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Assessment of Groundwater Nitrate Contamination from Agricultural Sources and Its Public Health Implications in Central Rajasthan

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Abstract: ***Groundwater in central Rajasthan—particularly in Jaipur, Ajmer, Tonk, and Nagaur districts—is under increasing ecological stress due to excessive agricultural fertilizer use. Nitrate contamination is becoming a major health concern, particularly for rural communities dependent on groundwater for drinking. This study assesses nitrate levels in agricultural wells across 16 villages and evaluates associated health risks, especially methemoglobinemia, gastrointestinal distress, thyroid dysfunction, and reproductive concerns. Groundwater samples from 128 wells were analyzed using spectrophotometric methods. A significant proportion (42%) exceeded the WHO guideline of 50 mg/L nitrate. Health surveys (n = 310 respondents) indicated higher prevalence of blue-baby syndrome risk factors in infants, digestive problems among adults, and possible endocrine disturbances. The study concludes that agricultural nitrogen fertilizers are the primary source of contamination and recommends integrated nutrient management and groundwater monitoring.***

Keywords: Nitrate contamination, groundwater quality, Rajasthan agriculture, public health, fertilizers, methemoglobinemia, water pollution, rural health.

1.1 Introduction

Central Rajasthan is a semi-arid region where groundwater serves as the primary source of drinking water for rural and peri-urban populations. Rapid agricultural intensification since the 1980s has increased nitrogen fertilizer consumption, especially urea and nitrate-based fertilizers. Although such inputs enhance agricultural productivity, they lead to nitrate leaching into groundwater due to sandy soils, irregular rainfall, and excessive irrigation practices.

Globally, nitrate contamination is recognized as a major environmental and public health hazard. Before 2018, numerous studies from the United States, China, and Europe documented strong links between high nitrate levels and infant methemoglobinemia, thyroid diseases, gastrointestinal cancers, and reproductive disorders. In India, nitrate contamination reports have been significant in states like Rajasthan, Punjab, Haryana, and Karnataka.

Rajasthan's nitrate problem is aggressive due to:

1. Sandy soil texture
2. Low organic matter
3. Excessive fertilizer application
4. Open wells and borewells vulnerable to leaching
5. Low sanitation in rural areas
6. High variability in rainfall and water recharge

This research evaluates the extent of nitrate contamination and its associated health implications in central Rajasthan, combining hydrochemical analysis and health surveillance.

1.2 Objectives

1. To analyze nitrate concentration in groundwater used by rural areas of central Rajasthan.
2. To determine major agricultural factors contributing to nitrate leaching.
3. To evaluate health outcomes associated with prolonged intake of nitrate-contaminated water.
4. To recommend remedial measures for safer water and sustainable fertilizer use.

1.3 Methodology

I. Study Design

Mixed-method environmental and epidemiological research.

II. Sampling Strategy

(a.) Area Covered: 16 villages across Jaipur, Ajmer, Tonk, Nagaur.

(b.) Well Samples: 128 groundwater sources (handpumps, wells, borewells).

(c.) Human Health Survey: 310 villagers across 158 households.

(d.) Sampling Method: Systematic random sampling.

III. Data Collection

1. Groundwater Sampling

(a.) Collected in sterilized polyethylene bottles.

(a.) Analyzed using UV–Visible spectrophotometry following APHA (2012) protocols.

2. Household Survey

(a.) Health symptoms questionnaire: digestive problems, skin disorders, breathlessness, fatigue, infant health issues.

(b.) Medical history review: thyroid conditions, anemia, reproductive complications.

3. Field Observation

(a.) Fertilizer application rates.

(b.) Irrigation methods.

(c.) Wastewater disposal practices.

IV. Data Analysis

(a.) Descriptive statistics

(b.) Spatial mapping of contamination clusters

(c.) Correlation between fertilizer use and nitrate levels

(d.) Health risk analysis

(e.) Ethical Considerations

(f.) Confidentiality assured; informed consent obtained.

1.4 Study Area

I. Geographical Characteristics

(a.) Central Rajasthan is characterized by:

(b.) Semi-arid climate

(c.) Sandy loam to loamy soils

(d.) High dependence on tube wells

(e.) Wheat, mustard, fodder crops

(f.) Increasing vegetable cultivation requiring heavy nitrogen input

(g.) Village Characteristics

Most villages lack piped water supply and depend heavily on shallow wells, making them vulnerable to agricultural runoff.

1.5 Observations

1. Groundwater Nitrate Levels

(a.) 42% wells showed > 50 mg/L nitrate.

(b.) 18% wells exceeded 100 mg/L nitrate (danger zone).

(c.) Highest levels observed in villages with intensive mustard-wheat cropping.

2. Fertilizer Consumption

(a.) Urea usage: average 240–300 kg/ha (higher than recommended 150 kg/ha).

(b,) Conventional farmers apply fertilizers without soil testing.

(c.) Excessive flood irrigation contributes to leaching.

3. Sanitation and Wastewater

(a.) 37% households lacked proper drainage systems.

(b.) Animal waste piles located near wells in 9 villages.

4. Reported Health Symptoms

(a.) Digestive issues: 53% adults (acidity, diarrhea, stomach pain).

(b,) Fatigue and breathlessness: 32%.

(c.) Skin disorders: 21%.

(c.) Infants with bluish skin episodes (suspected methemoglobinemia): 14 cases.

(d.) Thyroid dysfunction: 8% adults.

5. Vulnerable Groups

(a.) Infants under six months

(b.) Pregnant women

(c.) Adults with chronic anemia

1.6 Discussion

Nitrate enters groundwater easily in desert and semi-desert conditions due to low organic content and high permeability. The results clearly indicate that agricultural nitrogen fertilizers are the primary cause of contamination. Other contributing factors include animal waste and poor sanitation.

Health Implications

1. Methemoglobinemia (Blue Baby Syndrome)

(a.) High nitrate reduces oxygen-carrying capacity of blood in infants. The 14 observed suspected cases indicate a critical public health issue.

2. Thyroid Disorders

(a.) Nitrates inhibit iodine uptake, contributing to hypothyroidism.

3. Gastrointestinal Problems

(a.) Nitrates form nitrites and nitrosamines, potentially carcinogenic.

4. Reproductive Health Issues

(a.) Possible links with miscarriage risk and low fertility, supported by global research.

(b.) Comparisons with Earlier Studies (2018)

(c.) Research by Jain et al. (2005), Gupta et al. (2013), and Rao et al. (2017) also reported nitrate hot spots in Rajasthan, reinforcing this study's findings.

1.7 Results

1. 42% of groundwater sources exceeded safe nitrate limits.

2. Fertilizer overuse and flood irrigation were strongly correlated with higher nitrate levels ($r = 0.71$).

3. Health surveys confirmed increased gastrointestinal and thyroid issues.

4. Infants were the most vulnerable, with 14 suspected methemoglobinemia cases.

5. Areas with >100 mg/L nitrate showed 1.9 times higher digestive symptoms.

1.8 Conclusion

Groundwater nitrate contamination in central Rajasthan poses a serious public health threat. Agricultural fertilizer mismanagement and environmental conditions accelerate nitrate leaching. Without intervention, contamination and health risks will continue to rise. Immediate action is needed at household, community, and policy levels.

1.9 Recommendations

1. Integrated Nutrient Management (INM)

(a.) Promote organic manure, crop rotation, legume cultivation.

2. Soil Testing and Fertilizer Regulation

(a.) Mandatory soil testing before fertilizer purchase.

3. Safe Drinking Water Solutions

(a.) Reverse osmosis units in high-nitrate villages

(b.) Community awareness on boiling limitations (boiling does not remove nitrates)

4. Construction of Protective Well Platforms

(a.) Prevent wastewater infiltration.

5. Shift to Drip Irrigation

(a.) Reduce nitrate leaching by limiting excessive water use.

6. Medical Intervention

(a.) Routine screening for thyroid disorders

(b.) Infant monitoring in affected households

7. Policy Measures

(a.) Incentives for organic farming

(b.) Monitoring of nitrate hotspots

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