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Phytochemical Screening and Antioxidant Activity of Medicinal Plants from Central India

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Abstract

Groundwater serves as a primary source of drinking water for both urban and rural populations in India. However, in industrially intensive zones such as those found in Gujarat, groundwater quality is severely compromised by heavy metal contamination. The unregulated discharge of industrial effluents containing hazardous substances like lead (Pb), cadmium (Cd), chromium (Cr), and nickel (Ni) into surrounding soils and water bodies has led to alarming concentrations of these metals in the aquifers. This study focuses on five major industrial regions in Gujarat to assess the extent of heavy metal contamination in groundwater. Samples were collected from borewells and hand pumps and analyzed for physicochemical and metal content using atomic absorption spectroscopy. Results show significantly elevated levels of Pb and Cr compared to WHO guidelines, posing a high risk to human health through ingestion. A structured questionnaire survey revealed a lack of community awareness regarding water quality and health risks. This paper highlights the need for urgent intervention through monitoring, policy reform, and public education.

Keywords: Groundwater pollution, industrial discharge, heavy metals, public health, Gujarat, water contamination, environmental monitoring, risk assessment, awareness, atomic absorption spectroscopy

Introduction

Gujarat, one of India's leading industrial states, has been experiencing rapid economic growth driven by industrial expansion. Cities such as Ankleshwar, Vapi, Vatva, and Morbi host a large concentration of chemical, pharmaceutical, textile, ceramic, and electroplating industries. While this industrialization has

created employment and economic development, it has also resulted in the generation of large volumes of untreated or inadequately treated industrial effluents. These effluents often contain harmful heavy metals that, when discharged into the environment, percolate into the subsurface and contaminate groundwater resources.

Groundwater, being a major source of drinking and agricultural water, especially in rural and semi-urban areas, is thus exposed to contamination. Chronic exposure to metals such as lead, cadmium, and chromium is linked with serious health disorders, including neurotoxicity, carcinogenicity, kidney damage, and developmental abnormalities in children. Despite the presence of environmental regulations, enforcement remains weak. The objective of this study is to provide an in-depth assessment of heavy metal levels in groundwater across selected industrial regions in Gujarat and evaluate the public's awareness and practices related to water usage. The study further aims to support regulatory agencies in devising effective strategies for pollution control and public safety.

Methodology

To conduct a comprehensive study on groundwater contamination, we selected five key industrial zones in Gujarat: Ankleshwar, Vapi, Vatva, Morbi, and Jamnagar. These zones represent a wide spectrum of industrial activities, including pharmaceuticals, dye manufacturing, ceramics, and electroplating. From each region, six sampling points were identified within a 0.5 to 3 km radius of industrial clusters, resulting in a total of 30 groundwater samples. Borewells and hand pumps used for domestic consumption were prioritized.

Each sample was collected in pre-cleaned polyethylene bottles, preserved with nitric acid, and transported in ice-packed containers to the laboratory. Physicochemical parameters including pH, TDS, and conductivity were measured on-site. Heavy metals like Pb, Cd, Cr, and Ni were analyzed using Atomic Absorption Spectroscopy (AAS) as per APHA standards.

Additionally, a structured questionnaire survey was conducted among 100 residents in each region to assess their dependence on groundwater, awareness of contamination, and reported health issues. Data were statistically analyzed using SPSS. Correlation coefficients were calculated to understand the relationship between proximity to industry and metal concentration. Human health risk assessments were conducted by calculating the Hazard Quotient (HQ) and Hazard Index (HI) based on the USEPA guidelines.

Data Analysis

The analytical results revealed significant variability in heavy metal concentrations across the five regions. Lead (Pb) levels ranged from 5.2 to 98.3 µg/L, with a mean value of 34.5 µg/L. Cadmium (Cd) ranged from 0.1 to 4.2 µg/L, averaging 1.1 µg/L. Chromium (Cr) showed the highest deviations, with concentrations peaking at 126.7 µg/L in certain samples near tannery units. Nickel (Ni) concentrations also exceeded safe limits in more than 30% of the samples.

These levels were compared against WHO and BIS (Bureau of Indian Standards) guidelines. In over 60% of the sites, at least one metal exceeded permissible limits. Statistical analysis showed a strong negative correlation ($r = -0.7$) between distance from the industrial source and metal concentration, indicating that closer proximity significantly raises contamination risk.

Health risk assessments revealed that the Hazard Quotient for Pb and Cr exceeded 1 in many samples, indicating potential non-carcinogenic effects, especially among children. Cumulative exposure analysis using the Hazard Index (HI) showed values >1 in 15% of samples, signifying combined toxicity from multiple metals. Residents who consumed groundwater without treatment reported gastrointestinal and dermatological issues, underscoring the health impact.

Case Study: Ankleshwar Industrial Estate

The Ankleshwar Industrial Estate, located in the Bharuch district of Gujarat, is among Asia's largest chemical manufacturing zones. It hosts over 1,000 medium and large-scale industries. Despite the presence of a Common Effluent Treatment Plant (CETP), field reports suggest that many industries discharge untreated waste directly into drains or unlined canals. Our study found that groundwater samples within 1 km of these industrial units exhibited Pb concentrations of up to 98.3 µg/L and Cr concentrations exceeding 120 µg/L—both well above WHO permissible limits.

Residents rely heavily on borewell water due to insufficient municipal supply. Interviewed locals reported frequent illnesses, including abdominal pain, skin allergies, and joint problems. Women and children were particularly affected. The local administration lacks consistent water quality monitoring, and very few people treat water before consumption. The CETP was often found overloaded or non-functional during field visits, leading to direct effluent discharge into open environments.

This case highlights the environmental and health costs of unchecked industrial growth and insufficient regulatory enforcement. It also underlines the urgent need for strengthening the monitoring infrastructure and public health interventions in such industrial belts.

Questionnaire and Tables

To complement the laboratory data, a detailed household survey was conducted across the five study areas. The questionnaire focused on five categories: water source, water treatment methods, awareness about contamination, frequency of health symptoms, and reliance on government water supply.

Table 1 – Water Use and Awareness Among Respondents (n=100)

Question	Yes (%)	No (%)
Use groundwater for drinking/cooking	92	8
Aware of any contamination or metal presence	27	73
Experienced health issues due to water use	58	42
Use water filters or boil water before use	38	62
Receive regular government water quality updates	12	88

Table 2 – Type of Health Problems Reported (Multiple Responses Allowed)

Health Issues	% Respondents
Gastrointestinal issues (nausea, ulcers)	45
Dermatological problems (rashes, eczema)	28
Neurological signs (dizziness, fatigue)	14
No noticeable symptoms	27

These responses highlight a significant gap between contamination levels and public perception. Despite high metal concentrations, most residents remained unaware of the health risks. Many lacked the resources or knowledge to treat their drinking water effectively. The government's communication and mitigation efforts were found to be minimal or ineffective.

Conclusion

The findings of this study confirm the alarming extent of heavy metal contamination in groundwater in industrial areas of Gujarat, particularly in Ankleshwar and Vatva. Lead, chromium, and cadmium levels far exceeded national and international safety standards. There is a direct association between proximity to polluting industries and the intensity of contamination. Additionally, the human health risk analysis indicates significant exposure, especially for vulnerable groups like children and the elderly.

Public awareness is critically low, and existing water infrastructure fails to protect against these risks. Most households rely solely on groundwater without any purification. This underscores the need for immediate policy intervention, including: (a) stricter enforcement of industrial discharge regulations, (b) development of centralized monitoring systems, (c) public education programs, and (d) provision of safe alternative water sources.

In conclusion, sustainable industrial development in Gujarat must be balanced with ecological responsibility and public health safeguards. Future research should also explore bio-monitoring and long-term epidemiological studies in affected regions.

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