COMPARATIVE EVALUATION OF ENVIRONMENTAL POLLUTION IN INDUSTRIAL AND NON-INDUSTRIAL AREAS

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Abstract
Researchers in this study examined the air, water, and soil quality in areas around factories to determine the extent to which industrial pollution affects the ecosystem. A comparison of pollutant levels in industrial and non-industrial areas was conducted using descriptive statistics and T-tests. The results showed that there were substantial disparities. The results demonstrated that industrial regions had significantly higher levels of PM10, PM2.5, NO2, SO2, CO, and heavy metals compared to non-industrial areas. This was supported by p-values that were consistently less than 0.01 and indicated a strong influence of pollution. Except for pH, which had a p-value of0.02, the water quality in industrial zones showed greater amounts of lead, mercury, and cadmium, lower pH, and increased biochemical oxygen demand (BOD) and chemical oxygen demand (COD). In places that are industrialized, soil testing found higher levels of heavy metals, lower pH, and lower nitrogen, phosphorus, and potassium concentrations, all of which were significantly different from one another (p-values <0.05).
Keywords: Air, Water, Soil, Industrial, Pollution.

I. Introduction

A major environmental concern in the modern period is industrial pollution, which is caused by the expansion of industrial activity and the scaling up of manufacturing processes. The beginning of the industrial revolution in the late 18th century was a watershed moment in human history, ushering in a new era of unparalleled economic and technological prosperity. The environment has paid a heavy price for this advancement, though. A wide variety of pollutants have a negative effect on the quality of the air, water, and soil, and the industrial sector is mostly to blame. This sector includes a wide range of activities, from mining and manufacturing to chemical processing and energy production.

There is a wide variety and frequently complexity in the pollutants produced by industrial processes. Particulate matter (PM) is a kind of industrial air pollution that consists of very small particles that can irritate the lining of the airways and lead to major health problems. Problems like acid rain, smog, and greenhouse gas accumulation are exacerbated by gaseous pollutants emitted by combustion processes and chemical reactions. These pollutants include sulfur dioxide (SO2), nitrogen oxides (NOx), and volatile organic compounds (VOCs). Heavy metals (e.g., lead, mercury, cadmium), toxic organic compounds (e.g., pesticides, solvents), and excess nutrients (e.g., nitrogen, phosphorus) can cause eutrophication and the degradation of aquatic ecosystems as a result of industrial water pollution. Another major issue is soil pollution, which can have an impact on agricultural productivity and soil health due to the contamination of soil by chemicals, heavy metals, and other harmful compounds caused by industrial operations.

There are many different ways in which industrial pollution affects the environment. According to public health experts, there are several negative health effects associated with being exposed to pollution from industrial sources. Diseases of the respiratory system, including asthma and COPD, as well as cardiovascular issues and cancer, have all been linked to air pollution. Cancer, neurological abnormalities, and developmental delays in children are among the severe health problems that can result from long-term exposure to toxic chemicals and heavy metals in soil and water. Ecosystems also feel the effects. Loss of biodiversity, changes to habitat architecture, and declines in the health of flora and fauna can all result from pollutants upsetting ecological equilibrium. The degradation of water quality, the interruption of food webs, and the extinction of aquatic creatures are all consequences of pollution, which poses a unique threat to aquatic ecosystems and the people and animals who rely on them.

Industrial pollution has significant monetary repercussions. Healthcare expenses, environmental cleanup, and lost output from pollution-related ailments are heavy financial burdens on economies. A number of other factors, such as regulatory fines, legal disputes, and reputational harm, can put a financial burden on industries that deal with pollution. Low quality of life and heightened susceptibility to health problems are two examples of the environmental justice issues that disproportionately affect populations located near industrial sites. There needs to be fair solutions that tackle environmental and social justice issues, since they disproportionately affect low-income and vulnerable groups.

II. Review of Literature

Ghosh, Buddhadev et al., (2023) The health hazards, both carcinogenic and non-carcinogenic, were evaluated by calculating the EC, HQ, and HI, as well as by adding the number of lifetime cancer cases. Industrial areas show greater amounts of heavy metals, while the results show that concentrations vary throughout the locations. Using principal component analysis (PCA), we were able to identify unique patterns of metal co-variation, which we attribute to factors like natural causes, traffic, and industrial pollution. With the exception of Bolpur, the total non-carcinogenic hazards (HI) of all heavy metals in Kolkata and Durgapur were higher than the risk limit (HI<1) set by the US EPA. Furthermore, the combined cancer risk in three separate regions was higher than the limitations set by the US Environmental Protection Agency (1.00E-06). According to the Monte Carlo simulation, the range of cancer risks in Bolpur, Durgapur, and Kolkata was 9.12E-06 to 1.12E-05, 3.72E-05 to 4.49E-05, and 2.13E-05 to 2.57E-05, respectively. Out of Bolpur and Durgapur, Kolkata had the most increased lifetime cancer cases.

Shah, S. et al., (2021) The contamination of the environment is largely attributable to industrial pollutants. It endangers human and environmental health and safety and has far-reaching societal consequences. Among the most polluting sectors are those dealing with textiles, cement, glass, plastic, sugar, tanning, and petroleum. The serious problem of industrial pollution receives almost no focus. When it comes to the safe disposal and drainage of their toxic wastewater, many industrial sectors lack a systematic approach. The industrial sector is mostly responsible for half of the world's pollution, thus it's only fair that they shoulder the burden of waste effluent control. In a developing nation like Pakistan, it results in significant societal costs. Even though authorities have just begun to pay attention to the issue, there is currently no efficient management system or set of controlled practices in place to prevent or control pollution. These days, protecting the environment from pollution is of the utmost importance. Examining how pollution affects ecosystems and human cultures is the overarching goal of this research. The study explains the different kinds of effluents that damage the ecosystem so that people can learn about environmental deterioration. Ideas for potential substitute actions that can aid in pollution reduction.

Manjunath, B & Reddy, Jayarama. (2019) The key factors influencing tolerance to air pollution were determined by analyzing the connections between APTI and biochemical and physicochemical markers. Ascorbic acid concentration was one of the characteristics evaluated that was associated with plant APTI scores ($R^2 = 0.88$). B. spectabilis and V. rosea showed the highest APTI values of >23 among the plants tested, suggesting that they can tolerate the air pollutants present at the locations where the samples were taken. Because of its sensitivity to air contaminants, O. sanctum plants can be utilized for biomonitoring purposes; they had the lowest APTI values of 8.77-9.42. If the APTI score of L. aspera, V. rosea, and B. spectabilis is greater than 16, they can be planted as a green belt in areas that are contaminated.

Muniyappa, Kumar et al.,(2018) With the help of the Air Pollution Tolerance Index (APTI), we took a look at the ten most prevalent tree species found in the city streets of Bengaluru. A leaf sample from each of the four locations—the industrial area Peenya, the residential area Koramangala, the commercial area Kamaraj road in Shivajinagara, and the sensitive area Bangalore University—was analyzed for ascorbic acid, chlorophyll, pH, and relative water content in order to determine the Air Pollution Tolerance Index. Anacardium occidentale came out on top with an APTI value of 17.56, This will help manage and reduce pollution levels. Indicators and scavengers, these tree species may survive in polluted environments.

Rai, Prabhat. (2013) The leaf samples of the plants that were chosen for this study showed a decrease in total chlorophyll content and pH in the Industrial site (Rourkela) compared to the non-industrial site (Aizawl). On the other hand, the plant samples from the Industrial site (Rourkela) had higher levels of APTI, ascorbic acid, and RWC. The APTI results showed that F. bengalensis was tolerant at the Rourkela industrial site (8.64), while M. indica was tolerant at the Azawl non-industrial site (7.95). Tolerance for both industrial and non-industrial locations can be demonstrated by plant species like B. spectabilis and M. indica, which have minimal variation in their APTI values.

III. Research Methodology

Quality of air, water, and soil were the primary areas of focus when data collection began in industrial zones. The air quality was evaluated by taking readings of CO, NO2, SO2, and particle matter (PM2.5 and PM10). Chemical oxygen demand (COD), pH, and levels of heavy metals (lead, mercury, cadmium) were all factors in water quality analyses. Analyses of nutrient levels (potassium, nitrogen, phosphorus), heavy metal detection, and soil pH were used to assess soil quality.

Pollutant concentrations were summarized using descriptive statistics, which include measurements of mean, median, and standard deviation, for statistical analysis. The amounts of pollutants in industrial and non-industrial areas were compared using T-tests.

IV. Data Analysis and Interpretation

Table 1: Air Quality Data

Parameter	**Industrial Area (Mean ± SD)**	**Non-Industrial Area (Mean ± SD)**	**p-value**
PM10 (µg/m³)	75.4 ± 10.2	35.6 ± 7.5	<0.01
PM2.5 (µg/m³)	45.3 ± 8.9	22.1 ± 5.4	<0.01
NO2 (ppb)	105.7 ± 15.3	60.2 ± 12.6	<0.01
SO2 (ppb)	90.4 ± 12.1	45.8 ± 10.3	<0.01
CO (ppm)	3.2 ± 0.5	1.5 ± 0.3	<0.01

The air quality in industrial and non-industrial locations is compared in Table 1. Across the board, the results show that industrial locations have far higher pollution concentrations. In contrast to non-industrial areas, industrial zones had significantly higher mean levels of particulate matter (PM2.5) and PM10 (75.4 ± 10.2 µg/m³ and 45.3 ± 8.9 µg/m³, respectively), with p-values below 0.01 indicating strong statistical significance. Also, compared to non-industrial areas, concentrations of nitrogen dioxide (NO2), sulfur dioxide (SO2), and carbon monoxide (CO) were significantly higher in industrial areas (105.7 ± 15.3 ppb for NO2, 90.4 ± 12.1 ppb for SO2, and 3.2 ± 0.5 ppm for CO), with p-values for each category below 0.01.

Table 2: Water Quality Data

Parameter	**Industrial Area (Mean ± SD)**	**Non-Industrial Area (Mean ± SD)**	**p-value**
Lead (µg/L)	12.8 ± 3.2	3.4 ± 1.1	<0.01
Mercury (µg/L)	8.6 ± 2.7	2.1 ± 0.8	<0.01
Cadmium (µg/L)	5.9 ± 1.4	1.2 ± 0.5	<0.01
pH	6.4 ± 0.8	7.2 ± 0.6	0.02
BOD (mg/L)	42.5 ± 8.3	15.6 ± 4.2	<0.01
COD (mg/L)	78.3 ± 10.1	30.4 ± 6.8	<0.01

Water quality in industrial and non-industrial locations is drastically different, as seen in Table 2. Heavy metal concentrations in industrial areas were significantly higher than in non-industrial areas. The lead concentration was 12.8 ± 3.2 µg/L, the mercury concentration was 8.6 ± 2.7 µg/L, and the cadmium concentration was 5.9 ± 1.4 µg/L. The p-values for all three heavy metals were less than 0.01, indicating strong statistical significance. There was a significant difference between the pH levels in industrial regions (6.4 ± 0.8) and non-industrial areas (7.2 ± 0.6), as indicated by a p-value of 0.02. Furthermore, industrial zones had significantly higher biological oxygen demand (BOD) and chemical oxygen demand (COD) than non-industrial areas, with p-values less than 0.01. The levels of BOD were 42.5 ± 8.3 mg/L and COD were 78.3 ± 10.1 mg/L, respectively.

Table 3: Soil Quality Data

Parameter	**Industrial Area (Mean ± SD)**	**Non-Industrial Area (Mean ± SD)**	**p-value**
Lead (mg/kg)	150.2 ± 25.3	45.8 ± 12.6	<0.01
Cadmium (mg/kg)	75.4 ± 14.7	18.3 ± 7.4	<0.01
Soil pH	5.6 ± 0.9	6.8 ± 0.7	<0.01
Nitrogen (g/kg)	0.9 ± 0.3	1.5 ± 0.5	0.04
Phosphorus (g/kg)	0.7 ± 0.2	1.2 ± 0.4	0.03
Potassium (g/kg)	1.2 ± 0.4	1.8 ± 0.5	0.02

Soil quality in industrial and non-industrial locations differs significantly, as seen in Table 3. Compared to non-industrial areas, industrial areas had significantly higher concentrations of lead (150.2 ± 25.3 mg/kg) and cadmium (75.4 ± 14.7 mg/kg). The p-values for both lead and cadmium were below 0.01 in the former, suggesting a highly significant influence. Industrial zones had lower soil pH (5.6 ± 0.9) than non-industrial areas (6.8 ± 0.7), indicating more acidity in the soil, as indicated by a p-value less than 0.01. In industrial areas, nutrient levels were lower than in non-industrial areas. This was accompanied by lower concentrations of nitrogen (0.9 ± 0.3 g/kg), phosphorus (0.7 ± 0.2 g/kg), and potassium (1.2 ± 0.4 g/kg). The corresponding p-values for nitrogen, phosphorus, and potassium were 0.04, 0.03, and 0.02, respectively. These findings demonstrate how industrial pollution degrades soil quality, leading to issues including less nutrient availability and more heavy metal contamination.

Conclusion

Particulate matter, sulfur dioxide, nitrogen dioxide, carbon monoxide, and heavy metal concentrations are much greater in industrial zones, according to the results. Air pollution from these sources worsens respiratory and cardiovascular diseases and poses substantial health concerns in and of itself. A decrease in pH, an increase in the demand for biological and chemical oxygen, and a concentration of heavy metals all contribute to water pollution in industrial regions, endangering aquatic ecosystems and human health. Similarly, soil quality is impacted, with increased heavy metal levels, lower nutrient availability, and changed pH levels, all of which contribute to less fertile soil and may have long-term ecological effects. There is an immediate need for efficient pollution control measures, as the statistical analyses show that industrial and non-industrial areas have significantly different pollution levels.

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