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Use of Lakes Waters in the Town of Yamousoukro for Industrial Boiler Rooms

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Abstract: The industrialization of Côte D' Ivoire requires science an anticipation of the various projects of development. The town of Yamoussoukro, political capital of Côte D' Ivoire, is in the center of the country at 270 km in the North-East from Abidjan. It is situated at 6°7 ' of Northern latitude and 5°2 ' of Western longitude. Yamoussoukro is equipped with artificial lakes, which were created in 1970. This study dealt with ten of them numbered from 1 to 10. They are fed by two rivers and these rivers communicate between them. The analysis of 10 of the lakes of the city of Yamoussoukro reveals that the lakes have a relatively weak mineralization but that they stay polluted. It is the case of the hydrogen potential, turbidity and matters in suspension. The strong contents of these parameters make it difficult for these waters to be used in the industry. So, the analysis of the physicochemical parameters of the various lakes of the town of Yamoussoukro showed for a possible use in the boiler rooms The use of the waters of the 10 lakes of Yamoussoukro city in the industrial boiler room requires a double treatment: First is an environmental treatment and then a chemical treatment. The environmental treatment is a set of measures of regulation of the middle to reduce the organic pollution of waters. The chemical treatment consists, in a partial or total elimination of some raw water constituent by fixing, either by filtration, either by coagulation decanting. These methods, can contribute to the treatment of these lakes with success. Then, these waters could be used in the industry, notably in boiler room in order to obtain vapor which will use for infrastructures of the town.

Key words: Boiler room, analysis, pollution, water treatment, cleaning

INTRODUCTION

The water produced in Côte. D' Ivoire by private company SODECI especially becomes very expensive and insufficient for its using in the industrial machines. Also, the strategic place of the town of Yamoussoukro, political capital which abounds in highly-recognized institutions, requires that forecasting studies be made on its watery environment, for the installation of new factories (Leblond, 1990; Hawhen *et al.*, 1999).

Several studies were carried out on these lakes by the technical staff of the town hall of the city, in order to determine their physico-chemical characteristics and to control the eutrophication of those, especially their contribution in the urban development (Lhote, 2000; Ryding and Rast, 1994). This research about industrial water staying a major preoccupation and of actuality, the objective of this study is to try a new experiment while deciding to study the exploitation of water of 10 lakes of the town of Yamoussoukro for their use in an industrial
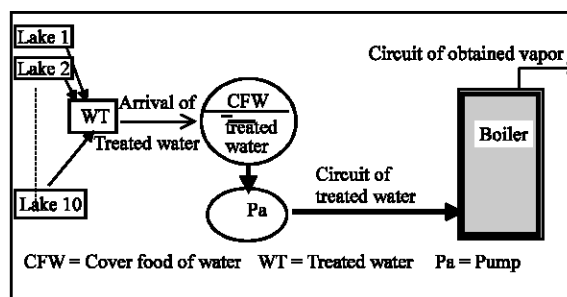

Fig. 1: Simplified diagram of an industrial boiler room

boiler room (Ray and Franzini, 1979; Malicet, 1980). Also, this research is to undertake statistical studies on the physico-chemical parameters of the lakes in order to establish a data base, to propose a method of possible treatment of these waters. Then, to design an installation of boiler room (Fig. 1) allowing to obtain vapor starting from the water of the lakes, being able to be to use in some infrastructures, such as the hospital and the hotel of the deputies of the town of Yamoussoukro.

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MATERIALS AND METHODS

Materials: Works achieved at the Laboratory of Engines and Machines with Energy Transformation (LMMCE) of Polytechnc National Institute of Yamoussoukro, Felix Houphouet Boigny (INP-HB), at the beginning of years 2000. The studies are achieved on water of 10 lakes of the town of Yamoussoukro for their use in an industrial boiler room (Sarco, 2001).

Methods: The methods used are those of standard AFNOR and ISO. The material used is the usual material of laboratory. The taking of sample took place each morning from 8 to 10 h, the entry and the exit of each lake. At each point, one liter of water is taken, down from 50 cm of depth, using a polyethylene bottle fixed on a pole of 5 m length. The samples were preserved in darkness and in a cold temperature.

Analysis of physico-chemical parameters (Rodier, 1976)
Temperature: For each lake invaded by macrophytes, the average temperature is about 27°C early in the morning. This high temperature, typical of the tropical countries, plays a fundamental role in the kinetics of biological and physicochemical reactions, as well as on the rate of constant equilibrium of these reactions (Vogel and Angenmann, 1996). The strong luminosity received by some of these lakes, completely bare and entirely exposed to the solar rays, raises their temperatures compared with other lakes. The presence of macrophytes has a clear reduction effect on the temperature of water they cover (lakes 5, 7, 8 9 and 10).

Potential of hydrogen (pH): Generaly the parameter pH primarily depends on the environment of the lake, especially the geological nature of the grounds covered by water, the external properties, the physicochemical and biological reactions which take place in the environment. In this study, the geological nature of the environment being identical for all the lakes, only the external properties, the physicochemical and biological reactions will be able to explain the variations of pH. It is advisable, however, to note that the physicochemical and biological reactions are mainly induced by the external properties. The examination of Fig. 1 shows that the lakes covered by macrophytes have less higher pH. That is undoubtedly due to the acid organic salting replaced by macrophytes roots; this results in a fall of pH. The lakes 3 and 4 whose pH remain highest have all kinds of plants removed and contain, on average, forty crocodiles. The external properties are sources of nutriments for these reptiles, the waste rejected by the latter would be the basis of this sensitive demarcation. The effect of the solar rays also influence the variation registered in the pH.

Dissolved oxygen (O_2): Observation of Fig. 2 reveals a rise of a high percentage of dissolved oxygen in lakes 2, 3, 4 and 6. Lakes 2, 3 and 4 are not covered by plants. It thus creates a direct contact between the free face of water and the atmospheric layer, which contributes to the dissolution of atmospheric oxygen in these waters. The value of the rate of dissolved oxygen strongly depends on the time at which the sample is taken. The variations show that it is necessary to be careful in interpreting the parameters and to compare only measurements carried out at the same period. Also, the photosynthetic phenomena which takes place on the level of the other lakes (breathing of the plants that cover water) are the basis of the variations found in the dissolved oxygen contents. The degradation of the organic matter of the plants also consumes the surrounding oxygen making the activity of the bacteria aerobic possible.

Permanganate index (IP): The measurement of oxydability was made on raw water (Fig. 2). This parameter gives us the organic quantity of matter contained in each lake. Lakes 3, 4, 5 and 6 have a permanganate index of about 5 mg of O_2 L^{-1}, whereas lake 7 appears as the lake which holds the most organic matter (9.57 mg O_2 L^{-1}). The other lakes, with an index below 5 mg L^{-1}, have a relatively low oxydability. One could explain the rather high rate of lake 7 by its particular position in relation to the popular districts which pour at places all used water and domestic waste, through streaming. It is also observed that at the time of our analysis, lake 7 was the only one covered with salad water. The decomposition of plants roots could be the probable cause of the increase in index.

Sodium and potassium: Concentration of sodium and potassium has two similar forms. The share lake 5 and 6 which hare very high sodium concentrations as well as potassium, the other lakes, except lake 8, do not present
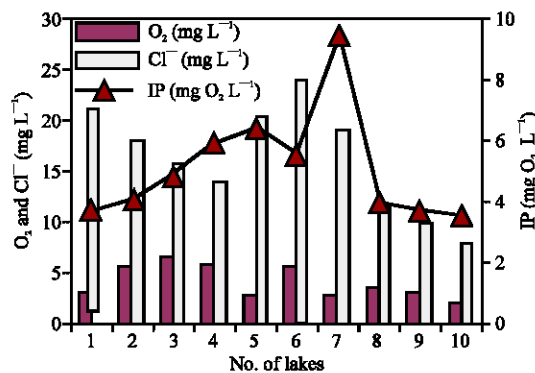

Fig. 2: Evolution of O_2, IP and CL^-

great variations compared to the average value. Lake 5 receives all water from the other lakes and used water from the surrounding popular districts before pouring them into lake 6. This situation explains the strong concentrations of sodium and potassium in lakes 5 and 6. The concentration of lake 7 is the result of the rejections coming from the urban zones where the system of water treatment is non-existent. With the accesses of lakes 1 and 10 are practiced agricultural activities. The use of the intrants could also influence the concentration in sodium and potassium.

Conductivity (Cond): Conductivity is overall higher in lakes 5, 6 and 7 and is less in lakes 1, 2, 3, 4, 9 and 10. The influence of the urban rejections, rich in rock salt, explains the high conductivity of lakes 5, 6 and 7 which is located at the center town except the lake 6 which, located at the south-west of the city, receives water from the other lakes. However, the weak mineral state of the other lakes (1, 2, 3 and 4) would be due to the fact that they are located in slightly urbanized zones. In addition, in the case of lakes 8 and 9 it could also depend on the presence of macrophytes and their localization. The conductivity of lake 10 is especially justified by the density of macrophytes on its surface and the weak urban rejection rate which it receives (Fig. 3). The average conductivity of this water of lake is 200 μS cm^{-1}; this testifies the weak mineralization of all the lakes.

Titrate Hydrotimetric (TH): The concentrations of calcium and magnesium (TH) in the lakes (Fig. 4). Lakes 4, 5, 6 and 7 have high enough contents in calcium and magnesium. However lake 4 is not covered like other lakes 5, 6 and 7. We can charge this difference in contents at the trophic state of the lakes, with the importance of the urban rejections that these lakes receive. In addition, lake 4 receives its load in calcium and magnesium of purification of the publicly-owned establishments upstream whose system of purification of worn water is failing.

Titrate of complete alcalimetric (TAC): The contributions external responsible for mineralization of the lakes have the same influences on all the dissolved salts contained in the lakes. The Fig. 5. thus take consecutive forms similar to the same causes. Ions HCO_3^- tend to establish an ionic balance in the lakes. The need for maintenance this balance ionic in each lake justifies this similarity.

Ions chlorides: Figure 5 shows the rate of ions chlorides in each lake. Lakes 1, 2, 5, 6 and 7 have high rates whereas those of lakes 8, 9 and 10% contents of relatively weak
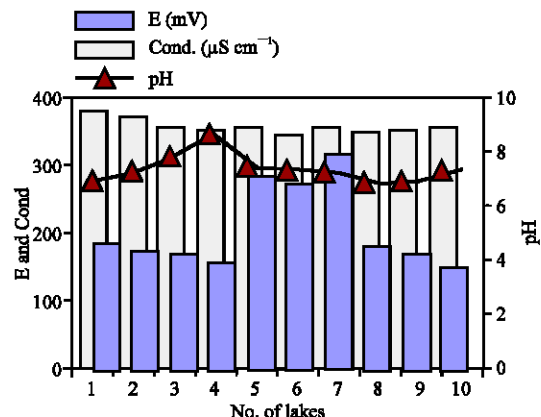

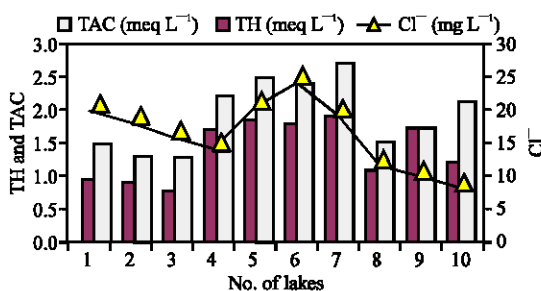Fig. 3: Evolution of potential difference E, Cond and pH
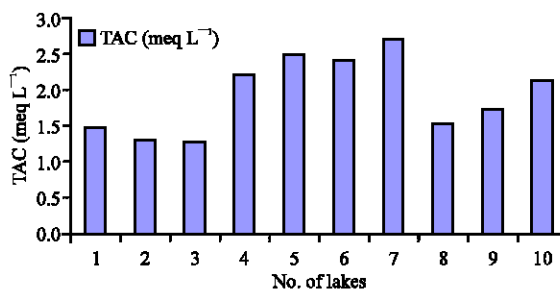

Fig. 4: Hardness of lakes

Fig. 5: Titrate of complete alcaimetric (TAC)

ions chlorides. The rejection of detergents, organochlorinated and any kind of waste in lakes 5, 6 and 7 (strongly populated zone) consolidate this strong concentration.

Suspended matter (MES): The suspended matter (MES) is generally vectors of pollutants like heavy metals, the organic pollutants, the pathogenic micro-organisms and the nutriments such as phosphorus (Meybeck *et al.*, 1989). If them MES can be taxed with organics, it should nevertheless be stressed that significant quantities of mineral particles are washed in rainy season (Wahl, 1966)

The positions upstream of lakes 1, 9 and 10 could explain their weak rate in suspended matter. The other lakes which receive almost all surface waters resulting from the popular districts strongly increased their suspended matter. The contribution of the organic matter due to the decomposition of the roots and sheets of the macrophytes is also one of the load factors in MES (Fig. 6).

Determination of the content of salts totally dissolved (TDS) on the whole of the lakes: In order to demineralize water, it is interesting to be able to determine quickly from one or two physicochemical parameters, the total content of dissolved salts in water.

Using equations of the correlations between the parameters, it is enough to determine certain physicochemical parameters such as TAC, TH, conductivity, to calculate salts totally dissolved (TDS). This data intervenes specially in the dimensioning of the resins or the proportioning of lime.

Thus, the equation of the TDS according to conductivity is obtained by the relation:

$$TDS = 360.33 \text{ (cond)} + 14.014 \qquad (1)$$

This curve is quasi linear (Fig. 7) with a coefficient of correlation R = 0.931

The evolution of the title of carbon dioxide (TCO_2) in each lake according to their titrate of complete alcalimetric (TAC) content is also given by the following relation:

$$TCO_2 = -94.797 \text{ (TAC)}^4 + 817.52 \text{ (TAC)}^3 - 2581.2 \text{ (TAC)}^2 + 3525.2 \text{ TAC} - 17441.2 \qquad (2)$$

Proposal for water treatment of ten (10) lakes: The treatment of lakes waters which we propose has three great stages (Pivorora, 1996; Alep, 2000) which are:

• Environmental treatment.
• Pretreatment.
• Physico-chemical Treatment.

a) Environmental treatment: The control of eutrophication to minimize the costs of water treatment. It is necessary to have an organic raw water matter relatively charged.

The reduction of pollution in the lakes in Yamoussoukro requires:

• Rehabilitation of collective systems (Fig. 8) of cleansing (station of purification of worn water).
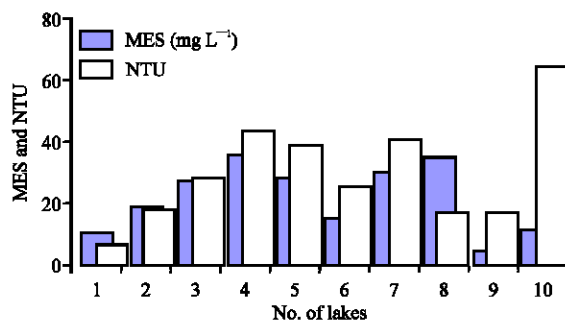

Fig. 6: Evolution of suspended matter (MES) and nephelimetric unit of turbidity (NTU)
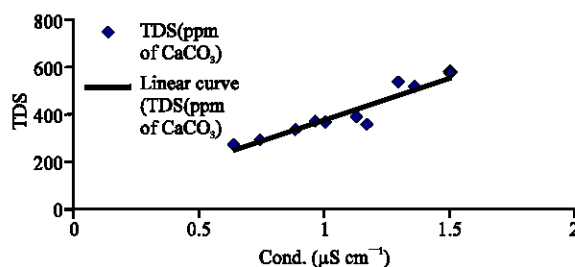

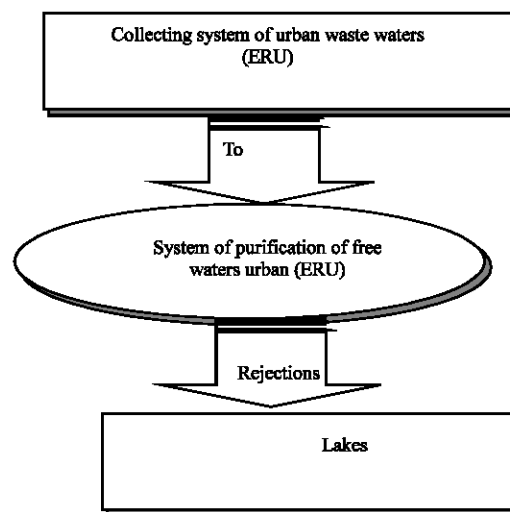Fig. 7: Evolution of dissolved total salts (TDS)

Fig. 8: Process of collective cleansing

• Encouragement policy of autonomous systems of cleansing (Fig. 9).
• Sensitizing of bordering populations for no-disposal of household carbage in water.

b) Pretreatment: Before any water treatment, the nondissolved matters of big sizes are eliminated by processes called preprocessing. These operations relate to mainly cleaning:
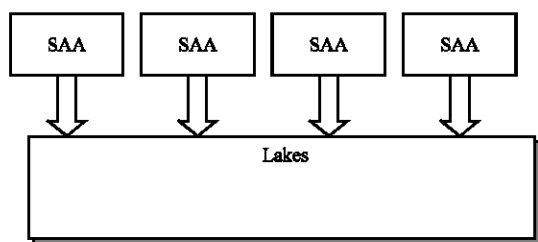
Fig. 9: Process of autonomous cleansing. ERU = Urban waste water and SAA = Autonomous system of cleaning

Desanding - filtration - flocculation.

Some dissolved, harmful matters with resins which intervene in demineralization, are also eliminated in the process of pretreatment by:

- Deferrization (precipitation of iron)
- Demanganization (precipitation of manganese)
- or dechloration (elimination of the ions chlorides)

c) Demineralization: Demineralization can be done by decarbonation followed by softening through chaining:

Cf-CF-DEG or by total demineralization
by the CF-Af-DEG Chainings,

or CF-DEG-AF

Cf-Af-DEG-AF

or CF-DEG-Af-AF by decarbonation with lime.

AF   = Strong anions
Af   = Weak anions
Cf   = Strong cations
CF   = Weak cations
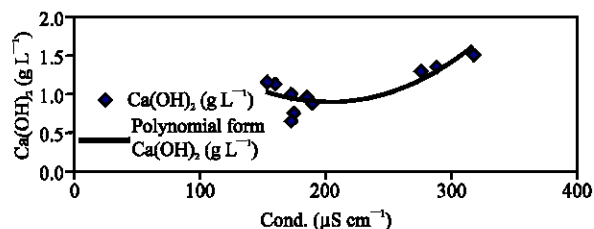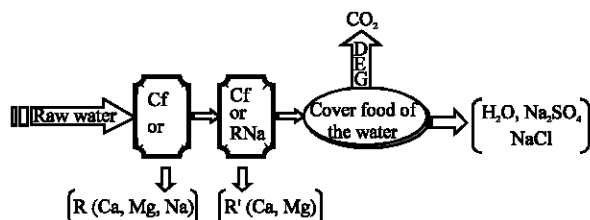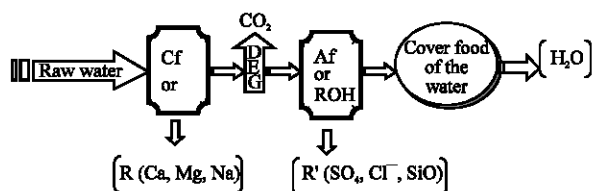DEG   = Physical degasification

Chaining Cf-CF-DEG

Fig. 10: $Ca(OH)_2$ (g L^{-1}) = f(cond)

Chaining CF-DEG-AF

Decarbonizing with lime: For a conductivity equal to 214 μS cm^{-1}, the lime amount equals 1.04 g L^{-1} and the dissolved total salts (TDS) = 488 ppm of $CaCO_3$. These two parameters enable us to measure either the ion exchanger or the lime amount necessary for decarbonation (Fig. 10).

RESULTS

Comparison of analysis of lake water (1 and 5) with the standard operation of three types of boiler: The Table 1 presents a comparison of the standards of three categories of boilers with the real characteristics of two lakes (lakes 1 and 5).

The standard of boilers show here that water of the two lakes (1 and 5) is very hard (TH = 4.75 and 9.2), disorders (NTU = 6.45 and 38.4) and too charged suspended matter (MES = 10 and 28) to be allowed in the boilers. One also notes the weakness of the potential of hydrogen. For reasons of equipment safety, of thermal efficiency, of vapor quality, exit pressure. It is impossible to inject such water directly in the boiler. It is thus important to carry out a preliminary treatment before any use. Water of the lakes studied has conductivities at the top of the standard of operation for the industrial boilers room (Fig. 11). This imposes a treatment of waters before their use in these types of boilers (Massin, 1982).

Comparison of the results of water treatment with the standard boilers: The Table 2 presents the standards of three categories of boiler at the theoretical outputs on cation and anion resins of water.
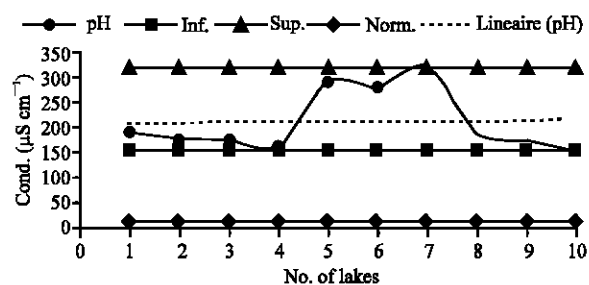
Fig. 11: Map of control of conductivity (cond). Inf = Minimal content of the measured parameter, Sup = Maximum content of the measured parameter, Norm = Normal content of the measured parameter and Lineaire = Linear trend of the measured parameter

Table 1: Comparison of raw waters and the standards of boilers

Characteristics of water	Standard boilers with their pressures			Two lakes	
	69 bars	35 bars	18 bars	Lake 1	Lake 5
TAC	< 10	<60	<80	7.40	12.40
TH	<0.05	<0.2	<0.2	4.75	9.20
PH	10.0-11	10.5-12	10.5-12	6.95	7.41
NTU	0	0	0	6.45	38.40
MES (mg L^{-1})	0	0	0	10.00	28.00

Table 2: Comparison physico-chemical parameters after water treatment

Characteristics of water	Standard boilers with their pressures			Used chaining for water treatment	
	69 bars	35 bars	18 bars	Cf-CF-DEG	CF-DEG-AF
TAC	< 10	<60	<80	0.3	0
TH	<0.05	<0.2	<0.2	0	0
PH	10.0-11	10.5-12	10.5-12	10.0-12	10.0-12

The results of the treatments meet the conditions of correct operation of targeted boilers here by our study. The methods of treatment suggested can thus satisfy the industrialists in the field of heating. The treatment of demineralization remains unchanged starting from the stage of pretreatment. The water pollution generates an additional cost to the level of the pretreatment and control of the eutrophication. These costs can make null and void a project of investment since the investment concerning water treatment is overall at a loss.

The general study gave conclusive results. Some of these results are presented in Table 3 and 4.

CONCLUSIONS

The analysis of the various parameters shows that the lakes are polluted. To consider their use in the boiler room will require, the protection of equipment and model of treatment. The correlations between the parameters

Table 3: Detailed characteristics of the water of the one lake (lake 5)

Card-index of analysis of water sample	
Origin: Town of Yamoussoukro (lake5).	
Nature: Water of lake (date: 20/02/2007)	
Physical characteristics	
Color and odor:	Disorder and odourless
Deposit:	38 mg L^{-1} (MY)
Resistivity with 27°C:	3472 Ω cm^{-1}
Conductivity with 27°C:	288 μS cm^{-1}
Turbidity:	38.4 NTU.
pH with 27°C:	7.41
Chemical analysis of filtered water	
(In French degrees)	
Total hardness (TH)	9.2
Carbonated hardness	9.2
Permanent hardness	0.0
Calcic hardness (TCa)	6.9
Magnesian hardness (TMg)	2.3
Free alkalinity	0.0
Title alcalimetric (MT)	0.0
Complete Title alcalimetric (TAC)	12.4
Salts of strong acids (SAF)	5.5
Total salinity	46.7
Silica (SiO$_2$)-	

Anions		
Organic matter (KMnO$_4$): 6.41 mg O$_2$ L^{-1}	**mg L^{-1}**	**meq L^{-1}**
Chlorides (Cl$^-$)	20.30	0.57
Sulphates (SO$_4^{2-}$)	21.10	0.44
Nitrates (NO$_3^-$)	0.18	-
Bicarbonates (HCO$_3^-$)	92.30	2.48
Total	133.90	3.50
Cations	**mg L^{-1}**	**meq L^{-1}**
Calcium (Ca++)	28.14	1.40
Magnesium (Mg++)	5.36	0.44
Sodium (Na$^+$)	66.78	2.90
Potassium (K$^+$)	42.66	1.10
Total	142.8	5.84

Table 4: Presentation of the characteristics of some bodies of the boiler room

Bodies characteristics	Boiler	Pump	Water-softener (vol. 1270 m^3)
Type of body	With water tubes	Helico-centrifugal	2 columns
Power (W)	27. 27 10^6	35.7 10^3	-
Operating pressure (bar)	30	Inlet: 0.75 Outlet: 30	-
Water flow	10 kg s^{-1}	10 kg sec^{-1}	20 m^3 h^{-1}
Speed (tr min^{-1})	-	1450	-
Temperature (°C)	350	-	-
Output (%)	-	85	-

make it possible to simplify some methods of chemical calculation. The rapid determination by several equations of load of salt in the lakes allows a fast dimensioning of volumes of ion exchanger for the water demineralization. The determination of the necessary quantity of lime found from the diagram can be determined also roughly by calculation. This research has shown that water of the lakes in Yamoussoukro freed from some pollutants, takes the characteristics of all the raw waters which undergo a treatment of demineralization. The proposals made on the treatment, should solve the environmental problems in the long run and reduce the impact of pollution on the cost of water treatment. Through this study we can extrapolate results over the other lakes which are not located in the

town of Yamoussoukro. Actually the prompt lakes with any industrial use are those which are in the environment of the town of Yamoussoukro because of the risk of drying up of those which are downtown. Finally, water of the lakes in the area of Yamoussoukro could be used for the production of water vapor in the industrial boiler rooms.

REFERENCES

Alep, S., 2000. Elimination of hardness and sulphates contained in water by nanofiltration. University of Alep (DGE).

Hawhen, P. and Lovins *et al.*, 1999. Natural capitalism: Creating the next industrial revolution. Little, Brown, pp: 415.

Leblond, P., 1990. Hydrological complexity of the small catchment area: Example in wet savanna Booro-Borotou (Côte D' Ivoire). ORSTOM, Paris, pp: 331.

Lhote, A., 2000. Criteria of evaluation of the quality of the water of a system tropical: Approach statistical. University of Poitiers (France).

Malicet, R., 1980. National union of the schools of boiler; using guide of the boiler station: Materials Equipment Automatism Pollution Safety Economy. Masson Edn., Paris.

Massin, M., 1982. General metallurgy and thermics treatment: Metallurgy practises for mechanics, tome 2; Édition Pycky, pp: 53-78.

Meybeck, M., D. Chapman and R. Helmer, 1989. Global Freshwater Quality. A First Assessment. Global Monitoring System, Blawell, pp: 1-306.

Pivorora, R., 1996. electromagnetic treatment water for intermediate pressure steam boiler. Petroleum Eng., Vol. 32.

Ray, K. and J. Franzini, 1979. Water Resources Engineering. 4th Edn., Edition Statement, New York, pp: 429-453.

Rodier, J., 1976. Analysis of the Water: Sea Waters, Natural, Waste. 7th Edn., Dunod, pp: 133-175.

Ryding, S.O. and W. Rast, 1994. Control of Eutrophisation of the Lakes and Tanks. Masson Edn., Paris, pp: 294.

Sarco, S., 2001. Pratical guide: Equipment of boiler Room. Vol. 3.

Vogel, G. and H. Angenmann, 1996. Atlas Biology. Masson Edn., Paris, pp: 1-566.

Wahl, H., 1966. Element of Chemistry Inorganic. Masson and Cie Edition, pp: 10-11.