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Research Article

Geochemical and Geospatial Distribution of Organic Contaminants in the Flood Plain of Ekpetiama, Niger Delta Region of Nigeria

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Abstract: This study investigated the geochemical and geospatial distribution of organic contaminants in the floodplain water and sediments of Ekpetiama in the Niger Delta Region of Nigeria. This study is necessary because there are limited data on the level of organic contamination in this section of the Niger Delta Region of Nigeria. The extinction of planktons in Ekpetiama became a source of concern to the residents. This concern is because this section of the coastal plain provides fisher folks with livelihood. So, there was a need to track the source of contamination in this part of the Niger Delta region. Previous studies have suggested a high level of Total Petroleum Hydrocarbon and Total Hydrocarbon Content as possible sources of reduced dissolved oxygen in similar deltaic terrain. A total of 10 water and 10 sediment samples were collected and analyzed in triplicate at an interval of 100 m in the flood plain. A particle size analyzer was used to perform particle size analyses of air-dried sediments. The American Public Health Association method (APHA) was used to do the chemical analysis of the water samples. Here, a liquid-liquid extraction procedure was performed on sediment samples using 30 mL of Dichloromethane (DCM) as the extracting agent. The results were subjected to statistical validation. The mean grain size ranged from 2.37-4.83, kurtosis (1.94-0.49), and skewness (-0.8-0.71). The contaminant indicators (pH, biochemical oxygen demand, chemical oxygen demand, dissolved oxygen and Total Organic Carbon) point to the presence of organic contamination of the flood plain. The results indicated a total petroleum hydrocarbon range of 0.47-0.87 ppm in water and 0.69-0.96 ppm in sediments and a total hydrocarbon content range of 1.10-2.80 ppm in water and 2.56-3.90 ppm in sediment# samples. The results were above the permitted limits of the World Health Organisation. The source of ecological damage is the abnormal concentrations of organic contaminants in the flood plain. These results significantly caused ecosystem damage and human health effects in the food chain. This study provides information to the National Oil Spill Detection and Response Agency for a cleanup process.

***Keywords*:** organic contamination, contaminant indicators, Niger Delta, total petroleum hydrocarbon, total hydrocarbon content, reverse distance weighting

1. Introduction

The study of source to sink of organic contaminants mostly from pesticides has generated lots of interest in the past decade. In the Niger Delta region of Nigeria, common organic contaminants are related to hydrocarbons [1]. Therefore,

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it is necessary to investigate the distribution of these hydrocarbon contaminants, to provide a baseline study for monitoring and mitigation to promote sustainable cleaning processes for environmental, economic and social benefits [2]. The livelihood of fisherfolk in the coastal communities of Ekpetiama and the ecological balance of the coastal plain in parts of the Niger Delta Region of Nigeria is threatened by the presence of organic contaminants [3].

The coastal waters and sediments remain the biggest pathways for the migration of these contaminants into the food chain. The textural characteristics of the sediments determine the availability and transport of contaminants along the path to the food chain. The determinant characteristics include mean, sorting, skewness and kurtosis [4-6]. Sediments with high clay content tend to impede contaminant migration because of their high porosity and low permeability. However, the high porosity and high permeability of floodplain sediments promote the migration of contaminants [7]. These contaminants are defined by some indicators, namely, pH, Biochemical Oxygen Demand, Chemical Oxygen Demand, Dissolved Oxygen and Total Organic Carbon. The presence of these indicators above the permissible limits points to the possible organic pollution of the pathway and the recipient. The presence and level of these indicators control the availability and degradability of organic contaminants [8-12].

Previous studies have indicated the presence of low dissolved oxygen and the extinction of certain plankton species [13]. The organic contaminants in this region come from hydrocarbons and other potential elements. Several of these contaminants are chemical compounds from crude oil analysed as Total Petroleum Hydrocarbon (TPH). The measurable impurities of hydrocarbons contained in a sample are analysed as the Total Hydrocarbon Content (THC) [14].

These contaminants when above permissible limits damage the ecosystem and are injurious to human health. When ingested, these contaminants cause high fever and gastrointestinal disorders [15-18].

Egirani and Chidi [18] and the current article represents part of a broad campaign and project on the distribution and impact of organic contaminants in the Niger Delta region. Therefore, they form part of an extensive project with more articles yet to be published. However, there are limited data on the possible causes of ecological damage to this section of the Niger Delta region and it is necessary to track the distribution of these contaminants in this part of the Niger Delta region. This tracking provides information for use by the National Oil Spill Detection and Response Agency as a baseline for monitoring.

2. Materials and methods

2.1 *Location and geology of Ekpetiama*

The study area is part of the Benin Formation in the Niger Delta Region of Nigeria. Ekpetiama lies within a flood plain adjacent to the Nun River. The floodplain has GPS coordinates of Longitude 5° 00' 28.4" N and Latitude 6° 15' 27.0" E. The geology of the area is characterised by recent sediments of the Benin formation discharged from the Niger and Benue rivers (Figure 1).

2.2 *Sampling and sampling techniques*

Ten (10) samples of flood plain sediments were collected at 100 m intervals at a depth of 1 m each. The sampling pattern is systematic, starting at zero (0) to 100 m and progressing at 100 m intervals to the last sampling point at 1,000 m. These samples are taken at a specific depth to ensure that the data has some equal vertical representation devoid of surface contamination by anthropogenic activities. This systematic sampling is used to determine the pattern or distribution of the contaminants. The sediments were deposited at the shoreline by flooding. These sediment samples are stored in sealed sample bags. The water samples were collected adjacent to the sediment samples at 1 m depth. The water samples were collected using a Winchester glass bottle handline operated.

2.3 *Particle size and experimental studies*

The sediment samples were oven-dried for 24 h, weighed and sieved using an automated shaker to dry for at least a day and then placed in plates. The corrected weight (g) and the cumulative weight (%) were both plotted against Phi values and were used to determine the mean grain size, sorting coefficients, skewness and Kurtosis as provided in [19].

The chemical parameters analyzed from both water and sediment samples included pH, Biochemical Oxygen

Demand (BOD), Chemical Oxygen Demand (COD), Dissolved Oxygen (DO), Total Organic Carbon (TOC) as contaminant indicators; and Total Hydrocarbon (THC), Total Petroleum Hydrocarbon (TPH) and iron (Fe) as contaminants as provided in [19-20] based on the American Public Health Association method.

The analytical procedure performed in triplicate followed the procedure in [21]. The chemicals and reagents used were analytical grade and supplied by Sigma-Aldrich in Dorset, United Kingdom. Samples analysed for pH (i.e., Portable Orion Model 290 pH meter, Leicester United Kingdom); Fe (i.e. A Perklin Elmer atomic absorption spectroscopy-Perkin Elmer AAS PinAAcle 900Z with furnace autosampler AS900, Ontario, Canada).

The Chemical Oxygen Demand (COD) was determined using a titrimetric technique. The Biochemical Oxygen Demand (BOD) of the samples were determined for the first and fifth days using the incubation techniques in [22]. The dissolved oxygen in the samples was determined using a DO metre (i.e., DO6+ LIAECDO601PLUSK, United Kingdom). The total organic carbon is determined by the titrimetric method. The Total Petroleum Hydrocarbon (TPH) in samples was determined using a liquid-liquid extraction procedure conducted on the sediment samples using 30 mL dichloromethane (DCM) as the extracting agent. The organic layer was separated from the aqueous layer and mixed with 5 g of anhydrous sodium sulphate. The extract concentrated at about 10 ml evaporated to dryness the TPH content was computed.

The THC in the samples was determined by treating the sample with 5 ml (0.1 M) sulfuric acid. 25 ml (0.1 M) n-hexane was added and stirred for 3 minutes. The organic layer separated from the aqueous layer and refluxed. The solvent boiled and the THC was calculated as provided in [23].

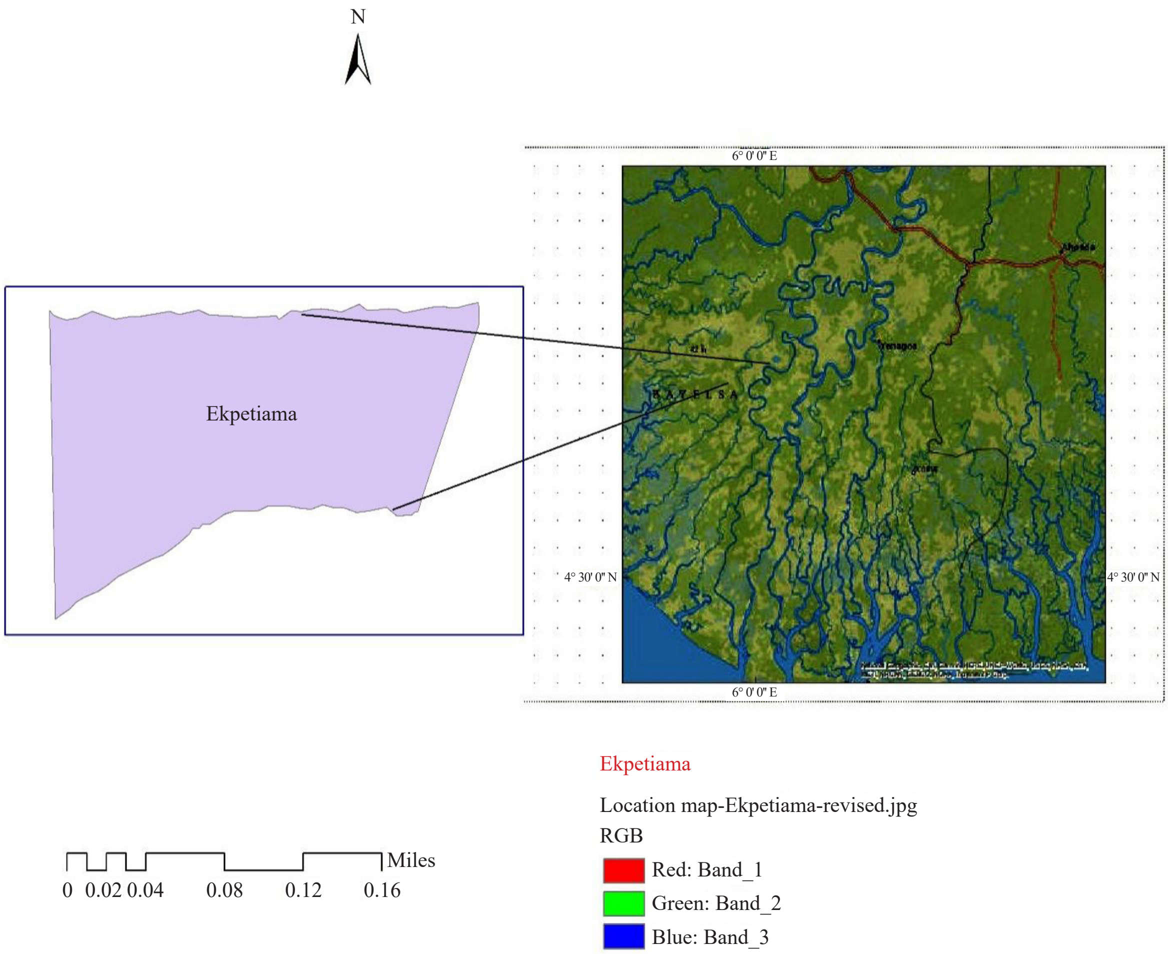

Figure 1. Location map of Ekpetiama

2.4 *Geoprocessing*

ArcGIS 10.8.1 is used to geoprocess the THC and THP results. The results of the chemical analyses were presented in an Excel spreadsheet, and converted to attribute tables. The attribute table was used to prepare the shapefile and to manipulate the spatial maps using the inverse distance weighting method expressed in percent (IDW).

3. Results and discussion

3.1 *Characteristics of the flood plain sediments*

The Ekpetiama floodplain sediments were analyzed to characterize the grain size both qualitatively and statistically (Table 1). The results for the contaminant indicators and contaminants are available (Table 2). The results were validated using the standard deviation statistic. Here, the standard deviation affirms no outliers or extreme value points in the results provided. It provides information on how data points deviate from the mean. The results of the inverse distance weighting (IDW) geoprocessing indicate a high concentration of THC in the eastern and isolated central region of the Ekpetiama floodplain. High TPH in sediment is available in the western part, the isolated central area of the Ekpetiama floodplain (Figure 2 & 3).

The COD ranges from 88.54 ± 0.02 ppm or ppm to 161.76 ± 0.01. These are above the regional and international guidelines (Table 2) for indicators in the aquatic and terrestrial environment. BOD ranges from 36.70 ± 0.02 ppm to 65.30 ± 0.02 ppm. Again, these are above the regional and international guidelines (Table 2). The pH ranges from 5.43 ± 0.08 to 7.25 ± 0.02.

Table 1. Summary of the textural characteristics of the Ekpetiama sediment

Sample	Mean	Kurtosis	Sorting	Skewness	Characteristics of the sediments
1	3.50	0.61	2.12	0.006	Very fine sand
2	2.37	0.68	1.99	0.71	Fine silt
3	3.17	0.49	2.28	0.11	Very fine sand
4	2.80	0.65	2.12	0.33	Fine sand
5	4.83	1.97	1.9	-0.72	Coarse silt
6	2.23	0.62	2.37	0.39	Fine sand
7	2.37	0.77	2.44	0.35	Fine sand
8	2.70	0.69	2.35	0.19	Fine sand
9	4.77	1.52	1.90	-0.8	Coarse sil
10	3.86	1.94	1.58	0.66	Very fine sand

Here, there are isolated cases of this indicator above regional and international guidelines (Table 2). Do ranges from 3.06 ± 0.02 to 5.14 ± 0.01. Again, there are isolated cases of this indicator rising above regional and international permissible levels. The TPH ranges from 0.47 ± 0.002 to 0.96 ± 0.02. This contaminant is recorded above the regional and international guidelines (Table 2). Iron ranges from 0.12 ± 0.002 to 2.66 ± 0.002. There are localized cases of this contaminant rising above regional and international contaminant guidelines (Table 2). The THC ranges from 1.40 ± 0.02 to 3.90 ± 0.02. Consequently, this contaminant records above the regional and international permissible limit. TOC ranges from 3.36 ± 0.02 to 6.50 ± 0.02, indicating an unacceptable range.

Table 2. Chemical analyses of the Ekpetiama water and sediment

Sample stations	Media	GPS reading (Degree decimal)		Distance (m)	Parameters (average)								
		Lat	Long		COD (ppm)	BOD (ppm)	pH	DO (ppm)	TPH (ppm)	Fe (ppm)	THC (ppm)	TOC (ppm)	COD/BOD × 100
1	Water	5.00965	6.2644	100	150.11 ± 0.04	62.24 ± 0.01	5.43 ± 0.08	4.88 ± 0.02	0.67 ± 0.02	0.12 ± 0.002	1.86 ± 0.08	4.20 ± 0.02	241.1
	Sediment				93.50 ± 0.02	38.76 ± 0.02	6.20 ± 0.015	3.06 ± 0.02	0.78 ± 0.02	1.76 ± 0.002	3.84 ± 0.02	4.86 ± 0.02	241.1
2	Water	5.00881	6.2621	200	134.70 ± 0.01	55.25 ± 0.02	5.60 ± 0.02	4.38 ± 0.01	0.87 ± 0.02	0.184 ± 0.002	1.60 ± 0.02	4.36 ± 0.02	243.8
	Sediment				98.73 ± 0.02	40.94 ± 0.01	6.65 ± 0.02	3.22 ± 0.01	0.80 ± 0.02	2.56 ± 0.002	3.65 ± 0.02	4.76 ± 0.02	241.16
3	Water	5.00681	6.26145	300	131.63 ± 0.02	54.57 ± 0.005	5.87 ± 0.01	4.30 ± 0.02	0.76 ± 0.02	0.146 ± 0.02	2.10 ± 0.01	3.87 ± 0.01	241.21
	Sediment				96.90 ± 0.02	40.18 ± 0.02	6.75 ± 0.05	3.15 ± 0.02	0.75 ± 0.02	2.26 ± 0.02	3.42 ± 0.01	4.54 ± 0.015	241.16
4	Water	5.00669	6.25878	400	156.85 ± 0.02	65.05 ± 0.02	5.78 ± 0.02	5.10 ± 0.02	0.64 ± 0.02	0.143 ± 0.001	1.43 ± 0.02	4.00 ± 0.02	241.12
	Sediment				88.54 ± 0.02	36.70 ± 0.02	5.95 ± 0.02	2.90 ± 0.02	0.87 ± 0.02	2.45 ± 0.002	3.90 ± 0.02	4.45 ± 0.02	241.25
5	Water	5.00955	6.25846	500	150.37 ± 0.01	62.34 ± 0.02	5.65 ± 0.02	4.90 ± 0.01	0.80 ± 0.02	0.215 ± 0.001	1.96 ± 0.02	4.94 ± 0.02	241.21
	Sediment				101.50 ± 0.02	42.10 ± 0.02	6.20 ± 0.02	3.30 ± 0.02	0.69 ± 0.02	2.66 ± 0.002	3.74 ± 0.02	6.50 ± 0.02	241.09
6	Water	5.0077	6.25844	600	161.76 ± 0.01	67.08 ± 0.01	5.85 ± 0.01	5.26 ± 0.02	0.76 ± 0.02	0.170 ± 0.002	2.00 ± 0.01	3.80 ± 0.02	241.14
	Sediment				98.40 ± 0.02	41.57 ± 0.02	6.83 ± 0.015	3.20 ± 0.02	0.72 ± 0.02	1.55 ± 0.002	2.70 ± 0.015	3.70 ± 0.01	236.71
7	Water	5.00747	6.26047	700	152.54 ± 0.02	63.26 ± 0.02	5.64 ± 0.02	4.96 ± 0.02	0.54 ± 0.02	0.126 ± 0.002	1.40 ± 0.02	3.10 ± 0.02	241.13
	Sediment				87.95 ± 0.02	36.46 ± 0.01	7.30 ± 0.02	2.84 ± 0.02	0.84 ± 0.02	1.44 ± 0.002	2.56 ± 0.02	3.74 ± 0.01	241.22
8	Water	5.00478	6.25468	800	151.92 ± 0.01	62.99 ± 0.02	5.67 ± 0.01	4.93 ± 0.01	0.47 ± 0.002	0.110 ± 0.02	1.10 ± 0.02	3.80 ± 0.02	241.18
	Sediment				91.65 ± 0.01	38.10 ± 0.01	6.85 ± 0.01	3.00 ± 0.01	0.96 ± 0.02	1.26 ± 0.02	2.86 ± 0.02	3.80 ± 0.02	240.55
9	Water	5.00656	6.25536	900	156.85 ± 0.02	65.06 ± 0.02	5.78 ± 0.02	5.10 ± 0.12	0.60 ± 0.001	0.213 ± 0.02	2.80 ± 0.01	3.94 ± 0.02	241.09
	Sediment				102.73 ± 0.02	42.60 ± 0.02	7.25 ± 0.02	3.36 ± 0.02	0.80 ± 0.02	1.65 ± 0.02	3.22 ± 0.01	3.87 ± 0.02	241.50
10	Water	5.00934	6.25505	1,000	157.46 ± 0.01	65.30 ± 0.02	5.65 ± 0.01	5.14 ± 0.01	0.76 ± 0.002	0.140 ± 0.02	2.00 ± 0.02	3.36 ± 0.02	241.13
	Sediment				106.10 ± 0.02	44.13 ± 0.01	6.55 ± 0.01	3.45 ± 0.011	0.84 ± 0.002	1.86 ± 0.02	2.75 ± 0.02	5.11 ± 0.02	240.43
		(WHO modified) [17]			130	50	6.5-8.5	3.0-5.0	0.01-0.30	0.3	0.2	4.0	

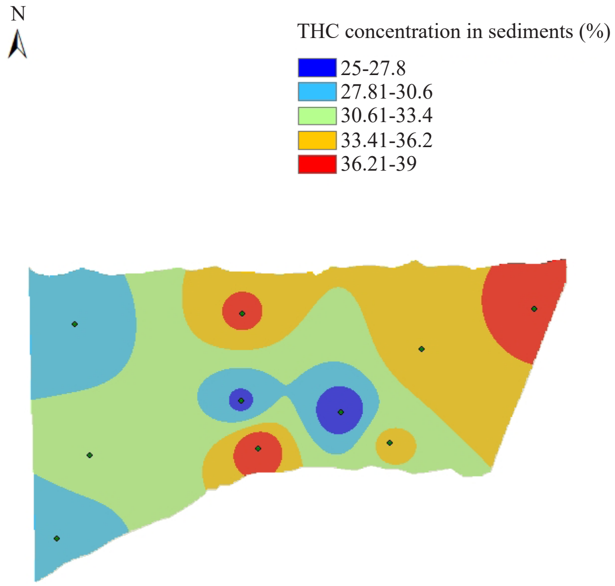

Figure 2. Map of THC in sediments with locations indicated in dots

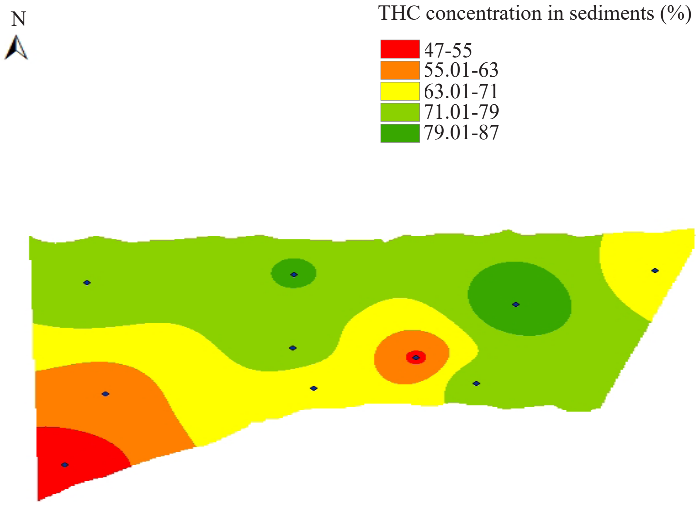

Figure 3. Map of THP in sediments with locations indicated in dots

3.2 *Discussion*

This study investigated The geochemical and geospatial distribution of organic contaminants in the flood plain of Ekpetiama, Niger Delta region of Nigeria. The study aims to reconstruct a bassline to monitor organic contaminants, Fe and their indicators. In the end, regulatory agencies are armed with sufficient information to deal with strategies for the decontamination of contaminants in the region. The results indicate an organically and Fe-contaminated environment that poses environmental, socioeconomic and health challenges to communities in the study area. The high peaks of organic contaminants are reflected where fertilisers and pesticides are used excessively by farmers. Therefore, policy formation is required to combat the indiscriminate application of fertilizers and pesticides in the study area.

The floodplain sediments ranged from fine silt to very fine sand. This characteristic depicts a poorly sorted deltaic terrain. This textural arrangement enhances the migration of contaminants along the shoreline of the floodplain. The contaminant indicators (pH, biochemical oxygen demand, chemical oxygen demand, dissolved oxygen, and Total Organic Carbon) are above the permissible limits of the World Health Organisation and other regional bodies. These indicators point to the presence of organic contamination of the floodplain. The results indicated a total petroleum hydrocarbon range of 0.47-0.87 ppm in water and 0.69-0.96 ppm in sediments and a total hydrocarbon content range of 1.10-2.80 ppm in water and 2.56-3.90 ppm in sediment. These results agree with previous studies pointing to organic contamination in the region [2-3, 7, 23-24].

Globally, there is remobilization of these organic contaminants during flooding of deltaic terrains. This episode requires an annual budget for decontamination and clean-up processes. The clustering of high concentrations of THC and THP in sediments and in sections of the Ekpetiama flood plain indicates that there is maturity of the contaminant in the flood plain sediments. This is because the concentration of organic contaminants in the floodplain sediment exceeds that in the water. The geological characteristics of the sediments significantly controlled the occurrence of these contaminants in this region.

4. Conclusion

Ecological damage and extinction of plankton species exist in this section of the Niger Delta Region. The source of ecological damage is the abnormal concentrations of organic contaminants in the floodplain. There is a high concentration of THC in the isolated eastern region of the Ekpetiama floodplain. In addition, a high TPH is available in the western part, an isolated central area of the Ekpetiama flood plain. These findings point to the fact that the distribution of the contaminants in the sediments is geologically controlled. These results significantly caused ecosystem damage and human health effects in the food chain. The result provides data to the National Oil Spill Detection and Response Agency for necessary action. It is recommended that the relevant government agency takes proactive steps to decontaminant the Ekpetiama floodplain.

Conflict of interest

I can confirm there is no conflict of interest with the publication.

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