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Determination and Comparison of Nitrate Levels in Bottled and Groundwater in Al-Qubbah City and Their Compliance with Drinking Water Standards

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تقدير ومقارنة محتوى النترات في المياه المعبأة والمياه الجوفية في مدينة القبة ومدى مطابقتها للمواصفات القياسية

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Abstract:

Safe drinking water is an essential natural resource critical for sustaining human health and community sustainability. Evaluating water quality and monitoring chemical pollutants ensure strict compliance with health standards and safeguard public welfare. This study aims to assess and compare nitrate ion (NO3-) concentrations in groundwater and commercial bottled water supplies across Al-Qubbah City, Libya. The investigation involved collecting 11 groundwater samples and 7 bottled water brands. Nitrate levels were quantified using UV-Visible spectrophotometry at 220 nm with organic interference correction at 275 nm following APHA standard methods. Statistical evaluations including mean, standard deviation, and Student's t-test were applied to compare the water sources at a significance threshold of p less than 0.05. The analytical results indicated that groundwater nitrate ranged from 4.51 to 26.52 mg/L (mean: 14.33 mg/L) whereas bottled water ranged from 0.29 to 5.89 mg/L (mean: 1.97 mg/L). All tested samples fully complied with the WHO maximum permissible limit of 50 mg/L and Libyan drinking water standards. Groundwater exhibited significantly higher concentrations than bottled water due to agricultural runoff and anthropogenic influences. Future studies should expand monitoring across wider hydrogeological zones and incorporate additional chemical parameters. Continuous periodic surveillance and sustainable agricultural nutrient management are strongly recommended to protect long-term water security.

Keywords: Nitrate, Groundwater, Bottled water, Al-Qubbah City, UV-Vis spectrophotometry, Water quality standards.

الملخص:

تعد مياه الشرب من أثمن الموارد الطبيعية الأساسية لاستدامة الحياة وصحة الإنسان، وتحديداً في المناطق التي تعتمد على مصادر متجددة وجوفية تبرز أهمية تقييم جودة المياه ومراقبة الملوثات الكيميائية لضمان مطابقتها للمواصفات القياسية وحماية الصحة العامة للسكان. وتهدف هذه الدراسة بشكل رئيسي إلى تقدير ومقارنة محتوى أيونات النترات (NO3-) في عينات المياه الجوفية والمعبأة بمدينة القبة – ليبيا. اعتمدت الدراسة على جمع 11 عينة من المياه الجوفية و7 عينات من المياه المعبأة التجارية، حيث تم تحليل تراكيز النترات باستخدام جهاز المطياف الضوئي للأشعة فوق البنفسجية والمرئية (UV-Visible Spectrophotometer) عند طول موجي 220 نانومتر مع تطبيق معامل تصحيح التداخل العضوي

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عند 275 نانومتر وفق الطرق القياسية المعتمدة (APHA). كما تم إجراء التحليل الإحصائي باستخدام المتوسط الحسابي والانحراف المعياري ومعامل التباين واختبار (T-test) لمقارنة الفروق بين المصدرين بمستوى معنوي P أقل من 0.05. أظهرت النتائج أن تراكيز النترات في المياه الجوفية تراوحت بين 4.51 - 26.52 ملجم/لتر بمتوسط 14.33 ملجم/لتر بينما تراوحت في المياه المعبأة بين 0.29 - 5.89 ملجم/لتر بمتوسط 1.97 ملجم/لتر. وقد تبين أن جميع عينات المياه المدروسة تقع ضمن الحدود المسموح بها وفق إرشادات منظمة الصحة العالمية 50 ملجم/لتر والمواصفات الليبية، كما سجلت المياه الجوفية تراكيز أعلى معنوياً مقارنة بالمياه المعبأة نتيجة التأثر بالأنشطة الزراعية ومخلفات الصرف. توصي الدراسة بضرورة استمرار برامج الرصد الدوري لمصادر المياه الجوفية في مدينة القبة وتوسيع نطاق الأبحاث المستقبلية لتشمل مؤشرات كيميائية وعنصرية إضافية مع تطبيق تدابير صارمة لحماية الخزانات الجوفية من التلوث الزراعي.

الكلمات المفتاحية: النترات، المياه الجوفية، المياه المعبأة، مدينة القبة، المطيافية الضوئية، جودة مياه الشرب.

1. Introduction

Water is an indispensible natural resource essential for sustaining life supporting human health and fostering socio-economic development.

In Libya groundwater serves as the principal source for municipal agricultural and domestic drinking supply.

However widespread public consumption of bottled water has expanded rapidly particularly in areas facing intermittent supply or localized water quality concerns.

With urban expansion intensive agricultural practices and potential contaminant infiltration into underlying karst aquifers regular monitoring of chemical parameters-specifically nitrate ions (NO_3^-)- is crucial to ensure compliance with national standards and WHO guidelines.

Nitrate is a highly soluble naturally occurring polyatomic ion formed during the environmental nitrogen cycle (Wongsanit et al., 2015).

Exogenous sources primarily stem from synthetic nitrogen fertilizers livestock manures unsealed septic fields municipal wastewater and atmospheric deposition (Lassaletta et al., 2009; Gao et al., 2012). Although nitrate itself exhibits low acute toxicity endogenous reduction converts it into nitrite (NO_2^-) within the human oral cavity and gastrointestinal tract (Brender et al., 2013).

Nitrite reacts with secondary amines to form carcinogenic N-nitroso compounds (IARC, 2010). Extensive clinical literature links elevated nitrate exposure in drinking water to infantile methemoglobinemia ('blue baby syndrome') where oxidized hemoglobin loses oxygen-carrying capacity in infants under six months (WHO, 2003; ATSDR, 2021).

Chronic low-dose exposure has also been associated with thyroid dysfunction (Gilchrist et al., 2010), adverse birth outcomes and long-term risk of colorectal carcinoma (HealthLink BC, 2025).

International regulatory bodies have established maximum contaminant levels to protect public health. The U.S. Environmental Protection Agency (U.S. EPA, 1991) mandates a limit of 10 mg/L measured as nitrate-nitrogen (NO_3-N) equivalent to 44.3 mg/L NO3-.

The World Health Organization (WHO, 2003) and Libyan National Standards (2008) enforce an upper limit of 50 mg/L as NO3- for raw drinking water and 10 mg/L NO3- for packaged bottled water.

Because baseline nitrate concentration in global groundwaters varies based on land use soil permeability and aquifer depth (Matiatos, 2016; Burow et al., 2010) localized empirical evaluation in Al-Qubbah is imperative.

1.1 - Statement of the Problem

Agricultural expansion and unmonitored waste discharge in the Al-Jabal Al-Akhdar region increase the risk of chemical contamination in local groundwater aquifers.

Given that local residents depend heavily on both well water and commercial bottled brands for daily consumption the potential health risks associated with nitrate accumulation remain unknown without comprehensive analytical verification.

This study addresses whether nitrate concentrations in drinking water sources across Al-Qubbah City remain within legally permitted health standards.

1.2- Research Significance

This research delivers baseline hydro-chemical data regarding drinking water safety in northeastern Libya.

By systematically comparing groundwater and bottled water quality the findings offer valuable empirical insight for public health authorities environmental monitoring bodies and municipal water management agencies.

1.3 - Research Objectives

1- To quantify nitrate concentrations in selected groundwater wells and bottled water brands within Al-Qubbah City.

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2- To conduct a comparative statistical evaluation between groundwater and bottled water nitrate levels.
3- To assess compliance with national Libyan standards (No. 17/2008) and WHO drinking water guidelines.
4- To evaluate the chemical suitability of these drinking water supplies for long-term human consumption.
5- To establish a reliable baseline chemical database supporting regional environmental health monitoring.

2- Literature Review

Nitrate is a inorganic anion composed of one nitrogen atom and three oxygen atoms in a trigonal planar arrangement (NO_3^- molecular weight: 62.005 g/mol).

It forms naturally in soil and aquatic environments through nitrification-the biological oxidation of ammonia to nitrite and subsequently to nitrate by Nitrobacter species (Wang & Li, 2019).

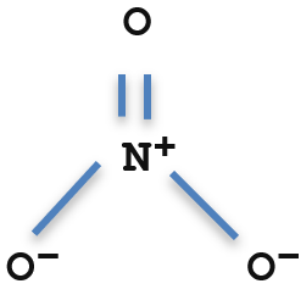


Figure 1: Chemical Structure of the Nitrate Anion (NO_3^-)

2.1 - Sources and Ingress Mechanisms of Nitrate

Nitrate contamination in hydrological systems arises from both diffuse (non-point) and localized (point) sources.

Natural contributions include atmospheric lightning discharge soil organic matter mineralization and biological nitrogen fixation (HealthLink BC, 2025).

Anthropogenic inputs heavily predominate in agricultural belts via inorganic fertilizer over-application, manure slurry disposal septic system leakage and urban surface runoff (Manassaram et al., 2006; Wang et al., 2015).

Nitrate ions migrate through the unsaturated soil vadose zone primarily via percolation and leaching, eventually entering both shallow unconfined aquifers and deep karst groundwater reservoirs (Wang & Li, 2019).

2.2- Health Impacts & Environmental Regulatory Limits

Elevated nitrate intake in humans presents significant epidemiological hazards.

In addition to acute infantile methemoglobinemia epidemiological studies highlight long-term metabolic disruption including thyroid uptake inhibition G6PD enzyme interactions and congenital malformations (Brender et al., 2013; ATSDR, 2021).

Consequently international standards mandate a maximum contaminant level (MCL) of 50 mg/L NO3- for raw drinking water (WHO, 2003; Libyan Standard No. 17/2008).

3- Materials and Methods

3.1- Study Area

The empirical investigation was conducted in Al-Qubbah City located in the Al-Jabal Al-Akhdar district of northeastern Libya (Latitude 32.767° N Longitude 22.230° E; elevation: 532–588 meters above sea level).

The region features elevated Mediterranean karst typography characterized by famous natural springs (e.g., Ain Al-Qubbah, Ain Al-Dabbousiya, Ain Al-Jarioula) and groundwater aquifers supplying municipal and residential wells.

Karst aquifers in Al-Jabal Al-Akhdar are vulnerable to surface chemical intrusion owing to well-developed secondary porosity and fracture networks.

3.2- Reagents and Analytical Equipment

Analytical grade reagents including Sodium Nitrate (NaNO3, purity ≥ 99.0%) Hydrochloric Acid (1N HCl) and double-distilled deionized water were utilized. Spectrophotometric measurements were performed using a Jenway 6405 UV-Visible Spectrophotometer equipped with 10 mm matched quartz cuvettes.

Precise masses were measured using a high-precision analytical balance (± 0.0001 g).

3.3- Sampling Protocol

Sampling was conducted between April 1 and May 10. A total of 11 representative groundwater samples (designated A1 to A11) were collected from municipal and private wells.

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Concurrently 7 distinct bottled water brands (designated B1 to B7) available across local commercial markets were collected. All samples were stored in pre-cleaned 500 mL high-density polyethylene (HDPE) bottles rinsed thrice with sample water refrigerated at 4°C and analyzed within 24 hours of collection.

Table 1: Groundwater Sampling Locations in Al-Qubbah City

Sample Code	Well Location / District
A1	Ras Tajo 1
A2	Ayad Al-Shanaq District
A3	Ras Tajo 2
A4	Al-Da'iri (Ring Road) District
A5	Daghoush District
A6	Tadhamon District
A7	Tali'a District
A8	Al-Baqi' District
A9	Ras Tajo 3
A10	Al-Thalathmiya 1 District
A11	Al-Thalathmiya 2 District

Table 2: Analyzed Bottled Water Brands

Sample Code	Brand Name
B1	ENO
B2	Arin
B3	Oral
B4	Al-Ayn
B5	Aquafina
B6	Aseel
B7	Al-Diyafa

3.4- Analytical Procedure & Spectrophotometric Determination

Nitrate analysis was executed following Standard Method APHA 4500-NO_3- B (Ultraviolet Spectrophotometric Screening Method).

A 1000 mg/L stock solution was prepared by dissolving 0.685 g of anhydrous $NaNO_3$ in distilled water and diluting to 500 mL. Working calibration standards (5, 10, 15, 20, and 25 mg/L NO_3^-) were freshly prepared. To suppress interference from dissolved organic matter 1 mL of 1N HCl was added per 100 mL of sample.

Absorbance was recorded at 220 nm (primary nitrate absorption) and 275 nm (dissolved organic matter background) against a distilled water blank corrected absorbance A.$NO_3$was computed using equation (1):

$$\mathbf{A_{NO3} = A_{220} - 2 \times A_{275}} \quad \textbf{--- (1)}$$

Where A_{220} is absorbance at 220 nm, A_{275} is absorbance at 275 nm, and A_{NO3} is corrected nitrate absorbance.

3.5 - Statistical Analysis

Data processing was performed using OriginPro and SPSS statistical software.

Descriptive metrics included arithmetic mean, standard deviation (SD) range minimum maximum and coefficient of variation (CV%).

A two-sample independent Student's t-test was conducted to assess statistical differences between groundwater and bottled water means at a significance threshold of $p < 0.05$.

4- Results and Discussion

4.1- Calibration Curve and Linearity

The linear regression analysis of calibration standards demonstrated excellent adherence to the Beer-Lambert law across the 5- 25 mg/L range.

The linear regression equation was established as: $\mathbf{A = 0.108 \times C + 0.12}$ yielding a coefficient of determination ($R^2 = 0.997$) confirming strong analytical precision.

A: Absorbance **C:** Concentration **R^2**: Coefficient of determination

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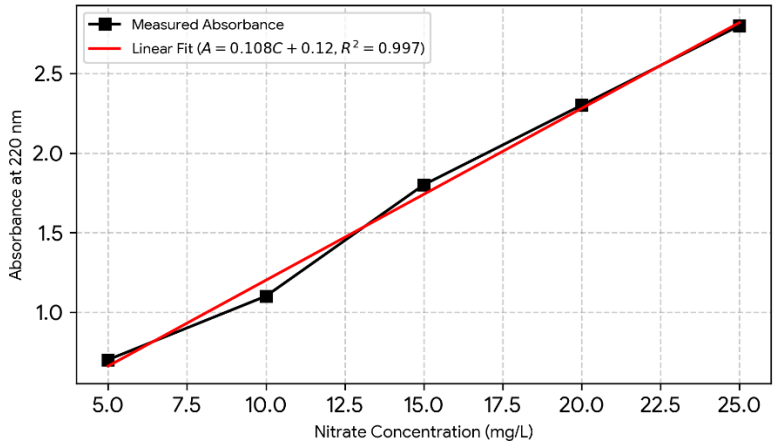


Figure 2: Calibration Curve for Sodium Nitrate Standards at 220 nm

4.2 - Groundwater Nitrate Content

Nitrate concentrations across the 11 groundwater wells exhibited noticeable geographic variation ranging from 4.51 mg/L (A11 - Al-Thalathmiya 2) to 26.52 mg/L (A8 - Al-Baqi') with an overall mean of 14.33 ± 6.92 mg/L (CV% = 48.30%).

All tested well samples remained below the WHO maximum permissible threshold of 50 mg/L.

However wells A7 (25.74 mg/L) and A8 (26.52 mg/L) exhibited elevated concentrations approaching 50% of the maximum standard limit.

This elevation is directly linked to regional agricultural practices localized fertilizer application and potential seepage from unlined cesspools.

Table 3: Nitrate Concentrations in Al-Qubbah Groundwater Samples

Sample Code	Nitrate Concentration (mg/L)	WHO Threshold Compliance (50 mg/L)
A1	13.46	Compliant (< 50 mg/L)
A2	8.08	Compliant (< 50 mg/L)
A3	18.56	Compliant (< 50 mg/L)
A4	12.61	Compliant (< 50 mg/L)
A5	10.85	Compliant (< 50 mg/L)
A6	12.25	Compliant (< 50 mg/L)
A7	25.74	Compliant (< 50 mg/L)
A8	26.52	Compliant (< 50 mg/L)
A9	9.40	Compliant (< 50 mg/L)
A10	15.70	Compliant (< 50 mg/L)
A11	4.51	Compliant (< 50 mg/L)
Mean ± SD	**14.33 ± 6.92**	---
Minimum	**4.51**	---
Maximum	**26.52**	---
Range	**22.01**	---
CV (%)	**48.30%**	---
p-value	**< 0.05**	**Significant**

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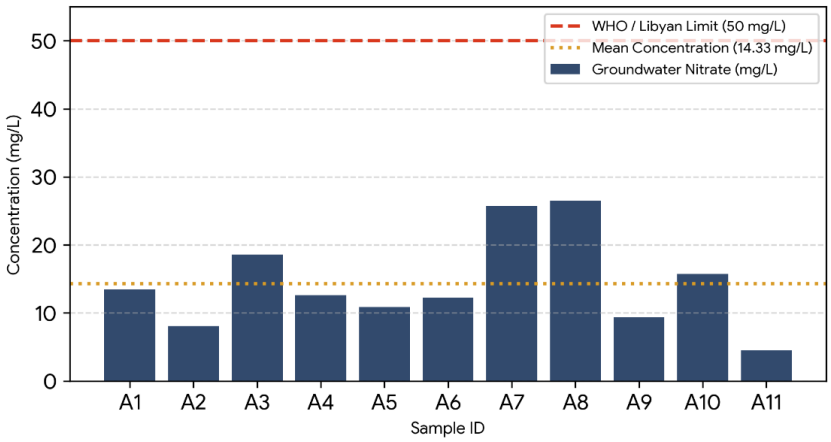


Figure 3: Nitrate Concentrations in Groundwater Samples (Al-Qubbah)

4.3 - Bottled Water Nitrate Content

Nitrate concentrations in commercial bottled water brands ranged between 0.29 mg/L (B2 - Arin) and 5.89 mg/L (B4 - Al-Ayn) with a mean of 1.97 ± 2.05 mg/L (CV% = 96.91%).

All analyzed bottled water samples fully satisfied both the WHO guideline (50 mg/L) and Libyan Standard No. 17/2008 for packaged drinking water (10 mg/L).

The low nitrate content reflects robust industrial purification steps including reverse osmosis and ion-exchange filtration.

Table 4: Nitrate Concentrations in Bottled Water Brands

Sample Code	Nitrate Concentration (mg/L)	Libyan Standard Compliance (10 mg/L)
B1	3.67	Compliant (< 10 mg/L)
B2	0.29	Compliant (< 10 mg/L)
B3	1.10	Compliant (< 10 mg/L)
B4	5.89	Compliant (< 10 mg/L)
B5	1.09	Compliant (< 10 mg/L)
B6	0.54	Compliant (< 10 mg/L)
B7	1.20	Compliant (< 10 mg/L)
Mean ± SD	**1.97 ± 2.05**	---
Minimum	**0.29**	---
Maximum	**5.89**	---
Range	**5.60**	---
CV (%)	**96.91%**	---
p-value	**< 0.05**	**Significant**

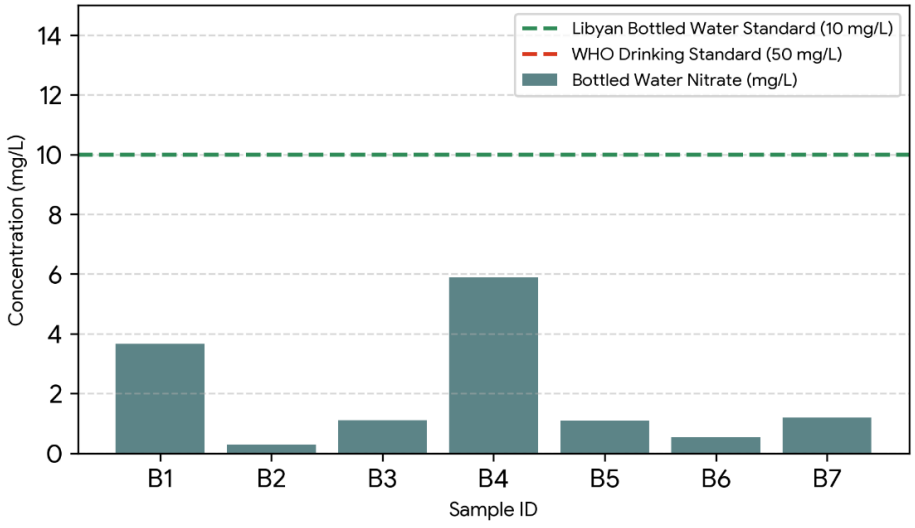


Figure 4: Nitrate Concentrations in Bottled Water Brands

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4.4 - Comparative Evaluation: Groundwater vs Bottled Water

A two-sample t-test revealed a statistically significant difference between groundwater (14.33 mg/L) and bottled water (1.97 mg/L) nitrate concentrations ($t = 5.55$, $p < 0.05$). Groundwater mean concentrations were approximately seven-fold higher than bottled water levels.

These empirical results align with international studies (e.g., Marhamati et al., 2021; Akbari et al., 2018; Fortunato et al., 2020) which confirm that commercial treatment suppresses nitrate levels relative to raw groundwater.

Conversely this study contrasts with findings by Abouglaida et al. (2022) who observed non-compliant nitrate levels in certain commercial bottled brands in western Libya highlighting differences in source water quality and factory purification rigor.

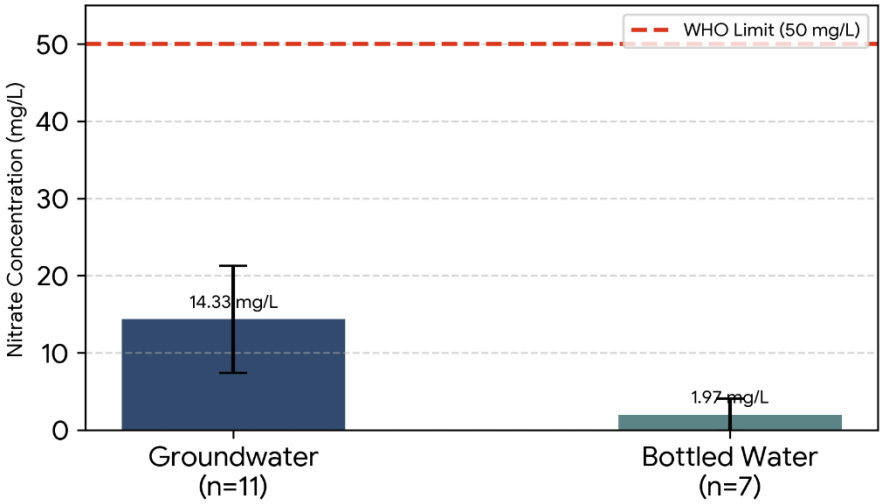


Figure 5: Comparison of Mean Nitrate Concentrations (Mean ± SD)

5- Conclusions and Recommendations

5.1- Conclusions

Nitrate ions were detected across all 11 groundwater and 7 bottled water samples collected in Al-Qubbah City.

Groundwater nitrate concentrations ranged from 4.51 to 26.52 mg/L (mean: 14.33 ± 6.92 mg/L), whereas bottled water concentrations ranged from 0.29 to 5.89 mg/L (mean: 1.97 ± 2.05 mg/L).

100% of analyzed groundwater and bottled water samples strictly complied with the WHO maximum allowable limit (50 mg/L).

Bottled water samples also complied with Libyan Standard No. 17/2008 (10 mg/L).

Statistically significant differences ($t = 5.55$, $p < 0.05$) exist between the two water categories driven by land-use practices impacting groundwater aquifers.

Both water supplies are deemed chemically safe regarding nitrate content for human consumption during the study period.

5.2- Recommendations

Establish routine continuous chemical monitoring programs for municipal and private groundwater wells across Al-Qubbah.

Expand future hydro-chemical investigations to encompass wider spatial coordinates and additional hydro-geological zones across Al-Jabal Al-Akhdar.

Implement sustainable agricultural nutrient management practices to restrict synthetic nitrogen leaching into karst aquifers.

Broaden water quality monitoring parameters to include nitrite (NO_2^-) ammonium (NH_4^+) heavy metals and microbiological markers.

Enhance public awareness regarding water resource protection and enforce environmental regulations governing waste disposal near wellheads.

Compliance with ethical standards

Disclosure of conflict of interest

The authors declare that they have no conflict of interest.

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