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Congo River Waters Characterization and their Disinfection by Calcium Hypochlorite and their Treatment by Flocculation using Lime and Aluminum Sulphate

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Abstract

The flocculation and the chlorination are two methods very used for the water treatment. The purpose of our study is the characterization of waters of Congo River, the determination of the dose of chlorine, lime and sulphate of aluminum necessary for their disinfection and their flocculation. It appears from all the results that, the best treatment by flocculation-coagulation is obtained by the application of a combination of 25 mg/L from sulfate of aluminum and 10 mg/L of lime. Whereas the best conditions of disinfection are obtained for 6 mg/L of hypochlorite of calcium and a pH value 6.48.

Keywords: Water surface, physicochemical composition, chlorination, flocculation, disinfection, Congo River.

Introduction

Given needs growing and the insufficient of the underground reserves, surface waters are more and more used these last years. Most of these waters contain organic matters resulting from the plant and animal life. This organic load is constituted for the greater part by humic substances[1]. Their presence in natural waters implies numerous problems which are often characterized by: i. a deterioration of the organoleptic quality of waters, ii. a bacterial development in the driving of the distribution network, iii. an important consumption of chlorine which can end in the formation of organohalogenated compounds potentially toxic[2,3].

This last aspect is doubtless the most disquieting, because it's direct incidence on the health of consumer. It thus important to eliminate this organic matter, responsible for the instability of water's quality. The coagulation-flocculation appears more and more as not only a process of clarification but also as a treatment of specific elimination capable, to a certain extent, of competing with expensive treatment as the adsorption on activated char or oxidation by the ozone[4]. The water constitutes a more and more rare, vulnerable and with difficulty renewable foodstuff. Of this fact awareness imposes to manage it in a rational way and to worry about effects of the quality of waters on the natural ecosystems, but especially on the public health[5,6].

It is thus important that water resources are effectively protected against any nuisance and they are treated to produce water which quality satisfies biological and physicochemical standard of drinkability.

Our study is centred on the characterization of the specific problems of quality and treatment of water which could be mobilized for the needs for production of drinking water in Congo-Brazzaville. The River Congo is place between Congo-Brazzaville and Congo-Kinshasa, making both capitals (Kinshasa and Brazzaville), the most moved closer to the World because situated on every bank of this river. It is the most powerful second river to the world, after the River Amazon, with a 42.000 ton / second debit. The objective of our study is the physicochemical characterization of its waters and the determination of adequate conditions of treatment to the optimal elimination of the organic and/or mineral constituents, for their future valorization. So, our study aims at an optimization of two physicochemical processes (Chlorination and Coagulation-flocculation) and appears in three parts.

Both first parts are dedicated to the physicochemical analysis and the disinfection of raw waters. This, to determine their composition in organic and mineral matters. Then an application of the chlorination, in the hypochlorite of calcium, will allow us to determine their consumption in chlorine[7,8]. In the third part, to reduce at most the organic matter and the formation of toxic substances during chlorination, we propose an optimization of the process of flocculation by essays in the combination of sulphate of aluminum and lime.

Material and Methods

Sampling: After several sampling at diverse places of the river, an average sample was set up for analyses in laboratory. The transport of samples since the taking point and the laboratory is made in an icebox at 4°C. When samples are preserved, they are put in the refrigerator. At the time of the dosages, samples are homogenized before proceeding to the analytical operations.

Methods of dosage: i. The mineral elements and suspension materials (SM) were measured by colorimetry using "colorimeter DR / 890 " of " HACH Be Right 48471-94", ii. pH and temperature with pH-meter HANNA " Hi 991001", iii. The conductimetry and the quantity of dissolved solid (TDS) with conductimeter " WTW Cond. 340i" of HACH, iv. Turbidimeter «ELAMOTTE 2020e" is used to determinate the turbidity.

pH Correction with Calcium hydroxide ($Ca(OH)_2$): 100 ml of sample are taken in a becher of 250 ml. We add in the becher a pinch of calcium carbonate ($CaCO_3$). After stirring, let sit the mixture during 15 minutes, then we measure balance pH. We dispose 6 becher of 250 ml containing each 100 ml of sample. We add in every becher, increasing volumes of calcium hydroxide [$Ca(OH)_2$] at 10 g/L. after roughness, and let sit during 15 minutes, we measure the pH in every becher. The becher which will have a pH near the equilibrium pH will allow us to determine the rate of treatment.

Disinfection with Calcium hypochlorite ($Ca(ClO)_2$): We arrange 10 becher of 150 ml containing each 100 ml of sample. In every becher, we add increasing volumes of Calcium hypochlorite (10 g/L). We shake and let sit during 30 minutes. After 30 minutes, by the colorimeter method, we measure total chlorine and residual chlorine in every becher, using the DPD (N, N, diethyl phenyl diamine) as reagent. The DPD gives a red color with chlorinated sample. With the values of total chlorine and residual chlorine, we draw the curve of disinfection to determine the rate of treatment in $Ca(ClO)_2$. This rate of treatment is a minimum point of the curve called: breakpoint.

Treatment of clarifying: The Jar test assays are realized with Stuart SW6 flocculator, by using a solution of sulfate of aluminum to 10 g/L. We arrange 6 bechers of 1000 mL containing each 500 mL of sample. We add in every becher, increasing volumes of sulfate of aluminum ($Al_2(SO4)_3$, $18H_2O$) and hydroxide of calcium ($Ca(OH)_2$) at 10 g/L. We shake quickly during 2 minutes and slowly during 20 minutes. We let rest during 20 minutes to favor the deposit of the formed plops. Then we measure the turbidity of every becher. The rate of treatment in the sulfate of aluminum (S.A) and the in the hydroxide of calcium is given by the mixture contained in the becher which has the smallest value of turbidity.

Results and Discussion

Physicochemical quality: The characteristic parameters of the physical quality and the composition in organic matters of the analyzed water are presents in table-1. We can observe that pH value of Congo River's water is in the WHO standards[9]. Congo River's water is shady and slightly acid, because the turbidity value is superior to the standard. This turbidity can be due to the presence of the dissolved materials and suspension materials, because their concentrations are superior to the WHO standard[10]. These results are consolidated by the rotten smell of this water. The strong turbidity of these waters is an indirect indicator of the microbiological risk that this water can possess. It is weakly mineralized water, because we note a low value of conductivity and a general mineralization value lower than the WHO standard.

Table -1
Physical and Organic Parameters

Parameters	Units	Sample	WHO standards
pH	-	6.73	6.5-9
Temperature	°C	20	12-30
Turbidity	NTU	11.76	5
Color	$mg.L^{-1}$ Pt-Co	7.5	15
Smell	-	Rotten	whithout
Flavour	-	-	whithout
Aspect	-	Trouble	-
Redox Potential	mV	126.19	-
T.D.S (Total dissolved solid)	mg/L	7	-
Conductivity	µs/cm	23	-
Résistivity	Ωcm	43478.26	-
Suspension materials (S. M)	mg/L	10	< 1
General mineralization	mg/L	31.39	< 600

The analysis of the mineral nitrogen table-2 shows that Congo River's water contains ammonium (NH_4^+) and Nitrites (NO_2^-) rates superior to the WHO standards. This pollution can result from domestic effluents, agricultural fertilizers and from certain industrial establishments[11,12]. The by-products of the nitrogen participate, with those some phosphor, in the eutrophication phenomena. Indeed, the ingestion of the nitrogenous compounds is a potential risk factor tumed out for the health. Nitrites, for example, settle on the heamoglobin at the place of oxygen and cause respiratory difficulties (asphyxia): it is the cyanosis which affects essentially the infants (been born or in gestation) and present a risk to short term. At the adult, they are transformed in nitrosamines and other nitrated compounds in the stomach[9,13].

During the chlorination, the nitrogenous compounds could react with the chlorine, to form monochloroamin compounds[14]. They can also be responsible of the unpleasant smells of waters, by the formation of aminoacids.

Table-2
Characteristic parameters of the mineral nitrogen

Parameters	Sample (mg/L)	WHO standards (mg/L)
NH_4^+	0.76	0.5
NO_2^-	0.57	0.1
NO_3^-	3.44	50

The measure of the hardness in table-3 shows that the hydrotimetric strength (TH) value of Congo River's water is 1.15°F (French Degree). This value is lower than the limit of the hydrotimetric strength for waters intended for the human consumption. Its value is fixed in 15°F and is present in table-4. If we compare this value with our sample, we can notice that the water of the River Congo is a soft water. Now, too soft water can present inconveniences for the health, further to the dissolution of metal of canalization such as iron or lead, which will then be ingested by the consumers.

Table-3
Alkalinity and fundamental elements

Parameters	Units	Sample	WHO standards
T.A	mg /L CaCO3	0	50
T.A.C	mg /L CaCO3	5	100
T.Ht	mg/L CaCO3	11.5	150
TH	°F	1.15	15
Ca^{2+}	mg/L	4.6	70
HCO_3^-	mg/L	6.21	200

Table-4
Standard for the hardness of drinks waters[13]

TH (°F)	0-7	7-22	22-32	32-54	54
Hardness of the water	soft	moderately soft	rather soft	hard	very hard

The analysis of metallic and not metallic ions in table-5 present very low concentration compared with the WHO standard. These results come confirmed the data on the general mineralization and the conductivity value. So, the physicochemical analysis show that raw waters of River Congo are soft water, weakly mineralized, very charged and very shady. These waters present a risk of corrosion for canalization (not formation of layer carbonated of protection). The optimization of the stages of disinfection and clarification thus turns out to be necessary

Table-5
Anions, Metallic and Non-metallic Cations

Parameters	Sample (mg/L)	WHO standards (mg/L)
Al^{3+}	0.067	0.2
Mg^{2+}	1.15	50
Cu^{2+}	0.00	1.00
K^+	1.67	12
Na^+	1.86	150
PO_4^{3-}	4.16	5
SO_4^{2-}	0.73	250
S^{2-}	0.072	0.1
Cl^-	3.67	200
Fe	0.13	0.2
SiO_2	8.27	12

Disinfection essay by hypochlorite of calcium: With the aim of eliminating the pathogenic bodies and maintaining the quality of the water, we submitted our samples to a treatment in the hypochlorite of calcium ($Ca(ClO)_2$). The objective of chlorination is the elimination of pathogenic germs, the oxidation of organic matter and some mineral elements, but also to maintain a residual disinfecting capable to make the microbiological protection of water[15]. The oxidizer use is the hypochlorite of calcium. The latter reacts in the water according to the reactions:

$$Ca(ClO)_2 + 2H_2O \longrightarrow 2HClO + Ca^{2+} + 2OH^-$$
$$HClO + 2H_2O \longrightarrow H_3O^+ + ClO^-$$

The disinfectant agents are the hypochlorous acid (HOCl) and the hypochlorite ion (ClO^-). In pH value < 7.5, hypochlorous acid is the dominant form, and when pH value > 7.5, hypochlorite ion is dominant form[15]. The table-6 shows the rates of total and residual chlorine according to the pH for every analyzed sample.

Table-6
Residual and Total Chlorine according to pH

Bechers 150 ml	Total Chlorine (mg/L)	Residual Chlorine (mg/L)	pH
1	1.08	0.25	6.77
2	2.16	0.33	6.82
3	2.7	0.47	6.88
4	3.24	0.5	6.97
5	3.78	0.45	7.08
6	4.32	0.37	7.17
7	4.86	0.32	7.23
8	5.4	0.46	7.30
9	5.94	0.54	7.38
10	6.48	0.59	7.41

By the method of the chlorination in the critical point or breakpoint, we determined the rate of treatment of these waters by the hypochlorite of calcium[8]. The figure-1 gives the critical point for raw water treated. We observe that River Congo's water breakpoint is situated at 6.75 mg/L. The table-7 collects the optimal conditions of disinfection of these waters.

Table-7
Optimal Conditions of Chlorination

Parameters	River Congo Waters
Residual Chlorine (mg/L)	0.32
Total Chlorine (mg/L)	4.86
Rate of treatment in $Ca(ClO)_2$ en mg/L	6.75
pH	7.23

It appear, with regard to these results, that in this case the dominant disinfection agent is the hypochlorous acid, because the pH value of disinfection is lower than 7.5. The presence of ammonia in these waters could be at the origin of this high demand in chlorine[16]. Because NH_4^+ reacts with hypochlorite ion and drive to the formation of NH_3 by the reaction:

$ClO^- + NH_4^+ \longrightarrow HClO + NH_3$

These results are agreement with the works of several authors, which show that humic substances have a maximal reactivity towards the chlorine with pH = 7 and this reactivity can vary according to the metal in solution and to the pH value. Besides the presence of aluminum (Al^{3+}) increase the demand of chlorine for basic pH value[16]. The presence of cations (Mg^{2+}, Ca^{2+}, Na^{+}) drive a progressive improvement of the yield on humic substances elimination. But, this improvement decrease nevertheless for strong contents in salt [17]. We also note that the rates of residual chlorine are superior to the standards of residual chlorine in the faucet after disinfection[16]. Indeed, the reaction of chlorine with the constituents of water can complicate when certain metallic elements such as the iron, the manganese and the aluminum are present in the water.

Besides, the doses of residual chlorine obtained, superior to the standards, prove that the simple disinfection is not enough for making drinkable the River Congo's water. The disinfection could be thus following by dechlorination with the bisulfate of sodium, to neutralize the excess of residual chlorine. The incidence of this excess of residual chlorine is the appearance in waters of an unpleasant flavour and the formation of toxics compounds such as trihalomethanes (T.H.Ms)[18].

Flocculation Essay: Influence of the Dose of Coagulant: Jar test essay allowed determining the optimal doses of coagulant, the times of appearance of plop, the turbidity, the pH and the rate of treatment with the lime. From the turbidity of the raw water and the decanted water, we have determined the yields of the reduction of turbidity by the formula:

$$R = \frac{T_{rw} - T_{tw}}{T_{rw}} \times 100$$

With: T_{rw} = Turbidity of raw water and T_{tw} = Turbidity of treated water

All the results are deposited in table-8. To illustrate these results, figures 2, 3 and 4 presents, respectively, the appearance time of the plop, the residual turbidity and the yields of reduction of the turbidity according to the dose of coagulant.

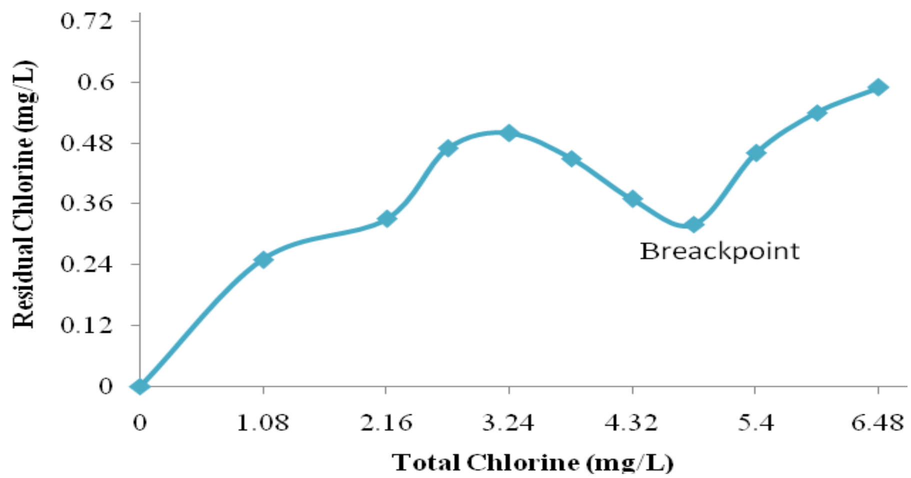

Figure-1
Determination of the breakpoint

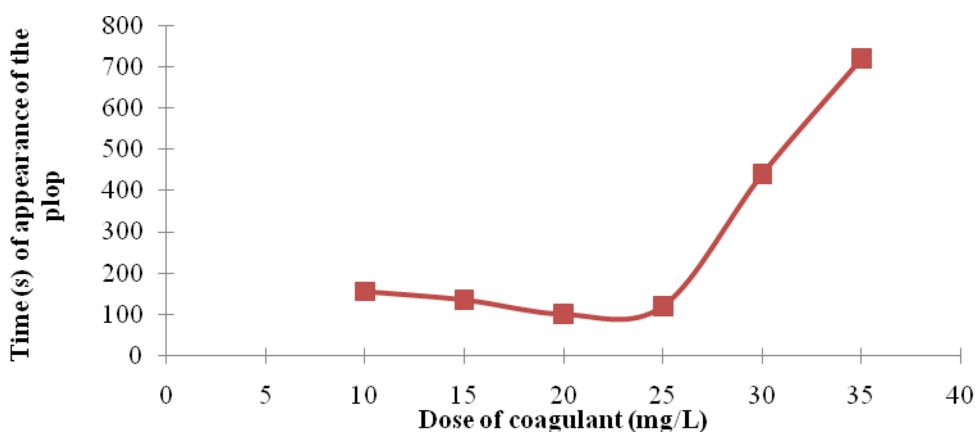

Figure-2
Appearance Time (s) of the plop according to coagulant dose

The appearance time of the plop in figure-2 evolve in two phase. In the first phase, it increases with the dose of coagulant until reach its minima, front of increases in the second phase. It minima is reached later 100s time (1mn 40s). It is necessary to note that this appearance time of plop is included in the fast phase of our jar-test essays. These results are according with others work, which has showed that this phase is the most important of the flocculation[19]. Furthermore, minima of appearance time of plop correspond to 20 mg/L of coagulant. This value does not correspond with the optimal dose reduction of turbidity presented in figure-3 which illustrates the evolution of the residual turbidity according to the dose of coagulant.

It appears in figure-3, that the residual turbidity follows the same tendencies as appearance time of the plop. We can observe in table-8, that the optimal value of elimination of turbidity (25 mg/L) is obtained at 6.48 pH value. These results according to those of others authors, which show that elimination of organic compounds during flocculation makes globally between 5 and 7 pH values[20]. The addition of the sulphate of aluminum in the water lowers the pH value. The use of the lime as additive drives to the formation of hydroxide of aluminum, thanks to an increase of pH, by a following mechanism of coagulation.

$$Al^{3+} + 3H_2O \longrightarrow Al(OH)_3 + 3H^+$$

Indeed, contrary to the employment of the only sulphate of aluminum (diffuse settling), the use of the lime favors the formation of the plops and accelerates their speed settling (settling in piston). The $CaCO_3$ formed during the reaction between water and lime, in tendency to form agglomerates of dense crystals settling in strong speed[21]. The reaction of lime on the raw water is extremely slow in the absence of germs of crystallization (crystals of $CaCO_3$), nevertheless in the presence of germs, the reaction of precipitation becomes fast. The presence of organic colloids being susceptible to obstruct the crystallization, the combination of lime and sulphate of aluminum is use to eliminate better colloids[22]. The evolution of the yields in figure-4, show that the yields increase according to the dose of coagulant until the optimal value, then it decreases after this value.

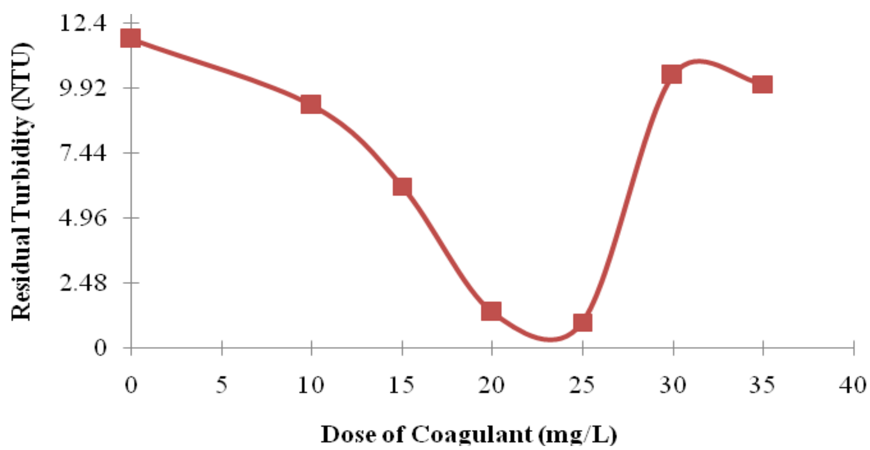

Figure-3
Residual turbidity (NTU) according to coagulant dose (mg/L)

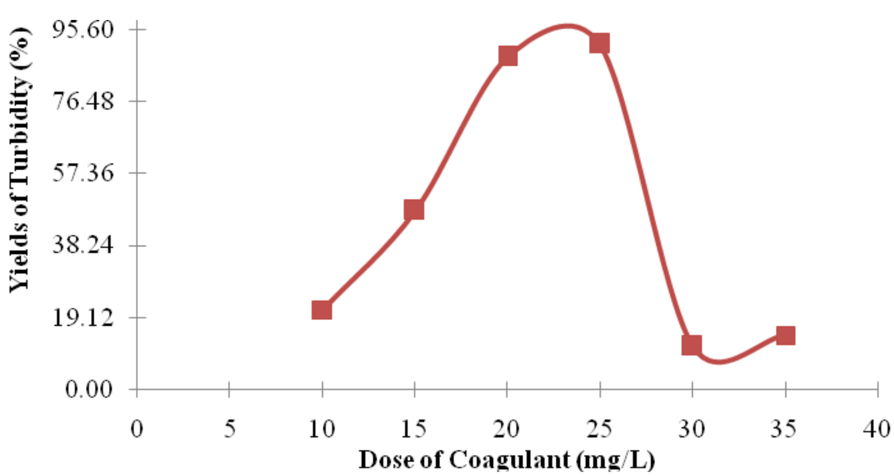

Figure-4
Yields elimination turbidity (%) according to coagulant dose (mg / L)

Table-8
Jar-Test Essays Results

Parameters	Waters of River Congo(Sample)						
	Raw water	Water treated by sulfate of Aluminum and Lime					
Number of Becher	0	1	2	3	4	5	6
Dose of Sulfate of aluminum (mg/L)	0	10	15	20	25	30	35
Dose of Lime (mg/L)	0	2	4	6	10	10	10
pH	6.73	6.70	5.96	6.52	6.48	6.35	6.17
Turbidity	11.76	9.27	6.18	1.37	0.98	10.42	10.07
Colour	9	5	2.5	0	0	8.5	6.25
Time of appearance of plop (mn, s)		2'35''	2'15	1'40''	2'	7'20''	12'
Yield of eliminat° of Turbidity (%)		21.17	47.45	88.35	91.67	11.39	14.37

We notice that action of sulphate of aluminum on River Congo' water is a function of its concentration. The yields evolve from 21 per cent (21%) and 92 per cent (92%). This evolution could be due to the quality of raw waters. Beside, the yield obtained after the optimal dose of coagulant corresponds to the cloudy created by the excess of coagulant. The results corresponding to the optimal dose of lime and sulphate of aluminum are grouped in table-9.

Table-9
Optimal Conditions of Flocculation

Parameters	River Congo Water
Optimal dose of sulfate of aluminum (mg/L)	25
Optimal dose of lime (mg/L)	10
Yield of elimination of turbidity (%)	91.67
pH	6.48

It thus appears that the optimal doses of sulphate of aluminum and lime vary according to the quality of the raw water, what would require in wastewater treatment plants, a continuous assessment of this quality, in particular, the turbidity and the organic matter.

Conclusion

The results of the physicochemical analysis of River Congo's water showed that these waters are turbid and weakly mineralized. This turbidity would be due to the presence of organic matters. We note besides that the pH value of river Congo's water (pH = 6.73) have corresponding to the WHO standards on the quality of drinkable waters. The disinfection in hypochlorite of calcium showed that these waters have a high demand in chlorine (6,75 mg/L) and a breakpoint situated at 7.23 pH value. This high demand in chlorine is justified by the presence of organic matters and ammonia content. However, if the disinfection was made after treatment, we can have the best yields that with raw water. The hypochlorite of calcium revealed a good disinfectant for the waters of River Congo. The jar-test, made with combination of lime and sulphate of aluminum, allowed improving the stages of clarification for the turbidity parameter. The yield is 91.67 per cent (91.67%). The optimal doses of sulphate of aluminum and lime are respectively 25 mg/L and 10 mg/L. The determination of the dose of sulphate of aluminum and lime is a major importance for the valorization of these waters. Through this study, we showed that sulphate of aluminum and lime would be the best flocculants for the treatment of River Congo's water. These results open a perspective for the valorization of these waters in drinkable water. The study shows, especially, the stake in the conservation of reserves in waters of Congo-Brazzaville.

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