



Physico-Chemical Treatment of a Wastewater Collector Loaded with Metals and Suspension Material by The Solution of Raw *Carica papaya* Latex

Togbe Finagnon Crépin Alexis^{1*}, Yete Pélagie¹, Yovo Franck¹
and Wotto Valentin¹

¹Department of Chemistry, Faculty of Science and Technology, University of Abomey-Calavi, Abomey-Calavi, Benin.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The papaya (*Carica papaya*), of the family Caricaceae, is a tree-like tropical plant, native to Central and South America. Papaya cultivation extends to all warm and humid countries. The present study consists in using the solution of raw *Carica papaya* latex (SLCP) cultivated in Benin as a natural biodegradable flocculant in a physico-chemical process to treat liquid discharges loaded with metals including iron, copper, zinc, and manganese; and suspended matter, and also to test its efficiency against other products commonly used in wastewater treatment. The tests were carried out on water samples from the wastewater collector that runs through the Agla district in Cotonou.

The comparative study with a commonly used flocculant, aluminium sulphate, showed outstanding competitiveness with a high flocculation power for the solution of *Carica papaya* raw latex. In six water samples from the collector with average concentrations of iron, copper, zinc and manganese of 18.20 mg/L ; 2.50mg/L ; 3.80 mg/L and 3.70 mg/L respectively, the percentages of metal removal exceeded 90% for iron and manganese and around 85% for copper and zinc with the combination FeCl₃ + SLCP. The NaOH + SLCP combination showed a very significant effect on the removal of metals (96% reduction) and suspended matter.

*Corresponding author: E-mail: abobosfr@yahoo.fr, finagnon.togbe@unstim.bj;

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1. INTRODUCTION

Demographic, economic and urban growth are causing various sources of environmental pollution, particularly in developing countries. Among these sources of pollution, the production of industrial wastewater, often discharged into the receiving environment (sea, rivers, soil) without prior treatment, causes a degradation of the physico-chemical and biological quality of this environment and generates many water-related diseases [1,2].

Within this framework and for a proper strategy of sustainable development of the environment, we were interested in the valorisation of a biodegradable natural product, as a suitable flocculant in the physico-chemical treatment process of a wastewater collector rich in iron, copper, manganese and zinc. The flocculant used is the latex extracted from the green fruit of the *Carica papaya* [3-5].

Iron, copper, manganese and zinc are elements which, in high doses, can cause significant health problems to humans, such as stomach cramps, skin irritation, vomiting, nausea and anaemia. Large amounts of these metals can also be found in soil, among the problems posed, the impact of a progressive and continuous accumulation of these metals in soils on their biogeochemical functioning [6,7].

Also, much work has been carried out to remove these metals and suspended matter from industrial effluents by physicochemical means [8-13]. The processes followed by these authors have involved several treatment steps as well as the use of chemicals that may have adverse effects on human health, such as iron chloride, alumina sulphate and chemical polymers.

This study, which is a continuation of this work, proposes to substitute chemicals with a solution of *Carica papaya* latex as a natural and biodegradable flocculant to treat metal-laden liquid effluents, such as metal-rich and suspended solids wastewater collectors.

A comparative study with an industrial flocculant (aluminium sulphate) was carried out to develop the effectiveness of *Carica papaya* latex solution as a competing flocculant.

2. MATERIALS AND METHODS

2.1 Materials

2.1.1 Sampling

Our study was carried out on water samples from the wastewater collector of Agla, one of the districts of the 13th arrondissement of the commune of Cotonou (Littoral department) in southern Benin. Six wastewater samples were taken and stored in jars labeled EC₁ to EC₆.

2.1.2 Preparation of *Carica papaya* Latex Solution (SLCP)

The papaya trees used for latex harvesting in this study come from a private plantation located in Zinvié in the commune of Abomey-Calavi in southern Benin. Latex was harvested from female papaya plants of the same variety (about ten plants with an average of 06 fruits per plant and average fruit weight of 0.6 kg; fruit age: 2 to 4 months). Latex is obtained by the "bleeding" method and extraction is carried out very early in the morning with aluminium incision blades (3 incisions with 2-3mm depth), plastic collectors and glass jars for latex recovery. The different exuded latex is collected and immediately put into different beakers, each containing 100 ml of distilled water then the mixture is homogenised by stirring to prevent coagulation. After 20 min of sedimentation, the supernatant was filtered on Wattman pleated filter paper and the collected filtrate was used as a flocculant (SLCP).

2.1.3 Description of the treatment process

The treatment of polluted water by the physico-chemical process "coagulation - flocculation" was carried out using a Jar-test system according to two main steps:

2.1.3.1 pH adjustment and coagulation

In order to adjust the pH of the solution, we used soda which generally contributes to coagulation. In parallel, iron chloride was also used as a coagulant in some tests. This step occurs under rapid agitation of 100 rpm for one minute.

2.1.3.2 Flocculation

After adjusting the coagulation-flocculation pH and to accelerate the settling of the suspended

matter, we added one of the two flocculants: either SLCP or industrial flocculant to promote the formation of macro flocs.

The addition of flocculant is done under a stirring of 80 rpm for 30 seconds followed by a slow stirring of 40 rpm and decanting for 30 minutes.

2.2 Methods of Physico-Chemical Analysis

The experimental study and all the analyses were carried out using the following equipment:

- Turbidimeter brand HACH DR/890,
- pH meter Mettler Toledo,
- UV-Visible spectrophotometer type UV-6300PC, VWR,
- Atomic absorption spectroscopy VARIAN SpectrAA-110.

The physico-chemical analyses of the wastewater were carried out at room temperature according to the methods described by Rodier in 1996 [14]. They covered the following parameters: pH, iron, manganese, copper and zinc.

The calculation of the discount rate of a parameter X, expressed as a percentage, is based on the following formula:

$$X = \frac{C_i(X) - C_f(X)}{C_i(X)} \times 100$$

C_i: Initial concentration of X in the wastewater

C_f: Final concentration of X in the treated wastewater.

3. RESULTS AND DISCUSSION

3.1 Characterisation of Waste Water Samples

Iron, copper, manganese and zinc were determined in water samples taken by atomic absorption spectroscopy. According to Table 1, the mean contents of the parameters practically correspond to the parameter values of the EC₄ samples. For this reason, only the EC₄ sample was used for further work in order to evaluate the flocculating and purifying power of SLCP. The average contents retained therefore for iron, copper, manganese and zinc in the wastewater collector are respectively 18.20 mg/L; 2.50mg/L; 3.70 mg/L and 3.80 mg/L.

3.2 Evaluation of the Flocculating Power of SLCP

In order to determine the appropriate working combination (coagulant / SLPC) for the coagulation-flocculation treatment, we performed tests on two types of chemicals (iron chloride and soda). The latter is commonly used in the physico-chemical treatment of industrial effluents [8,9].

The treatment of the water samples from the wastewater collector by coagulation-flocculation was carried out on two combinations noted respectively 1 and 2 (iron chloride/ SLCP and soda/ SLCP).

The various treatment trials were carried out in a zone of optimal pH between 7 and 12 corresponding to the adequate precipitation of iron, manganese, copper and zinc [15-17].

For each test carried out on one litre of wastewater solution; the pH is adjusted in

Table 1. Some physico-chemical parameters of the wastewater samples to be treated

Samples	Parameters							
	pH ± 0,25	CE (µs/cm) ± 170	Turb. (NTU) ± 70	TDS (mg/L) ± 258	Fe (mg/L) ±1,60	Cu (mg/L) ± 0,81	Mn (mg/L) ± 0,62	Zn (mg/L) ± 0,35
EC ₁	7,90	1330	725	1760	18,30	2,60	3,30	3,83
EC ₂	7,76	1383	745	1670	18,02	2,22	3,75	3,90
EC ₃	8,00	1340	736	1749	18,35	2,45	3,80	3,85
EC ₄	7,80	1327	728	1730	18,20	2,50	3,70	3,80
EC ₅	7,60	1310	720	1724	18,17	2,60	3,75	3,68
EC ₆	7,74	1260	696	1747	18,16	2,80	3,40	3,74
Average contents	7,80	1325	725	1730	18,20	2,50	3,70	3,80

combination 1 with soda followed by coagulation with 5 ml of a 40g/l iron chloride solution and in combination 2 with lime, immediately followed by a flocculation step with 0.2 ml of SLCP (Table 2).

The choice of these doses was dictated by the results of numerous studies carried out for the treatment of industrial waste [18-20].

The analysis in Table 2 shows that in both types of treatment, the formation of flocs is swift and optimal at pH 10. Outside this area and for pH values above 10, the treatment with the combination 1 (iron chloride / SLCP) in the presence of soda is more advantageous.

3.3 Evaluation of the Purifying Power of SLCP

3.3.1 Metal removal

To evaluate the purifying power of SLCP, we followed the evolution of iron, copper, manganese and zinc concentrations in water samples from the wastewater collector using SLCP and aluminum sulphate as flocculating agents.

The pH 10, considered to be the optimum flocculation pH for good precipitation of iron, copper, manganese and zinc is adopted.

The results in Table 3 show that the removal of iron, copper, manganese and zinc pollutants ranges from 96% to 97% for the Soda + SLCP treatment combination and from 84% to 91% for the FeCl₃ + SLCP treatment.

The tests carried out show similar results for the combinations Soda + SLCP and Soda + Al₂(SO₄)₃ for a removal rate of about 96% with concentrations of Fe, Cu, Mn and Zn in the treated sample that vary respectively between 0.36 and 0.546 mg/l for iron, 0.075 and 0.112mg/l for copper, 0.148 and 0.155mg/m for manganese and between 0.152 and 0.151 mg/l for zinc. These values meet the discharge standards in force in Benin [21].

On the other hand, for the FeCl₃ + SLCP and FeCl₃ + Al₂(SO₄)₃ combinations, we recorded slightly low values ranging from 84.5% to 92% abatement rate.

3.3.2 Removal of suspended solids

The EC₄ sample, like all other samples taken from the sewage collector, is rich in organic matter and does not settle quickly. To evaluate the efficiency of SLCP in the treatment of water loaded with suspended solids, we compared the flocculant capacity of SLCP to that of Aluminium Sulphate generally used for the treatment of water loaded with suspended solids, on the EC₄

Table 2. Processing conditions for different samples

pH Adjuster	Sodium hydroxide						Lime					
Coagulant	FeCl ₃ , 6H ₂ O						Lime					
Flocculant	SLCP						SLCP					
pH	7	8	9	10	11	12	7	8	9	10	11	12
Flakes shape	M	M	B	B	B	M	M	M	B	B	B	B
Time (mn)	3	2	2	1	1	1	2	2	1	1	1	4

B: Big ; M: Medium

Table 3. Evolution of the concentrations of Fe, Cu, Mn and Zn ions in the sample EC₄

Elements	Fe (mg/L)	Cu (mg/L)	Mn (mg/L)	Zn (mg/L)
Before treatment	18,20	2,50	3,70	3,80
After treatment NaOH + SLCP	0,36	0,075	0,148	0,152
% of elimination	98%	97%	96%	96%
Après traitement FeCl ₃ + SLCP	1,64	0,387	0,351	0,58
% of elimination	91%	84,5%	90,5%	84,74%
After treatment NaOH + Al ₂ (SO ₄) ₃	0,546	0,112	0,155	0,151
% of elimination	97%	95,5%	95,8%	96,02%
After treatment FeCl ₃ + Al ₂ (SO ₄) ₃	1,82	0,375	0,296	0,57
% of elimination	90%	85%	92%	85%

sample, to determine the different optimal parameters (pH, amount of flocculant, settling time) of the two flocculants, to estimate the turbidity abatement capacity of each and to evaluate their aptitude for such a treatment.

The EC₄ sample is pH-adjusted with sodium hydroxide, then flocculated with SLCP or aluminum sulphate and finally decanted. The flocculant is added to the solution to be treated during the rapid stirring phase (100 rpm) of 1 to 2 min followed by a moderate stirring (40 rpm) of 15 to 20 min.

3.4 Optimisation of the Flocculation Ph

To optimise the flocculation pH, we have fixed the dose of the two flocculants. To one litre of water to be treated, we add 0.1 ml of 1% aluminum sulphate in water and 1 ml of 10% SLCP in water.

Turbidity was monitored as a function of pH for a settling time of 30 minutes for all tests.

With regard to the results shown in Fig. 1, the turbidity showed a three-zone evolution of pH for both flocculants:

- In the pH range between 6 and 10.50 the turbidity reaches its maximum while sedimentation remains slow.
- For the two zones of pH less than five or greater than 10.8, very good flocculation is noted, with low turbidity. The optimum pH value of 11.50 ensures good solid-liquid separation, thus increasing the performance

of the treatment process in terms of removal of suspended solids.

3.5 Determination of the Optimal Concentration of the Flocculant

After 5 minutes of settling, we monitored the turbidity as a function of the added volume of SLCP and Aluminium Sulphate. The pH is fixed at 11.50.

It can be seen from Fig. 2 that the results obtained show a minimum turbidity for a volume of 0.1 ml of 1% Aluminium Sulphate and 0.7 ml of 10% cactus juice. It is also noted that the volume of the latter is approximately the same as that of the Aluminium Sulphate.

3.6 Determination of the Optimal Settling Time

The results obtained in Fig. 3 indicate that, for a pH of 11.50 and a volume of 0.1 ml of 1% industrial flocculant, or 0.7 ml of 10% SLCP (optimal conditions obtained), that the low turbidity value is obtained by a treatment with 13 to 15 minutes of settling time for both flocculants.

This shows that the efficiency and reliability of the treatment remains closely dependent on the smooth running of the decantation phase.

These observations suggest that the two combinations studied (soda-ash/SLCP) and (soda-ash/Aluminium sulphate) have a similar effect on the elimination of suspended matter by sedimentation.

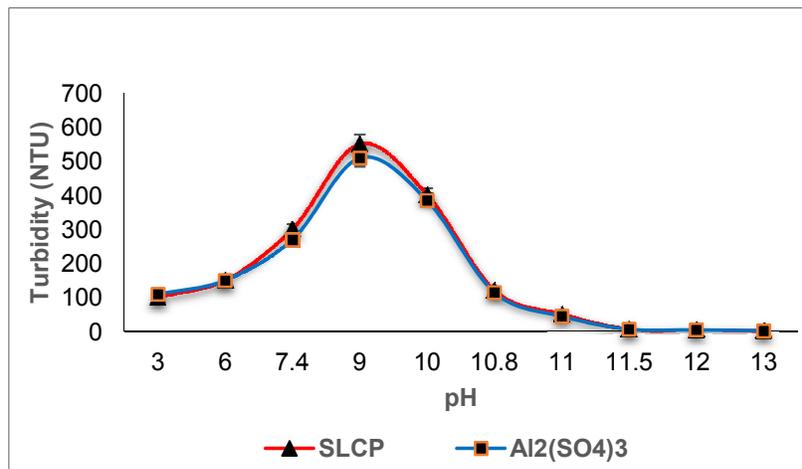


Fig. 1. Turbidity variation as a function of pH

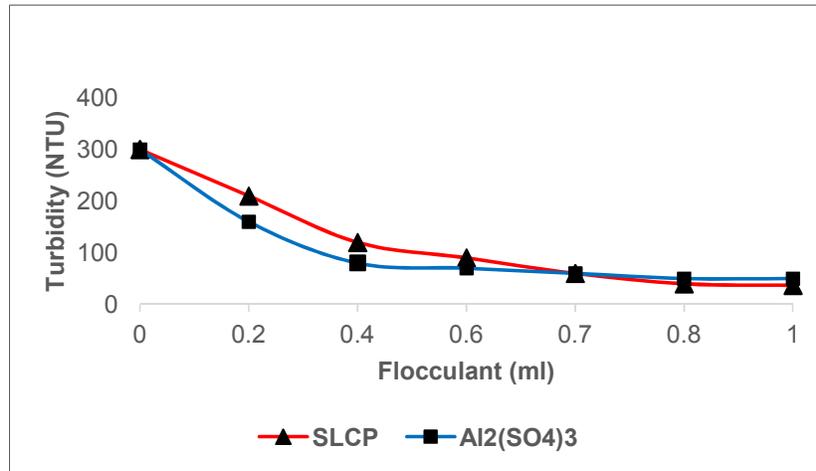


Fig. 2. Variation of turbidity as a function of flocculant volume

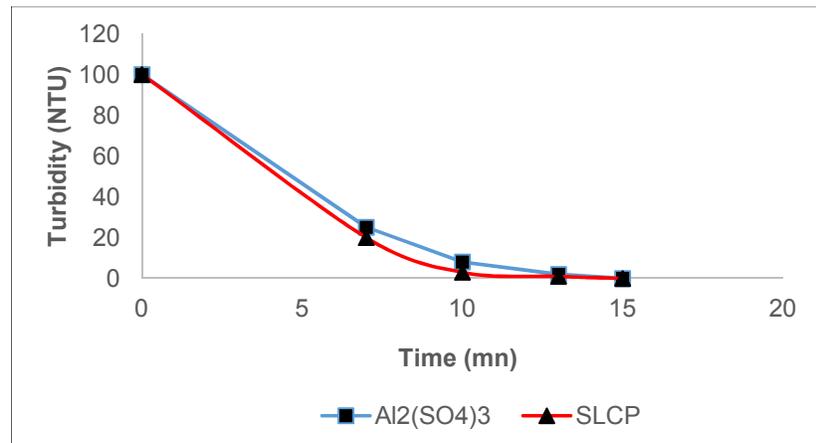


Fig. 3. Turbidity variation as a function of settling time

This study has allowed us to highlight the positive effects of the *Carica Papaya* latex solution in the treatment of a wastewater collector. The results show a good efficiency of the *Carica papaya Latex Solution* for the removal of iron, copper, manganese, zinc and suspended solids with removal rates above 96% for metals to 98% for the suspended matter.

The performance for suspended matter removal is similar to that obtained with processes using an aquatic plant [22]. Among other advantages, *Carica papaya Latex Solution* is a possible alternative to chemical coagulants and flocculants. As a result, the Physico-chemical properties of the treated sample are not altered and the

sludge produced is free of chemical polymers.

4. CONCLUSION

At the end of this work, we used the *Carica papaya* latex solution as a natural flocculant for the treatment of a wastewater collector. Based on the results obtained during this study, we can draw the following conclusions:

- *Carica papaya* latex solution has a outstanding flocculation capacity in the presence of soda alone or mixed with iron chloride.
- The efficiency of this solution, relative to the removal of iron, copper, manganese, zinc and suspended matter, is comparable to that of Aluminium Sulphate.

- The combination of soda ash and *Carica papaya* latex solution appears more interesting, as it offers a more economical alternative in terms of wastewater treatment and is less toxic.

Moreover, the characterisation of the polymer responsible for flocculation is necessary as these first results are encouraging. Also, to better exploit the advantages offered by *Carica papaya* latex solution, we will consider applying it to drinking water taken from surface water used without treatment in some rural regions.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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