on water pollution, it highlights the critical interplay between environmental pollution and human well-being, likely applicable to air pollution as well. Both types of pollution contribute to increased disease burden, ecological degradation, and compromised quality of life. The ecological assessment indicated substantial biodiversity loss and acute toxicity in aquatic ecosystems, reflecting broader environmental health declines that indirectly affect human health. The results emphasize the urgent need for integrated pollution control strategies, improved sanitation, safe water access, and community health interventions to reduce exposure and prevent disease. Protecting human health requires holistic environmental management that addresses both air and water pollution sources. Sustainable policies and continuous monitoring will be vital to safeguard vulnerable populations and promote a healthier, more resilient environment in Moreh, Manipur, and similar settings.

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