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Assessment of Impact of Cement Industry on Surface and Ground Water Quality

Er. Ateeb Khan[1], Dr Sanjay Sharma[2]
[1]*M.E. Scholar,* [2]*Professor Department of Civil Engineering, National Institute of Technical Teachers Training and Research, Chandigarh*

Abstract: ***This study aims to assess the impact of the cement industry on surface and groundwater quality. The research focuses on a specific cement plant location Athwajan Srinagar J&K and evaluates the physico-chemical parameters of water samples collected from various points around the plant. Parameters such as pH, temperature, turbidity, dissolved oxygen, total dissolved solids, hardness, calcium, alkalinity, sulphate, nitrate, fluoride, chloride, and iron are analyzed to determine the extent of pollution. The study employs a combination of field surveys, laboratory analysis, and statistical methods to compare water quality between areas affected by cement industry emissions and control sites. The findings will highlight the adverse effects of cement industry activities on surface and groundwater quality, including potential health risks for local communities and ecological impacts.***
The objective is to provide a comprehensive understanding of the environmental implications of cement production and to identify strategies for mitigating these impacts. This research will contribute to the development of sustainable practices in the cement industry and inform policy decisions aimed at protecting water resources and public health.

I. INTRODUCTION

Water is an essential resource for life, playing a crucial role across ecological, industrial, and societal sectors. However, growing urbanization, industrialization, and climate change have intensified water-related challenges, including scarcity and pollution. Surface water
sources—such as rivers and lakes—are vital for drinking, agriculture, and ecosystems, yet they are increasingly threatened by industrial waste, especially from sectors like cement manufacturing. Similarly, groundwater, often considered cleaner, is under threat due to untreated industrial effluents and poor waste management.
The cement industry, though central to infrastructure development, contributes significantly to water contamination and environmental degradation through the discharge of suspended solids, heavy metals, and other pollutants. In India, which ranks second globally in cement production, environmental impact assessments (EIAs) are legally mandated to mitigate these effects.
Water Quality Index (WQI) is a key tool used to evaluate and communicate the status of water resources by integrating multiple parameters into a single, interpretable score. This study focuses on understanding the impact of cement industry activities on water quality using WQI and aims to identify contamination sources and propose strategies for sustainable water resource management.

II. OBJECTIVES OF STUDY

1) To assess current water quality, especially in areas surrounding cement producing plants. Identify the sources and pathways of water contamination associated with the produce of the cement.
2) To identify the levels of the main pollutants found in water bodies affected by the cement industry, such as suspended solids, heavy metals, and chemical additives.
3) To examine thoroughly each of the collected water samples in search of important aspects including chemical, biological and physical indicators (These factors may include factors such as pH, turbidity, nitrates, sulphate, total dissolved solids (TDS), calcium chloride etc.)
4) To compare the surface water quality and the groundwater quality regulation standards that are drafted and issued by the relevant national and regional environmental agencies with the data on water quality.
5) To Find out the health and environmental risks due to water pollution from cement industry and to give recommendations for minimizing the adverse effects on the environment and suggest water quality controlling for the cement industry.

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III. LITERATURE REVIEW

Several studies have explored the environmental impact of cement industries on water quality and ecosystems across different regions.

1) Water Quality Degradation: Mbaka (2023) and Obaje & Ipeaiyeda (2017) observed significant deviations from WHO water quality standards in rivers near cement plants in Kenya and Nigeria, respectively. Aga et al. (2020) reported high turbidity, TSS, and low DO in the Ngo River due to effluents, impacting aquatic life. Uddin et al. (2011) studied groundwater near cement plants over several years and found chemical concentrations exceeding safe limits. Conversely, Ali et al. (2013) found minimal groundwater pollution near a cement plant in Jhansi, India.
2) Effluent & Pollutant Effects: Ibrahim et al. emphasized how industrial discharges compromise water usability for drinking and agriculture. Lone & Subramani highlighted severe pollutant emissions (CO, NOx, SOx, dust), correlating them with water and health issues. Bajuri examined cement dust impacts on water, soil, and health, revealing elevated metal content and microbial degradation.
3) Efficiency & Environmental Management: Zhang et al. used dynamic efficiency models to show regional disparities in wastewater treatment efficiency in China. Dawoudian et al. classified environmental impacts of cement factories into severity levels, noting water pollution as a major contributor (70% of total impact).
4) Agriculture & Socio-economic Impact: Kayalvizhi et al. (Ariyalur district) and Shukla et al. (Rewa) found declining water and soil quality, crop yields, and increasing mitigation costs. Mishra et al. highlighted sustainable practices and policy challenges in the global cement industry, emphasizing India's growing role.
5) Ground & Surface Water Analysis: Kaur & Malik (2011) found poor surface and groundwater quality in Chandigarh, while Kadam & Reddy applied statistical and geospatial modeling to assess groundwater contamination in Andhra Pradesh. AL-Taay et al. (2016) reported biodiversity and ecosystem damage due to cement dust and emissions in Iraq.
6) Chemical & Theoretical Assessments: Cowie & Glasser modeled chemical reactions between cement and natural waters using
7) MINEQL and Fick's Law to predict long-term water-cement interactions, offering theoretical insights into water-induced degradation of cement structure

IV. INFERENCES DRAWN

Based on the critical review of existing literature, the following inferences have been drawn:

1) Site Selection: Accurate assessment of the geographical location where the study is conducted is essential for obtaining reliable results.
2) Climatic Factors: Climate and rainfall patterns are often overlooked, yet they significantly influence the transport and dilution of pollutants in both surface and groundwater.
3) Use of Equipment: The adoption of modern and efficient equipment can substantially reduce data collection time and improve measurement accuracy.
4) Pollution Control: There are effective and scalable methods available to reduce pollution caused by the cement industry, which need to be more widely implemented.
5) Temporal Monitoring: Longitudinal studies are necessary to capture the long-term impacts of cement industries on water quality.
6) Soil and Geomorphology: Integrating geomorphological and soil characteristic assessments can enhance the depth and accuracy of environmental evaluations.
7) Geological Assessment: Understanding the regional geology and rock types can offer vital insights into groundwater movement and vulnerability to contamination.
8) Topographic Analysis: Detailed study of topography can aid in understanding pollutant flow and accumulation in a given area.
9) Drainage Patterns: Analyzing local drainage systems can improve predictions of pollutant dispersion and accumulation, especially in areas surrounding cement plants.

V. RESEARCH METHODOLOGY

A. *Objective of the Case Study*

Assess surface and groundwater quality in Athwajan, Srinagar.
Collect water samples from:
Surface water: Jhelum River, nearby ponds.

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Groundwater: Hand pumps, bore wells around the cement industry site.
Use sterilized sample bottles; store at 4°C until lab testing.
Analyze samples using Horiba U52 (field) and UV-Vis spectrophotometer (lab).

B. Testing of Samples

Sampling Type: Grab sampling at fixed time/depth.
Sampling Method:
Surface water: Collected manually from selected river/pond points.
Groundwater: Collected from bore wells and hand pumps.

C. Testing Process

Lab analysis of physical, chemical, and biological parameters.
Identify pollutants and evaluate water usability for drinking, agriculture, aquatic life.
Calculate Water Quality Index (WQI) for holistic assessment.
Horiba U52
Multi-parameter field testing device. Measures 11 parameters simultaneously: pH, ORP, DO, turbidity, conductivity, salinity, water depth, TDS, SW-SG, temperature.
Durable and waterproof; suitable for rivers, lakes, coastal areas, and wastewater treatment plants. Enhances efficiency and reduces need for multiple instruments. Water Quality Index (WQI) Summarizes water quality into a single value based on test results.
Integrates various parameters: physical, chemical, biological.
Helps identify pollution levels and prioritize corrective actions.
Useful for environmental agencies and policymakers for decision-making.

D. Water Quality Parameters (Brief Definitions)

Parameter	Description
pH	Measures acidity or alkalinity.
Color	Indicates presence of suspended or dissolved substances.
Turbidity	Water clarity; influenced by particles.
Odour	Indicates contamination by organic or chemical substances.
Hardness	Amount of calcium and magnesium ions.
Calcium	Influences taste and water hardness.
Alkalinity	Water's ability to neutralize acids.
Total Solids	Total dissolved and suspended substances.

E. Dissolved Oxygen (DO) Essential for aquatic life.

Temperature	Affects biological and chemical processes.
Sulphate	Impacts taste; may originate from industry.
Nitrate	Common pollutant from agriculture/sewage.
Fluoride	Beneficial in low amounts; harmful in excess.
Chloride	Impacts taste and corrosion.
Iron	Can cause staining, taste changes, corrosion.

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VI. RESULTS AND DISCUSSION

A. Data Collection & Water Quality Analysis

Water samples were collected from six surface water locations between February and May, adhering to the Central Pollution Control Board (CPCB) guidelines (CPCB, 2007). The Arithmetic Mean method was employed to compute Water Quality Index (WQI) values at each site, based on monthly average values of key physico-chemical parameters. Water quality classification was based on the WQI grading scale:

WQI Range	Water Quality	Grade
0–25	Excellent	A
26–50	Good	B
51–75	Poor	C
76–100	Very Poor	D
>100	Unsuitable for Drinking	E

B. Sampling Locations

Six stations were selected within the study area:

Code	Location	Direction & Distance
SW1	Jhelum River	200 m SW
Code	Location	Direction & Distance
SW2	Namblabal	~4.5 km SE
SW3	Panthrathen	~4.0 km NW
SW4	Khonmoh	~4.5 km NE
SW5	Zooni Pora	~4.0 km ESE
SW6	Khrew	~7.5 km E

C. Physico-Chemical Results Summary

All measured parameters (pH, turbidity, TDS, hardness, etc.) were compared against BIS: 10500 (2012) drinking water standards. The water quality showed temporal consistency across months with minor variations. pH values at all sites ranged between 6.55 and 8.03, indicating neutral to slightly alkaline water.

Turbidity exceeded the BIS limit of 5 NTU at several sites, notably at SW1 (Jhelum River), indicating moderate suspended particulate load.

TDS, hardness, and conductivity were highest at SW1, reflecting increased mineral content, while SW6 (Khrew) showed the lowest values.

Heavy metals (Iron) and nitrates remained within permissible limits at all locations. Fluoride concentrations varied from 0.12 to 0.55 mg/L, remaining under the 1 mg/L BIS limit.

Overall, water quality ranged from "Good" to "Poor" across sites and months. WQI computation revealed that:

SW1 (Jhelum River) showed relatively higher contamination due to elevated turbidity and TDS.

SW6 (Khrew) demonstrated the best water quality, falling in the "Good" category.

D. Trend Analysis

The temporal analysis across February to May shows stable trends in water quality with minor monthly fluctuations, suggesting no significant seasonal impact during this period. However, slight improvements were observed at some sites in April and May, likely due to dilution from snowmelt and rainfall.

E. Ground Water Sampling Locations

Groundwater and potable water samples were collected from six representative locations around the mine site using hand pumps and bore wells. The sites, situated in different directions from the mining boundary, included Jhelum (SW, ~700m), Ali Abad (SE, ~1.5 km), Sem Pora (E, ~4.0 km), Natipora (W, ~5.0 km), Khonmoh (NE, ~4.0 km), and Badamibagh (adjacent to mining site).

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F. Ground Water Quality Results

A comprehensive analysis was conducted from February to May for various physicochemical parameters. All samples showed pH values ranging between 6.04–7.70, mostly within BIS limits (6.5–8.5), with slight acidity noted at Jhelum and Ali Abad. Turbidity at Sem Pora exceeded BIS limits (5 NTU), suggesting higher suspended particles. Electrical conductivity was highest in Sem Pora (up to 720 µS/cm), indicating higher ionic concentration. Hardness and alkalinity values were within acceptable limits across all sites, though Sem Pora and Badamibagh showed higher values. Total Dissolved Solids (TDS) ranged between 350–598 mg/L, all below the 2000 mg/L upper limit. Fluoride, nitrate, and iron levels remained within BIS permissible limits, with Badamibagh showing the highest nitrate concentration (~12.7 mg/L). Chloride and calcium values varied moderately, with maximum calcium detected in Sem Pora and Badamibagh.

Overall, the groundwater quality in the study area was found to be within permissible limits for most parameters, with localized concerns related to turbidity and slightly acidic pH in specific locations.

VII. CONCLUSION

The present study comprehensively evaluated the impact of cement industry operations on groundwater quality around the proposed mine site by analyzing water samples collected from six strategic locations—Jhelum, Ali Abad, Sem Pora, Natipora, Khonmoh Village, and Badamibagh. The assessment focused on physicochemical parameters across multiple months and compared the observed values against BIS: 10500-2012 drinking water standards. The findings reveal that most parameters across all sampling stations fall within the permissible limits prescribed by BIS; however, variations in pH, turbidity, total dissolved solids (TDS), electrical conductivity, hardness, calcium, chloride, and iron levels were evident, especially in areas in close proximity to the cement plant and associated activities. Elevated turbidity levels at some stations (e.g., Sem Pora and Jhelum) and higher hardness and calcium concentrations in areas like Sem Pora and Badamibagh suggest the potential influence of cement dust deposition, leaching of construction materials, and possible contamination through surface runoff or groundwater interactions.

Furthermore, the spatial variation in parameters such as chloride, fluoride, sulphate, and nitrate may indicate diffuse pollution from anthropogenic sources, including industrial discharge, domestic effluents, and vehicular emissions associated with mining logistics. These results underscore the need for a robust environmental monitoring framework in industrial zones, particularly near ecologically sensitive and residential areas. Continued and unregulated expansion of cement industries without stringent environmental controls could exacerbate groundwater contamination and reduce potable water availability in the long term.

To mitigate these effects, it is essential to implement:

Regular water quality surveillance at all major groundwater sources;

Adoption of sustainable and cleaner production techniques in cement manufacturing; Buffer zones and greenbelt development around operational areas to limit dust and runoff impacts;

Community engagement and awareness programs to promote water conservation and health safety.

VIII. SCOPE FOR FUTURE WORK

This study lays the groundwork for deeper investigation into the environmental impacts of cement industries on groundwater. Future research should focus on long-term monitoring of water quality to assess cumulative effects, and detailed analysis of heavy metals and microbial contamination. Hydrogeological modeling can help simulate pollutant transport, while remote sensing and GIS tools can support spatial analysis of land and water changes. Comparative studies across industrial zones and interdisciplinary assessments of ecosystem and public health impacts are also recommended. Additionally, evaluating current regulations and exploring sustainable technologies can guide improved environmental management practices.

IX. LIMITATIONS OF THE STUDY

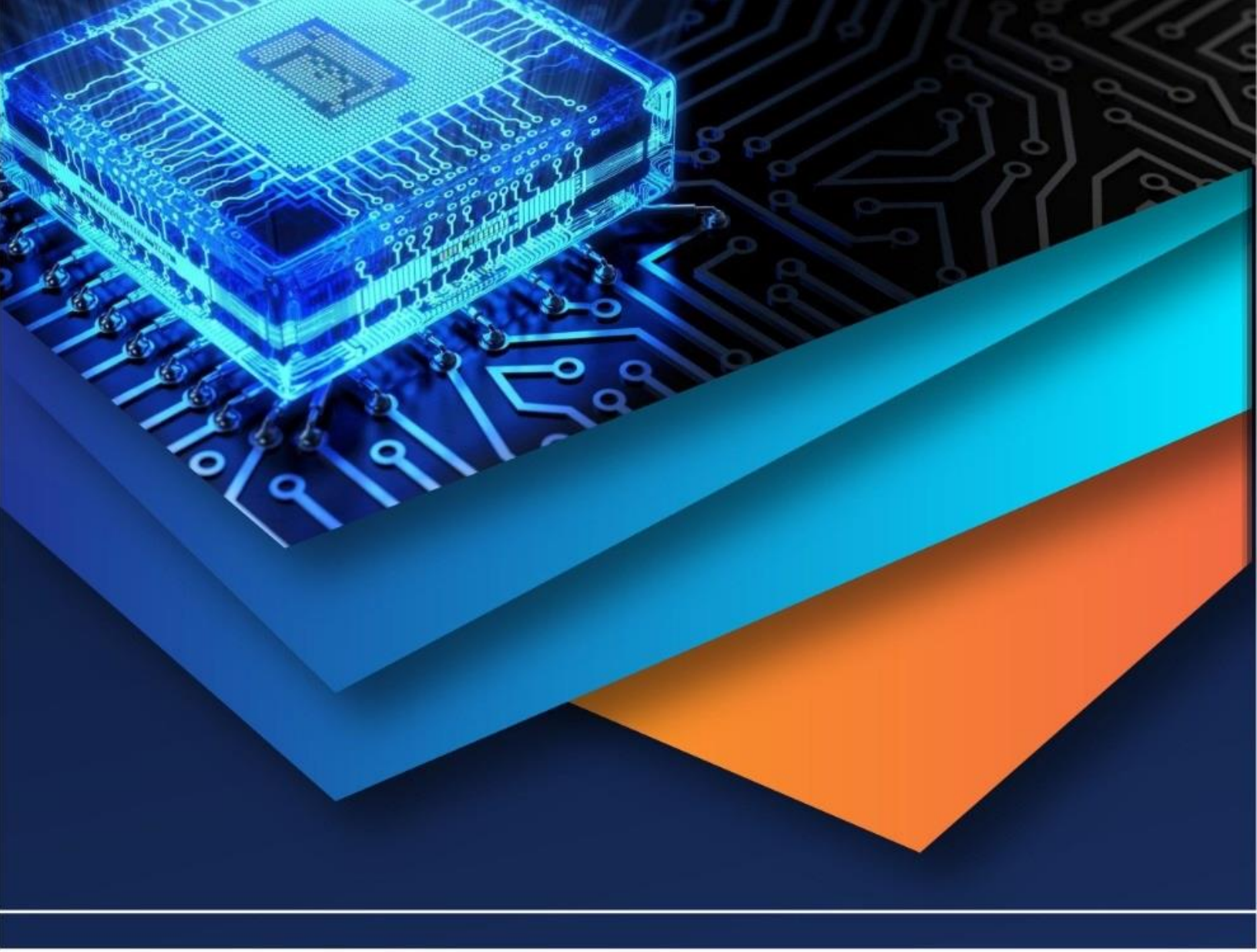
This study, while comprehensive, has certain limitations. The water quality analysis was limited to a specific period (February to May), which may not capture seasonal variations. Only six groundwater locations were sampled, potentially limiting spatial representation. The study focused primarily on physico-chemical parameters, excluding microbial and advanced heavy metal analyses. Furthermore, the impact of cement industry activities was assessed without direct correlation to health outcomes or ecosystem degradation. Future studies incorporating broader temporal, spatial, and biological data are needed for a more holistic understanding.

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