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Study of Pollution by Anionic Surfactants and Orthophosphates in M'koa Lake (Jacqueville, Côte d'Ivoire)

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Abstract: This study aims to assess the pollution of the surface water from M'koa Lake by both anionic surfactants and orthophosphates, and to identify the sources of pollution by these compounds. Three sampling campaigns were conducted at different seasons at six (6) sampling stations, identified in M'koa Lake by taking into account potential sources of pollution. The measurement of anionic surfactant concentrations was performed by the methylene blue colorimetric method, and the determination of orthophosphates was performed by the vanadomolybdophosphoric acid colorimetric method. In addition, the samples were analyzed in order to find six physico-chemical parameters of surface water quality which are temperature, pH, electrical conductivity, turbidity, oxygen saturation, transparency. The determination of these parameters were made according to both the French AFNOR standard and the methods described by Rodier. The obtained average concentrations of anionic surfactants in the water of M'koa Lake range from 0.23 ± 0.04 $mg.L^{-1}$ to 1.43 ± 0.68 $mg.L^{-1}$. Concerning orthophosphates' content they range from 0.12 ± 0.05 $mg.L^{-1}$ to 0.17 ± 0.04 $mg.L^{-1}$. These results indicate that M'koa Lake is subjected to pollution both by anionic surfactants and pollutant enriched by orthophosphate. And, the presence of orthophosphates in lake waters was not due solely to detergents. Washing stations, Berge 1 and 2, and M'koa hotel have the highest levels of anionic surfactants. Also, turbidity and transparency values indicate water quality deterioration of M'koa Lake favoured by the presence of phytoplankton corresponding to the eutrophication of the water of the studied Lake.

Keywords: Detergent, Organic Pollution, Physico-chemical Parameters, Eutrophication Surface Water, Fresh Water

1. Introduction

Phosphorus (P) and surfactants are one of the most used and abundant ingredients in household and industrial detergents, to a lesser extent in pesticides, herbicides, paints [1-4]. Indeed, a proportion of phosphorus in detergents and cleaning compounds contains tripolyphosphate, which is slowly mineralized to orthophosphates (PO_4^{3-}) in water [5]. Orthophosphate is soluble and considered to be the only type of P that is directly assimilated by most plants, including alga [5]. Excessive concentrations of orthophosphate in water cause eutrophication [6-8], which is defined as the enrichment of water bodies by nutrients and the consequent deterioration of quality due to the luxuriant growth of plants such as algae and its repercussions on the ecological balance of the waters affected [8, 9]. Concerning surfactants, in the absence of adequate treatment discharges of sewage, they show in the surface waters of a deplorable stability, so that there is a gradual accumulation effect. These organic molecules are absorbed by aquatic organisms and cause an imbalance in the aquatic ecosystem [10-12]. The surfactants are also responsible not only for causing foam in rivers and but also for reduction of water quality [11]. These are the most commonly used anionic surfactants in the detergent formulation [3, 4, 10, 12]. In Côte d'Ivoire, studies have been made about surface waters and water reservoirs. The results of the different studies indicate that the aquatic systems, without both adequate wastewater discharge system and treatment plants, undergo heavy physico-chemical and bacteriological pollution [13-16]. Several studies have been conducted to assess the quality of surface water in Côte d'Ivoire [13-15]. However, very few studies have been made on detergents in surface water. M'koa Lake is located in the center of Jacqueville's town and has a watershed constituted by three different kinds of area namely marshy, agricultural and urban. According to this observation, this paper aims at evaluating the levels of anionic surfactants and orthophosphates in the M'koa Lake water, and identifying the point sources of pollution of these compounds.

2. Material and Methods

2.1. Study Area

The city of Jacqueville is like an island (a peninsula), which is delimited by the Ebrié lagoon, the Atlantic Ocean and the city of Abidjan respectively at the north, the south and the west of concerned town (Figure 1). Onsite sanitation is autonomous practiced, and there is no politic of wastewater management politics that means the way of treating wastewater of each one differs. Jacqueville has 32,288 inhabitants [17], the economic development of the region is based on coconut (cultivation, trade; business). The city of Jacqueville is subject to the subequatorial climate (Attiean type) with four seasons: a long rainy season (from May to July), short dry season (from August to September), short rainy season (from September to November) and long dry season (from December to April). Temperatures are ranging from 21°C to 34°C [18]. M'koa Lake in Jacqueville which is the subject of this study, is a shallow natural lake, fed by infiltration with a maximum depth of 3.9 m and an spread which is area of about 0.180 km^2. M'koa Lake watershed consists of a marshy area, an agricultural area mainly composed of coconut groves and/or fallow crops, an urban area and its batch of wastewater discharges (Figure 2).

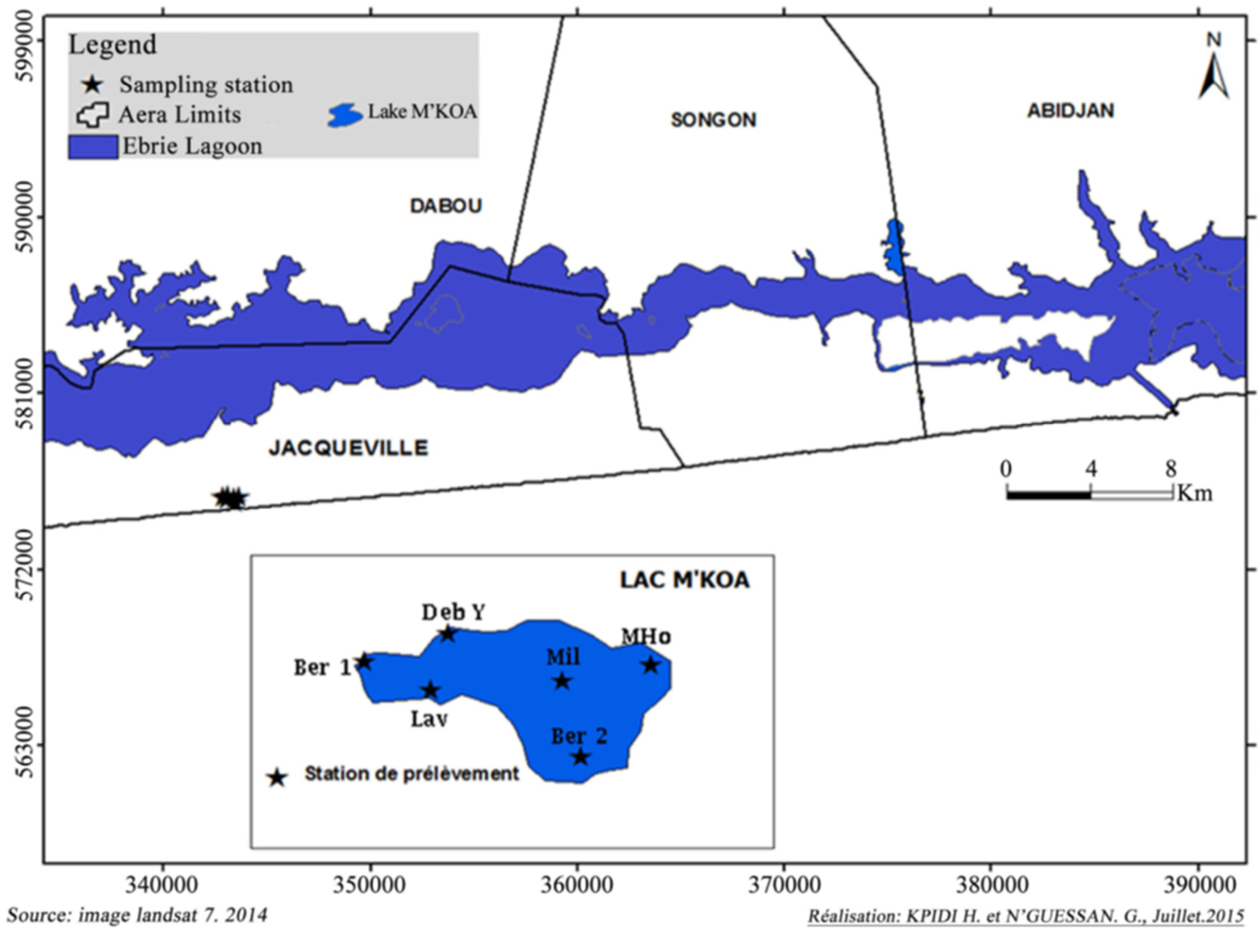

Figure 1. *Mapping of the study area [19].*

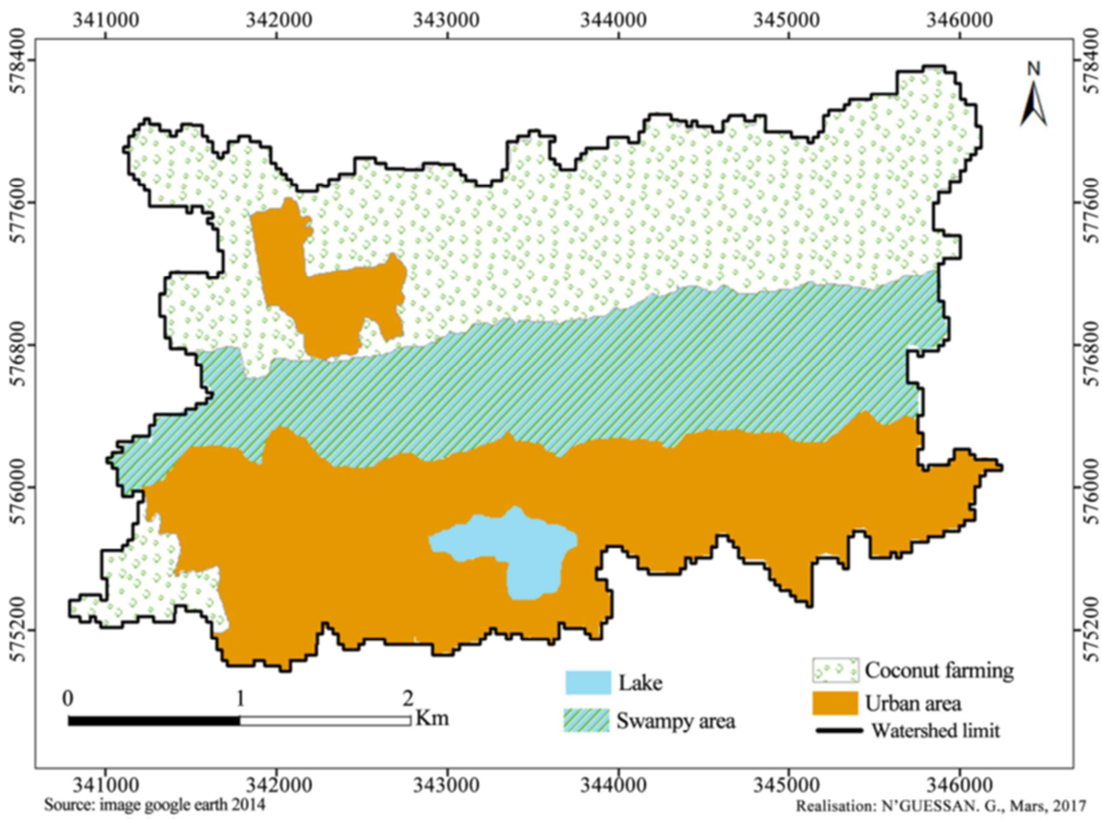

Figure 2. *Occupation of the M'koa Lake watershed.*

2.2. Physico-chemical Analyses

Three sampling campaigns of M'koa Lake surface water were carried out at different climatic seasons, November 2017 (short rainy season), March 2018 (long dry season), and May 2018 (long rainy season). Samples have been collected at six (6) stations taking into account both the potential sources of pollution and accessibility (Figure 1 and Table 1). And then samples were analyzed in order to find anionic surfactants et orthophosphate. In addition, the samples were analyzed in order to find six physico-chemical parameters of surface water quality which are temperature, pH, electrical conductivity, turbidity, oxygen saturation, and transparency. For each test, physical parameters namely: Temperature, pH, electric conductivity, oxygen saturation and transparency were measured in situ using a multi-parameter probe model HQ 40d (HANNA HI 99301), a HANNA HI 9146 oximeter, and a Secchi disk respectively. Anionic surfactants concentrations were determined by using the methylene blue colorimetric method [20], orthophosphates were measured according to the vanadomolybdophosphoric acid colorimetric method [21], and turbidity was measured with the HACH Lange 2100Q turbidimeter at ~~in~~ laboratory [22]. Samples were collected, transported and stored according to the procedures defined by AFNOR [23] and Rodier [24]. All chemicals were used of the highest purity available (Merck), and all glassware and laboratory equipments were carefully cleaned before using with HCl to minimize potential contamination. Water samples were collected by using glass bottles of 1.000 mL for surfactants (pH < 2 with H_2SO_4), 500 mL for turbidity and orthophosphates parameters. The samples were stored at +4°C until they were analyzed. Samples were filtered using 0.45 µm Whatman GF/C glass microfiber filters. Orthophosphates and Anionic surfactants were determined using UV Spectrometer (HACK-DR6000) at the Laboratory of the Ivoirian Anti-Pollution Center (LCE-CIAPOL).

2.3. Analysis of Anionic Surfactants by Methylene Blue Active Substances (MBAS) Method

The determination of low levels (typically 0-20 mg.L^{-1}) of anionic surface active materials by MBAS as described by ISO 7875-1 [20] is used in the analysis of a wide range of samples, including surface and potable waters. Higher concentrations can be diluted before analysis. Methylene blue dyes were used to determine anionic surfactants. A volume of 20 mL of the sample solution was put into a 40 mL vial (vial A) equipped with a screw-cap and Teflon liner. Then 2 mL alkaline buffer, and 1 mL natural methylene blue solution, followed by and 5 mL of chloroform, were added to vial A in that order. The vial was subsequently sealed using a holed screw-cap and Teflon liner, before being vigorously shaken using a vortex mixer for 2 min. After shaking, the content of the vial was left to awaitallowed to phase separation. The screw-cap was loosened to release the pressure inside. Once the two phases were separated, a Pasteur pipette was used to transfer the chloroform layer into a new vial (vial B) containing 22 mL ultra-pure water and 1 mL acid methylene blue solution. Vial B was then shaken using a vortex mixer for 2 min. The cap was loosened for a few seconds and then re-tightened. After the chloroform had completely separated from the water (after about 2 min), the chloroform layer was collected using a Pasteur pipette and put into a 10 mm quartz cell. The absorbance of the chloroform phase was measured with ultra-violet spectrophotometer at a wavelength of 650 nm.

2.4. Physico-Chemical Descriptors of the Quality of Surface Water

pH, temperature, electric conductivity, oxygen saturation, turbidity, and transparency are the physico-chemical descriptors of the quality of surface water. Temperature is the most important kinetic factor for all chemical and biological reactions in aquatic environments. It plays a fundamental role in the kinetics of physico-chemical and biological reactions and the value of equilibrium constants. In addition, a temperature above 15°C promotes the development of microorganisms, intensifies the biodegradation of organic matter [25]. The value of this parameter is influenced by the ambient temperature but also by possible discharges of hot waste water. Sudden changes of temperature of more than 3°C are often harmful [26]. The pH of natural water can vary from 4 to 10 depending on the acidic or basic nature of the crossed lands. Low pHs (acidic waters) increase the risk to find metals in ionic form which is the most toxic form. High pH increases ammonia concentrations which is toxic for fishes [26]. Electrical conductivity is a numerical expression of the ability of a solution to conduct electrical current, and most of the inorganic salts in solution are good conductors. The conductivity of a natural water is between 50 and 1500 µS / cm [26]. Knowledge of the content in terms of dissolved salt is important in so far as each aquatic organism has own specific requirements according to this parameter. Aquatic species do not generally support significant variations in terms of dissolved salts which can be observed for example in the case of wastewater rejection. Dissolved oxygen (concentration or % saturation) is too important as parameter in assessing the health status of a lake. It depends mainly on the respiration of the planktonic populations photosynthesis and the mineralization of biomass [27]. Overall, the higher the dissolved oxygen concentration, the greater the ability of the river to absorb pollution. At a temperature of around 25°C, the quality objective of 50% oxygen saturation corresponds to a concentration of 5 mg $O_2.L^{-1}$ [26]. Water transparency depends on the amount of particles (algae or sediment from erosion) in the water. In other words, when the water is murky or cloudy and contains a lot of particles, the light cannot penetrate as deeply into the water column. Turbidity reflects the presence of suspended particles in the water (organic debris, clays, microscopic organisms, etc.). It reduces both photosynthesis and the dissolved oxygen content because of the presence of biodegradable colloids [24, 26, 28]. Water turbidity is a good indicator in predicting the state of health of the wetland in order to maintain its ecosystem [24].

2.5. Data Statistical Analyses

The physico-chemical parameters of water coming from M'koa Lake were tested by univariate analyses (mean, standard deviation, minimum and maximum). Analyses of variance (ANOVA with one-factor) were used to test the significance between the averages of the different physico-chemical and biological parameters. The Tukey test was used to determine the significant differences between the stations. The mainPrincipal component analysis (PCA) presents in a limited space, the relationships between the studied parameters. All these analyses were made by using STATISTICA 7.1. Software.

Table 1. *Sampling stations and their corresponding GPS coordinates.*

Station	Code	GPS coordinats	Station characteristics
Berge 1	Ber 1	5° 12.415'N; 4° 2.045'W	Hotel residence + septic tank at ± 10m In height
Washing	Lav	5° 12.370'N; 4° 24.948'W	Washing "fanico", bare and steep terrain + strong erosion
Berge 2	Ber 2	5° 12.267'N; 4° 24.728'W	Laundry and dishes in the water, swimming and garbage dump nearby
M'koa Hotel	MHo	1° 12.410'N; 4° 24.627'W	Hotel infrastructure
Y. Landing	Deb	5° 12.457'N; 4° 24.922'W	Low-traffic pavilion house
M'koa Middle	Mil	5° 12.383'N; 4° 24.756'W	Deepest area of the lake

3. Results

3.1. Concentrations of Anionic Surfactants in M'koa Lake Water

Anionic surfactants contents of M'koa Lake's water range from 0.23 ± 0.04 $mg.L^{-1}$ to 1.43 ± 0.68 $mg.L^{-1}$. It can be seen that concentrations of anionic surfactants are higher in areas near domestic effluent discharge points (Berge 1 and 2 stations, M'koa hotel and washing stations), than those which are far away from them (Middle station) (Table 2). On the other hand, Landing Y. station located near a domestic discharge area is characterized by a low concentration of anionic surfactants. It should be noted that the Y. landing station receives wastewater from a low-traffic pavilion house. In addition, pH, temperature, electrical conductivity, oxygen saturation, turbidity and transparency mean values of these samples are presented in Table 3. Relationship between anionic surfactant concentrations and physico-chemical parameters was determined by "Linear regression analysis". No linear relation between anionic surfactant concentrations and physico-chemical parameters were found ($p > 0.05$). Applying Tukey test showed no significant difference between all the stations.

Table 2. *Average values of anionic surfactants and orthophosphates contents at different sampling stations of M'koa Lake.*

Station	Anionic surfactants / PO_4^{3-} ($mg.L^{-1}$) Mini	Anionic surfactants/PO_4^{3-} ($mg.L^{-1}$) Moy	Anionic surfactants/PO_4^{3-} ($mg.L^{-1}$) Maxi
Lav	0.53 / 0.08	1.13 ± 0.74 / 0.17 ± 0.09	1.96 / 0.25
Ber 2	0.78 / 0.07	1.43 ± 0.68 / 0.12 ± 0.05	2.14 / 0.16
MHo	0.33 / 0.12	1.29 ± 1.01/ 0.16 ± 0.06	2.35 / 0.22
Deb	0.20 / 0.12	0.23 ± 0.04 / 0.17 ± 0.04	0.28 / 0.19
Mil	0.15 / 0.09	0.24 ± 0.12 / 0.15 ± 0.08	0.38 / 0.24
Ber 1	1.10 / 0.11	1.27 ± 0.26 / 0.15 ± 0.04	1.57 / 0.19

Figure 3 shows that the concentrations of anionic surfactants in M'Koa Lake water vary according to the period and the place of sample collection. The highest concentrations were recorded in March, i.e., during the long dry season (low-flow period), with values ranging from 0.28 $mg.L^{-1}$ to 2.35 $mg.L^{-1}$, compared to those in May, varying from 0.15 $mg.L^{-1}$ to 0.78 $mg.L^{-1}$. The latter period corresponds to the long rainy season (flood's period). At the sampling stations, the highest levels have been observed at ber 1, lav, ber 2 and M'koa stations respectively with concentrations of 1.57 $mg.L^{-1}$, 1.96 $mg.L^{-1}$, 2.14 $mg.L^{-1}$ and 2.35 $mg.L^{-1}$.

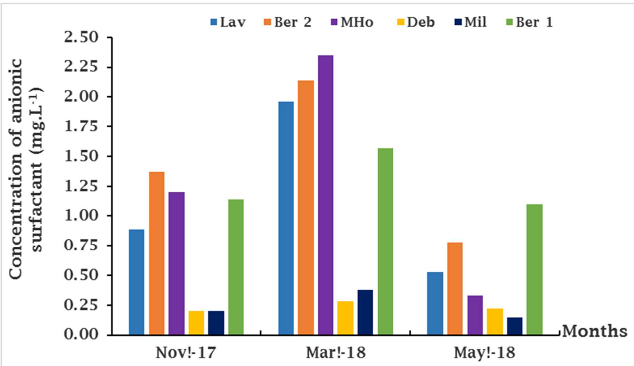

Figure 3. *Concentration of anionic surfactants as a function of surface water sampling periods in M'koa Lake.*

3.2. Concentrations of Orthophosphates in M'koa Lake Water

Mean orthophosphate (PO_4^{3-}) levels in M'koa Lake waters range from 0.12 ± 0.05 $mg.L^{-1}$ to 0.17 ± 0.04 $mg.L^{-1}$. In contrast, with anionic surfactants, the spatial variation of orthophosphate concentrations is relatively low between the different stations (Table 2). No significant variation between orthophosphate sampling stations was recorded ($p > 0.05$). Figure 4 shows the concentrations in orthophosphate based on sampling dates of surface waters of M'koa Lake. The highest values are recorded during the March season (long dry season) with concentrations ranging from 0.13 $mg.L^{-1}$ to 0.25 $mg.L^{-1}$, compared to 0.07 $mg.L^{-1}$ at 0.12 $mg.L^{-1}$ during the May campaign (major rainy season). Like anionic surfactants, the majority of orthophosphates would not drained to the lake by runoffs. On one hand, it is also noted that in March the washing station has the highest value e (0.25 $mg.L^{-1}$). On the other hand, in May the lowest value (0.07 $mg.L^{-1}$) is recorded at Bank Station 2. No linear relation between orthophosphates concentrations and physico-chemical parameters were found ($p > 0.05$). Applying Tukey test showed no significant difference between all the stations.

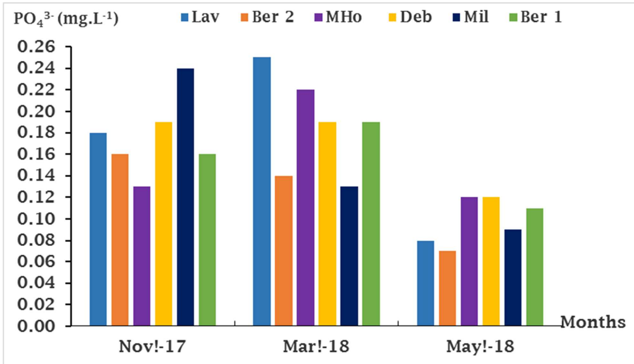

Figure 4. *Concentration of orthophosphates as a function of surface water sampling periods in M'koa Lake.*

3.3. Physico-Chemical Characteristics of M'koa Lake Surface Water

Table 3 presents the results of the physico-chemical analyses of M'koa Lake water at various stations. For each parameter at a given station, the minimum, maximum, and middle values are indicated. Thus, the high gap between maximum and minimum for most of measurements which have been done reflect significant disturbance in the lake system. Seasonal fluctuations in the water levels are therefore very important and significantly disturb the environment. However, there is relatively low variation between the different stations in terms of temperature, pH, transparency and turbidity. The average pH values of the different stations range from 7.54 ± 1.44 to 8.20 ± 0.55. These values suggest a relatively alkaline nature of the lake, which could be justified by its low mineralization (average electrical conductivities are between 108.25 ± 28.78 µS/Cm and 114.05 ± 36.13 µS/Cm.). The average oxygen saturation values are varying from 67.87 44.07% to 106.00 ± 19.58% which characterize a satisfactory oxygenation of the Lake's water. Concerning transparency, very low average values of 0.39 ± 0.13 to 0.52 ± 0.05 m are noted. Finally, turbidity, which refers to the content of suspended particles (matters) in water that disturb it, has average values for the different stations ranging from 30.77 ± 19.65 NTU to 42.37 ± 11.15 NTU. No significant variation between sampling stations from one parameter to another was recorded ($p > 0.05$).

Table 3. *Characteristics of physico-chemical parameters of M'koa Lake water.*

Station		pH	T (°C))	CE (µs/cm)	Oxyg Sat (%)	Transp (m)	Turb (NTU)
Lav	Aver. ± σ	8.20 ± 0.55	30.70 ± 1.08	111.97 ± 21.57	106.00 ± 19.58	0.52 ± 0.05	35.10 ± 4.40
	min - max	7.56 - 8.54	29.80 - 31.90	89.00 - 131.80	83.90 -12.12	0.46 - 0.55	30.70 - 39.50
Ber 2	Aver.± σ	7.95 ± 0.51	30.67 ± 0.99	108.25 ± 28.78	98.70 ± 14.78	048 ± 0.06	29.07 ± 2.80
	min - max	7.37 - 8.34	30.00 - 31.80	87.90 - 128.60	81.70 -108.50	0.44 - 0.55	31.20 - 53.50
MHO	Aver. ± σ	7.57 ± 0.76	30.80 ± 104	108.65 ± 33.45	96.80 ± 15.39	0.47 ± 0.13	42.37 ± 11.15
	min - max	7.12 - 8.45	30.10 - 32.00	85.00 132.30	79.20 107.70	0.35 - 0.60	31.20 - 53.50
Deb	Aver. ± σ	7.69 ± 0.81	30.87 ± 10	109.73 ± 30.17	95.47 ± 18.00	047 ± 0.12	36.20 ± 4.90
	min - max	6.82 - 8.43	30.10 - 32.10	88.40 - 131.06	77.60 113.60	0.40 - 0.60	31.30 - 41.10
Mil	Aver. ± σ	7.67 ± 1.05	30.77 ± 107	110.50 ± 29.98	93.53 ± 17.15	049 ± 0.08	32.47 ± 0.75
	min - max	6.60 - 8.69	30.10 - 32.00	89.30 - 131.70	78.10 - 112.00	0.40 - 0.55	31.70 - 33.20
Ber 1	Aver. ± σ	7.53 ± 1.44	31.00 ± 16	114.05 ± 36.13	6787 ± 4407	039 ± 0.13	30.77 ± 19.65
	min -max	6.15 - 9.03	29.50 - 32.80	88.50 - 139.60	29.70 - 116.10	0.35 - 0.60	11.10 - 50.40

T: temperature, EC: electrical conductivity, Oxyg Sat: oxygen saturation, Transp: transparency, Turb: turbidity.

3.4. Correlation Between Physico-Chemical Parameters of M'koa Lake Water

The main component analysis (PCA) was used to assess the physico-chemical parameters that could influence the concentration of anionic surfactants and orthophosphates in water. Table 4 presents the eigenvalues of the first three (3) PCA factors. Thus, the recorded which are taken into account are the cumulative variances factors and the factorial weight of the variables. The first two factors of the PCA, which alone represent 74.28% of the total inertia and sufficient for the interpretation of the correlations between the different parameters were considered. The ordination factor 1 represents 58.0% of the total inertia and it is negatively and strongly correlated with oxygen saturation and transparency. Conversely, temperature, electrical conductivity and pH are positively correlated. Also, anionic surfactants are weakly correlated with factor 1. That factor reflects an increasing gradient of degradation of organic matter. As for the factor 2 expressing 16.29% of the total inertia, it is positively correlated with dissolved phosphorus (PO_4^{3-}) and with turbidity. Factor 2 expresses a phosphorus fixation gradient. Differences were not found for anionic surfactants and orthophosphates ($p > 0.05$), and Orthophosphates were no significantly correlated to anionic surfactants along M'koa Lake ($p > 0.05$).

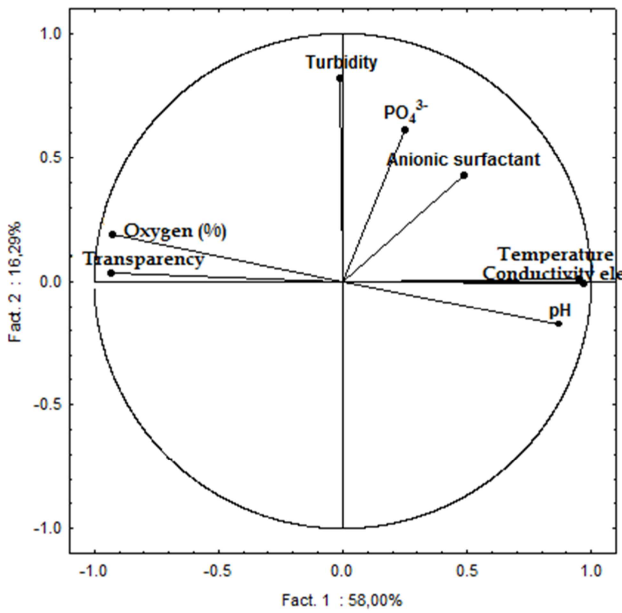

Figure 5. *Correlation circle of the physico-chemical variables of the PCA.*

Table 4. *Eigenvalues, cumulative variances and factor weights of the variables of the 3 first PCA factors.*

Facteurs	F1	F2	F3
Val propre	4.64	1.3	0.98
% Total variance	58	16.29	12.2
Cumul val propre	4.64	5.94	6.92
Cumul %	58	74.28	86.49
	Poids factoriel		
pH	0.871	-0.173	-0.311
Température	0.971	-0.007	-0.080
Cond élect	0.950	0.015	-0.298
Sat oxyg	-0.927	0.190	-0.242
Transparence	-0.936	0.035	-0.164
Turbidité	-0.012	0.824	-0.547
PO_4^{3-}	0.247	0.610	0.601
Tensioactif anionique	0.490	0.430	0.198

4. Discussion

The average anionic surfactants concentrations at the different stations ranged from 0.23 ± 0.04 $mg.L^{-1}$ to 1.43 ± 0.68 $mg.L^{-1}$. And according to sampling date, the highest levels have been observed at Berge 1, Washing, ber 2 and M'koa Hotel stations respectively with concentrations of 1.57 $mg.L^{-1}$, 1.96 $mg.L^{-1}$, 2.14 $mg.L^{-1}$ and 2.35 $mg.L^{-1}$. These areas would correspond to strong anthropogenic activities around the Lake. In fresh waters, anionic surfactants concentrations maximum recommended are 0.1 $mg.L^{-1}$, and are of the same order of magnitude as those of the urban effluents treated by a biological treatment [3, 29]. These results indicate that M'koa Lake is subjected to a high level of pollution by anionic surfactants. These concentrations are above the expected ones according to the socio-economic development and population density of the city of Jacqueville. Indeed, previous studies on streams, receiving untreated urban effluents in big agglomerations, showed anionic surfactants concentrations far below those obtained in the water of M'koa Lake. For example, water from Besaya and Ason estuaries, both situated on the Spanish coast, and receiving untreated urban wastewater from several cities, with an estimated population of 162500 inhabitants exhibited an anionic surfactants concentration of 0.50 $mg.L^{-1}$ [30]. Besides, a concentration of less than 0.01 $mg.L^{-1}$ was recorded in the waters of the Balfour River in South Africa [31]. The shallow waters of M'koa Lake and the low rate of renewal of the receiving watercourses close to the wastewater discharge outlets reduce the degree of dilution of the effluents. These factors could explain the higher anionic surfactants levels observed in the waters of M'koa Lake compared to those obtained in other highly contaminated surface waters [30, 32, 33]. Studies conducted on household detergents in Burkina Faso, which could be found here in Côte d'Ivoire, give the highest concentration of anionic surfactants at 2.6 $mg.L^{-1}$ [34]. The results of anionic surfactants concentrations in M'koa Lake revealed elevated values between 1.57 $mg.L^{-1}$ and 2.35 $mg.L^{-1}$, and shows well the low dilution of surfactants in lake waters. The average contents of orthophosphate (PO_4^{3-}) levels in the waters of M'koa Lake ranged from 0.12 ± 0.05 $mg.L^{-1}$ to 0.17 ± 0.04 $mg.L^{-1}$. Algal growth can occur if the concentration of sewage effluent has a orthophosphates concentration between 0.1 $mg.L^{-1}$ and 0.5 $mg.L^{-1}$ subsequently causing eutrophication in the receiving waters of urban effluent [8]. M'koa lake is victim of this phenomenon, in fact, the presence of phytoplankton has been shown in M'koa Lake [35]. Most PO_4^{3-} measured in M'koa Lake are believed to have an exogenous origin. In fact, the levels of anionic surfactants in the M'koa lake showed that the lac receiving anthropogenic releases, and on the other hand, a proportion of phosphorus in detergents and cleaning compounds contains tripolyphosphate, which is slowly mineralized to orthophosphates (PO_4^{3-}) in water [5]. However, Orthophosphates were no significantly correlated to anionic surfactants along M'koa Lake ($p > 0.05$). Indeed, phosphorus can come from human and animal wastes, food-processing effluents, commercial fertilisers, agricultural land runoffs and household detergents. And, in water and wastewater, P is present in the form of orthophosphate, polyphosphates and organic phosphorus. Polyphosphates and organic P are converted to orthophosphate by hydrolysis/or microbial mobilisation [36]. However, average contents of orthophosphate (PO_4^{3-}) levels in the waters of M'koa Lake is lower than that recorded (0.25 mg L^{-1}) in Ayamé 2 Lake (Côte d'Ivoire) [37], and that recorded (0.40 $mg.L^{-1}$) in Zowla Lake (Togo) [38]. Studies have shown that both Lakes are highly eutrophic, due to commercial fertilisers, agricultural land runoffs, and phosphate ore industry [37, 38]. Similarly, mean dissolved oxygen levels (concentration and/or % saturation), water from Lake Ayamé 2 and Lake Zowla showed that they were generally less oxygenated with 0.5 $mg.L^{-1}$ to 3.6 $mg.L^{-1}$ (less than 50% saturation), and between 3.7 $mg.L^{-1}$ to 6.4 $mg.L^{-1}$ (30% to 70% saturation) respectively, compared to 67.87 ± 44.07% at 106.00 ± 19.58% for M'koa Lake waters, which corresponded to a good oxygenation of the waters of M'koa Lake [26]. On the other hand, the comparison values of transparency (0.39 ± 0.13 m to 0.52 ± 0.05 m) and turbidity (29.07 ± 2.80 NTU to 42.37 ± 11.15 NTU) of the waters of M'koa Lake, with Lake Backré, Côte d'Ivoire (1.91 ± 0.62 m and 2.80 ± 0.42 m and 2.23 NTU to 3.97 NTU [39]) shows a difference in water quality. The temperature with a maximum average value of 31.00 ± 0.16°C is the main characteristic of the tropical areas [18]. The pH values, ranging from 7.54 ±1.44 to 8.20 ± 0.55, mean that M'koa Lake water is alkaline. The pH values obtained in this study are higher than those of Buyo Lake, Côte d'Ivoire (7.20 ± 0.50), which was not affected by urban effluent discharges, but by agricultural land runoffs [40]. In general, alkaline agents in detergents would increase the pH of wastewater [3], however, no correlation has been established between pH values and anionic surfactants concentrations in M'koa Lake water.

5. Conclusion

M'koa Lake is subject to heavy pollution by anionic surfactants and orthophosphates from urban effluent discharges and direct activities around the lake. In fact, the results showed that the average concentrations of anionic surfactants in the waters of M'koa Lake varied from 0.23 ± 0.04 $mg.L^{-1}$ to 1.43 ± 0.68 $mg.L^{-1}$. For orthophosphates, the average concentrations range from 0.12 ± 0.05 $mg.L^{-1}$ to 0.17 ± 0.04 $mg.L^{-1}$. And, the presence of orthophosphates in lake waters was not due solely to household and industrial detergents. The Washing stations, Berg 1 and 2, and M'koa Hotel are the most polluted sites affected. And among the physico-chemical parameters studied, only turbidity and transparency values indicate water quality deterioration of M'koa Lake favoured by the presence of phytoplankton, corresponding to the eutrophication of the water of the Lake under study.

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