Journal of
Environmental & Analytical Toxicology

Gebre et al., J Environ Anal Toxicol 2016, 6:3
DOI: 10.4172/2161-0525.1000363

Research Article | Open Access

The Pollution Profile of Modjo River Due to Industrial Wastewater Discharge, in Modjo Town, Oromia, Ethiopia

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Abstract

Introduction: Accelerated water quality change due to industrial pollution is one of the major environmental concerns throughout the world. In Ethiopia, Pollution of surface water is largely a problem due to rapid urbanization and industrialization. The main objective of this study was to determine the pollution profile of Modjo River throughout study sites.

Methods: A cross-sectional study was conducted to assess water pollution along Modjo River. Ten sampling sites were selected based on wastewater discharge, accessibility and pollution feasibility of river water. The sampling frequency was for two rounds composite sample taken from Modjo River. The chemical parameters were determined in the laboratory by using standard instrumental method AAS and UV-VIS.

Results: Temperature, Electrical conductivity, Turbidity and PH were within the acceptable limit of surface water standard. Ammonia Nitrogen (NH_3-N), BOD, Phosphorous, Nitrate Nitrogen (NO_3-N) was all above acceptable limit except for BOD and Ammonia Nitrogen in station 1 within acceptable limit. TDS above standard limit in Stations 5, 6, 7, 8, 10 were above acceptable limit. COD of station 2, 3, 4, 8, 9 and above the acceptable limit. For chromium stations 3, 6, 8, 9 and 10 above acceptable limit of surface water standards.

Conclusion and recommendations: The study result found that there was change on the physico-chemical parameters from upstream to downstream areas, which indicates an introduction of pollution load from industrial wastewater. It is recommended that National Environmental Quality Standard (NEQS) should be strictly enforced on all industries to install facilities and treat wastewater effectively.

Keywords: Sewage; Pollution; Microorganisms; Waste water

Abbreviations: AAS: Atomic absorption spectrophotometry; APHA: American Public Health Association; BOD: Biochemical Oxygen Demand; COD: Chemical Oxygen Demand; DO: Dissolve Oxygen; EC: Electrical conductivity; EPA: Environmental Protection Agency; NTU: Nephelometric Turbidity Units; SIT: Stevens Institute of Technology; TDS: Total dissolved solids; THM: Trihalomethane; UNEP: United Nations Environmental Programme; UNIDO: United Nations Industrial Development Organization; UV-VIS: Ultraviolet and visual spectrophotometry.

Introduction

Accelerated water quality change due to industrial pollution is one of the major environmental concerns throughout the world. Industrial effluents and domestic sewage contribute large quantities of nutrients and toxic substances that have a number of adverse effects on the water bodies and the biota [1]. Pollution of surface and ground water is largely a problem due to rapid urbanization and industrialization [2,3]. The quality of surface water affected by natural processes (precipitation, weathering processes and soil erosion) and anthropogenic effects (urban, industrial and agricultural activities and the human exploitation of water resources) [4,5].

Pollution may result from point sources or diffuse sources (non-point sources). The major point sources of pollution to freshwaters originate from the collection and discharge of domestic wastewaters, industrial wastes or certain agricultural activities, such as animal husbandry. Most other agricultural activities, such as pesticide spraying or fertilizer application, are considered as diffuse sources. The atmospheric fall-out of pollutants also leads to diffuse pollution of the aquatic environment [6].

An estimated 90% of wastewater in developing countries was still discharged directly into rivers and streams without any waste treatment or after retention period in stabilization ponds [7].

Wastewater is a good nutrient broth for growth of microorganisms. The components of a typical wastewater may not be ascertained, but it contains nutrient, microorganism, toxic component, debris etc. The indiscriminate discharge of wastewater into receiving environment is a major cause of threat in public health [8]. Water contaminated by effluents from various sources is associated with heavy disease burden [9] and influence the current shorter life expectancy in the developing countries compared with developed nations [10].

Environmental pollution derived from domestic and industrial activities is the main threat to the surface water qualities in Ethiopia. The majorities of industries in the country discharge their wastewaters into nearby water bodies and open land without any form of treatment [11,12].

Industrial and chemical pollution constitute the third major (land degradation and urban sanitation are first and second respectively) problem in Ethiopia. Chemical waste from the industries has poisoned Lake Koka and the Awash River, destroying the ecosystem. A scientific

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Received February 19, 2016; **Accepted** March 30, 2016; **Published** April 04, 2016

Citation: Gebre AE, Demissie HF, Mengesha ST, Segni MT (2016) The Pollution Profile of Modjo River Due to Industrial Wastewater Discharge, in Modjo Town, Oromia, Ethiopia. J Environ Anal Toxicol 6: 363. doi:10.4172/2161-0525.1000363

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study conducted to determine the concentrations of heavy metals in the extract from watermelon grown around Lake Koka where pollutants (chromium, iron, nickel and lead) contributed by Modjo River [13].

The objective of this study was to determine the pollution profile of Modjo River throughout study sites.

Materials and Methods

Study setting

The study was conducted at Modjo, central Ethiopia. It is located 75 kilometers to East of Addis Ababa, the capital of the country. The Modjo Town is one of the industrial zones in the country. Modjo town got the name from the nearby Modjo River, located in the eastern Shoa zone of Oromia regional state. This town has a latitude and longitude of 8°39′N 39°5′E 8.65°N 39.083°E with an elevation between 1788 and 1825 meters above sea level. It is the administrative center of Lome woreda (Figure 1).

A cross-sectional study was conducted from March to May 2010 on the analysis of pollution status in Modjo River. The study design includes both observational and laboratory analysis. A sanitary survey was carried out in Modjo River to find out the source of water pollution.

Sampling sites (Stations)

Sample stations were selected based on accessibility, safety, potential sources of pollution, and wastewater disposal sites. The stations were randomly distributed along the course of the river with more emphasis on polluted sites [14]. Sampling stations were points located the immediate downstream of industrial effluents inter into Modjo river.

To determine the pollution load from industrial wastewater, ten representative composite samples were collected from down industrial wastewater discharge into Modjo River. The ten sampling stations in the river were designated as Station-1 to Station-10 (Figure 2) as they reflect different industries along the watercourse of the river. Sampling site Station-1 represents the upper stream where the river enters into the town while Station-10 represents the downstream of the river ending at Modjo town. Sampling sites Station-2 to Station-9 were selected in between Station-1 and Station-10 and grouped as middle steam sites of Modjo River.

Physical parameters: Temperature, Electrical Conductivity, Turbidity.

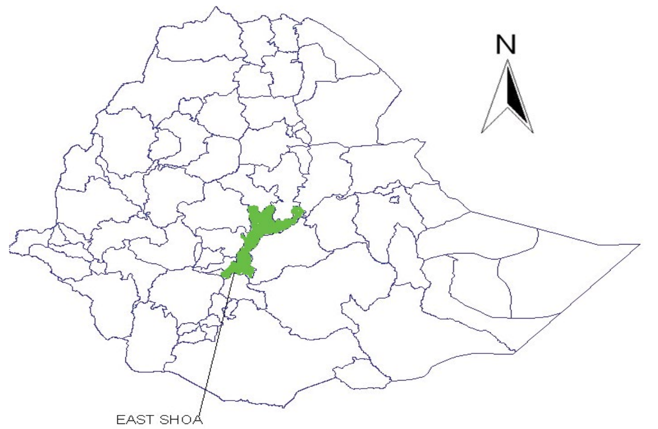

Figure 1: East Shoa Zone (Arc, view, 3.2, GIS).

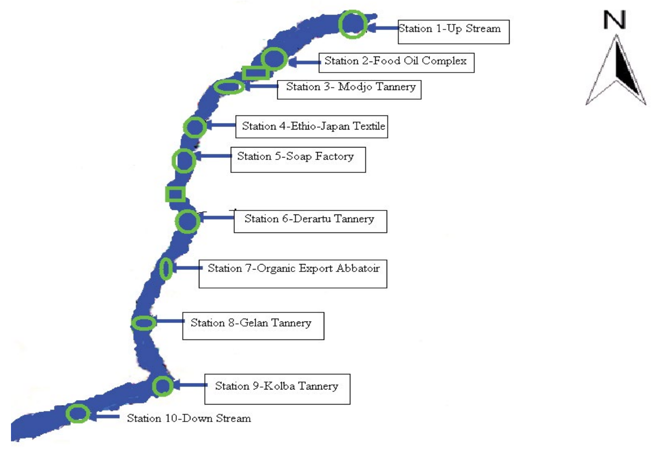

Figure 2: Sketch Map of Modjo River.

Chemical Parameters: TDS, pH, BOD, COD, Chromium, Nitrate-Nitrogen (NO_3-N), Nitrite-Nitrogen (NO_2-N), Ammonium Nitrogen (NH_4-N) and Orthophosphate.

Methods of data collection

Composite samples were taken from Modjo River for the two round sampling frequencies. Sample collections were considering both spatial and temporal variations'. Samples were collected using the conventional [15] standard methods.

The sample should be mixed before the sample water poured; the sample bottle should be clean, filled to the brim, airtight and kept under cold conditions. Then, the collected samples were kept in a one liters plastic bottles. All sample bottles were stored in cold box and delivered on two days to laboratory. All samples were kept in the refrigerator until laboratory processing and analysis [16,17].

Sampling techniques

Rivers generally have only one spatial dimension (i.e., longitudinal) and a pronounced time variability whereas groundwater's are characterized by low, to very low, time variability and two to three spatial dimensions [6].

Water sample collection started by dividing the river into three parts (left, right and center) across the width of the river. Then from each sites, 300 ml of water sample was taken and mixed in to plastic bottle. Due to the variety of wastewater, discharge during working hours, the data collection times also based on pick hours (09:00 AM, 11:00 AM and 03:00 PM).

After finishing data collection, the three-sample re-mixed and taken one liter for each ten stations of sampling sites. Therefore, all water samples were composited with a time and place interval in to plastic bottles for laboratory analysis.

Physicochemical sample analysis

pH and temperature were measured by pH meter. Electrical conductivity (EC) and total dissolved solids (TDS) were measured by conductivity meter (Hanna instruments, version HI 9828). The turbidity was measured onsite using a microprocessor turbid meter (HACH Company, Model 2100 P).

Water samples for chemical measurement was collected and filtered through filter paper. BOD could be determined using titration method (Azide Modification of the Winkler Method). UV-VIS (Ultraviolet and visual spectrophotometry) analysis for COD and BOD of thermo reactor model HACH, 5000.

Chromium was determined using flame method i.e., AAS (Atomic absorption spectrophotometry. The concentrations of orthophosphate as P (Stannous Chloride Method), Ammonia-nitrogen (Direct Nesslerization Method), Nitrate- nitrogen (Phenoldisulfonic Acid Method) and Nitrite- nitrogen (Diazotization Method) were determined in the laboratory by the standard UV-VIS (Ultraviolet and visual spectrophotometry) analysis (HACH DR/2010, and 5000, USA).

Data quality assurances

Samples were properly taken to laboratory analysis. For a test that needs to be done on the sampling site, it was done as soon as possible at the sampling sites. AAS, UV-VIS, turbidity meter, pH and conductivity meter were the standard instrument used for measuring physico-chemical parameters. The standard reagent used during laboratory analysis were Nessler reagent for ammonia nitrogen test, Sulfanilamide reagent for nitrite nitrogen test, Phenol disulfonic acid reagent for nitrate nitrogen test, Ammonium molybdate reagent for phosphate test, Alkali iodide azide reagent for BOD test, Sulfuric acid reagent for COD test and standard chromium solutions for chromium test were used during laboratory investigations. Computing standard error and standard deviation also performed while data analysis part.

Statistical analysis

Data were entered using SPSS 16. Descriptive statistics was used to depict the findings. The mean and standard deviation were calculated. Person Correlation was performed to the association between physico-chemical parameters.

Ethical consideration

Ethical approval and clearance was obtained from Public Health and Medical Science College of Jimma University. Cooperation letter written from Jimma University was submitted to Modjo town Health Bureau to get permission to proceed the study.

Results

Physical parameters

The mean value result of physical parameters was displayed in Table 1 below. In station 9, the mean value of temperature and electrical conductivity while turbidity was high in station 5, while lowest value for temperature in station 2, electrical conductivity in station 1 and turbidity in station 2.

Chemical parameter

The results of DO value for all stations were approximately equal to 5.67 mg/l. Maximum mean value of pH was in station 10 and minimum pH was in station 2. The least TDS value was in station 4 and maximum TDS value was in station 8. The highest mean BOD and COD value was registered in station 7 and station 8, while the least value was recorded in station 1. The highest mean value of chromium was recorded in station 10 while the least value was in station 1 and station 2 (Table 2).

The result showed that mean values of ammonium nitrogen was in station 8 while the lowest value was in station 1. The mean values of NO_3-N were maximum in station 9 while least value was recorded in station 5. Similarly the maximum mean value of NO_2-N was in station 10 whereas least value was in station 7. Finally maximum mean value of PHOs was in station 9 whereas least value was recorded in station 6 (Table 3).

Correlation of physico chemical parametrs

The person correlation result showed that, Temprature was significantly correlated with stations (r=0.8 at p-value=0.003), pH significantly correlated with stations(r=0.71 at p-value=0.02) and NO_3N significantly correlated with stations (r=0.68 at p-value=0.03 BOD strongly correlated with COD (r=0.942, at p=0.00). BOD significantly cooralated with NH_4-N (r=0.69 at p-value=0.016) and NO_3N (r=0.69, at p=0.028). COD significantly corraleted with chromium (r=0.77 at p-value=0.026) and NH_4N (r=0.75 at p-value=0.012), at P=0.033). TDS significantly correlated with NO_2N (r=0.86 at p-value=0.01). NH_4-N significantly correlated with NO_3-N (r=0.697 and at p=0.025). pH significantly corraleted with NH_4N (r=0.74 at p-value=0.014), NO_3N (r=0.74 and at p=0.014) andphosp (r=0.73 at p-value=0.017). EC significantly corraleted with NH_4N (r=0.87 at p-value=0.001), pH (r=0.73 at p-value=0.016), BOD (r=0.77 at p-value=0.009) and COD (r=0.72 at p=0.018) and NO_3-N (r=0.78 and at p=0.008) (Table 4).

Discussion

The mean values of temperature for all sampling stations were in between 18.45 to 23.8°C. The mean values of temperature in station -9,

Sampling Station	Mean T°C	Mean Electrical conductivity in μS/cm	Mean Turbidity in NTU
Station 3	21.95 ± 0.64	419.45 ± 0.78	366.6 ± 1.27
Station 4	22.6 ± 2.83	211.35 ± 1.91	438.4 ± 0.71
Station 5	22.55 ± 1.64	236.2 ± 1.69	830.45 ± 0.78
Station 6	23.6 ± 0.71	218.4 ± 1.13	718.45 ± 0.78
Station 7	23 ± 1.41	307.3 ± 1.594	669.85 ± 0.21
Station 8	23.5 ± 23.5	394.25 ± 1.06	564.6 ± 0.85
Station 9	23.8 ± 0.436	427.55 ± 1.2	763.95 ± 0.07
Station 10	23.2 ± 0.14	238.15 ± 1.77	619.25 ± 1.06

Table 1: The mean value results of physical parameter analysis of water samples from Modjo River along the sampling stations, May 2010.

Sampling Station	pH	TDS mg/L	BOD (mg/L)	COD (mg/L)	Chrom (mg/L)
Station 1	7.74 ± 0.34	383.5 ± 0.78	61.2 ± 0.92	86.3 ± 0.78	
Station 2	6.69 ± 0.61	486.9 ± 0.21	132.2 ± 0.64	180.7 ± 0.99	
Station 3	8.83 ± 0.11	388.1 ± 1.27	354.2 ± 0.36	460.5 ± 0.64	3.86 ± 0.007
Station 4	8.28 ± 0.11	262.5 ± 0.85	110.9 ± 1.27	150.5 ± 0.71	0.31 ± 0.007
Station 5	8.16 ± 0.06	549.9 ± 1.49	81.7 ± 0.56	95.7 ± 0.99	0.23 ± 0.007
Station 6	8.46 ± 0.27	548.6 ± 0.64	85.8 ± 1.13	130.9 ± 1.2	1.34 ± 0.006
Station 7	8.14 ± 0.06	505.5 ± 0.78	161.8 ± 0.35	110.5 ± 0.71	0.16 ± 0.004
Station 8	9.93 ± 0.6	565.9 ± 1.34	161.8 ± 0.35	253.9 ± 0.14	3.65 ± 0.001
Station 9	11.08 ± 1.03	394.5 ± 0.78	230.5 ± 0.71	341.7 ± 0.49	3.85 ± 0.063
Station 10	8.85 ± 0.07	854.5 ± 0.78	220.5 ± 0.64	341.9 ± 0.14	8.02 ± 0.24

Table 2: The mean value results of chemical parameter analysis of water samples from Modjo River along the sampling stations, May 2010.

Station	NH_4-N (mg/L)	NO_3-N (mg/L)	NO_2-N (mg/L)	PHOs (mg/L)
Station 1	0.11 ± 0.01414	0.7375 ± 0.00354	0.1145 ± 0.00636	0.2895 ± 0.01344
Station 2	0.18 ± 0.01414	3.265 ± 0.09192	0.224 ± 0.00566	0.695 ± 0.07778
Station 3	35.115 ± 0.44548	5.435 ± 0.34648	0.1175 ± 0.02475	0.625 ± 0.09192
Station 4	0.3575 ± 0.00354	0.726 ± 0.00849	0.138 ± 0.01131	0.77 ± 0.02828
Station 5	0.4285 ± 0.04031	0.71 ± 0.01414	0.22 ± 0.04243	0.745 ± 0.10607
Station 6	0.349 ± 0.01273	4.225 ± 0.03536	0.18 ± 0.08485	0.18 ± 0.07071
Station 7	0.235 ± 0.00707	3.44 ± 0.05657	0.08 ± 0.07071	0.2685 ± 0.02616
Station 8	39.1 ± 0.56569	6.445 ± 0.06364	0.345 ± 0.19092	0.875 ± 0.03536
Station 9	29.85 ± 1.3435	7.84 ± 0.05657	0.0805 ± 0.09829	19.15 ± 1.06066
Station 10	4.445 ± 0.34648	5.92 ± 0.02828	0.58 ± 0.08485	0.515 ± 0.0495

Table 3: The mean Concentration of nutrients in water samples from Modjo River along the sampling stations, May 2010.

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	Stat	Tem	EC	TUR	pH	TDS	BOD	COD	Chrom	NH_4N	NO_3N	NO_2N	Phos
Stat	1	**0.825**	0.483	0.481	**0.706**	0.600	0.272	0.330	0.599	0.295	**0.681**	0.490	0.406
		0.003	0.157	0.160	**0.023**	0.067	0.447	0.351	0.117	0.407	**0.030**	0.150	0.244
Tem		1	0.552	0.554	**0.723**	0.266	0.272	0.277	0.209	0.348	0.494	0.173	0.301
			0.098	0.097	**0.018**	0.458	0.447	0.438	0.619	0.325	0.147	0.633	0.399
EC			1	-0.011	**0.733**	-0.040	**0.773**	**0.723**	0.285	**0.870**	**0.782**	-0.091	0.509
				0.976	**0.016**	0.913	**0.009**	**0.018**	0.495	**0.001**	**0.008**	0.803	0.133
TUR				1	0.468	0.213	-0.262	-0.251	-0.175	-0.060	0.018	-0.035	0.291
					0.173	0.555	0.465	0.484	0.679	0.870	0.960	0.924	0.414
pH					1	0.036	0.453	0.550	0.456	**0.742**	**0.740**	0.041	**0.727**
						0.922	0.188	0.099	0.256	**0.014**	**0.014**	0.910	**0.017**
TDS						1	0.066	0.146	0.619	-0.098	0.347	**0.863**	–0.223
							0.856	0.687	0.102	0.788	0.325	**0.001**	0.535
BOD							1	**0.942**	0.597	**0.694**	**0.689**	0.076	0.286
								0.000	0.118	**0.026**	**0.028**	0.835	0.423
COD								1	**0.769**	**0.750**	**0.764**	0.251	0.358
									0.026	**0.012**	**0.010**	0.485	0.310
Chrom									1	0.403	**0.720**	**0.727**	0.177
										0.322	**0.044**	**0.041**	0.675
NH_4N										1	**0.732**	**-0.002**	0.417
											0.016	0.997	0.230
NO_3N											1	0.275	0.544
												0.442	0.104
NO_2N												1	-0.281
													0.432
PHO													1

Table 4: The correlation of physico-chemical parameters of Modjo River, May 2010, Ethiopia.

station -6, station-8 and station-10 were the highest values. The reason for high values may be due to the addition of wastewater from Gelan, Derartu, Ethio-Japan textile and Kolaba tannery industry discharged into Modjo River.

Surface waters are usually within the temperature range 0°C to 30°C, although "hot springs" may reach 40°C or more [18]. The temperature values for all stations were within the permissible limits of NEQS. The temperature of Modjo river water was below 25°C.

The mean value of EC in Modjo River was between 104.4 to 427.6 µS/cm. This observation is supported by a similar study of the Modjo River 119 to 341 µS/cm [19].

The turbidity values of station -5, station -9, station-6 and station-1 was the highest values. Normal values range from 1 to 1,000 NTU [6]. Even though, the turbidity values were within the acceptable limit of the normal values, there was an increase from upstream site to downstream sites. This may be because of the industrial effluents enters to Modjo river contains high organic and inorganic matter which raised the actual values. Similar study in Modjo River showed that turbidity (265 to 689 NTU) [19] the range was of this study greeter than the previous study.

The pH values ranged from 6.69 and 11.08. All pH values except station-9 were within the permissible limits for industrial effluents set by NEQS.

The values of TDS ranged from 262.5-854.5 mg L^{-1}. The TDS value of station -10, station -8, station-5, station-6 and station-7 was high. Similar study in Hulka River in Ambo showed that TDS 81.5-388 mg/L [20].

The values of chromium ranged from 0-8.02 mg L^{-1}. The chromium values of station -10, station -3, station-9, station-8 and station-6 were greater than NEQS standards (1 mg/L). The highest value in station -10 was due to accumulation of chromium from all tannery effluents but the highest values of the next staton-10 were may be all of them were tannery industrial effluents which realizes the chemicals into the river water after tanning process. Metal compounds are not biodegradable. Similar studies in Modjo river found that 3.71 to 5.31 mg/l [12].

The BOD values ranged from 61.15 to 354.15 mg L^{-1}. The BOD value of station -3, station -9, station-10 and station-8 was highest. Similar study in Hulka River in Ambo showed that BOD 46- 250 mg/L and in Modjo river 11.13 to 260.64 mg/L [12].

The COD values was ranged from 86.25 to 460.45 mg/L. The COD values of majority of the stations were above the permissible limits of NEQS. The reason for increase of COD were due to industrial effluents enters to river water contains both organic and inorganic carbon compounds. Similar study in Hulka River in Ambo showed that COD 23- 540 mg/L [20] and in Modjo river 22.02 to 607 mg/L [12].

The ammonia nitrogen and nitrate nitogen values of station -8, station -3, station-9 and station-10 was highest. Total ammonia concentrations measured in surface waters are typically less than 0.2 mg l^{-1} N but may reach 2-3 mg l^{-1} N [6]. The levels of ammonia nitrogen in similar study of Tikur Wuha River was in the range of (2.93–6.8 mg/l) and was below the standared discharge limit 30 mg/l [11].

The mean value of phosphuruse in this study was ranged from 0.18 to 19.15 mg/l. Similar studies on Modjo River reported that the values of phosphate ranged from 0.6-1.9 mg/l [21]. In most natural surface waters, phosphorus ranges from 0.005 to 0.020 mg l-1 PO_4-P [6]. All station of phosphorus concentrations was above the surface water requirements.

Significant correlation observed between some of physico chemical parameters (p-value<0.05).

Conclusions

The physical parameter analysis result showed that in all stations temperature, EC and turbidity values were within the acceptable standards of surface water. PH, TDS, turbidity COD, BOD, chromium, nitrogen and phosphorous values were increasing from upstream to downstream. It is recommended that National Environmental Quality Standard (NEQS) should be strictly enforced on all industries to install facilities and treat wastewater effectively.

Acknowledgements

We would like to express our special thanks to Jimma University for financial support. Our thanks go to Mrs. Mulu B. the Modjo town environmental health co-coordinator for her assistance during sample taking.

Authors Contributions

AEG conceive the study design, analysis of the sample and prepared the manuscript. MTS, STM and HFD participated analysis and preparation of the manuscript.

Conflict of Interest

The authors declare that they have no conflict of interest.

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