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A comprehensive investigation of groundwater quality in lagos state university, EPE, Lagos State, Nigeria

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Abstract

Groundwater is a major source of drinking water especially in developing countries. Continuous monitoring of groundwater quality is necessary to determine its suitability for drinking. This work was carried out to comprehensively investigate the groundwater quality in Lagos State University, Epe, Lagos State, Nigeria with a view to determine its suitability for drinking and domestic purposes. 20 different locations where groundwater samples were collected were selected and coordinated with handheld Global Positioning System (GPS) for the purpose of universal identification and visualisation. Groundwater samples were taken from boreholes in the identified and coordinated locations using 1 litre treated plastic bottles labelled GW 1 – GW 20. All the samples were analysed for physicochemical paramters such as pH, total dissolved solids (TDS), total hardness, calcium, biochemical oxygen demand (BOD), chemical oxygen demand (COD) among others. Heavy metals which include lead, chromium, cadmium and nickel and microbiological parameters like coliform and aerobic mesophilic count were also analysed usinh the standard methods for examination of water and waste water as prescribed by American Public Health association / American Water Works Association / Water bEnvironment Federation (APHA/AWWH/WEF, 2017). The results revealed that the pH values of groundwater samples investigated varied between 3.8 and 6.8 with an average value of 4.655 and a standard deviation of 0.659. The concentration of lead ranged between 0.003 and 0.15 mg/L with a mean value of 0.046 mg/L. nickel concentrations varied between 0.0068 and 0.2 mg/L with a mean of 0.053 mg/L. The average concentrations of pH, lead and nickel were above the threshold limits stipulated for drinking water quality by Nigerian Standards for Drinking Water Quality (NSDWQ) and World Health Organisation (WHO). The correlation coefficient revealed lead was positive weakly correlated with chromium, iron, cadmium and nickel while nickel was negative strongly orrelated with chromium. It was concluded that LASU, Epe groundwater is unfit for drinking and domestic purposes.

Keywords: Analysis Of Variance; Comprehensive; Groundwater; Investigation; Quality; Lagos State University

1. Introduction

Groundwater is underground water in rocks, sands, cracks and spaces in soil. It si stored and slowly moves through geological formations of sand, soil and rock which is referred to as aquifer (Groundwater Foundation, 2024). It is recharged or replenished by snow melt and precipitation which percolates through the soil matrix (Susus and Salami, 2011; Salami *et al*., 2013; Salami and Susu, 2015 and Adeyemo and Salami, 2022). Groundwater is a major source of water supply for humanity. Globally, 2.5 billion people totally depend on groundwater resources for the satisfaction of their basic daily water needs (Groundwater Project, 2024). It is the major source of drinking water in most part of the world (IAH, 2020 and Salami *et al*., 2019). Hence ensuring renewable and safe supply of groundwater for drinking is very vital for sustainable development for any nation (Peiyne et al., 2021).

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In Nigeria especially in the university campuses, groundwater is the main source of water for drinking and domestic purpose. This implies the quality of groundwater in Nigeria university campuses should be given adequate attention. Several scholars have worked on quality of groundwater in Nigeria university campuses (Magnus et al., 2011; Auwal and Kwaya, 2022; Owamah, 2019; Yakubu *et al*., 2022 and Odigie *et al*., 2021and David et al., 2023). Ogundana and Tababi (2014) evaluated groundwater potential in college of engineering, Afe Babalola University, Ad – Ekiti, in Southern Nigeria. The evaluation revealed that a depth in the range between 40 and 50 m should be dug in order to get suitable groundwater. Olusegun *et al*. (2016) investigated the groundwater potentila and aquifer protection capacityaround Osun State University College of Health Sciences. The investigation showed that the study area might have good potential for groundwater but the groundwater is unsafe hence the authors suggested that water treatment facilities should be established in the study area.

David *et al*. (2017) examined groundwater quality in Covenant University, Ota, Ogun State. The groundwater supply were analysed for pH, turbidity, chloride, total dissolved solids (TDS), sulphate, hardness, iron, nitrate and cadmium. The examination indicated that the groundwater samples analysed were within the permissible limits for drinking water by Nigerian Standard for Drinking Water Quality (NSDWQ) except for iron and cadmium which made the authors to report that the groundwater in the examined area was unfit for drinking. Bayowa *et al*. (2018) studied the groundwater potential around Ladoke Akintola University of Technology, Ogbomoso, Southern Nigeria. The study pointed that the groundwater of the study area was generally low as a result of the clay content of the aquifer.

Doris and Mildred (2021) characterised water quality inn Federal University of Petroleum Resources, Effurun, Delta State, Nigeria. The collected water samples were characterised for TDS, conductivity, temperature, pH, chloride, total hardness, turbidity and total coliform bacteria. The results of the characterisation revealed that the water samples were aqcidity though the heavy metal load was relatively low and below the permissible limit of the regulatory body. The coliform bacteria of the watewr samples was high and the authors concluded that the water was unsafe for drinking. Temitope *et al*. (2023) carried out geoelectric investigation of groundwater potential in University of Abuja, Abuja, Nigeria. The work reported that the aquifer of the investigated area comprised a thick weathered layer of overburden and weathered basement having a low resistivity which indicated a potential productive groundwater yeild.

It is evident from the myraid of literature that the investigation of groundwater quality in Lagos State University (LASU), Epe, Lagos State is rare in the literature. Therefore the aim of this work is to comprehensively investigate the grou dwater quality in LASU, Epe campus with a view to determine the suitability for the groundwater for drinking and domestic purpose which justifies this work. Moreover, correlation matrix and analysis of variance (ANOVA) will be developed using genrated data, to detrmine the significance of the generated data for decision making especially by the university management which further justifies this work.

2. Methodology

2.1. The Study Area

LASU, Epe campus was a formal military barrack before 1996 (Salami *et al*., 2021). It was converted to a full fledge academic campus in 1996. The campus is on coordinate 3.9896^{o}E and 6.588^{o}N (Salami and Folami, 2021). The campus is a large span of land which runs into thousand of acreage. It houses the School of Agricultural, School of Part Time Studies, Faculty of Environmental Sciences and Faculty of Engineering which compriese departments of chemical, civil, mechanical, industrial, aerospace and electronic and computer engineering. The campus is beautifully along the coaster valley of Epe and surrounded by vast hectres of land use by the villagers for agricultural purpose (LASU Handbook, 2015). Some students and staff resident on campus using the available accommodation provided by the university management while the remaining staff and students are resident off the campus. The satellite image of the study area id shown in Figure 1.

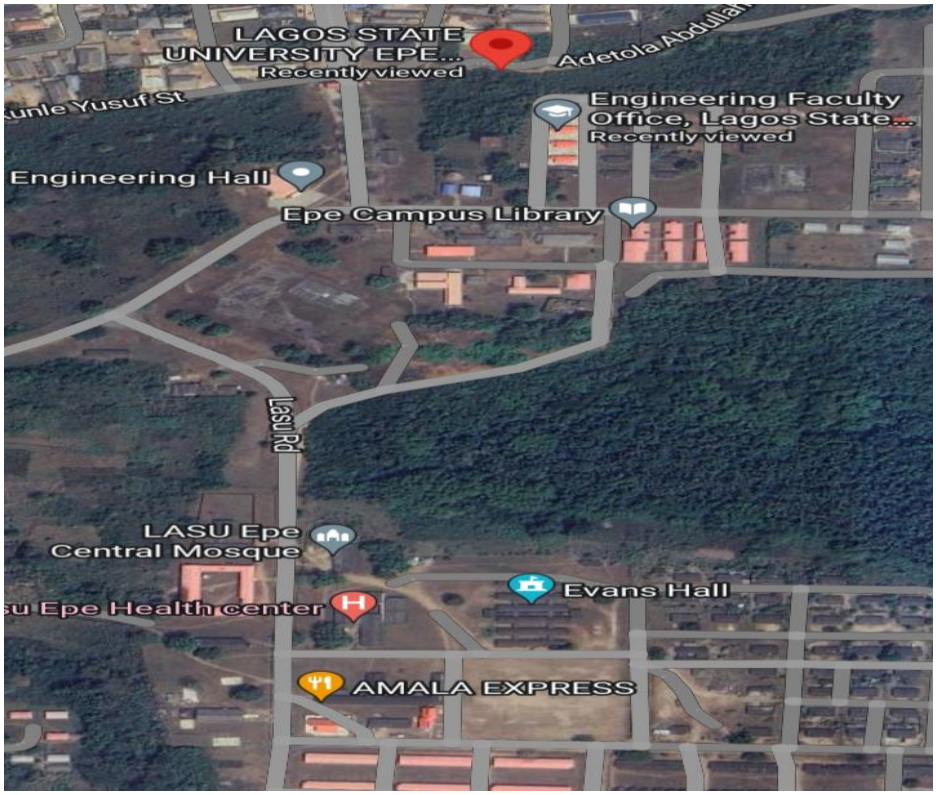

Figure 1 The satellite image LASU, Epe Campus

2.2. Coordination of Sampling Locations

20 variuos sampling points were chosen within LASU Epe campus for collection of groundwater samples and labelled 1 – 20. The sampling locations were coordinated with the aid of handheld Global Positioning System (GPS) (Etrex 12 Garmin model) for the purpose of universal visulisation and identification of the sampling points. The locations of the selected sampling points are depicted in Figure 2.

2.3. Sampling and Analysis

Groundwater samples were taken from the boreholes in the identified and coordinated locations in the month of November, 2023 using 1 litre plastic container already treated by soaking in 10 % nitric acid and rinsed with de – inised water in order to avert contamination. During the sampling, the treated containers were rinsed for three times with groundwater to be sampled prior to filling and they were labelled GW 1 – GW 20. The samples were transferred to the laboratory without delay, for analysis of physicichemical properties, heavy metals and microbiological parameters using the standard methods for examination of water and wastewtaer as prescribed by American Public Health Association, American Water Works Association and Water Environment Federation (APHA/AWWH/WEF, 2017). All the analysis were performed in triplicate and the results were found reproducible within $\pm$ 2 % error. The analysis data were statistically analysed by calculating and setting up a correlation matrix and one way ANOVA using the in – built solver tool in Microsoft Excel version, 2010.

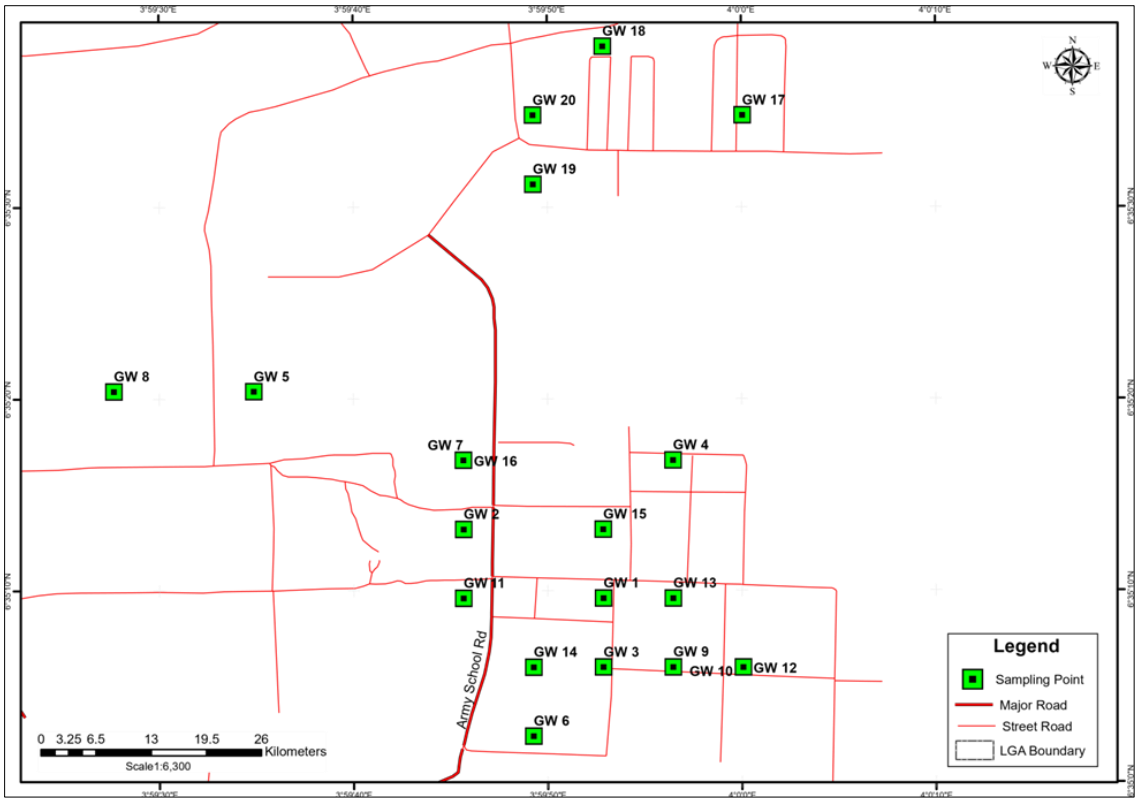

Figure 2 Locations of the sampling points

3. Results and discussion

The statistical analysis of the groundwater samples investigated as well as the guidelines for drinking water quality by NSDWQ and WHO is presented in Table 1. The pH of all the groundwater examined varied between 3.8 and 6.8 with an average of 4.655 and a standard deviation of 0.659. pH measures the concentration of hydrogen ions in a substance. The average value which is also referred to expected value revealed the groundwater in LASU, Epe is acidic. The pH for drinking water is between 6.5 and 8.5 and between 7.0 and 8.5 according to the guidelines for drinking water quality by NSDWQ and WHO. This is an indication that in term of pH, groundwater of LASU, Epe is not fit for drinking.

Auwal and Kwaya (2022) assessed the groundwater quality in Bayero University new campus and its environs. Bayero University was 7.4 which showed the groundwater was not acidic or basic. Fadipe *et al*. (2020) examined the groundwater quality I Osun State University campus. The work indicated the average pH of groundwater assessed was 7.49 hence the groundwater can be said to be fit for drinking in term of pH. It is worth mentioning that the groundwater quality of university campuses should be investigated to determine its suitability for drinking as it has been shown that in term of pH, LASU, Epe campus groundwater is not fit for drinking while Osun State University and Bayero University groundwater may be assumed to be fit for drinking. The acidity of LASU, Epe campus may be attributed to proximity of the LASU, Epe campus to the logoon with salty water.

Water hardness is a function of calcium and magnesium in water. Water is considered to be very hard if the hardness is above 180 mg/L and moderately hard if the hardness is between 61 and 120 mg/L (Quality of Groundwater, 2025). In this work, the hardness of groundwater samples investigated varied between 10 and 50 mg/L with a mean of 22.75 mg/L and a standard deviation of 13.325. This implied that the water was soft and is suitable for bathing , laundering and dish wasging based on the hardness values. Moreover, the stipulated limits for hardness in drinking water are 150 and 100 mg/L according to NSDWQ and WHO respectively. This revealed that the groundwater assessed is not bad for drinking based on its hardness values. TDS is the combined measurement of all organic and inorganic substances that are dissolved in a given amount of water. The TDS values in the groundwater assessed ranged between 11 and 173.25 mg/L with a mean of 65.175 and a skewness of 1.187. The threshold limit for drinking water quality is 500 mg/L as stipulated by NSDWQ and WHO. All the TDS values were within the regulatory limit.

Table 1 Numerical values of parameters examined in the groundwater samples

S/N	Paramters Mg/L	Min	Max	Range	Mean	SD	Skewness	*NSDWQ	**WHO
1	EC (Us/cm)	20	315	295	118.5	81.51	1.1865	1000	1000
2	pH	3.8	6.8	3.0	4.655	0.659	2.174	6.5 – 8.5	7 – 8.5
3	Total solid	5	350	345	155.5	99.162	0.5873	-	-
4	TDS	11	173.3	162.25	65.175	48.131	1.1869	500	500
5	Total hardness	10	50	40	22.75	13.325	1.3377	150	100
6	Total Alkalinity	0	20	20	8.951	5.817	0.0121	-	5
7	Calcium	4.01	20.04	16.03	9.053	5.39	1.322	-	70
8	Nitrate	0.024	9.51	9.496	8.248	2.142	- 3.43	50	10
9	Nitrite	0.004	4.998	4.994	0.257	1.116	4.472	0.2	0.1
10	Chloride	2.499	34.98	32.49	12.162	8.259	1.348	250	200
11	Sulphate	0.64	39.84	39.20	11.28	9.384	1.614	100	100
12	Total phosphate	1.06	7.69	6.63	5.246	2.27	- 0.51	-	-
13	Ammonical nitrogen	1.19	15	13.81	2.584	2.93	4.435	-	-
14	COD	5	17	12	8.9	3.323	1.097	-	-
15	BOD	0.3	7.2	6.9	3.946	2.28	- 0.395	-	-
16	Silica	2.496	7.06	4.564	4.184	1.302	0.868	-	40
17	Magnesium	0.025	2.227	2.7024	0.78	0.631	2.011	20	2.0
18	Zinc	0.005	0.160	0.165	0.046	0.051	1.532	3.0	-
19	Potassium	0.367	12.83	12.464	6.771	2.51	0.01	-	1.0
20	Lead	0.003	0.015	0.012	0.046	0.0034	-0.513	0.01	0.01
21	Copper	0	0.055	0.055	6.77	0.024	-0.25	1.0	1.0
22	Boron	0.002	0.009	0.0088	0.01	0.002	0.215	-	0.4
23	Manganese	0.004	0.171	0.1672	0.028	0.043	1.446	0.2	0.05
24	Cadmium	0	0.006	0.006	0.0011	0.0023	1.6446	0.003	0.003
25	Nickel	0.007	0.2	0.1932	0.053	0.04	4.218	0.02	0.02
26	Chromium	0.005	0.027	0.0221	0.0011	0.0050	-1.877	0.05	0.05
27	Iron	0.012	0.074	0.0624	0.0289	0.0189	1.406	0.3	0.3
28	Sodium	1.562	14.31	12.75	0.0209	3.548	1.42	200	-
29	AMC	0	95	95	0.0275	30.713	0.0855	-	100
30	Coliform	0	16	16	5.413	5.79	1.727	10	-

EC means Electrical conductivity; pH has no unit; Source: *NSDWQ (2015) and **WHO (2008)

The concentrations of chloride in the groundwater samples examined varied between 2.499 and 34.989 mg/L with an average of 12.163 mg/L and a skewness of 1.346. The threshold limits for chloride are 250 and 200 mg/L based on NSDWQ and WHO respectively. The concentrations of chloride in this work were within the regulatory limit. The presence of sulphate in groundwater is a pointer tpo dissolution of mineral such as gypsum in the surrounding rock formation. As water passes through rock and soil formation which consist of sulphate minerals, part of the sulphate dissolves into the groundwater. The concentrations of sulphstye in this work ranged between 0.64 and 39.84 mg/L with a mean of 11.282 mg/L. The values of sulphate were below the threshold limits of sulphate for drinking water quality

as stipulated by NSDWQ and WHO. The low concentrations of sulphate in the groundwater samples investigated may be due to absence of mineral containing sulphate in the rock and soil fromation of LASU, Epe campus.

The concentartions of lead in this work ranged between 0.003 and 0.015 mg/L with a mean of 0.046 mg/L and a standard deviation of 0.0034. The threshold limit for lead is 0.01 mg/L according to NSDWQ and WHO which implied that on average, the groundwater examined is contaminated with lead. The presence of lead in groundwater is an indication that the aquiifer where the groundwater is taken may be susceptible to lead contamination as a result of its geological composition or containing naturally occuring lead. It is worth mentioning bthat based on the average concenteration of lead in the investigated groundwater samples, the groundwaterin LASU, Epe campus is not bfit for drinking and domestic use. The presence of lead in LASU, Epe groundwater may be due to the geological composition of LASU, Epe campus or the soil contains naturally occuring lead. Previous work of Auwal and Kwaya (2022) revealed that the groundwater of Osun State University new campus was not contaminated with lead which differed from LASU Epe campus groundwater. It can be inferred that groundwater of each tertiary campus must be investigated inorder to adjudge the groundwater suitable for drinking or not.

The concentrations of cadmium in the groundwater examined varied between 0 and 0.006 mg/L with an average of 0.00114 mg/L. the threshold limit for cadmium in drinking water is 0.003 mg/L according to NSDWQ and WHO. Though the average value of 0.00114 mg/L for cadmium in the investigated groundwater samples was below the regulatory value, however, some groundwater samples have cadmium concentrations above the regulatory threshold. These include GW 17 (0.006 mg/L), GW 18 (0.006 mg/L), GW 19 (0.0051 mg/L) and GW 20 ?(0.0057 mg/L). Based on the concentrations of cadmium in GW 17 – GW 20 samples, LASU, Epe campus groundwater may be declared unfit for drinking . The contamination of LASU, Epe campus groundwater by cadmium may be as a result of agricultural activites which have released heavy metals into the soil matrix and eventually reached the aquifer where the groundwater is store.

Nickel is a toxic metal which accumulates in the body when ingested via contaminated water which can leads to adverse health effect like skin irritation, gastrointestinal issues, respiratory irritation and skin cancer (Fatemeh *et al*., 2024). The concentrations of nickel in the groundwater samples assessed varied between 0.0068 and 0.2 mg/L with a mean of 0.053 mg/L and a standard deviation of 0.0409. The stipulated limit for nickel in groundwater according to NSDWQ and WHO is 0.02 mg/L. the average value of nickel was beyond the regulatory limit which revealed LASU, Epe campus groundwater is unfit for drinking and domestic use. Nickel in groundwater can be as a result of improper waste disposal, industrial activities and natural source. The presence of nickel in LASU, Epe campus may be attributed to natural source which involved dissolution of nickel – rich rock in rainwater and industrial activities like application of chemical fertilzers and pesticides on the soil.

Table 2 Cioefficient matrix for heavy metals in the investigated groundwater

	Zinc	**Lead**	**Copper**	**Cadmium**	**Nickel**	**Chromium**	**Iron**
Zinc	1.00						
Lead	0.774	1.00					
Copper	0.1928	-0.1495	1.00				
Cadmium	-0.287	0.1866	-0.5916	1.00			
Nickel	0.1549	0.0195	-0.3004	-0.1598	1.00		
Chromium	0.1671	0.0165	-0.0165	0.07336	-0.7173	1.00	
Iron	0.889	0.2487	-0.2487	0.4859	-0.1278	-0.1803	1.00

The coeefficient matrix for heavy meatls in the groundwater samples investigated is depicted in Table 2. A coefficient matrix is a matrix comprising the coefficients of variables in a set of data. A ciorrelation coefficient indicates the strenght and direction of the relationship between two variables and it ranges between -1 and 1. Lead was positive weakly correlated with cadmium, nickel, chromium and iron but negative weakly correlated with copper. Copper was negative cadmium but negatively weakly correlated with nickel iron and chromium. Cadmium can be said to be positive moderated correlated with iron while nickel was negative strongly correlated with chromium.

4. Conclusion

A comprehensive investigation of groundwater quality in Lagos State University, Epe, Lagos State, Nigeria has been carried out. The pH of groundwater samples examined ranged between 3.8 and 6.8 with a mean value of 4.655 and a standard deviation of 0.659. The revealed the groundwater in LASU, Epe is acidic. The hardness of the groundwater varied between 10 and 50 mg/L with an average of 22.75 mg/L which indicated that the groundwater was soft. The concentrations of lead in the groundwater samples assessed ranged between 0.003 and 0.015 mg/L with an average value of 0.046 mg/L which was above the threshold value of 0.01 mg/L for lead according to NSDWQ and WHO. The comcentrations of cadmium in the groundwater samples examined ranged between 0 and 0.006 mg/L with a mean of 0.0014 mg/L. Though the average of cadmium concedntration was below the standard stipulated by NSDWQ and WHO, however the concentrations of cadmium in GW 17 – GW 20 were above the threshold limit value. Nickel concentrations varied between 0.0068 and 0.2 mg/L with a mean of 0.053 mg/L which was above the stipulated limit of 0.02 mg/L by NSDWQ and WHO. The correlation among the heavy metals revealed lead was positive weakly correlated with cadmium, chromium, nickel and iron while nickel was negative strongly correlated with chromium. It weas obvious from this work that the average concentrations of pH, nickel and lead were beyond the threshold values accordinG to guidelines for drinking water quality by NSDWQ and WHO hence it was concluded trhat the groundwater in LASU, Epe is unfit for drinking and domestic purpose.

Compliance with ethical standards

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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