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Urban lake system eutrophication – A case study

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ABSTRACT The dynamic eutrophication process study of Yamoussoukro lake system in Côte d'Ivoire was carried out from February 1997 to January 1998. It appeared that this phenomenon is related to the nutriments that are phosphorus mainly and nitrogen. It was shown that the fluctuations of these nutriments depend on the climatic phenomena, the rural activities such as the bush fires and the urban activities including the domestic rejections. The total phosphorus average optimal value obtained at the beginning of the rainy season was of 0,18 mg/L. That also corresponded to the increase of watery plants quantity @ JASEM.

The invading aquatic plants constitute one of the major problems that threaten the aquatic life in the Côte D'Ivoire rivers and lakes. The Yamoussoukro lakes are currently the seat of this dangerous phenomenon. This established fact, related to a contribution in nutritive elements specially phosphorus and Nitrogen is called eutrophication, (Stoianov et al., 2000; Wulff et al., 1989; Nixon, 1990; Per and Mats, 2002; Barroin, 1976). The lakes object of eutrophication phenomenon, present varied trophic answers although supplied with the same water origin. The harmful effects of the proliferation of the aquatic plants (algae and macrophytes) contribute to the filling of the wells located in alluvial tablecloths and disturb the normal fish life. This phenomenon that generally affects the stagnant masses of water or with renewal seems to be an ecological problem with an economic implication. Works achieved in zone tropical tried to study the phenomenon of the eutrophication in statics mode. (Barroin, 1976; Ado et Mama, 2001). The aim of this work was to achieve a dynamic study during a one-year cycle within the framework of the monitoring of eutrophication in tropical zone of savannah. Although entrophication measurements are usually 3 to 5 years, the follow-up of the physicochemical parameters that characterize such a system better is made in term of evolution during one year. This step has the advantage of making it possible the critical periods localization, to raise more easily the causes of the phenomenon by connecting them to the environment factors, to arise the characteristics related to the activities of the populations, as well as the mode of pollution in nutriments responsible of the eutrophication.

MATERIALS AND METHODS

The study area: The zone of study is located in West Africa precisely in the town of Yamoussoukro in Côte d'Ivoire. The annual average temperature of the city is approximately 32 °C and an average precipitation of approximately 1400 mm. The demographic data of 1997-1998 reveal a city with an approximate population of 200 000 habitants of which about 83% live in the districts slopes of the lakes. The work was completed on a whole of 10 lakes forming a mud communicating system. At the origin, the current sites of the lakes consisted of hollows supplied with brooks. In 1975 with an aim of creating the current lakes, these hollows were cleaned and dams was built without draining system that appeared at the time useless. The flows are done in the direction Lake I $\rightarrow$ Lake II $\rightarrow$ Lake III $\rightarrow$ Lake IV $\rightarrow$ Lake V, then in the direction Lake X $\rightarrow$ Lake IX $\rightarrow$ Lake VIII $\rightarrow$ Lake V as shown by figure 1. The basins slopes of the first series of lake (lake I to Lake V) are the seat of relatively significant rural activities. Water of the lakes has an annual average temperature of 28 °C except lake VII (26,5 °C). Figure 1 illustrates the plan of the site. The lake system was divided into two parts according to the conditions of the immediate surrounding on the one hand and the visible presence of watery plants on the other hand. Thus the lakes located in the northern (lake I to lake IV) constitute the first block (NLS) and the lakes located in the southern side (lake V to lake X) constitute the second block (SLS).

Sampling and analytical methods: Samples were collected along the lengths of the lake with a depth of 0.5 m in polystyrene containers during the period February 1997 to January 1998. The sampling was carried in the morning between 8 and 10 o'clock. The choice of sites was based upon the need for representation from natural variation condition along the length. So, 12 points (1 point by lake except for the lake V where there were 3 points) of the lake system were selected in order to represent a wide range of trophic conditions.

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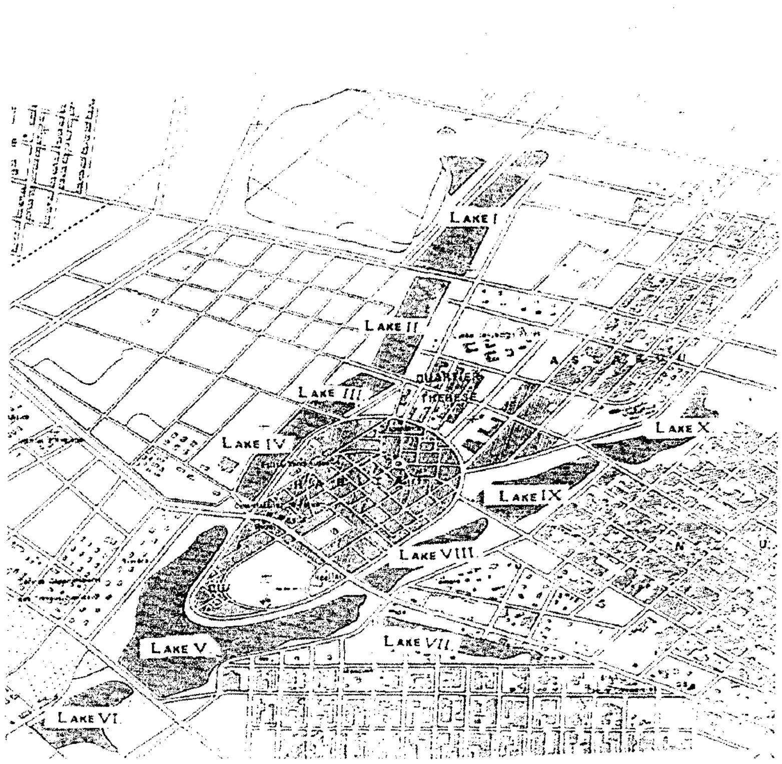

Fig 1. The plan of the site

The physico-chemical parameters like pH, temperature, conductivity and dissolved oxygen were performed directly on the site using respectively transportable pH meter SHOT GREAT ECG 817T, conductivity meter WTW LF 90 and oxygen meter WTW OXI 196. Prior to analysis for total phosphorus (Ptot), 50 mL of samples were acidified with 5 mL of concentrated sulfuric acid and carried to boiling in the presence of 5 mL of sodium sulfate solution. 150 ml of distilled water was added to the residue and after filtration, 20 mL of the solution obtained was proportioned using a spectrophotometer UVIKON 810. As for phosphorus, before determination of total nitrogen (Ntot), 50 mL of the sample to which is added 10 mL of sulfuric acid is mineral-bearing. The mixture was steam distilled and 200 mL of distillate was neutralized with a sulfuric acid solution in the presence of boric acid. The determination of suspended matter was carried out on 200 mL sample, filtered using a filter GF6 (0.47 □m). Drying was done in a heating oven at 105 °C. The chemicals were of Merck origin analytical quality.

Generally, whatever the parameter chosen, the values obtained are higher northern side (NSL) than southern side (SLS). The pH depends on the geological nature of the grounds, the external contributions and the physicochemical and biological reaction. The grounds being the same one for all the lakes, the variations of pH thus depend on the last two factors mentioned. The pH relatively low on the Northern side is primarily due to the presence of macrophytes, known to release acids compounds like gallic, ellagic and tannic acids (Saito et al, 1989). The dissolved oxygen on the Southern side is weaker. That is due to the presence of the macrophytes that constitute a barrier for dissolution in water of atmospheric oxygen. Moreover, the production of oxygen by the phytoplankton is negligible because of the lack of luminosity due to vegetative cover. The conductivity of the lake in a general way represents a weak mineralization. However it is stronger Southern side because of the external contributions due to the strong urbanization in the south, where leave more than 66% of the population of the city. These results are in conformity with those obtained in other work completed on these same lakes and at the same period (Lothe, 1999). The quantities obtained for the essential cations are indicated in table 2.

RESULTS AND DISCUSSION

The results related to Physico-chemical parameters of the study area are presented in Table 1.

Table 1: Physico chemical parameters

Mouth	Temperature (°C)		pH		DO (mg/L)		Conductivity (µS/cm)	
	NSL	SLS	NSL	SLS	NSL	SLS	NSL	SLS
February	27.07	27.63	7.70	6.30	4.69	1.47	–	–
	(0.83)	(0.48)	(1.4)	(0.20)	(0.43)	(0.30)		
March	29.29	28.01	8.20	7.00	3.90	1.90	188.10	336.75
	(0.39)	(1.25)	(0.73)	(0.44)	(0.27)	(0.74)	(25.00)	(74.38)
April	30.44	28.41	8.41	6.75	4.16	1.38	187.15	352.70
	(0.20)	(0.95)	(0.54)	(0.37)	(0.31)	(0.77)	(20.89)	(63.01)
May	29.26	28.05	7.76	6.80	3.19	1.37	139.29	255.90
	(0.16)	(0.59)	(0.35)	(0.27)	(0.38)	(0.89)	(7.34)	(52.13)
June	28.74	27.83	7.81	6.69	3.69	1.24	125.57	257.08
	(0.19)	(0.58)	(0.34)	(0.33)	(0.35)	(0.88)	(12.05)	(96.90)
July	27.56	27.68	8.10	7.06	3.85	1.89	136.00	272.25
	(0.45)	(0.61)	(0.55)	(0.25)	(0.69)	(1.00)	(16.80)	(87.73)
August	27.49	26.6	8.51	7.02	4.27	2.43	140.71	263.10
	(0.30)	(0.73)	(0.66)	(0.32)	(0.90)	(1.19)	(13.19)	(46.90)
September	27.59	27.97	8.02	7.40	3.49	2.45	117.29	254.15
	(0.33)	(0.94)	(0.56)	(0.47)	(0.65)	(1.18)	(07.23)	(64.49)
October	27.54	27.62	7.86	7.33	3.32	1.97	119.57	254.77
	(0.26)	(0.71)	(0.51)	(0.36)	(0.59	(0.90)	(10.26)	(62.38)
November	28.61	28.36	7.97	7.66	3.81	3.08	154.57	300.85
	(0.25)	(1.07)	(0.31)	(0.55)	(0.80)	(1.68)	(15.65)	(77.97)
December	27.33	27.52	7.98	7.58	2.89	2.27	159.86	300.38
	(0.17)	(0.71)	(0.21)	(0.45)	(0.51)	(1.07)	(20.23)	(64.19)
January	26.77	26.53	8.21	7.63	3.19	2.18	159.57	299.54
	(0.28)	(1.20)	(0.59)	(0.69)	(0.94)	(1.17)	(20.14)	(56.04)

Brackets numbers represent the standard deviation.

***Table 2**: Annual average of the principal elements concentration*

Element	K (mg/L)		Ca (mg/L)		Mg (mg/L)		Na (mg/L)	
	NSL	SLS	NSL	SLS	NSL	SLS	NSL	SLS
Mean value	7.48	18.23	14.73	21.96	4.28	5.18	11.35	19.8
Standard deviation	0.47	7.86	0.69	5.9	0.49	1.5	1.65	6.4

The temperatures values are raised and practically constant on each side of the system. These levels of temperature, characteristic of the tropical zones play a significant role in the kinetics of the physico-chemical and biological reactions. However the Northern side invaded by the macrophytes present of the temperatures generally less high than those obtained on the southern side.

Results related to phosphorus

The total phosphorus values in crude water are higher than those obtained in filtered water. This is normal since Ptot(EB) integrates the quantity of phosphorus contained in the phytoplankton and the other watery organizations. Table 3 makes it possible to say that the ratio Ptot(EB)/Ptot(EF) is equal to two.

Table 3: Details of the results related to phosphorus on a year

Mouth	Precipitation mm	Ptot(EB) mg/L SLS	Ptot(EB) mg/L NSL	Ptot(EF) mg/L SLS	Ptot(EF) mg/L NSL	PO_4^{3-} mg/L SLS	PO_4^{3-} mg/L NSL	SM mg/L SLS	SM mg/L NSL
February	37.5	0.256	0.287	0.108	0.125	0.007	0.040	22.07	27.62
		(0.105)	(0.075)	(0.071)	(0.036)	(0.012)	(0.026)	(0.83)	(0.48)
March	135,3	0.190	0.247	0.020	0.073	0.000	0.034	29.29	28.01
		(0.111)	(0.247)	(0.013)	(0.125)	(0.000)	(0.041)	(0.39)	(1.25)
April	115.5	0.176	0.263	0.025	0.115	0.000	0.059	30.44	28.41
		(0.077)	(0.153)	(0.014)	(0.010)	(0.000)	(0.086)	(0.20)	(0.95)
May	277,0	0.116	0.228	0.010	0.041	0.000	0.045	29.26	28.05
		(0.041)	(0.146)	(0.011)	(0.021)	(0.000)	(0.066)	(0.16)	(0.59)
June	182.0	0.103	0.196	0.013	0.032	0.000	0.045	28.74	27.83
		(0.046)	(0.127)	(0.012)	(0.013)	(0.000)	(0.058)	(0.19)	(0.58)
July	83.0	0.099	0.212	0.000	0.035	0.000	0.036	27.56	27.68
		(0.044)	(0.160)	(0.000)	(0.052)	(0.000)	(0.052)	(0.45)	(0.61)
August	94.0	0.124	0.190	0.000	0.025	0.000	0.042	27.49	26.60
		(0.064)	(0.133)	(0.000)	(0.047)	(0.000)	(0.067)	(0.30)	(0.73)
September	258.0	0.103	0.221	0.000	0.026	0.000	0.031	27.59	27.97
		(0.036)	(0.124)	(0.000)	(0.060)	(0.000)	(0.065)	(0.33)	(0.94)
October	100.0	0.070	0.182	0.000	0.007	0.000	0.012	27.54	27.62
		(0.054)	(0.097)	(0.000)	(0.028)	(0.000)	(0.027)	(0.26)	(0.71)
November	64.0	0.024	0.045	0.000	0.011	0.000	0.009	28.61	28.36
		(0.015)	(0.024)	(0.000)	(0.018)	(0.000)	(0.023)	(0.25)	(1.07)
December	44.0	0.034	0.056	0.010	0.013	0.000	0.005	27.33	27.52
		(0.017)	(0.059)	(0.006)	(0.012)	(0.000)	(0.010	(0.17)	(1.07)
January	3.6	0.050	0.077	0.013	0.020	0.008	0.01	26.77	26.83
		(0.030)	(0.073)	(0.006)	(0.028)	(0.008)	(0.018)	(0.28)	(1.20)

Ptot(EB) : Total phosphorus in crude water; Ptot(EF): Total phosphorus in filtered water; SM: Suspended matter; Brackets numbers represent the standard deviation

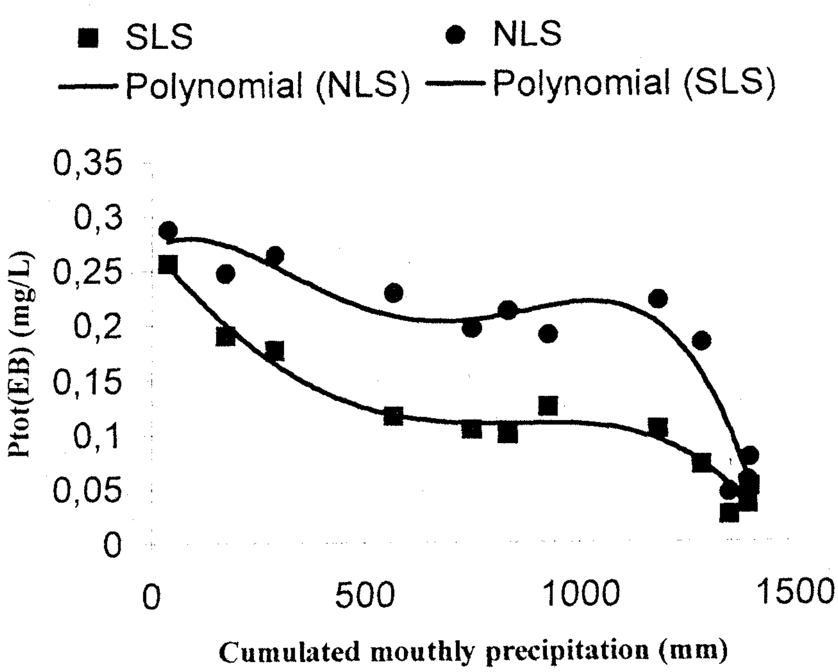

Fig 2. Evolution of Ptot(EB) as a function of the cumulated monthly precipitation

The evolution of Ptot(EB) according to cumulated monthly precipitation shown by figure 2 is the same at northern side as southern side. A regular reduction is observed from February to May followed by stabilization until September and a decrease again until January. The first phase, corresponding to the dry season represents consumption by the macrophytes of phosphorus without a significant contribution of the external. In the period of rainy season (May-September), the external contributions (ashes from bush fire, household refuse, the manures used for the enrichment of the grounds) through streaming waters become significant and compensate the consumption by the plants that find in this period a great vitality. Stabilization is partly due also to dilution related to the increase in the flows of water. From November starts the dry season. It results from it a reduction of the external contributions and thus a reduction of the phosphorus content. Moreover, the ratio Ptot/MS in crude water as in filtered water seems to be constant in the course of time (figure 3 and 4). This represented a balance between the phosphorus of the suspended matter and water on the one hand, and dissolved phosphorus and plants consumption on the other hand.

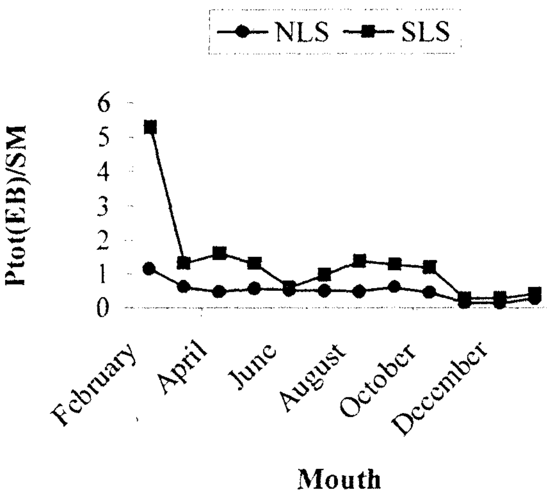

Fig 3. Ptot(EB)/SM as a function of the date

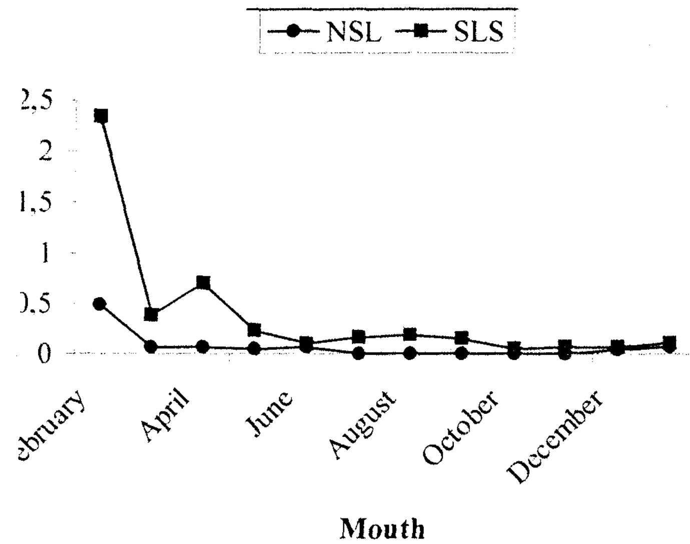

Fig 4. Ptot(EF)/SM as a function of the date

With regard to the evolution of the phosphate concentration, it is advisable not to lose sight of the fact that the phosphates present at the moment of the taking away in various studied water, come at the same time not only from the natural and exogenic but from endogenous contributions too. Measurements were carried out here on filtered water. Seasonal evolution of the average phosphate rate all the confused lakes, must be interpreted by holding account owing to the fact that it is in this form that phosphorus is assimilated by the plants. In a general way the phosphate content remains constant and weak as illustrated by table 1. At the northern side of the system, the concentration out of phosphate is equal to zero all the year while southern side it varies from 0,009 to 0,059 mg/L. The strongest concentrations are observed from April to September. This period corresponds to the strong proliferation of the macrophytes. It is indeed mainly in the phosphate shape that the plants absorb phosphorus. The phosphate contribution due to the first rains support the growth of the plants and increases consequently their phosphate consumption. That explains the fall of the phosphate rate observed from October to January.

Results related to nitrogen

In a General way, the evolution of total nitrogen follows rather well the evolution of precipitation (figure 5). The total nitrogen is the more significant since the precipitation is strong. The nitrogen thus seems to come primarily from urban waste drained by rainwater. However, there is no significant difference between the contents in crude water on the southern side and the northern side on the one hand, and on the other hand in filtered water on the southern side and the northern side of the system. Moreover, the total nitrogen content is weaker southern side than northern side. That is related to the consumption of nitrogen by the macrophytes present abundantly at the south of the lake system. The purifying effect of these watery plants is highlighted here. The observation of figure 6 shows that the Ntot/Ptot ratio in crude water remains practically constant from July to October before growing in December. However its value remains higher than 7.2. Phosphorus is then the limiting factor for the growth of macrophytes (Ryding et Rast, 1993; Droop, 1973).

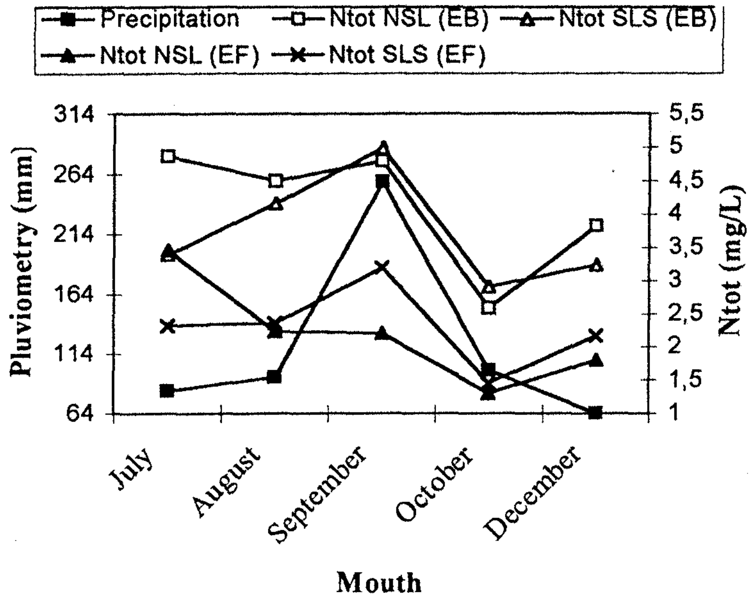

Fig 5: Evolution of NtotEB as a function of the Mouth

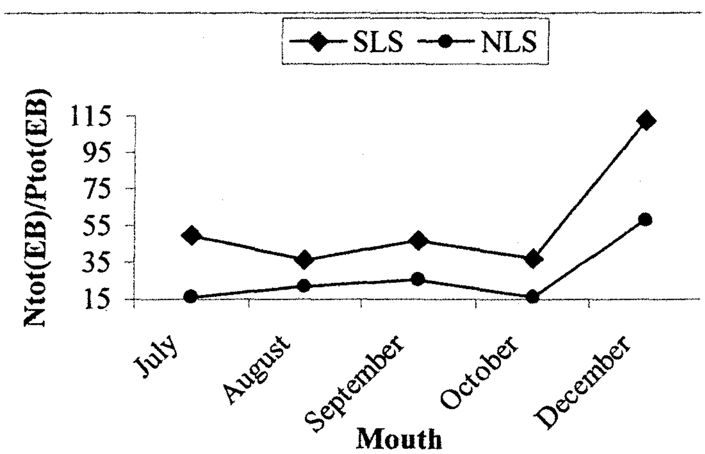

Fig 6. Evolution of Ntot(EB)/Ptot(EB) as a function of the mouth

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