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Determination of Chemical Contaminants of Groundwater in District 17 of Kabul City

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ABSTRACT

Water quality assessment is crucial for identifying and mitigating potential contamination sources that impact human health, ecosystems, and industries. This study investigates groundwater quality in District 17 of Kabul City, Afghanistan, by analyzing various chemical parameters. The district, established in 2003 due to rural-urban migration, covers 70 square kilometers with approximately 400,000 inhabitants and 42,000 residential homes. Four groundwater samples were collected from wells across District 17 and analyzed in laboratories following standard methods adhering to WHO guidelines and Afghan National Standards. The study examined fluoride, sulfate, nitrate, iron, pH, and electrical conductivity. Findings revealed an average fluoride concentration of 0.76 mg/L within the acceptable range. Sulfate levels were normal, with the lowest reading at 297.5 ppm. However, the average nitrate content of 12.425 ppm exceeded the 10-ppm standard, indicating potential contamination. The average iron content of 0.24 ppm was acceptable, and the water pH of 7.65 was suitable. Notably, the electrical conductivity measured 1258 µS/cm, surpassing expected standards and suggesting groundwater quality issues. The findings serve as a baseline for future research and developing strategies to address water pollution and quality concerns in Kabul City. Comprehensive assessments of groundwater resources are vital for maintaining public health, environmental sustainability, and industrial operations.

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Introduction

Water is an indispensable resource for sustaining life on Earth. Its quality has been extensively studied in scientific literature due to its profound impact on human health, ecosystem vitality, and industrial operations. The most widely accepted definition of water quality encompasses its physical, chemical, and biological characteristics, which determine its suitability for various biotic species and human uses (Abbasi & Abbasi, 2011). Water resources are pivotal in regulating natural ecosystems, climate patterns, and human development. Their quality significantly influences agriculture, industry, and life itself. Rapid industrialization since the late eighteenth century has led to the deterioration of water quality and aquatic biota, exposing the human population to waterborne diseases (Meinhardt, 2008).

Water is one of the most valuable factors of life, both in its genesis and continuity and survival. It is involved in any vital phenomenon that affects the health and survival of creatures in some way. A famous example in this area can be mentioned in the water search projects on Mars, which means that the presence of water on a planet indicates the existence of life (the effects of life) on it; therefore, water means life(Nazari-Sharabian et al., 2020). It is a misconception that many people think that the world's water is running out because today's water resources are the same as they were thousands of years ago (when human civilization began). Sufficient fresh water and beyond human needs fall annually through precipitation (rain). And they know it (Postel et al., 1996).

Water consumption occurs in various sectors, including agriculture, industries, and household uses. Each year, the world's population derives 9% of potentially accessible freshwater (runoff), and 90% is used in animal husbandry. Industries account for about 7% of the total; the rest is used in household business (Davis & Heathcote, 2005). Domestic uses, trade and industries, public consumption, and waste influence the water consumed in cities. Domestic uses include all water used for household and hotel affairs, including washing, cooking, drinking, and sanitary activities (Davis & Heathcote, 2005). According to census statistics in U.S. cities, water per person per day is 670 liters, which is still valid in all cities, including cooling systems, irrigating flowers, lawns, and other places in and around homes. In contrast, UN statistics in Afghanistan indicate a daily usage of 20–30 liters due to a lack of access to water, with more than 20% of the population unable to access safe drinking water (Rockström, 2012).

The amount of commercial and industrial water use depends on the nature of these activities and their related characteristics. Depending on the type of industry or business interactions, water is used in large quantities in industrial fields such as papermaking, metal smelting, food, and leather. Public consumption covers all public utility buildings such as municipal halls, confinements, schools, public services, fireworks, parks, and road washing. Additionally, the ratio of non-compliance with standards in the construction and work of water supply systems or the proper and timely monitoring of them leads to waste, accounting for 10% of total water consumption (Rockström, 2012).

Scientists generally categorize the following practical factors as contributing to increased water consumption: city size (larger cities tend to have better water supply facilities and higher consumption), population characteristics (economic condition and lifestyle of residents), and the presence of industrial and trade centers (which can significantly increase water demand). Increasing awareness of water resources' importance and limited nature is crucial in changing attitudes towards responsible water use (Amahmid et al., 2019).

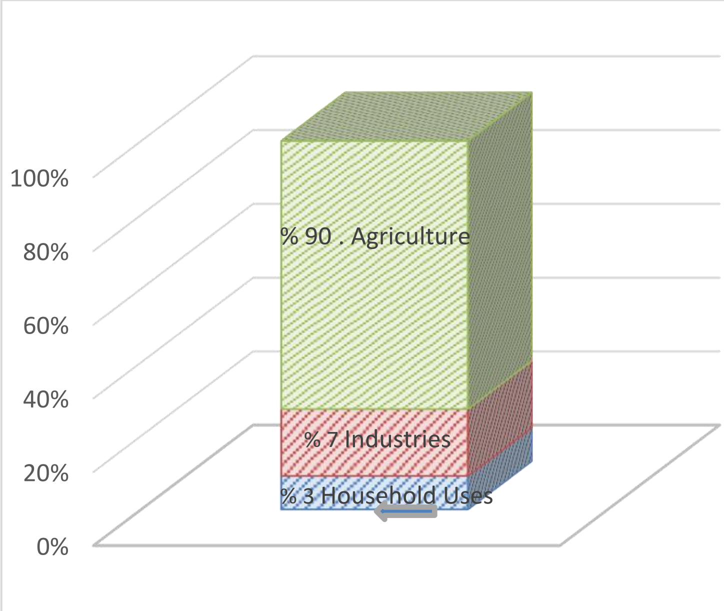

Figure 1: Water consumption in different fields(Rockström, 2012)

Throughout history, ancient civilizations have flourished in the vicinity of water resources, recognizing the importance of purifying water and removing particulate matter, taste, and odor. However, it took centuries for humans to realize that the senses of sight, smell, and taste were insufficient to determine water quality (Rockström, 2012). The use of various methods to improve the flavor and aroma of water can be traced back to 4000 BC, with ancient Sanskrit and Greek writings indicating the use of alum by Egyptians in 1500 BC to purify water and deposit suspended particles (Kanna, 2016). Between 460 and 354 BC, Greek scientists invented a filter cloth through which they passed boiling water, believing it to be a safe method for obtaining potable water (Sedlak, 2014). Iranian chemists, such as Jaber B. Hayyan, employed the distillation method for laboratory-scale water purification (Hashim et al., 2009).

At the beginning of the twentieth century, efforts to purify water focused on preventing the transmission of infectious diseases and providing water without hardness and fewer minerals. Water softeners, which used sodium ions to replace hardening minerals in water, were introduced to the market in 1903. The substitution theory, in which harmless ones replace harmful ions, significantly impacted the water treatment industry and was used to remove lead, mercury, and other heavy metals from water (Azimi et al., 2017). As densely populated cities emerged in various parts of the world, ensuring access to pure and safe water for the growing population became increasingly crucial (Azimi et al., 2017).

Filtration and chlorination have recently been considered the most effective water purification methods. Over the years, other methods such as ozonation, reverse osmosis, and activated carbon filtration have been applied to disinfect water. These advancements were driven by the discovery of chlorine-resistant pathogens in water that can cause diseases like hepatitis and gastroenteritis (Kanna, 2016). Thus, water treatment is one of humanity's most significant achievements in preserving and promoting public health in the twentieth century.

Many water treatment methods used in modern treatment plants today have been employed for hundreds or thousands of years, complemented by newer filtration techniques like reverse osmosis and activated carbon. Strategies to prevent contamination of surface and groundwater sources have been elucidated through logical arguments and conclusive remarks (Joo & Tansel, 2015).

This research focuses on water-related issues in Kabul and analyzing various chemical parameters in water. It consists of two parts: theoretical research and practical laboratory research. The issue's historical background, water consumption patterns, and influencing factors are examined initially. The study aims to address the diverse water demands and requirements effectively (Alfarra et al., 2012). The chemical parameters of water in the 17th district of Kabul City were practically analyzed, with results indicating distinct characteristics in four samples (Kegel et al., 2010). A comprehensive evaluation of the research findings was conducted by comparing the data against established standards; conclusions were drawn regarding the suitability of the water for consumption or other purposes, enhancing the informative value of the study. Recommendations for controlling and mitigating chemical water pollution in Kabul City are proposed, and various water usage scenarios impacting water quality are considered, emphasizing the need for effective quality management (Kegel et al., 2010). To be more specific, the objectives of this research article are:

1. To provide specific and measurable information about groundwater quality in Kabul City by analyzing physical and chemical parameters.
2. To identify and quantify some physical and chemical groundwater parameters in the 17th district of Kabul through practical laboratory analysis.
3. To propose achievable and time-bound solutions for treating and preventing water pollutants in the 17th district of Kabul city based on the research findings.

Methods and Materials

Four groundwater samples from wells in different parts of District 17 were considered to determine water quality parameters. These groundwater samples underwent analysis at the Ministry of Public Health and Ministry of Energy and Water laboratories, where various devices were utilized to measure the water's physical, chemical, and biological parameters. The values obtained for the tested parameters were then compared against the recommended values set by the World Health Organization (WHO) and the Afghan National Standards.

Study Area

The study was conducted in District 17 of Kabul City, Afghanistan. The district was established in 2003 due to the migration of people from rural areas to the city center, leading to a population increase in the Chamtala Plain and the outskirts of Kabul. It covers an area of 70 square kilometers, with a population of approximately 400,000 inhabitants and 42,000 residential homes. The district comprises eight towns constructed by the Ministry of Urban

Development and one town, Gheybi Baba, built by the Kabul Municipality Office. Before the district's creation, the areas were unofficially sold to people by influential individuals without proper land regulations or urban planning.

Table 1: Specifications of 17th District of Kabul City:

Name	Location	Areas Included	Area	Urban Zone	Field of cultivation	Empty Earth
District 17	Northwest	Shakardara	56 km^2	16.7%	9%	74.3%

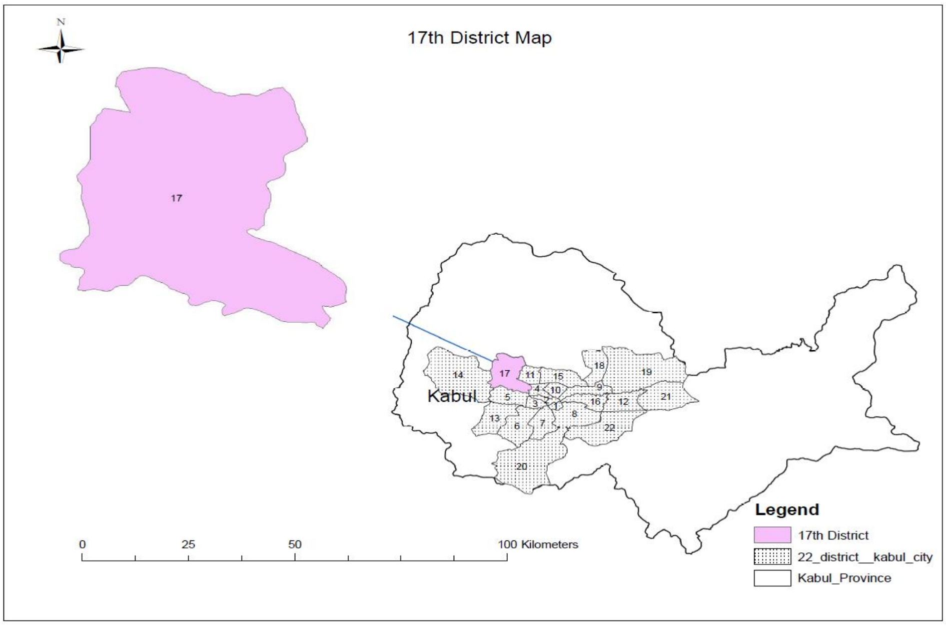

Figure 2. Map of the 17th District of Kabul City (Author)

Water Sampling

Four groundwater samples from wells in different District 17 areas were collected to determine water quality parameters. The sampling process involved:

- Initial aerial photograph survey and sampling point selection.
- Supplementary field surveys are used for the final sampling point selection.
- Proper sample packaging for transportation to laboratories.
- Before sampling, bottles were rinsed thrice with well water. Sample number, date, and coordinates were recorded.

Water Quality Analysis

The Ministry of Public Health and Ministry of Energy and Water laboratories measured water's physical, chemical, and biological parameters. Parameters like pH, turbidity, total dissolved solids (TDS), conductivity, hardness, alkalinity, ions, and microorganisms were tested using standard protocols from the World Health Organization (WHO) and Afghan National Standards. Measured values were compared with guidelines to assess quality and suitability for drinking, irrigation, or industrial use.

Analytical Procedures

Standard laboratory procedures were followed, including:

- Sample handling and preparation techniques
- Use of certified reference materials and standards for instrument calibration and method validation
- Analysis of blank samples and duplicates for monitoring interferences and precision
- Adherence to established laboratory protocols and operating procedures
- Participation in proficiency testing programs or inter-laboratory comparisons

Data Analysis

Data from water quality analyses were statistically analyzed using Microsoft Excel for descriptive statistics like means, ranges, and standard deviations. Results were presented in tables and graphs for interpretation and comparison with established standards.

Equipment and Materials

The following equipment and materials were utilized:

- Delagua Bacteriological Kit No. 3 (DELAGUA) for multiparameter water quality testing
- Standard laboratory glassware and equipment
- Reagents and chemicals for specific analytical tests
- Calibrated instruments for pH, conductivity, turbidity, and other parameters
- Incubators and culture media for microbiological analysis

Figure 3. Delagua bacteriological kit(Turner & Mathew, 1991)

Finding and Discussion

In this research, the following parameters are tested in the area to assess the water quality of the 17th district area, which includes physical and chemical parameters and are compared with national and WHO standards. Parameters are as follows: fluoride, Sulphate, Nitrate, iron, pH, EC. A set of groundwater parameters for 17 districts of Kabul city is determined and included in Table 2 below.

According to Table 2, the average amount of fluoride in groundwater is 0.76 ppm, and the permissible limits of fluoride in water are 1.5 ppm, or (0.6–1.7 mg/L). Considering the above norm, fluoride does not exceed the specified limit.

Table 2: Analyzed quantity of chemical parameters of groundwater in the 17th district of Kabul

Indicators / Experience / Number	Fluoride ppm	Sulfate ppm	Nitrate ppm	Fe ppm	pH
1	0.48	40	11.9	0.08	7.6
2	0.7	490	9.8	0.7	7.6
3	0.79	520	11	0.1	7.8
4	0.07	140	17	0.08	7.6
Medium	0.76	297.5	12.425	0. 24	7.65

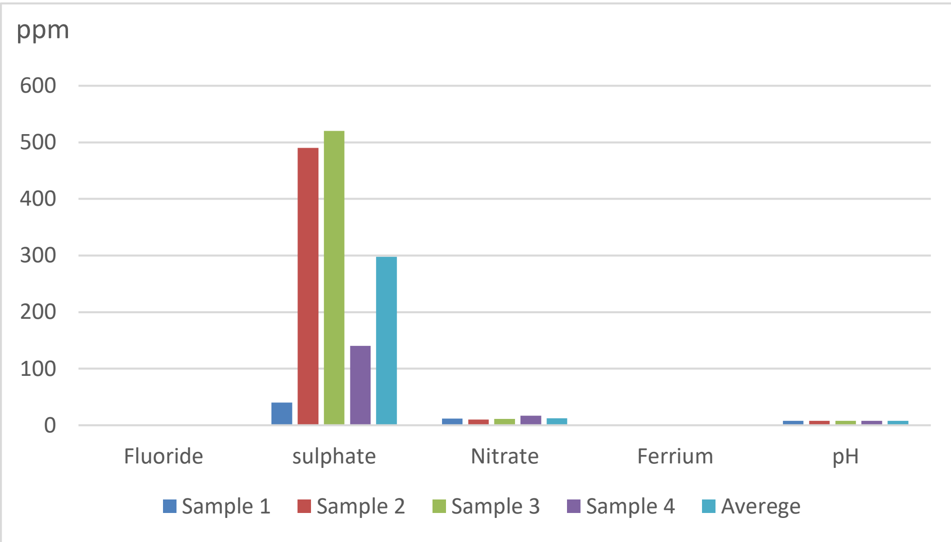

Figure 4. Chemical parameters of groundwater in the 17th district of Kabul

The average concentration of Sulphate in water is 297.5 ppm, as mentioned in the table, and the third parameter is Nitrate, whose average amount in the water is 12.425 ppm. The primary sources of Nitrate are plant and animal residues, animal excrements, Nitrate fertilizers, and sewage in the ground.

Based on the data in Table 3 below, the average amount of electrical conductivity in the 17th district is 1258 µs/cm. According to the limits set by the (WHO) guideline, the water electric conductivity limit is 1900 µs/cm.

Table 3: Electrical Conductivity of Water of 17th District of Kabul City:

Experience / Number / Region	1	2	3	4	5	average
District 17	560µs/cm	1208µs/cm	1270µs/cm	2100µs/cm	1155µs/cm	1258µs/cm

The fourth parameter is Ferrium; the average amount of iron in the water sample was 0.24 ppm. According to the WHO norm, the suitable amount of iron in water is 0.30 ppm. The concentration increases with the integration of water from mineral areas into water resources. The average pH value received by the experiment compared to the standards determined is 7.65. The optimal pH of drinking water is confirmed to be 6.5–8.5 to assess the degree of alkalinity or acidity of water.

This study aimed to assess the quality of groundwater in Kabul city, identify sources of pollution, understand contamination pathways, and propose solutions for water treatment and prevention of pollution. The chemical parameters of water in the 17th district of Kabul were analyzed to assist residents in purifying water and improving their quality of life. The study results, detailed in Table 4, provide valuable information on water quality in the 17th district of Kabul.

Table 4: Average Values of Groundwater Parameters in Three Areas of Kabul City

Indicators / Experience Number	Fluoride ppm	Sulfate ppm	Nitrate ppm	Ferrium ppm	pH
Medium	0.76	297.5	12.425	0. 24	7.65

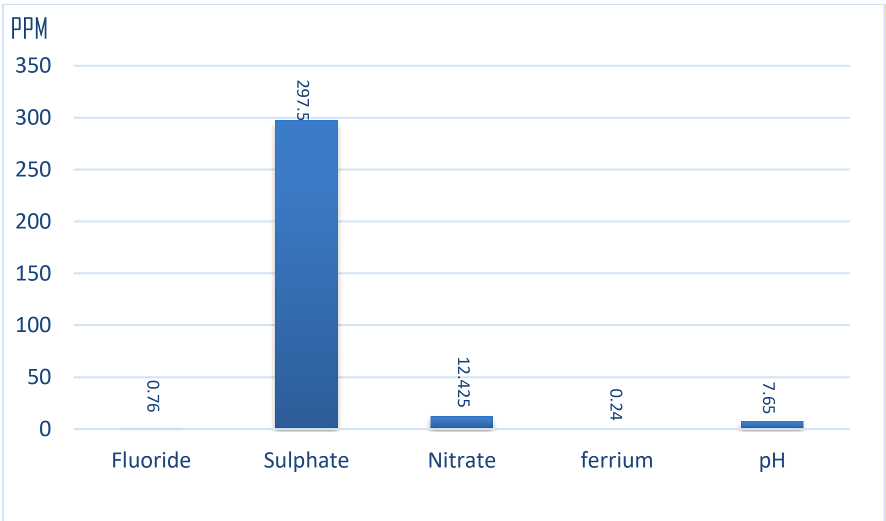

Figure 5. Average dependency of the studied parameters in the 17th district of Kabul city

The data from Tables 2 and 4 indicate that the average fluoride level in the groundwater in the research area is 0.76 ppm. The acceptable range for fluoride in water is typically 1.5 ppm (0.6-1.7 mg/L). Based on these limits, the fluoride concentration in the area's waterfalls is within safe levels. Fluoride is beneficial for dental health at a concentration of one milligram per liter, and children can benefit from this amount to prevent tooth decay (Clarkson & McLoughlin, 2000). Excess fluoride can lead to fluorosis or poisoning, causing symptoms such as bone pain and discoloration of teeth. However, the water being studied is considered safe for use.

The average Sulphate concentration in the water was 361.25 ppm, as shown in Tables 2 and 4. The WHO guideline for Sulphate in water is 5000 ppm. Sulphate comes from various sources, including gypsum and other minerals containing Sulphate. Natural water sources have Sulphate concentrations ranging from 1-1000 mg/L. High Sulphate levels in water can affect taste and odor, with hydrogen sulfide being produced when Sulphates are reduced, resulting in a rotten egg smell. While Sulphates are not harmful, magnesium Sulphate can cause diarrhea. The Sulphate levels in the water samples did not exceed acceptable levels, making the water safe for consumption.

The average Nitrate level in the 17th district of Kabul was 12.425 ppm. Nitrate primarily comes from plant and animal residues, waste, fertilizers, and sewage. Groundwater typically contains Nitrate concentrations ranging from 1-1000 mg/L. High Nitrate levels in water can affect taste and cause physiological effects when consumed. Excessive Nitrate intake has been linked to health issues such as excitement, blood poisoning, and cancer. However, the Nitrate levels in the area under study are within safe limits and do not pose a health risk.

The average iron concentration in the water was 1.5 ppm, above the WHO recommended limit of 0.30 mg/L. Iron levels in clean water typically range from 1.001-1.5 mg/L and can increase in water sources with mineral deposits. While excess iron may darken the water slightly, it does not affect its suitability for consumption or industrial use. The pH of the water in the 17th district is 7.65, within the standard range of pH=6.5 -8.5. High or low pH levels can impact the taste of water, with high pH leading to a soapy flavor and low pH resulting in a sour taste. The effects of pH extremes are more pronounced in infants and individuals with sensitivities.

The electrical conductivity in the 17th district was 1258 µs/cm, below the WHO limit of 1900 µs/cm. However, the water conductivity exceeded the acceptable limit at 2199 µs/cm, indicating high salt content. Therefore, the water in the area is unsuitable for use due to its high electrical conductivity level.

Conclusion

The data from Tables 2 and 4 indicate that the average fluoride level of the groundwater in the area is 0.76 ppm. The acceptable range for fluoride in water is typically 1.5 ppm (0.6-1.7 mg/L). Based on these limits, the fluoride concentration in the area's waterfalls is within safe levels. Fluoride is beneficial for dental health at a concentration of one milligram per liter, and children can benefit from this amount to prevent tooth decay (Clarkson & McLoughlin, 2000). Excess fluoride can lead to fluorosis or poisoning, causing symptoms such as bone pain and discoloration of teeth. However, the water being studied is considered safe for use.

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Recommendations

- The findings of this research on water contamination in District 17 of Kabul City underscore the urgent need to address water quality issues and implement effective measures to safeguard this vital resource. Based on the study's results and observations, the following recommendations are proposed:
- Implement stringent wastewater treatment measures: The contamination of surface water in the city, caused by mixing domestic sewage and effluents from residential areas, poses a significant threat to water resources. Establishing and upgrading wastewater treatment facilities is imperative to ensure that effluents are adequately treated before being discharged into water bodies or the environment.
- Develop and improve sewage infrastructure: Residential areas' lack of proper sewage systems contributes significantly to water contamination. Constructing and maintaining appropriate sewage networks throughout the city, including District 17, is crucial to prevent the seepage of untreated sewage into groundwater and surface water sources.

- Enhance public awareness and education: Implementing public awareness and education campaigns can be vital in promoting responsible water usage and waste disposal practices. These initiatives should emphasize the importance of water conservation, proper waste management, and the potential consequences of water pollution on human health and the environment.
- Strengthen regulatory frameworks and enforcement: Robust regulatory frameworks and strict enforcement mechanisms are essential to ensure compliance with water quality standards and environmental regulations. Authorities should collaborate with stakeholders, including residential communities, industries, and agricultural sectors, to develop and implement comprehensive water management strategies.
- Promote sustainable water resource management: A long-term, sustainable approach to water resource management is crucial. This includes investing in alternative water sources, such as rainwater harvesting and water recycling systems, implementing water conservation measures, and promoting water-efficient practices in various sectors, including agriculture and industry.
- Foster interdisciplinary collaboration and research: Continued research and multidisciplinary collaboration among experts from various fields, including water resources, environmental science, public health, and urban planning, are necessary to develop holistic solutions and innovative strategies for addressing water contamination challenges in Kabul City.

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Conflicts of Interest

The authors declare that there is no conflict of interest.

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