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Original Article

Ambient Air Quality and General Health Outcomes in Nigde (Turkey) between 2011 and 2017

Ertan Kara [1], Hasan Göksel Özdilek [2], *Emine Erman Kara [3], Fatih Balcı [4], Burcu Mestav [5]

1. *Department of Public Health, Faculty of Medicine, Cukurova University, Adana, Turkey*
2. *Department of Environmental Engineering, Terzioglu Campus, Faculty of Engineering, Canakkale Onsekiz Mart University, Canakkale, Turkey*
3. *Department of Environmental Engineering, Faculty of Engineering, Nigde Omer Halisdemir University, Nigde, Turkey*
4. *Department of Anaesthesiology and Resuscitation, Kayseri City Hospital, Kayseri, Turkey*
5. *Department of Statistics, Terzioglu Campus, Faculty of Arts and Sciences, Canakkale Onsekiz Mart University, Canakkale, Turkey*

***Corresponding Author:** Email: emineermankara@gmail.com

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Abstract

Background: We aimed to provide information for health practitioners and other related people about the association between ambient air quality and adverse health outcomes in the general population of Nigde, a central Turkish city, within the context of current health data epidemiological evidence.

Methods: The present study highlights the connection between health problems and time series of particulate matter (PM_{10}) and sulphur dioxide (SO_2) in Nigde, Turkey between 2011 and 2017. Significant morbidity is linked to ambient air pollution, resulting in a significant economic cost to society.

Results: We found that the required funds to treat cancers and chronic obstructive pulmonary disease triggered by ambient air pollution in Nigde, exceed 9 million US dollars per year, even when only the city center is taken into account.

Conclusion: As Turkish cities grow and urban population density increases, air pollution issues need to be given priority in order to protect the health of the public and support sustainable development for future generations. It is recommended that particulate matter concentration in this urban center should be significantly reduced to minimize health problems.

Keywords: Ambient air pollution; Environmental health; Health outcomes; Turkey

Introduction

There is growing interest in the study of the negative health effects of ambient air pollution on the public, as is apparent in the scientific literature in recent years. The Committee on Environmental Health of the American Academy of Pediatrics published a policy statement in 2004 emphasizing the connection between ambient air pollution and children's health (1). Children are known to be more under danger from the negative health effects of air pollution agents due to their higher minute inhalation, immature immune systems, the longer time periods they spend out-

side (2, 3). In vigorous and energetic activities, and the progressing development of their lungs during the early postneonatal period (2-4). Especially over the past decade, there has been a marked increase in results from many research areas (such as animal toxicology, population exposure, observational epidemiology, etc.) showing that ambient air quality parameters both exerted a greater impact on established health endpoints and are also associated with a wider number of disease outcomes (5).

A large number of epidemiological publications have reported an association between exposure to criteria air pollutants and several morbidity (6, 7) and mortality (8, 9) outcomes in citizens. Ambient air pollution, which is mainly the result of fuel burning, is responsible for 3 million deaths a year in the world (8, 9). Nearly forty years after the well-known London smog of 1952, it was reported that 160 people lost their lives because of smog due to vehicle traffic and calm meteorological conditions in London in December 1991 (10).

Indoor and outdoor air pollution is very important for the public health. However, indoor pollution is more important because pollutants reach higher concentration indoor air when compared with outdoor. Because of this air exchange rate is very important to reduce indoor air pollution (11). For about atmospheric pollution crowded and extensive industrialized cities are very important. To investigate atmospheric pollution and determine pollution sources many studies were conducted (12-15).

The criteria air pollutants in Turkey consist of two air pollutants that are regulated based on their potential to cause adverse health and/or environmental effects: particulate matter (PM_{10}) and sulphur dioxide (SO_2). This is despite the fact that there are other criteria air quality parameters in other countries, for instance, nitrogen dioxide (NO_2), ozone (O_3), and carbon monoxide (CO) (5). In the present study, we aim to highlight the adverse health outcomes associated with exposure to these two criteria air pollutants in the public in Nigde, a central Turkish city.

We aimed to provide information to health practitioners about the current epidemiological evidence related to the associations between ambient air pollution and adverse health outcomes in individuals.

Materials and Methods

Turkey has installed many air pollution-monitoring stations (reporting hourly) in almost all provincial centers and some district centers. The air quality parameters (namely, sulphur dioxide (SO_2) and particulate matter (PM_{10}) were taken from a Turkish air quality monitoring station located in the city of Nigde (the provincial center). Hourly data were transformed into monthly averages. The data in this study is data collected outdoors, and therefore our study concentrates on the relationship between outdoor air quality and health outcomes. However, we also recognized that there was no clear demarcation line between indoor and outdoor air pollution when considering the air quality parameters above. The link between indoor air quality and the health outcomes studied is equally important.

Health data were taken from both the state hospital and two private hospitals serving in Nigde provincial center. Statistics concerning four different health problems were obtained from these three different institutions. These are bronchitis, bronchiolitis, chronic obstructive pulmonary disease (COPD), and asthma. Reported correlations between these health problems were computed. Time series analysis was also performed to see whether there is an improvement in general health or not. Finally, Mann-Kendall trend test and Poisson regression tests were completed to determine which health problems are on the rise between 2011 and 2017.

The initial value of the Mann-Kendall statistic, S, is assumed to be 0 (e.g., no trend). If a data value from a later time is higher than a data value from an earlier time, S is incremented by one. On the other hand, if the data value from a later time is lower than a data value sampled earlier, S is decremented by one. The net result of all such in-

crements and decrements yields the final value of S.

Calculate the variance of S, VAR(S), by the following equation:

$$VAR\ (S) = \frac{1}{18}((n(n-1)(2n-5)) - (\sum tp(tp-1)(2tp+5)))$$

The second part of the equation is for the tied groups (if any). The term tp is the number of observations in the p^{th} group.

Computation of a normalized test statistic Z as follows was completed:

$$Z = \frac{S-1}{[VAR(S)]^{\frac{1}{2}}} \quad \text{if } S>0$$

$$Z = 0 \quad \text{if } S=0$$

$$Z = \frac{S+1}{[VAR(S)]^{\frac{1}{2}}} \quad \text{if } S<0$$

The trend is said to be decreasing if Z is negative and the computed probability is greater than the level of significance. The trend is said to be increasing if the Z is positive and the computed probability is greater than the level of significance. If the computed probability is less than the level of significance, there is no trend.

Furthermore, Poisson regression is used since air pollution and health is examined in relative risk model. The case rate λ_t at the time point t is modeled as follows:

$$\ln(\lambda_t) = \beta_0 + \sum \beta_i x_{it}$$

With being the number of cases y observed at time t divided by the number of subjects N (population) at risk at time t. The model can be rewritten as:

$$\ln(y_t) = \ln(N_t) + \beta_0 + \sum \beta_i x_{it}$$

This model was tested using the R project version 3.4.4 (2018-03-15) statistical software.

Results

In Nigde, annual mean PM_{10} concentration between 2010 and 2017 generally exhibited a non-changing trend, which showed peaks in autumn and, especially, in winter months. Fig. 1 presents SO_2 and PM_{10} concentration in ambient air in Nigde (provincial center). As shown in Fig. 1, SO_2 concentration decreased from 2010 to 2017 due to increased natural gas use for heating space in workplaces and dwellings. However, particulate matter was almost stable, showing a seasonal increase observed in winter months.

The annual average PM_{10} concentration in Nigde was compared to the California (USA) ambient air quality standard and it was found that it exceeds the Californian standard (20 μg/m^3). Table 1 shows annual average PM_{10} concentration in ambient air in Nigde.

Annual patient numbers showed no significant reduction in terms of lung disease between 2010 and 2017. However, there was a notable decrease in both female and male patients suffering from lung disease in terms of their average age in the same time.

Table 1: Annual mean PM_{10} concentration in Nigde (2010-2017)

Year	*Annual mean PM_{10} concentration (μg/m^3)*
2010	77.53 (SD 68.72)
2011	81.78 (SD 78.20)
2012	79.41 (SD 72.68)
2013	74.13 (SD 80.29)
2014	68.36 (SD 60.63)
2015	75.11 (SD 87.46)
2016	73.42 (SD 55.10)
2017	66.70 (SD 47.38)

Pearson correlation between monthly average SO_2 and PM_{10} concentrations was weak (0.06%). This value shows that particulate matter emission is independent from sulphur dioxide emission in urban air in Nigde. In fact, particulate matter is caused by factors such as construction activities, traffic, erosion and dust blown up into the air.

The decrease in sulphur dioxide is mainly due to increasing natural gas use in house and workplace heating. Table 2 illustrates cumulative natural gas users in Nigde between 2010 and 2017.

The Pearson correlation coefficient was computed to be 73.89% between the numbers of natural gas users and the average annual sulphur dioxide concentration of urban air in Nigde. This finding is significant since there has been a notable improvement in urban air quality in terms of urban sulphur dioxide concentration, especially after 2012. This correlation coefficient is significant ($r^2_{critical}$=72.9%; df=6; α=0.05 (one tailed)) indicating that heating fuel (for instance natural gas is better than coal and lignite) is an important cause of the drop in sulphur dioxide in ambient air in Nigde city center. The peak number of diagnoses reported as air pollution-related diseases was reported in 2016 in females with asthma and in males with chronic obstructive pulmonary disease between 2011 and 2017, despite the fact that 2017 had not finished at the time when the data of this article were treated.

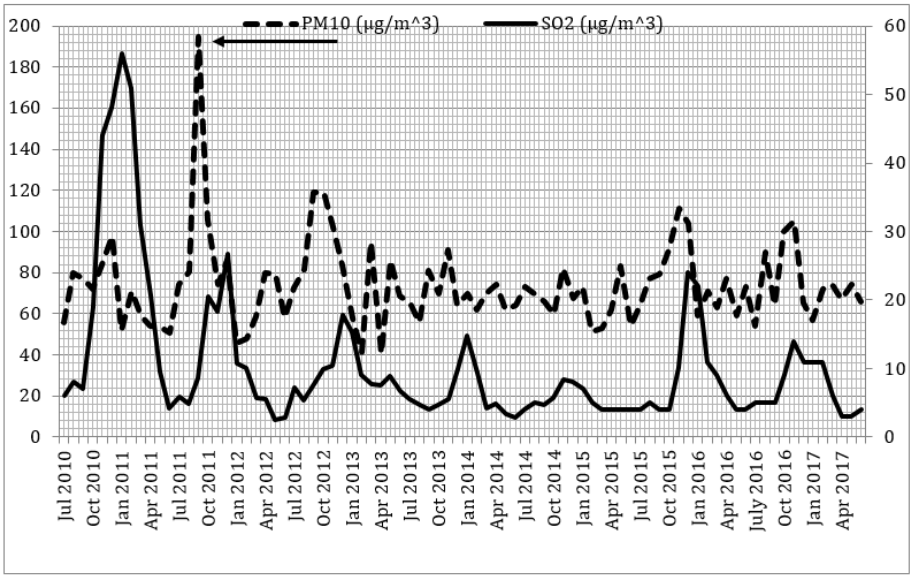

Fig. 1: Ambient air SO_2 and PM_{10} concentrations (monthly averages) in Nigde (2010-2017)

Table 2: Cumulative natural gas consumers (dwellings and workplaces) in Nigde (2010-2017)

Year	*Pre 2010*	*2010*	*2011*	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*
No of units	14,029	18,205	23,461	30,230	34,423	38,681	41,461	44,002	45,665

Four individual health problems were chosen because they are all directly linked to ambient air quality: bronchitis, bronchiolitis, chronic obstructive pulmonary disease (COPD), and asthma. The Pearson correlation coefficient (regardless of patients' sex) showed a strong correlation between these problems in the period of January 2011 and March 2017. Table 3 shows pair-wise correlation of these problems.

Bronchitis was not affected by particulate matter (PM_{10}) based on the Poisson regression results. Bronchiolitis, on the other hand, was affected by the ambient PM_{10} concentration. The model parameters of bronchiolitis are given in Table 4.

Table 3: Pearson correlation of health problems in Nigde (January 2011-March 2017)

Count of	*Bronchitis*	*Bronchiolitis*	*COPD*	*Asthma*
Bronchitis	1	0.6912*	0.7596*	0.5772*
Bronchiolitis		1	0.6701*	0.7285*
COPD			1	0.8334*

*All correlation coefficients were found significant (two tailed test based on 0.01 confidence interval, d.f. = 73). It means that all these health problems are inter-correlated

Table 4: Poisson regression model parameters for bronchiolitis

Variable	*Estimate*	*Standard error*	*z value*	*Pr (>|z|)*
Intercept	-13.04821	0.550941	-23.684	$<2*10^{-16}$
Gender	-0.336192	0.009287	-36.199	$<2*10^{-16}$
PM_{10}	0.091243	0.008976	10.116	$<2*10^{-16}$

$$ln(y_t) = -13.04821 - 0.336192 * sex + 0.091243 * PM_{10}$$

The highest increase in terms of annual counts of air pollution-related health problems was found in bronchiolitis, regardless of sex. In both males and females, the annual bronchiolitis count was found to have increased by over 75% between 2011 and 2017 (excluding the final year due to the fact that it was not finished) when two equal periods (the first includes 2011 to 2013 and the last includes 2014 to 2016) were taken into account. Asthma is another problem showing an increasing trend (over 46% in males and nearly 56% increase in females) between the same times. Table 7 provides average periodic counts and changing rates of the health problems examined. Especially in late winter days suffers of bronchiolitis and asthma were in large numbers compared to late autumn and early winter. It seems that people adopt themselves for PM_{10} but later they suffer from such air pollution related problems because of long-lasting PM_{10} episodes.

Similarly, significant effect of PM_{10} on COPD and asthma counts was found. Tables 5 and 6 provide model parameters of Poisson regression for these health problems respectively.

It is noteworthy that numbers of bronchiolitis and asthma cases increased over the past six years in Nigde as shown in Fig. 2. COPD affected males much more than females. Morbidity of COPD among males is twice (in some months three times) higher than that of females in Nigde. Asthma, on the other hand, seems to affect females worse compared to the monthly asthma counts of males. The other two health problems (bronchitis and bronchiolitis) are close to each other in terms of morbidities among males and females.

Table 5: Poisson regression model parameters for chronic obstructive pulmonary disease

Variable	*Estimate*	*Standard error*	*z value*	*Pr (>|z|)*
Intercept	-6.558321	0.261327	-25.096	$<2*10^{-16}$
Gender	-0.762898	0.006953	-109.714	$<2*10^{-16}$
PM_{10}	0.006273	0.004394	1.427	0.153437

$$ln(y_t) = -6.558321 - 0.762898 * sex + 0.006273 * PM_{10}$$

Table 6: Poisson regression model parameters for asthma

Variable	*Estimate*	*Standard error*	*z value*	*Pr (>|z|)*
Intercept	-10.68753	0.258632	-41.323	$<2*10^{-16}$
Gender	0.904374	0.006119	147.792	$<2*10^{-16}$
PM_{10}	0.063704	0.004252	14.982	$<2*10^{-16}$

$$ln(y_t) = -10.68753 + 0.904374 * sex + 0.063704 * PM_{10}$$

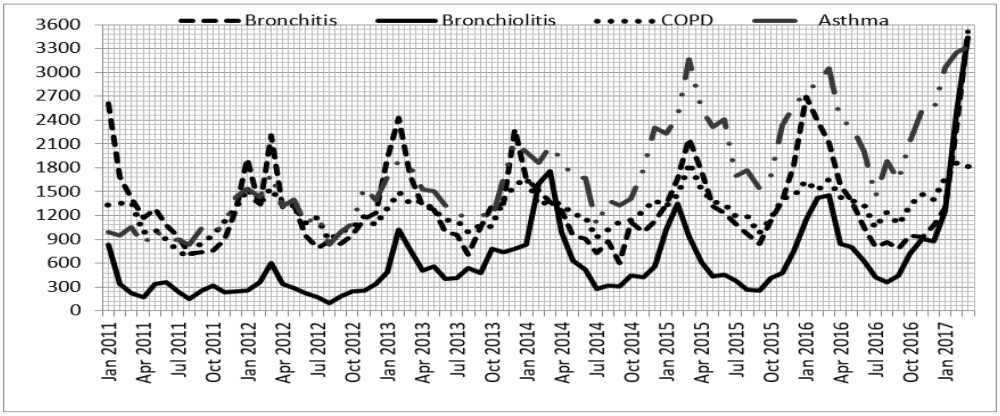

Fig. 2: Time series of monthly air pollution-related diseases (total counts) in Nigde, Turkey

As a rough estimate, each COPD sufferer costs approximately 2,800 US dollars to treat the disease properly in Turkey. Therefore, the total cost to treat an extra 1,000 new cases of COPD is approximately 3 million US dollars. Probably, smoking or second hand smoking is a major concern in COPD (Table 7 indicates this situation very well) since smoking among males far exceeds smoking rates in females in Turkey.

Table 7: Time series analysis of health problems examined (two-halves method)

Variable	*Average count (2011-2013) A*	*Standard deviation (2011-2013) A*	*Average count (2014-2016) A*	*Standard deviation (2014-2016) A*	*Average count (2011-2013) B*	*Standard deviation (2011-2013) B*	*Average count (2014-2016) B*	*Standard deviation (2014-2016) B*
Gender								
Males	7753	739	7508	1052	2805	1391	4927	469
Females	7815	771	7952	1004	2034	867	3573	616
Total	15568	656	15460	951	4839	1119	8500	889
Gender	Average count (2011-2013) C	Standard deviation (2011-2013) C	Average count (2014-2016) C	Standard deviation (2014-2016) C	Average count (2011-2013) D	Standard deviation (2011-2013) D	Average count (2014-2016) D	Standard deviation (2014-2016) D
Males	9346	620	11029	994	4724	1045	6906	902
Females	4756	765	4874	185	10562	2136	16535	5497
Total	14102	2590	15903	3431	15286	3534	23441	6343
Gender and problem	A males	A females	B Males	B females	C males	C females	D males	D females
Percent change	-3.16	1.75	75.67	75.64	18.01	2.48	46.19	56.56

Note that **A** stands for bronchitis; **B** stands for bronchiolitis; **C** stands for COPD; and **D** stands for asthma in this table.

Regardless of sex-dependent morbidity, asthma is responsible for one-third of all (34.85%) counts (of the four health problems) examined here. Bronchitis and COPD follow asthma as almost one-fourth (for each) of reported counts.

Based on the Mann-Kendall trend statistics, bronchitis cases showed a non-changing trend ($S=160$; $T=0.058<T_{critical}=0.218$ for $\alpha=0.05$) in Nigde between 2011 and 2017. On the other hand, bronchiolitis, chronic obstructive pulmonary disease, and asthma cases are on the rise, based on the Mann-Kendall trend test results.

Based on the Mann-Kendall trend test results, bronchiolitis cases were statistically significant increasing trend in Nigde between 2011 and 2017 ($S=1153$; $T=0.415>T_{critical}=0.218$ for $\alpha=0.05$). Similar to bronchiolitis cases, a statistically significant increasing trend in chronic obstructive pulmonary disease cases was detected in Nigde between 2011 and 2017 ($S=836$; $T=0.301> T_{critical}=0.218$ for $\alpha=0.05$). Finally, for asthma, a statistically significant rising trend was observed in Nigde between 2011 and 2017 ($S=1683$; $T=0.606>T_{critical}=0.218$ for $\alpha=0.05$).

Discussion

Many human activities have negated any decrease in PM emissions and resulting indoor air pollution caused by many city center homes switching from coal to natural gas for their winter heating, namely traffic, construction, loss of green space, which are increasing.

While it was emphasized that sulphur dioxide levels in Nigde City center diminished notably between 1995 and 2010, particulate matter in Nigde has increased markedly due to increased construction activities, loss of green cover in the city center, ever-increasing traffic congestion, and the rising numbers of dry days related to global and local climate change (18). All these factors seem to be playing a role in public health.

Annual patient numbers show that there was no significant reduction in terms of lung disease between 2010 and 2017. However, there was a notable decrease in both female and male patients suffering from bronchitis in terms of their average age in the same time. Interestingly, the number of cigarettes sold per year in Turkey increased markedly in 2012 and in 2015 compared to the previous years of these two years. Although there is no provincial data about number of cigarettes sold, nationwide less than 1290 cigarettes per capita were sold (and consumed) in 2010, 2011, 2013, and 2014 (regardless of age, sex, and place) whereas 1331 cigarettes were sold and consumed per capita in 2012 and 1319 cigarettes were sold and consumed per capita in 2015 in Turkey. Not only ambient air but also the consumption of cigarettes or living/constantly being with someone who consume cigarettes is clearly a factor that triggers respiratory problems. However, it is also worth noting that this process is to some extent reversible. Approximately 5 years after quitting smoking, chronic bronchitis risk in past smokers approached that the level found in people who had never smoked (19).

It should be noted here that not only air quality in the external environment but also personal smoking habits, workplace air quality, time spend in badly aerated indoor environments, etc. are other important factors that cause health problems in the general public. However, our study is based on data collected from external air monitoring and focuses specifically on the relation of air pollution outside the home to health outcomes. One factor that affects health of people is the green active green space per capita in urban areas. In Nigde, this ratio is low (4.09 m^2 per capita) (20). Not only the space but also quality of green cover plays an important role in providing quality ambient air to citizens. A Green Plan that is a long-term strategy to solve regional environmental problem focusing on increasing active green space should be developed by responsible officials. Figures 3 and 4 show land cover in Nigde in 2012 and 2019 respectively. It was concluded that if green area in a city increases natural mortality and mortality due to heart failure decrease based on data covering 72 provinces (out of total 81 provinces) in Turkey (21).

Fig. 3: Land cover in Nigde in 2012 (16)

Fig. 4: Land cover in Nigde in 2019 (17)

It was also noted that green area per capita in some Turkish cities is low, such as 6 m^2 per capita in Istanbul, 5 m^2 per capita in Izmir, 5.6 m^2 per capita in Samsun, 3.82 m^2 per capita in Sanliurfa, and 3.1 m^2 per capita in Balikesir (22).

The population increase is less than 1% per year in Nigde, based on 2011 and 2016 province-wide population data. Therefore, it is a valid assumption that numbers of air pollution related health problems/cases are in general slightly showing an increasing trend in Nigde at present, all other factors considered. The average expected life decreased in Nigde from 75.4 years to 74.7 years for males and from 81.3 years to 80.6 years for females between 2013-2014 and 2015-2017 (23) One factor caused this drop can be spelled as ambient air pollution in Nigde. Countrywide expected life did not change for males (75.3 years) but dropped from 80.7 to 80.2 for females between 2013-2014 and 2015-2017 (23).

It is well documented that increased incidence of cancer and heart attacks are triggered by ambient air pollution. The extent of the problem of ambient air quality in Nigde is illustrated by the fact that a non-smoker in the center of Nigde is exposed to air pollution equivalent to smoking 2.5 cigarettes per day. It is well documented that a 1.4 cigarette smoking intake per capita among a population of one million has a risk of 1 in a million extra incidence of cancer/heart attack (24). This means that we can probably expect an extra 236 cancer/heart attacks cases per year in Nigde as a result of ambient air pollution. Similarly, in Istanbul, the largest metropolitan area in Turkey, the total number of expected cancer/heart attack cases per year generated by ambient air quality probably amounts to 5788 extra cases - irrespective of smoking and purely based on the contamination of ambient air, due to industry, traffic, space heating, etc. As a result, it is clear that some people become susceptible to this pollution that is equal to smoking 1.5 cigarettes per person per day.

One cancer treatment operation costs nearly 14,000 US dollars (without chemotherapy and treatment medicine) in Turkey. Furthermore, one CPOD treatment is 2,800 US dollars in Turkey. If one takes these amounts into account, a total monetary burden to treat these problems properly exceeds 9 million US dollars per year, only taking into account the provincial center or city of Nigde.

It was warned that increasing particulate matter would cause higher costs due to increasing health problems in Nigde in terms of asthma cases (18). Between 2008 and 2010, if air was assumed to be totally pure (no SO_2 and PM_{10}), the naturally occurring number of asthma sufferers has been recorded about 303 per month in Nigde (18). In this study, the maximum asthma count was found to be 2,437 in March 2017 in Nigde.

Conclusion

As our urban centers grow and population density increases, we need to be aware of ambient air pollutants and their effects on the public. Further studies are needed in Turkey to improve our understanding of ambient air quality on the health of the public, to aid policy-makers and urban planers to make decisions that lead to sustainable and healthy development.

Ethical considerations

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors

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Conflict of interest

Non-declared.

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