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Assessment of Soap and Cosmetic Effluents quality in Metallic Trace Elements from Yopougon Industrial Area, Abidjan, Ivory Coast

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Abstract: In this study, the concentrations (mg / L) of trace metal elements (TME) in an effluent from an industrial soap and cosmetic unit (SCI11) were evaluated. Four (4) composite samples and a witness sample (1) were collected. Nine (9) physicochemical parameters (T, pH, E_H, SS, Al, Cr, Fe, Pb, and Zn) were analyzed according to AFNOR standards. The results showed that these effluents are characterized by high mean concentrations of suspended solids (266.75 ± 147.20 mg / L and Cr (0.678 ± 0.068 mg / L) which are far beyond the reference values of the Service Inspection of Classified Installations (SIIC). On the other hand, the mean concentrations of TME Fe, Al, Zn, respectively at 0.585 ± 0.03 mg / L, 0.618 ± 0.030 mg / L, and 0.244 ± 0.015 mg / L are in agreement with the SIIC reference values. The study also found that the effluent is behaving like a reducer with a mean E_H redox potential of (-13 ± 1.87 mV). Mean values of pH (6.67 ± 0.60) and temperature T (29.58 ± 0.82 ° C) are in the order of the values recommended by the SIIC. Overall, the PCA analysis has shown that this effluent is a source of TME pollution and physical SS pollution.

Keywords: Effluents, Soap factories, Cosmetics, Pollution, TME

1. Introduction

The management of industrial liquid rejections remains a challenge for developing countries, particularly our country Côte d'Ivoire [1]. Yopougon is one of industrial areas of abidjan, where factries are concentrated [2]. This area is confronted to the serious plague which is linked to the managing of effluents. This fact is due to the lack of sanitation facilities [3,4]. In this area, the soap and cosmetics factories that are located are almost affected by this sad observation [5]. This sector of activity is faced to a rapid growth due to an increased need of the population in terms of detergents and cosmetics [5]. These industrial units are among backbones of ivorian economy because they strongly contribute to the economic growth with significant volume of production [5]. The effluents from the various production activities requiring the use of water. After using water it rejected into the Ebrié lagoon without prior treatment [6]. However, the formulation of detergent and cosmetic products contains various physicochemical raw materials such as metallic trace elements (TME), surfactants, dyes or pigments, bleaching agents, etc. In these detergent and cosmetic effluents, TMEs have a wide range of applications in the formulation of conservators, adjuvants and pigments [7]. Several studies on TME carried out in different environmental compartments have shown their negative impacts [8, 9,10]. Indeed, TMEs are persistent, toxic and ecotoxic beyond certain level of concentration thresholds [11,12]. Several studies have shown contamination and accumulation of these TEMs both in agricultural products from the aquatic ecosystem and in the atmosphere [13]. To deal with this environmental pollution, the industrial effluents from soap and cosmetics factories must be analysed before discharging them is necessary. In recent years, the scientific community has focused on the treatment of soap and cosmetic effluents in order to provid a suitable solution to the management of this type of liquid waste [14]. Processes (physical, chemical and advanced oxidation) have shown their effectiveness in the treatment of this type of effluent [14, 15]. However, these processes are expensive so that is why they mostly remained at the experimental stage without being valorized. Faced to this limit, the Circular Economy, which is a research axis in sustainable development, constitutes an alternative solution for the management of effluents [15-20]. Indeed, this path of research allows decontamination and reuse of effluents by combining experimental and theoretical approaches [16-20]. To achieve this aim, a physicochemical and microbiological characterization of the target effluent is first necessary. In Yopougon industrial area, the effluents from soap factories have been the subject of recent studies [6, 21]. Studies by our research team have shown that these effluents are indicators of pollution. However, the suspected impact of TMEs in these effluents in our previous study was not evaluated [6, 21] although they are involved in the formulation of detergents and cosmetics as colorants, zeolites etc. For a more complete study, the evaluation of the quality of the effluents from soap factories and cosmetics in terms of TME is necessary. In the present study, the contents of five (5) TEM such as Al, Cr, Fe, Pb and Zn have been determined. And the physical parameters namely pH, T and SS in the effluent of an industrial unit were measured too. This assessment allowed both to determine the typology of the effluent and to point out the various physico-chemical reactions induced by the effluent.

2. Materials and Methods

2.1 Materials

Located in sub-Saharan Africa, Côte d'Ivoire is one of the economically strong countries in West Africa. Its agricultural policy, coupled with its important industrial fabric, make Côte d'Ivoire an essential country of the West African Economic and Monetary Union (AEMOU) [22]. Abidjan, its economic capital, brings together the country's major industrial areas [23]. Yopougon industrial area is a very wide industrial hub which is located west of Abidjan town. It covers an area of 645 hectares [23] and has around 400 factories divided into various sector of activities [23]. It is an area with a very high industrial density (concentration). In fact, 45% of Abidjan's industries belong to this area [23]. In addition, most soap and cosmetic industries (SCIs) are concentrated in this area [6, 21, 23]. Consequently, the result is a high production of soap and cosmetics effluents (SCE) which are thrown into the Ébrié lagoon without prior treatment [6, 21, 24]. Mapping of the study area (Figure 1) shows a few soap and cosmetic factories.

The "SCI11" soap and cosmetic unit (Figure. 1) was selected for sampling study. It has been chosen choice according to its strong growth due to the amount of both its capital and its production volume and the diversity of its detergent and cosmetic products on the market [25]. The good vitality and dynamism of this industrial unit of soap and cosmetics, requires the use of various chemical species in the production process, thus generating large scale of effluents. This "SCI11" unit was not studied in our previous works. The study material is therefore Effluents of Saop et Cosmetic from this factory. The equipment needed for effluent samples collection from the “SCI11” soap and cosmetics unit consists of a GPS (*GPS map 60CSx GARMIN*) used for determining the geographical coordinates of the sampling sites, a landing net which was used to collect liquid samples, polyethylene and glass bottles and a cooler for storing samples. The hydrogen potential (pH), the temperature (T) and the redox potential (E_H) are measured at the different sampling sites (in situ measurement) using a multi-parameter HI 8314 probe. The suspended matter (SS) (NF T 90-105) is obtained by filtration using wattman filters with a porosity of 0.45 µm. This measurement is carried out in the laboratory. The studied trace elements were analyzed by a graphite furnace atomic absorption spectrophotometer (Varian Spectr AA 110), operational in graphite furnace mode with electrothermal atomization (dosage in mg / L) and in flame mode (dosage in µg / L). Water used for manufacturing commercial products of "SCI11" unit, served as witness control effluent in the various tests.

2.2 Methods

During each week of the month of October 2019 a campaign of effluent sampling is carried out from the "SCI11" unit. During the process, which lasts about 5 hours, the effluent flows continuously and stored in a tank before being discharged. Sampling is made by using polypropylene bottles of 250 mL and 1 L, washed and rinsed beforehand with distilled water [26, 27]. For each sample, the scoop is immersed in the tank about 25 cm deep to collect a sample of 250 mL. Four 250 mL effluent samples, taken at 90-minute time intervals, are mixed to obtain a composite sample of 1L per campaign. The witness sample was collected in a 1 liter bottle from the tap of the tank containing water of the unit which is deserves to domestic use and formulation. The bottles are labeled and stored at 4 ° C in a ice box, then transported to the laboratory within 24 hours for analysis [26, 27]. The samples which were used for the determination of TME were treated with nitric acid ((HNO_3, 10%) as soon as collected up to pH = 1.5 to ensure good conservation of the constituents [26, 27]. For the measurement of the pH, the temperature (NF T 90-008) and the redox potential (NF ISO 10390), the samples were taken in polyethylene bottles. These measurements in situ are carried out with an electrochemical probe of the HI 8314 brand. In 25 mL of the sample which will analyzed, which is previously homogenized, the electrochemical probe is introduced into the sample and the reading is carried out according to the selected physical parameter. The probe is rinsed with distilled water after each measurement.

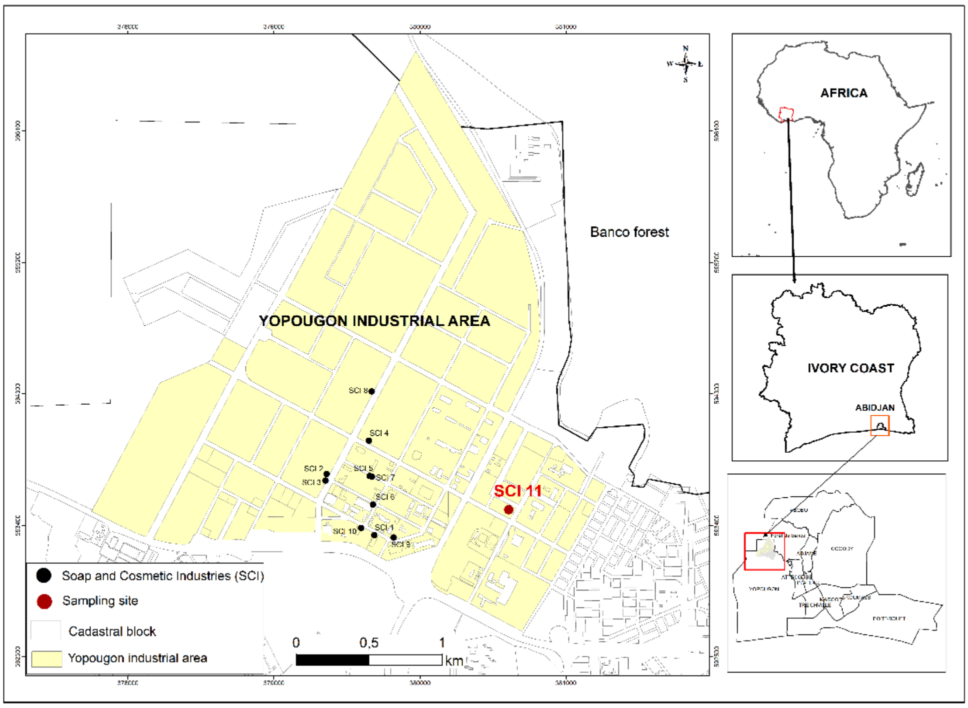

Figure 1 Some soap and cosmetic units from the study area [6, 21, 23]

For the measurement of suspended matters (NF T 90-105), the samples are collected with a polyethylene bottle. These samples are filtered by the Wattman filter with a porosity of 0.45 µm. TME analysis is performed according to ISO 15856 using a graphite furnace atomic absorption spectrometer (SAA Varian Spectr AA 110). The method is based on measurement by atomic absorption spectroscopy with electrothermal atomization**.** All glassware must be carefully cleaned before any TME dosage by rinsing it with dilute nitric acid ((HNO_3, 10%) and then several times with ultrapure water [27, 28]. The sample is injected into a graphite tube and electrothermally heated at various stages to atomize the analyte**.** This atomization takes place in three stages: drying; decomposition and atomization. Thus, the graphite tube, positioned in the head of the furnace, provides an inert gas and a powerful voltage to heat this tube. This then causes dislocation and then atomization of the sample into free atoms [27,28]. The produced signal is, under optimum conditions a sharp, symmetrical peak, narrow half-width. The height of the peak is, for most elements, proportional to the element concentration in the solution; however, for some elements it is preferable to work from a peak area [27, 28]. Statistical processing of data through Shapiro-Wilk normality tests, descriptive statistics (mean and standard deviation), correlation matrix, Principal Component Analysis (PCA), were carried out using *XLSTAT* software. 2016. The raw and average values of the determined effluent parameters are compared with the reference values to locate the pollution level of the soap and cosmetic effluent.

3. Results and discussion

3.1- Results

3.1.1 Comparison of the values of the analyzed parameters with the reference values.

The evolution results of the concentration of each TME during the four sampling campaigns are compared with the reference values of the Service Inspection of Classified Installations (SICI) and those of the World Health Organization (WHO) [29, 30] and are presented in Table 1 below.

During all four (4) campaigns, it is observed that the concentrations of TME in the effluents are lower than SICI reference values, except of chromium (Cr) which concentrations are greater than the limit value of 0. 1 mg / L. The lead (Pb) concentration remains constant (0.005 µg / L) in all effluents and in witness sample. On the other hand, in water deserved to the preparation of detergents and cosmetics, the concentrations of chromium (Cr), aluminum (Al), and iron (Fe) are higher than the reference values (V_{WHO}) of the WHO. It is also noted that the Cr concentrations in all effluents remain higher than the reference value (V_{SICI} = 0.1 mg / L) of the SICI. Over the study duration, the mean values of all physicochemical parameters which have fixed were examined. The average values of the physico-chemical parameters which have been measured in the different samples are presented in Table 2.

Table 1 ETM concentrations in soap and cosmetic effluent samples (SCE) and in witness sample (SCE0), compared to the reference values of SICI (V_{SICI}) and WHO (V_{WHO})

Samples	*SCE1*	*SCE2*	*SCE3*	*SCE4*	*SCE0*	V_{SICI}	V_{WHO}
Cr (mg/L)	0.585	0.668	0.778	0.680	0.389	***0.100***	***0.050***
Al (mg/L)	0.629	0.652	0.571	0.620	0.540	***5.000***	***0.100-0.200***
Fe (mg/L)	0.548	0.572	0.636	0.585	0.491	***5.000***	***0.200***
Zn (mg/L)	0.224	0.242	0.267	0.244	0.102	***2.000***	***3.000***
Pb (µg/L)	0.005	0.005	0.005	0.005	0.005	***0.500***	***0.010***

Table 2 Average values of the physicochemical parameters measured over all four campaigns. The minima and maxima are also indicated.

parameters	*Moy±DS*	*Min*	*Max*
T (°C)	29.580±0.820	28.800	30.900
pH	6.670 ±0.600	5.850	7.540
E_H (mV)	-13.000 ±1.870	-16.000	-11.00
SS (mg/L)	266.750 ± 147.200	100.000	500.000
Cr (mg/L)	0.678 ± 0.068	0.585	0.778
Al (mg/L)	0.618 ± 0.030	0.571	0.652
Fe (mg/L)	0.585 ± 0.032	0.548	0.636
Zn (mg/L)	0.244 ± 0.015	0.224	0.267
Pb (µg/L)	0.005 ± 0.000	0.005	0.005

Table 3 Pearson correlation matrix between the physicochemical parameters of studied soap and cosmetic effluents.

parameters	T	pH	E_H	SS	Cr	Al	Fe	Zn
T	**1.00**							
pH	**0.84**	**1.00**						
E_H	0.41	-0.15	**1.00**					
SS	-0.36	0.20	**-1.00**	**1.00**				
Cr	**0.86**	**1.00**	-0.11	0.16	**1.00**			
Al	**-0.98**	**-0.72**	-0.58	0.53	**-0.75**	**1.00**		
Fe	**0.94**	**0.98**	0.06	-0.01	**0.99**	**-0.85**	**1.00**	
Zn	**0.87**	**1.00**	-0.09	0.14	**1.00**	**-0.76**	**0.99**	**1.00**

Analysis of Table 2 shows that the mean effluent temperature which equals 29.58 ± 0.82 °C is below the SIIC limit value of 40 ° C. The average pH value is 6.67 ± 0.60 during all 4 campaigns. This value complies with the SICI direct discharge pH limit value is ranging from 5.5 mg / L to 8.5 mg / L. The values of the redox potential remain less than 40 mV with an average value of -13.00 ± 1.87 mV [31]. The mean concentration of SS equals 266.75 ± 147.20 mg / L which indicates that the concentration in terms of SS of the effluent from this factory is greater than the limit value (150 mg / L) of the SIIC. All the effluents have also, a mean concentration in terms of iron (Fe) which equals 0.585 ± 0.032 mg / L. This avarage value is much lower than the limit one which equals 5 mg / L and required by the SICI. As far as Zn is concerned, the mean value of its concentration is 0.244 ± 0.015 mg / L. This average value is much lower than the reference one (2 mg / L) which is required by the SICI. In addition, the average concentration of aluminium (Al) is 0.618 ± 0.030 mg / L which is in agreement with the value recommended by the SICI (5 mg / L). However, it is observed that the effluent has an average concentration of chromium (Cr) which equals 0.678 ± 0.068 mg / L and this value exceeds largely the standard one (0.1 mg / L) required by SICI.

3.1.2- Correlation between physicochemical parameters

The correlation matrix reveals correlations between analyzed physicochemical parameters (Table 3). Analysis of the table shows significant correlations (in blue bold) between certain parameters. Indeed, temperature is positively correlated with pH, Cr, Fe and Zn. On the other hand, it shows a strong negative correlation with Aluminium (Al). Strong positive correlations of the pH are observed with Cr, Fe and Zn. However, this parameter has a negative correlation with Aluminium (Al). Examination of Table 3 also reveals that the redox potential (E_H) has a strong negative correlation with the SS. As far as chromium (Cr) is concerned, it is perfectly and positively correlated with Zn and Iron but negatively correlated with Al. Regarding Al, it shows negative correlations with Fe and Zn. Finally, Iron establishes a strong positive correlation with Zn.

3.1.3- Effluents typology

A principal component analysis (PCA) was applied to the experimental values of the different parameters. Table 4 indicates the eigenvalues of the factorial axes. Factors F_1 and F_2 respectively express 69.32% and 30.65% of the total variability. These two factors express 99.97% of the explained variance. They thus provide the maximum information (100%) about physicochemical quality of characterized soap and cosmetic effluents. The correlations between physicochemical parameters of effluent and the factor axes are given in Table 5.

Table 4 Eigenvalues and factors

	F_1	F_2
Own value	5.55	2.45
Variability (%)	69.32	30.65
cumulative%	69.32	**99.97**

Table 5 Correlation coefficients between physicochemical parameters of effluent and factors F_1 and F_2

	F_1	F_2
T	**0.97**	-0.25
pH	**0.95**	0.31
E_H	0.17	**-0.99**
SS	-0.12	**0.99**
Cr	**0.96**	0.27
Al	**-0.90**	0.43
Fe	**0.99**	0.11
Zn	**0.97**	0.25

In blue, the most significant correlations

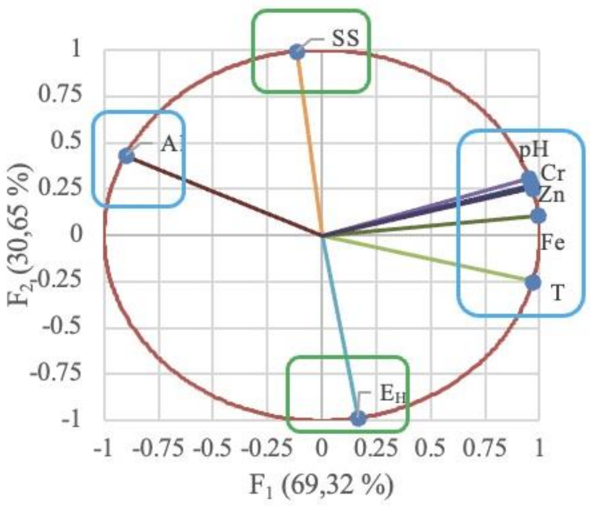

Figure 2 Correlation circle of analyzed parameters in the factorial plane (F_1-F_2).

Analysis of Table 5 reveals significant correlations between factors F_1 and F_2 and certain analyzed physicochemical parameters. Indeed, the factor F_1 defines a strong positive correlation with parameters such as temperature T, pH, Cr, Fe and Zn. In contrast, this factor F_1 shows a strong negative correlation with Al. These parameters contribute to the formation of the pollution parameter related to F_1. Factor F_1 characterizes soap and cosmetic (SCE) effluents with TME pollution which is influenced by pH and temperature (T). Moreover, the factor F_2 is negatively correlated with E_H. It opposes to this parameter, SSs with a strong positive correlation. This factor reflects a physical pollution parameter of soap and cosmetic effluents (SCE). This pollution is influenced by the redox potential. Figure 2 illustrates the correlation circle of the analyzed parameters and highlights the different oppositions of the groups of parameters in the factorial plane (F_1-F_2).

3.2- Discussion

The effluent from the soap and cosmetic industry "SCI11" has an average temperature which is 29.58 ± 0.82 ° C. This value is lower than the guide one T<40 ° C [32]. Therefore, this industry could use a semi-boiling process or a cold process for detergent and cosmetic products manufacturing. The recorded pH mean value during the analyzes (6.67 ± 0.60) is within the interval recommended by SICI. These pH and temperature values of effluent from this factory are conform with those measured in our former work referenced (Jean Missa Ehouman, 2018), at the level of the effluents from certain soap and cosmetic units in the same area, specialized in manufacturing. toiletries and cosmetics. The measured mean value of redox potential (-13.00 ± 1.87 mV) at the level of these effluents over all four campaigns is less than 40 mV. Consequently, these effluents are reducing, according to Rodier [31]. This reducing nature of effluent is linked to the strong presence of SS. Indeed, the redox potential establishes a perfect negative correlation with SS. The increase in SS in the effluent is the cause a reduction in the redox potential, thus increasing the effluent reducer skill. This reducing property of these effluents contributes to the speciation of TMEs. TMEs are generally present in the aquatic environment, in cationic, colloidal and particulate form. These non-degradable TMEs enter the aquatic environment through the drainage of suspended matters and are spread in the different compartments (water, sediment, flora and fauna) certainly constituting an impact on aquatic biodiversity. The mean concentration of 266.75 ± 147.20 mg / L of effluent in terms of SS is above required value (150 mg / L). These values are similar to those found by Ehouman et al, for certain soap and cosmetic industries in the same area [6, 33]. SS are the transport vectors of metallic trace elements by absorption in the aquatic environment according to M. Ponthieu et al, [34]. The presence of TME, even at low concentrations in the effluents constitutes a danger for aquatic flora and fauna. In addition, the drainage of these SS in the lagoon limits the penetration of light into the environment This fact will cause a decrease in the oxygen content which is required for the survival of aquatic species [35]. Principal component analysis revealed that factor (F1) is a pollutant parameter of metallic trace elements. Admittedly, the effluent has mean concentrations in terms of TME (Al, Fe, Pb and Zn) which are in strong agreement with recommended standards in effluents, but these TME concentrations present a danger for aquatic biodiversity through an accumulation process [36]. This process is favored by the transformation of TME in several forms (ionic, solid). Consequently, strong observed correlations of the kinetic factors (T, pH) (Table 7) with analyzed TMEs, justify the danger that these effluents present both for biodiversity and human being health [37]. Also, Cr has high concentrations in these effluents. The chromium in these effluents occurs in different forms in the receiving environment. This speciation of chromium (trivalent: Cr^{3+}, hexavalent: Cr^{6+}) is governed by temperature and pH [38]. This is justified by the strong positive correlation of Cr with temperature and pH. Trivalent chromium is considered non-toxic and relatively immobile in nature, while highly toxic and mobile hexavalent chromium is soluble in the marine environment [39]. In addition, Cr present in effluents undergoes oxidation reactions to be transformed into Cr (VI) in the presence of microorganisms [40]. The use by the industrial unit of certain pigments such as $FeCr_2O_4$ chromite and $ZnAl_2CrO_4$ chromium granite is susceptible to explain the presence of certain TMEs in the effluent [41]. In particular, the concentration of Cr, which remains correlated with those of Fe and Zn, thus explaining that an increase of Fe and Zn concentration in effluent leads to an increase of Cr content. The toxic and ecotoxic effects of Cr have been studied. These studies have shown the impact of industrial discharges rich in chromium on various aquatic species (molluscs, fish, algae) and on sediments [42]. It should be noted that there is no less presence of this TME in the witness effluent for domestic use. This effluent can impact the health of people working in the factoy. Because, chromates or dichromates cause burns, ulcers of the skin and mucous membranes as well as irritation of the upper respiratory tract in human being [43].

4. Conclusion

This work made allow to assess the quality of trace metal elements (TME) of an effluent from soap and cosmetics factories from Yopougon industrial area. The concentrations of TME (Al, Fe, Pb and Zn) measured in these effluents in conformity with the limit values for industrial discharges except chromium. This metallic element appears as a tracer of element trace pollution. In addition, the results reveal that the effluent of "SCI11" is a metallic pollutant type factory which can impact aquatic biodiversity. It is therefore necessary to set up a process for managing this effluent with regard to its typology. At the end of this study, we recommend both that decision-makers in charge of the environment and industry to take care of the use and fate of nanoparticles which are involvedin the formulation of detergents and cosmetics. Côte d'Ivoire State must oversee the creation of this type of industry. However, given the typology of this effluent, its management through the circular economy remains the appropriate way to explore. In addition to previous work, it will be necessary to carry out a microbiological characterization of this effluent. Also, other formulation micropollutants must be analyzed.

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Conflict of interest

The Authors has no conflicts of interest to declare that they are relevant to the content of this article.

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