Preliminary assessment on the microplastic contamination in the atmospheric fallout in the Phuoc Hiep landfill, Cu Chi, Ho Chi Minh city

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Abstract:

Microplastic pollution has become a global issue in recent years. Since the early 2000s, scientists have investigated the occurrence of microplastics (MiPs) in the environment. While research on marine MiPs is more advanced at present, there are immense gaps of knowledge regarding continental MiPs. Airborne MiPs are one source of MiPs in the aquatic environment. In the scientific literature, there have been only three publications on presence of MiPs in atmospheric fallout. In developing countries, where plastic waste management is weak, studies on the presence of MiPs in this area are limited. This current study presents a preliminary assessment of the presence of MiPs in atmospheric fallout sampled from the Phuoc Hiep landfill, Ho Chi Minh city (HCMC). The results of this work show that MiP concentrations vary between 1,801 items $m^{-2}d^{-1}$ and 913 items $m^{-2}d^{-1}$ in the dry and rainy seasons, respectively.

Keywords: **atmospheric fallout, microplastics, Phuoc Hiep landfill.**

Classification number: **5.1**

Introduction

Nowadays, plastic pollution is an emerging concern worldwide. Global plastic production increases annually by approximately 3% and reached 335 million tons in 2017 [1], which has led to a dramatic change of the type of solid wastes discharged into the environment. Especially in developing countries, where plastic wastes are often mismanaged or abandoned in illegal dumping sites, plastic pollution is significantly contributing to environmental pollution [2]. As a result, plastic particles can be transferred to aquatic environments. Many studies have shown that plastics are found from continental aquatic system such as lakes, canals, and rivers to the oceans along the coastal zones, seabed sediments, beach sands, floating on the water's surface and even in frozen ice in the Arctic and Antarctic regions [3].

The existence of plastic waste in the aquatic system poses challenges to the world's environment. The 2030 Agenda for Sustainable Development and its Sustainable Development Goals dedicated several necessary goals that are relevant to this issue (e.g. SDG 11, SDG 12, SDG 14), especially Target 14.1 which states: "By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution". More seriously, under impacts from many factors such as mechanical processes, oxidation, and biodegradation, microplastics (MiPs), i.e. plastic particles comprised between 1 μm and 5 mm in

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size [4] are formed and can last thousands of years in the environment due to their chemical stability and durability [5]. MiPs are considered as a new pollutant that is of great concern by the world due to its deleterious effects on the survival and reproduction of aquatic organisms [6] through ingestion and accumulation [7] as well as its effect on human health through seafood, salt ingestion, and inhalation of airborne MiPs [8].

Recent years, global studies have shown the distribution of MiPs and their harmful effects on marine environments such as seas [9-11], freshwater lakes [12, 13], rivers [14, 15], and terrestrial environments in Vietnam. Authors also reported that the concentrations of MiPs in the water of HCMC's canals and the Saigon river varied from 270 to 518×10^3 fibres m^{-3} and from 7 to 223 fragments m^{-3} [16].

While the presence of MiPs in the marine environment is widely documented, their sources, dynamics, and fate in rivers and estuaries remain poorly understood and largely undocumented [17, 18]. Among the sources of MiPs, urban inputs such as wastewater treatment plant effluents are increasingly studied while the atmospheric compartment is mostly neglected, though the fact that the presence of MiPs in atmospheric fallout has become an environmental and social challenge due to their ability to spread toxic additives, organic, and inorganic contaminants that adhere to the MiPs' surface, the aquatic environment, or even directly to the human body during inhalation [17]. So far, there have only been three publications on MiPs in atmospheric fallout in Donguan (China), Paris, and a remote area called French Pyrenees (France), which all show that there was a significant concentration of MiPs in the atmosphere in those areas [19-21].

HCMC, the economic capital of Vietnam and one of the most dynamic developing cities from South East Asia, was chosen to study MiPs in atmospheric fallout. This study aimed to determine the occurrence of MiPs in atmospheric fallouts at Phuoc Hiep landfill, during the dry and rainy seasons, and point out the physical characteristics of suspected items.

Materials and methods

Sampling

Sample collection was conducted during both dry and rainy seasons at the Phuoc Hiep landfill (10°57'53.8"N 106°26'18.7"E) located in the northwest of HCMC and operated by the HCMC Urban Environment Company Limited (Citenco) (Fig. 1). The designed disposal volume of this landfill is around 4.4 million tons. There were 8 samples collected during the dry season (December 2018 and January 2019) and the rainy season (May and June 2019) with a sampling duration of 3 or 4 days for each sample (Table 1).

Fig. 1. Sampling location.

The design of the sampling device employed in this research was based on a previous study [19], which consisted of a 250 mm diameter glass funnel placed on a 10-litre glass bottle to collect rainwater and air dust falling into the funnel area and into the bottle. The sampling device was placed at a height of 3 m above ground (Fig. 2).

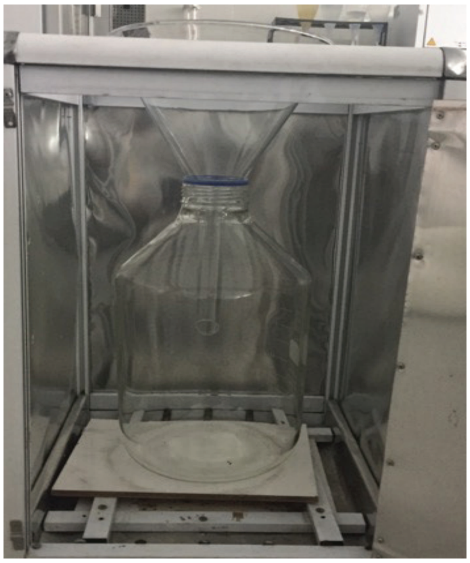

Fig. 2. The sampling devices.

Digestion protocol

The samples were digested before filtration to degrade organic matters for better stereomicroscopic observation. The extraction method was based on the protocol proposed by Ref. [22] (Fig. 3) and briefly described as follows:

Step 1: sieving the sample through a 1-mm sieve to remove big organic pieces.

Step 2: density-separating the sample, using NaCl (Merck®, 1.18±0.02 gcm^{-3}), the sample : NaCl volume ratio was 1:1.

Step 3: adding 1 g of sodium dodecyl sulfate (SDS, Merck®) to the sample and storing the sample at 50°C for 24 h.

Step 4: adding 1 ml of biozym SE (protease and amylase, Spinnrad®) and 1 ml of biozym F (lipase, Spinnrad®) to the sample and storing the sample at 40°C for 48 h.

Step 5: adding 15 ml of hydrogen peroxide (H_2O_2, Merck®) to the sample and storing the sample at 40°C for 48 h.

Step 6: filtering the sample through glass fibre filters (GF/A, Whatman®, 1.6 µm porosity), using a glassware filtration set.

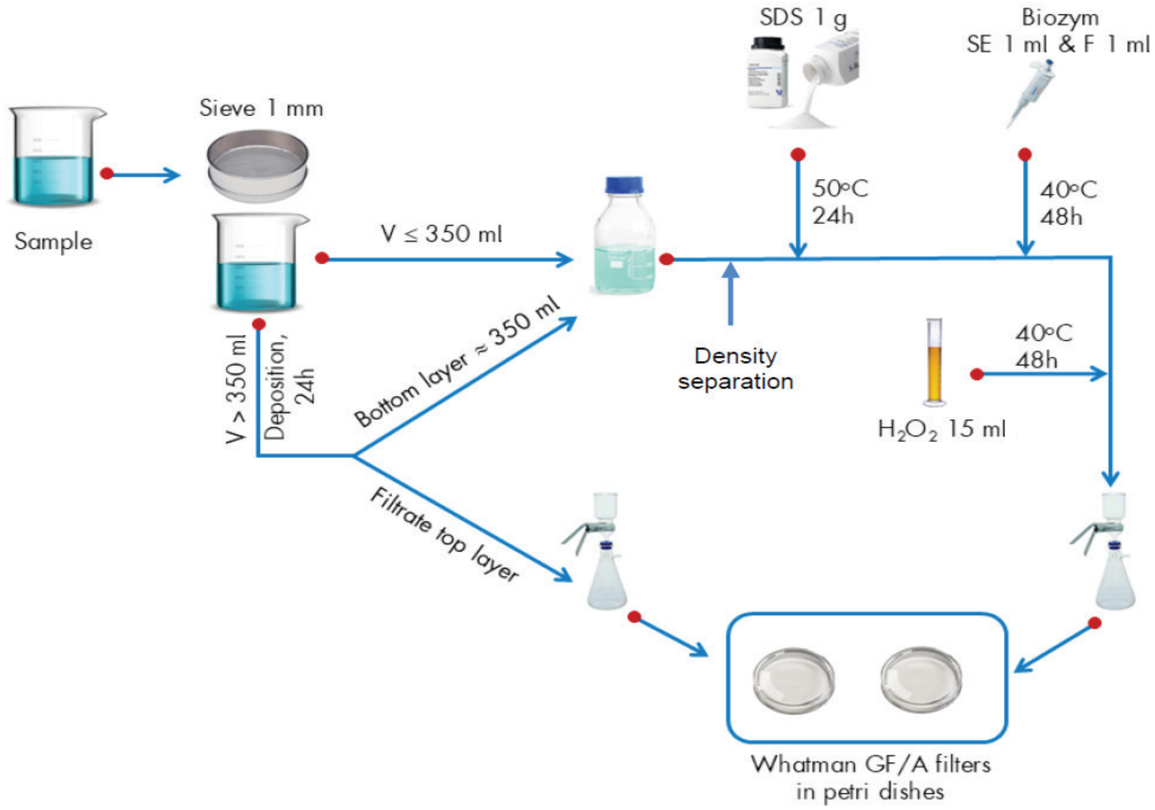

Fig. 3. Protocol for extraction of microplastic fibres from atmospheric fallout samples.

So far, MiP qualitative analyses were mostly carried out using FTIR (Fourier Transform InfraRed Spectrometry) combined with a microscope [11]. In this study, due to the unavailability of the equipment, the MiPs were defined based on the criteria proposed by Ref. [23]. The filters after the treatment period will be observed by a S6D stereomicroscope integrated with a MC170 camera and LAS software (Fig. 4) for analysing physical characteristics (quantity, shape, size, colour) of the MiPs. It is worth emphasizing that the size range of the MiPs observed in this study were 100 µm to 5 mm for the fibres' length and fragments' longest dimension.

Fig. 4. S6D stereomicroscope integrated with a MC170 camera.

Results and discussions

Microplastic occurrence

There were a total of 1,791 microplastic fibres and fragments observed from 8 samples, with fibres being more predominant than fragments (1,142 fibres or 64% compared to 649 fragments or 36%) (Fig. 5). The concentration of MiPs was calculated from the number of MiP fibres and fragments, the diameter of the sampling funnel (250 mm), and the sampling duration (Table 1, Fig. 6).

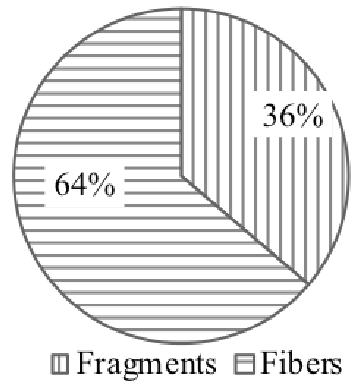

Fig. 5. Percentage of total microplastic fibres and fragments found in all samples.

The concentration of MiPs (both fibres and fragments) was 1,356.8 items $m^{-2}d^{-1}$, roughly 50 times more than what was measured in Paris, which was 2 to 355 items $m^{-2}d^{-1}$ of sizes ranging from 200 mm to 5 mm, and under the conditions of filtration without digestion step [20]. Similar to the results reported by these two sites, fibre was found to be the dominant shape initially identified by visual observation of the suspected items in the atmospheric fallout.

The concentration of the observed MiP fragments and fibres fluctuated during the sampling time, and a particularly large number of items were found during the dry season (Fig. 6). During the dry season, the average concentration of fibres found at the sampling site was 1,333.5 items $m^{-2}d^{-1}$, about 3 times more than the concentration of observed fragments, which was 467.7 items $m^{-2}d^{-1}$. During the rainy season, the concentration of MiPs did not show any significant difference, with concentrations of 515.7 and 396.8 items $m^{-2}d^{-1}$ for fragments and fibres, respectively. Besides, the concentration of MiPs in the dry season (1,801.2 items $m^{-2}d^{-1}$) was 2 times greater than in the rainy season, about 912.5 items $m^{-2}d^{-1}$ (Table 1). This indicates that there is less microplastic accumulation in the atmospheric fallout at the Phuoc Hiep landfill during rainy days, which may be due to the impact of rainfall limiting air pollutant concentrations [24]. MiP monitoring should be carried out to better understand the temporal variation of MiP concentration.

Table 1. Concentration of microplastic fibres and fragments found at Phuoc Hiep landfill.

Season	Sampling time	Sampling duration (days)	MiP counts		MiP concentration (items $m^{-2}d^{-1}$)		Average seasonal MiPs concentration (items $m^{-2}d^{-1}$)		
			Fragments	*Fibers*	*Fragments*	*Fibers*	*Fragments*	*Fibers*	*Total*
Dry	20/12/2018	4	24	129	122.2	657.0	467.7	1,333.5	1,801.2
	24/12/2018	3	27	185	183.3	1,256.3			
	03/01/2019	4	54	217	275.0	1,105.2			
	07/01/2019	3	190	341	1,290.2	2,315.6			
Rainy	16/05/2019	4	25	59	127.3	300.5	515.7	396.8	912.5
	27/05/2019	3	37	64	251.3	434.6			
	03/06/2019	4	176	86	896.4	438.0			
	06/06/2019	3	116	61	787.7	414.2			

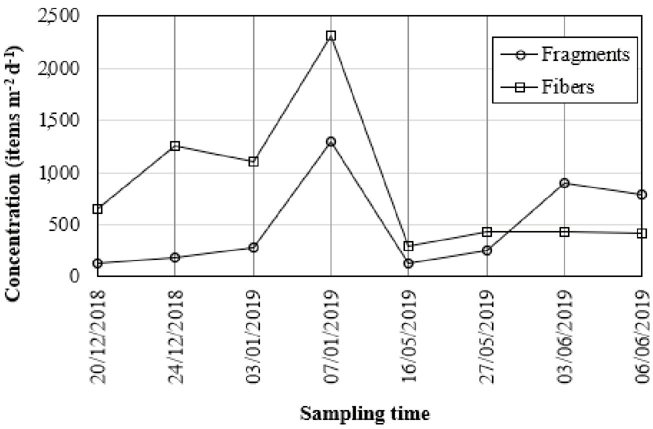

Fig. 6. Concentration of microplastic fibre and fragments concentration (items $m^{-2}d^{-1}$) with sampling time.

Physical characteristics of microplastics

Concerning the size of MiPs found at this study location, within the observation size range stated previously, i.e. 100 µm to 5 mm for fibres' length and fragments' longest dimension, most of the fibres and fragments are considered to be in the small size range (Fig. 7). As seen in Fig. 7A, the smallest fibres ranging from 100-500 µm in length were predominant at nearly 74.5% of the total fibres counted, while longer fibres were relatively rare. This result was similar to the length distribution of fibres shown by Ref. [20].

The fragments were predominant over a small surface area, with 409 fragments in the surface area range of 1,000-10,000 μm^2, which occupied 63% of the total number of fragments observed for all dry and rainy days (Fig. 7B).

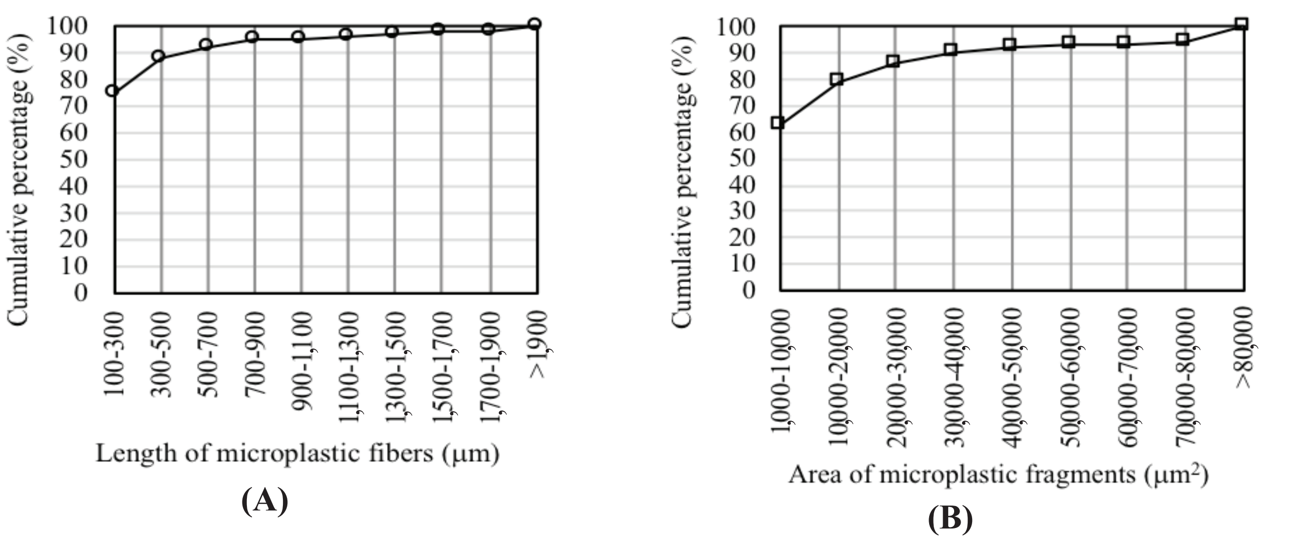

Fig. 7. Cumulative percentage of (A) length of microplastic fibres (mm) and (B) area of microplastic fragments (mm^2).

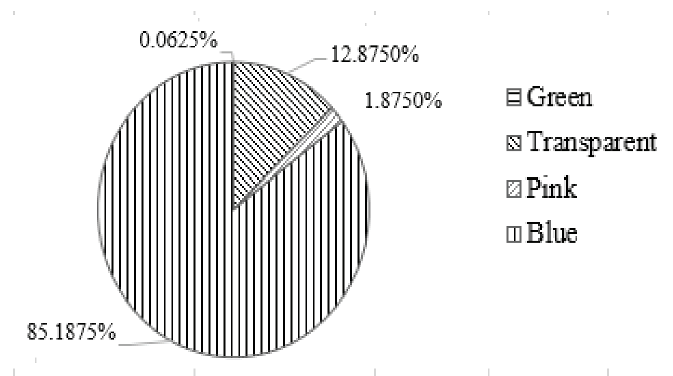

Fig. 8. Total microplastics with colours found in the atmospheric fallout collected in the Phuoc Hiep landfill.

In terms of colour, blue MiPs were the most dominant for both fibres and fragments (Fig. 8). At different sampling times, blue fibres fluctuated from 89% for the sample collected on Jan 03, 2019 to 99% for the sample collected on June 06, 2019, as seen in Fig. 9A. The other colours, in decreasing order, were pink (1 to 9%), transparent (0 to 2%), and green (0 to 1%). For fragments, the percentage of MiP colours fluctuated more in comparison to that of MiP fibres. At different sampling times, blue fragments fluctuated from 12% for the sample collected on June 6, 2019, to 100% for the sample collected on June 03, 2019, as seen in Fig. 9B. The other colours, in decreasing order, were transparent (0 to 88%) and pink (0 to 1%). There was no green colour found among all the samples. The microplastic fibres and fragments found in the sample collected from the Phuoc Hiep landfill under a stereomicroscope is shown in Fig. 10.

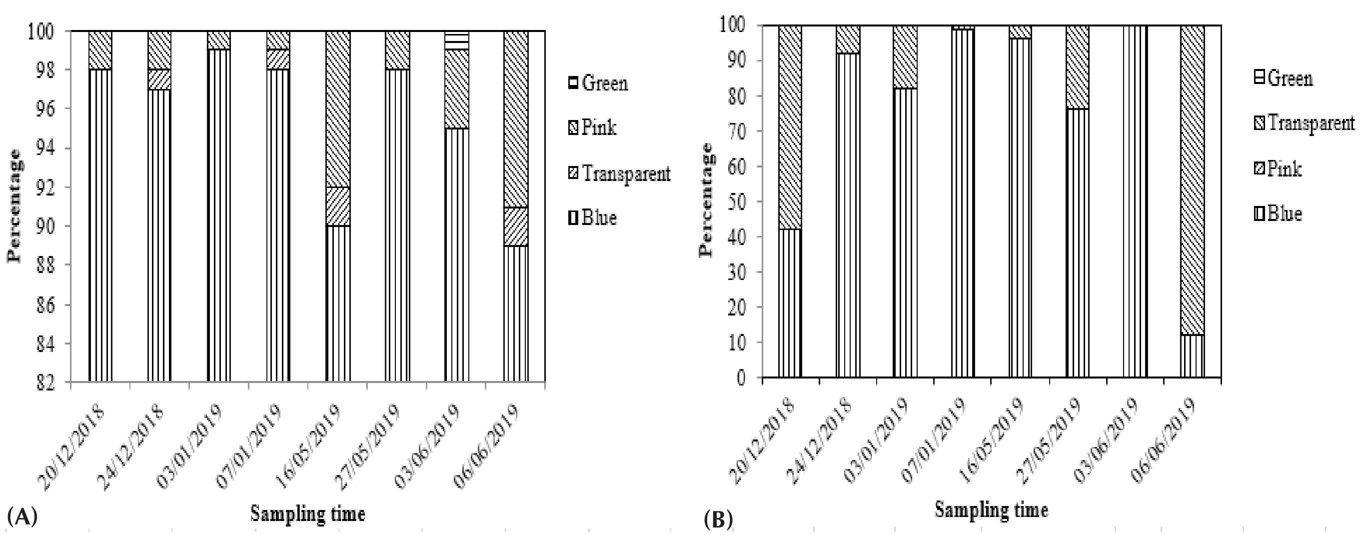

Fig. 9. Colour distribution of MiPs in the atmospheric fallout samples taken at Phuoc Hiep landfill for (A) fibres and (B) fragments.

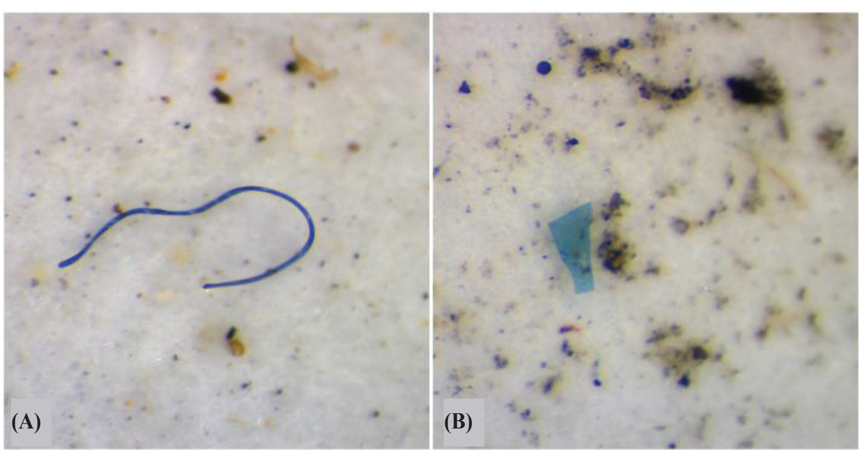

Fig. 10. An example of a microplastic (under stereomicroscope) from the sample collected at the Phuoc Hiep landfill in the form of (A) fibre and (B) fragment.

Comparing the results obtained from this study to the MiPs on the surface water of the Saigon river [16], there may be some similarities in terms of size range and colour distribution of MiPs found in the atmospheric fallout. Further study should be carried out to determine if any correlation in MiPs size and colour exists.

Conclusions

This study reported a significant amount of MiPs found in atmospheric fallout at the Phuoc Hiep landfill, Cu Chi, HCMC. In particular, the results showed that the concentration of MiPs in the atmospheric fallout at Phuoc Hiep landfill were 1,801.2 items $m^{-2}d^{-1}$ and 913 items $m^{-2}d^{-1}$ in dry and rainy seasons, respectively. Physical characteristics such as shape, colour, and size of the microplastic particles were also clarified and discussed. Future work aimed at providing more data on MiP accumulation in the atmosphere needs to be considered and implemented throughout the world. Besides, scanning electron microscope and Fourier-transform infrared spectroscopy should be carried out in further studies for surface texture and chemical composition analyses of atmospheric microplastics.

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The authors declare that there is no conflict of interest regarding the publication of this article.

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