



## ENVIRONMENTAL HEALTH RISK ASSESSMENT OF GROUNDWATER NITRATE AND NITRITE EXPOSURE AMONG FARMERS IN COASTAL AREA OF REMBANG, CENTRAL JAVA, INDONESIA

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### Abstract

**Background:** The increasing use of fertilizers and pesticides in agricultural areas may contaminate groundwater with nitrate and nitrite, posing health risks. **Objective:** This study aimed to assess the health risk from nitrate and nitrite exposure through groundwater consumption among farmers in the coastal area of Rembang, Central Java. **Methods:** A cross-sectional study was conducted in Gunungsari Village, Kaliore Subdistrict. Groundwater samples from seven households were analyzed using spectrophotometry and compared with national drinking water standards. Respondent characteristics were obtained through questionnaires, and Chronic Daily Intake (CDI) and Risk Quotient (RQ) were calculated for children and adults. **Results:** This study showed that nitrate concentrations were below the limit (10 mg/L), while one sample exceeded the nitrite standard (8 mg/L vs. 1 mg/L). CDI values ranged from 0.017–0.021 mg/kg/day in adults and 0.082 mg/kg/day in a child, all with RQ <1. **Conclusion:** Groundwater samples in the agricultural area of Rembang generally indicated no immediate health threat of nitrate and nitrite contamination. **Suggestion:** Continuous monitoring and community education are needed to prevent chronic exposure and potential long-term effects from endogenous nitrosation.

### Abstrak

**Latar Belakang:** Peningkatan penggunaan pupuk dan pestisida di daerah pertanian dapat mencemari air tanah dengan nitrat dan nitrit, yang berpotensi menimbulkan risiko kesehatan. **Tujuan:** Studi ini bertujuan untuk menilai risiko kesehatan akibat paparan nitrat dan nitrit melalui konsumsi air tanah di kalangan petani di daerah pesisir Rembang, Jawa Tengah. **Metode:** Studi potong lintang dilakukan di Desa Gunungsari, Kecamatan Kaliore. Sampel air tanah dari tujuh rumah tangga dianalisis menggunakan spektrofotometri dan dibandingkan dengan standar air minum nasional. Karakteristik responden diperoleh melalui kuesioner, dan Chronic Daily Intake (CDI) serta Risk Quotient (RQ) dihitung untuk anak-anak dan dewasa. **Hasil:** Studi ini menunjukkan bahwa konsentrasi nitrat berada di bawah batas (50 mg/L), sementara satu sampel melebihi standar nitrit (8 mg/L vs. 1 mg/L). Nilai CDI berkisar antara 0,017–0,021 mg/kg/hari pada dewasa dan 0,082 mg/kg/hari pada seorang anak, dengan semua RQ <1. **Kesimpulan:** Sampel air tanah di kawasan pertanian Rembang secara umum tidak menunjukkan ancaman kesehatan segera akibat kontaminasi nitrat dan nitrit. **Saran:** Pemantauan berkelanjutan dan pendidikan masyarakat diperlukan untuk mencegah paparan kronis dan efek jangka panjang potensial akibat nitrosasi endogen.

## BACKGROUND

Despite continuous efforts, the global community is still grappling with the challenge of meeting the sixth Sustainable Development Goal (SDG), which seeks to guarantee that everyone has access to safe and affordable drinking water by 2030. As of 2020, approximately 2 billion people worldwide still do not have access to safely managed drinking water. In numerous countries, the percentage of individuals with access to safe drinking water remains low, posing difficulties in achieving this SDG target. For example, if current trends continue, only 37% of the population in sub-Saharan Africa will have access to safely managed drinking water by 2030.<sup>1</sup>

In recent times, the challenge of ensuring access to safe drinking water is not solely due to biological pollutants but also because of the rising presence of chemical substances contaminating water sources. These emerging contaminants (ECs) in drinking water are a concern for public health because of their widespread occurrence in the environment and their potential harmful effects.<sup>2</sup>

Groundwater serves as an essential source of drinking water, especially in rural and farming regions. In numerous developing nations, like Indonesia, farming communities depend significantly on groundwater to fulfill their daily needs. Nevertheless, agricultural activities, such as the widespread use of nitrogen-rich fertilizers and pesticides, can result in the seepage of nitrates and nitrites into groundwater supplies.<sup>34</sup> Once these chemicals enter the water system, they are challenging to eliminate and can build up to levels that present considerable health hazards.<sup>56</sup>

High concentrations of nitrate and nitrite in drinking water have been linked to various adverse health outcomes. These include methemoglobinemia, commonly referred to as "blue baby syndrome," reproductive problems, cardiovascular conditions, and certain cancers, particularly those affecting the gastrointestinal tract.<sup>78</sup> Research conducted globally indicates that prolonged exposure to nitrates, even at levels below the currently advised limits, may still pose chronic health hazards. Groups such as children, pregnant women, and agricultural workers may face heightened risks due to a combination of environmental and occupational exposures.<sup>9</sup>

In Southeast Asia, the swift expansion of agricultural practices has led to a heightened application of pesticides and nitrogen-based fertilizers, posing considerable threats to groundwater quality.<sup>10</sup> Farmers who apply these chemicals are deemed a high-risk group due to their direct contact with pesticides during work and the potential consumption of tainted groundwater, which is their main drinking water source.<sup>111213</sup> Indonesia, being one of the region's largest agricultural producers, encounters specific difficulties, particularly in coastal and alluvial plain regions where groundwater is the primary water supply.<sup>14</sup>

Rembang Regency, situated on the northern coast of Central Java, is an ideal location for studying nitrate and nitrite exposure. Agriculture is not only the primary occupation in Rembang but also the main economic driver, significantly contributing to the local gross regional domestic product. The area is predominantly engaged in the cultivation of rice, maize, and secondary crops, with extensive use of nitrogen-based fertilizers and pesticides.

Farmers in Rembang face a dual exposure risk as they apply pesticides directly and consume untreated groundwater, increasing their health risks.<sup>15</sup> Despite these vulnerabilities, there is a scarcity of empirical research on nitrate and nitrite-related health risks in this area, underscoring the necessity for localized studies. Such research could provide evidence to inform regional water safety management and broader national policies on agricultural sustainability and occupational health.

Most research on the health risks associated with nitrates and nitrites exposure has been carried out in wealthy countries, leaving a gap in evidence from low- and middle-income countries. In Indonesia, especially in rural farming areas, there is a significant lack of information on groundwater pollution and health risk evaluations. Additionally, there is scant research on the combined risks that farmers face from simultaneous exposure to pesticides and groundwater pollutants. This study seeks to evaluate the health risks linked to nitrates and nitrites in groundwater among farmers who use pesticides in Rembang, Indonesia. The results are anticipated to offer scientific understanding regarding the level of health hazards, guide local stakeholders, and aid in formulating strategies for groundwater management and safeguarding occupational health in farming communities.

## METHOD

This study was conducted in Gunungsari Village, Kaliore Subdistrict, Rembang Regency, Central Java, Indonesia, an agricultural area characterized by intensive pesticide use in rice cultivation. The target population comprised farmers who used groundwater as their drinking water source. Respondents were selected using a purposive sampling method.

Ethical clearance was obtained from the Health Research Ethics Committee, Faculty of Public Health, Universitas Diponegoro (No. 153/EA/KEPK-FKM/2025).

A structured questionnaire was used to collect household-level data, including name, sex, age, body weight, length of residence, and average daily water intake. Groundwater samples were collected in plastic bottles and analyzed in a laboratory for nitrate and nitrite concentrations using spectrophotometric methods. The results were compared with the national drinking water standards set by the Ministry of Health Regulation No. 32 of 2017, which stipulate maximum allowable limits of 10 mg/L for nitrate and 1 mg/L for nitrite.<sup>16</sup>

Individual characteristics and water quality data were presented descriptively. For respondents consuming groundwater with concentrations exceeding the standards, Chronic Daily Intake (CDI) and Risk Quotient (RQ) were calculated. Respondents were categorized into two groups: children (<17 years) and adults (≥17 years).

The CDI was calculated using the following parameters: contaminant concentration (C), daily ingestion rate (R), exposure frequency (fE), exposure duration (DE), body weight (WB), and averaging time (tavg = DE × 365 days).

$$CDI = \frac{C \times R \times fE \times DE}{WB \times tavg}$$

The RQ was obtained by dividing CDI by the reference dose (RfD), which is 1.6 mg/kg/day for nitrate and 0.1 mg/kg/day for nitrite.

$$RQ = \frac{CDI}{RfD}$$

An RQ value <1 indicates no significant health risk, while RQ ≥1 suggests potential adverse health effects requiring attention.

## RESULT

In Gunungsari Village, seven households from the target population were identified as using groundwater. Detailed information about each family member in these households was collected, including their name, sex, age, body weight, length of residence, and average daily water consumption. This information was utilized to assess the health risks linked to the nitrate and nitrite levels in the groundwater they consumed.

**Table 1. Nitrate and Nitrite Concentration of the Groundwater**

Sample	Nitrate (mg/L)	Standard (mg/L)	Nitrite (mg/L)	Standard (mg/L)
Groundwater 1	< 0.03	≤ 10	< 3	≤ 1
Groundwater 2	< 0.03	≤ 10	8	≤ 1
Groundwater 3	< 0.03	≤ 10	< 3	≤ 1
Groundwater 4	< 0.03	≤ 10	< 3	≤ 1
Groundwater 5	< 0.03	≤ 10	< 3	≤ 1
Groundwater 6	< 0.03	≤ 10	< 3	≤ 1
Groundwater 7	< 0.03	≤ 10	< 3	≤ 1

Table 1 provides information about the nitrate and nitrite concentration in the groundwater. Of the seven groundwater samples analyzed, all nitrate concentrations were <0.03 mg/L, below the standard limit of 10 mg/L. Therefore, no calculations were carried out on the health risks due to nitrate content in all groundwater samples consumed.

However, one sample (Sample 2) showed a nitrite concentration of 8 mg/L, exceeding the permissible limit of 1 mg/L. The groundwater nitrite tester recorded levels below 3 mg/L in six other samples. Due to the non-definitive nature of this measurement, the health risk analysis was limited to households consuming water with a nitrite concentration of 8 mg/L. This particular household comprises five individuals: four adults and one child.

**Table 2. Chronic Daily Intake of Nitrite**

Respondent	C (mg/L)	R (L/day)	DE (year)	fE (day/year)	WB (kg)	Tavg (day)	CDI (mg/kg/day)
Adult 1	8	0.15	55	350	56	19580	0.021
Adult 2	8	0.15	65	350	61	23140	0.019
Adult 3	8	0.15	25	350	70	8900	0.017
Adult 4	8	0.15	4	350	65	1424	0.018
Child	8	0.15	3	350	14	1095	0.082

Table 2 showed that in the household consuming water with elevated nitrite levels, CDI values ranged from 0.017 to 0.021 mg/kg/day among adults and 0.082 mg/kg/day for one child respondent.

**Table 3. Risk Quotient of Nitrite**

Respondent	CDI (mg/kg/day)	RfD (mg/kg/day)	RQ
Adult 1	0.021	0.1	0.21
Adult 2	0.019	0.1	0.19
Adult 3	0.017	0.1	0.17
Adult 4	0.018	0.1	0.18
Child	0.082	0.1	0.82

As shown in table 3, All calculated RQ values were <1, indicating no health risks associated with current nitrite exposure.

## DISCUSSION

The RQ values obtained (<1 for all respondents) indicate that current nitrate and nitrite exposure through groundwater consumption does not pose significant health risks to the study population. Similar findings were reported in a study from Cihambulu Village, Subang, where groundwater nitrate and nitrite exposure among agricultural communities also remained below the health risk threshold.<sup>17</sup>

In contrast, studies in Iran and Egypt reported groundwater nitrate contamination exceeding permissible levels, particularly in agricultural areas affected by fertilizer runoff.<sup>18,19</sup> Such differences may be attributed to variations in agricultural intensity, soil type, and hydrological conditions. For example, nitrate contamination tends to be lower in clay, sandy, or peat soils compared with other soil types.<sup>20</sup>

The relatively low risk observed in this study may also be explained by the community's drinking water habits. Most residents prefer bottled water for consumption, using groundwater mainly for non-drinking purposes due to its slightly turbid, mineral-rich appearance.

Nevertheless, although current risk levels are low, continuous monitoring remains essential. Future research should consider assessing potential genotoxic or carcinogenic effects among individuals consuming groundwater exceeding nitrite limits, as prior studies have linked nitrate and nitrite intake to endogenous nitrosation, a process that can lead to the formation of carcinogenic N-nitroso compounds within the human body.<sup>21,22</sup>

## CONCLUSION

Groundwater samples in the agricultural area of Rembang generally met national standards for nitrate and nitrite, with only one sample exceeding the nitrite limit. Although the calculated Risk Quotients for both adults and children were below 1, indicating no immediate health threat, ongoing surveillance and preventive measures are warranted. Given the potential for endogenous nitrosation and long-term carcinogenic effects, especially in populations with chronic low-level exposure, future studies

should integrate biomonitoring and molecular assessments. Public health authorities should also promote safe groundwater use, regular water testing, and farmer education to reduce cumulative environmental and occupational risks.

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