PARTICIPATION IN THE STOCKHOLM JUNIOR WATER PRIZE BENIN 2024

IMPROVING THE "M.E.S" SETTLING PROCESS IN WASTEWATER TREATMENT THROUGH THE USE OF PLANT-BASED REAGENTS : AN ECOLOGICAL AND ECONOMICAL ALTERNATIVE FOR REINFORCING THE TEACHING OF EXPERIMENTAL SCIENCES IN MIDDLE AND HIGH SCHOOLS LACKING SUITABLE LABORATORIES AND/OR SUFFICIENT REAGENTS.

PRESENTE PAR APLOGAN INSONDABLE LUCIUS FÊNOU

LYCEE TECHNIQUE COULIBALY, COTONOU BENIN

Summary

Conducting hands-on experiments plays a crucial role in students' understanding of scientific principles. However, the lack of laboratories and appropriate equipment in secondary schools limits this opportunity. This project aims to respond to this problem by focusing on a concrete application: the improvement of the coagulation - decantation process of MES in the treatment of wastewater. Using local plants (okra and aloe vera) as natural. This research explores environmentally friendly and cost-effective solutions for water treatment, while providing students with an opportunity for hands-on learning and technical skills development.

After the various experiments carried out in the laboratory of the Lycée Technique Coulibaly, we noted that the aloe vera powder is the one which acted effectively on the decantation with an abatement rate of 91.82% at an optimal dose of 1000 mg/l.

CONTENTS

LIST OF ABBREVIATIONS AND ACRONYMS

UNESCO: United Nations Educational, Scientific and Cultural Organization

LTC: Coulibaly Technical High School

MES: Suspended Matter.

ACKNOWLEDGEMENTS

I would like to express my gratitude and appreciation to all those who made this study possible.

I would like to thank :

- Principal Ephrem de SOUZA of the Lycée Tchnique Coulibaly in Cotonou and all his technical staff.
- Mr. Frédéric S. ENONHEDO, Workshop Manager of the Water and Sanitation specialty of the Lycée Technique Coulibaly, for his daily support,
- Mr. Jean Miracle AGUIAR, for his advice,
- The NGO FREEE for the various training courses carried out.

Introduction

According to UNESCO's 2014 status report on the education system in Benin, 2 out of 3 secondary schools (i.e. 66.67%) do not have a school laboratory. The report presented in 2019 by the European Union and the Dutch Institute for Multiparty Democracy specifies that according to the 2018-2030 education sector plan in Benin, the construction of 31 laboratories on average per year is planned. Which gives us by extrapolation, a total of 124 laboratories in 2024. Comparing this number to that of colleges in 2024 (880 colleges[1]), we note that only 14% of colleges have laboratories.

This lack of equipped laboratories and adequate chemical reagents (in the colleges that have them) constitutes a major obstacle to scientific education and the participation of learners in resolving environmental challenges, particularly those related to water. Faced with this reality, this project aims to fill the gap relating to the insufficiency of reagents by proposing an innovative and accessible approach to study and improve the settling process of MES in wastewater treatment.

Wastewater treatment is a crucial issue for preserving water quality and protecting the environment. However, conventional treatment methods, such as decantation by adding coagulant, often have limitations in terms of efficiency and cost, particularly in contexts where resources and infrastructures are limited.

Faced with these challenges, the use of aquatic plants in the settling process is emerging as a promising and ecologically sustainable solution. This will allow students to carry out experiments relating to water treatment in order to participate effectively in solving the resulting challenges.

This project therefore proposes to explore and develop this approach using simple and accessible materials and equipment, adapted to the educational environments of secondary schools. By providing learners with a hands-on, hands-on opportunity to experience and understand the fundamentals principles of wastewater treatment, this project aims to strengthen their scientific skills and awareness of environmental issues, while contributing to innovative and sustainable solutions for Water Management.

[1]According to the official website of the Ministry of Secondary Education, Technical and Vocational Training https://enseignementsecondaire.gouv.bj/volet-enseignements/enseignement-secondaire-genera

I. Project issues and objectives

A. Project issues

Conducting experiments is a hands-on approach that strengthens learners' understanding of scientific principles and helps them internalize concepts in meaningful ways. It allows young people to put their scientific knowledge into practice by handling equipment, carrying out measurements and observing real phenomena, encourages the development of their practical and technical skills and promotes the development of critical thinking and scientific curiosity. But to achieve this, reagents and equipment must be available in sufficient quantity and quality. Yet in our middle and high schools, we suffer from a lack of laboratories (66% of middle schools do not even have a laboratory and those that do lack the equipment needed to achieve the excellence we're looking for). Given this situation, how can we encourage creativity and scientific discovery ? how can we afford to try different approaches and new hypotheses ?

To answer these different questions, we decided to focus our research on how to improve the settling process in wastewater treatment by using available plants and at lower cost plant-based reagents. The product thus obtained would be an ecological, economical and accessible alternative for us.

B. The project's objectives :

This project aims to:

- Develop a simple experimental method adapted to the limited resources of educational establishments to improve the settling process of MES in wastewater treatment.
- Evaluate the effectiveness of using of aquatic plants in the wastewater settling and purification process, based mainly on turbidity.
- Raise awareness among students and teachers of the environmental and socio-economic benefits of using aquatic plants in wastewater treatment, and actively involve them in the implementation and monitoring of the project.

II. Literature review

The settling process is a fundamental step in wastewater treatment, aimed at separating suspended particles and suspended matter from the water using gravity. During this process, solid particles heavier than water tend to settle at the bottom of a tank or vat, forming a deposit called "sludge", while the purified water floats and can be directed towards other processing steps. Decantation can be used as a preliminary step or as the main process in wastewater treatment systems, depending on the water quality requirements and the characteristics of the stream to be treated.

Discussing this concept in her master's thesis[2], Lisa POMETI specifies that four settling models are generally recognized depending on the concentration of suspended solids and the tendency of the particles to flocculate.

- **Granular settling (Class I)**: This model is used when the concentration of particles in the solution is sufficiently low to be able to consider that each particle settles independently (negligible interactions with neighboring particles).
- **Flocculent settling (Class II)**: This model is used when the particles flocculate during their settling. The sedimentation rate, shape and density of particles change over time and a single mathematical equation is impossible. Laboratory measurements must then be carried out to determine the appropriate values of the design parameters. This model announces the notion of coagulation-flocculation.
  Coagulation results from the addition of chemical reagents to an aqueous dispersion, in order to assemble the fine dispersed particles into larger aggregates.Flocculation is considered a distinct process that takes place at the end of coagulation. It consists of promoting the growth of macroscopic flocs with or without the use of additives such as flocculation adjuvants..
- **Piston settling (Class III)**: This model is used when the interactions between particles are no longer negligible. The settling speed decreases; the particles adhere to each other and the mass formed settles into a piston, forming a clear interface between the sludge and the supernatant liquid. This decantation takes place at constant speed
- **Settling by compression (Class IV)**: This model describes the phenomenon of sludge thickening. The particles in contact form semi-rigid pseudo-lattices through which the contained liquid is evacuated. The bed then settles at a decreasing speed.

[2] Master's thesis on: Exploration of solid-liquid separation concepts for ammonia water in a mining context

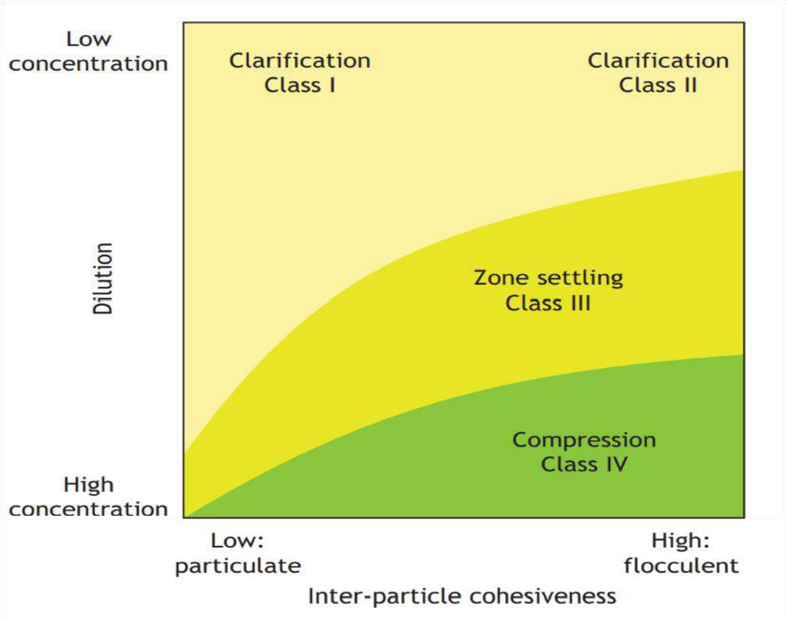


Figure 1: settling models according to solids characteristics

Source: Master's thesis on: Exploration of solid-liquid separation concepts for ammonia water in a mining context

Presentation of selected plants

Figure 2: Okra pods.
Source: LTC laboratory work

Okra is a plant of the Malvacea family. It belongs to the genus Abelmoschus. Originally from Africa, okra is a fruit-vegetable which was discovered around a millennium BC It comes from a robust plant, around 8cm, more or less strongly branched[3].

The sheet established on Okra by the "DeSIRA" program[4]states the following: "Okra (Abelmoschus esculentus) is an herb widely cultivated for its fruits which are eaten like vegetables. Abelmoschus esculentus (2n = 130) is probably an amphidiploid (allotetraploid),

[3]http://gombolfbpgr7.canalblog.com/archives/2014/01/13/28943560.html
[4]Development Smart innovation throuth Research in Agriculture, June 2022

derived from A. tuberculatus (2n = 58), a wild species from India, and a still unknown species with 2n = 72 chromosomes.

Phytochemical composition

Okra is considered a functional food with multiple health benefits due to the many bioactive compounds found in its tissues. Among these compounds we find polyphenols, which are mainly oligomeric catechins and flavonol derivatives (Agregán et al., 2022).

Table 1: Phenolic compounds, ascorbic acid, total flavonoids and total non-flavonoids of okra seeds (Abelmoschus esculentus)

Phenolic compounds (mgEAG/100 g)	**Ascorbic acid (mgEAA/100 g)**	**Flavonoids of totals (mgEQ/100 g)**	**Total non-flavonoids (mgEQ/100 g)**
185 ± 0.10	70 ± 0.01	38 ± 0.00	147 ± 0.10

EAG – Gallic Acid Equivalent, EAA – Ascorbic Acid Equivalent, EQ – Quercetin Equivalent.
Source: Adetuyi et al. (2014)

Aloe vera

Aloe vera is a succulent plant, with evergreen leaves, shallow roots, growing in clumps and even colonies, due to its ability to produce suckers. The stem with a woody base is short (between 50 cm and 1 m high) and bears alternate leaves at the end, embedded in each other, couplets (particularly for young plants) then aging into a rosette.

Each leaf is composed of 3 layers:

- The outer layer, a thick cuticle which has a protective function and gives rigidity to the plant,
- The average middle layer of latex, the chlorophyll parenchyma from which a bitter and yellow sap flows spontaneously after cutting: the juice. The juice is rich in hydroxyanthracene glycosides, mainly aloin A and B: this is the plant's drug
- An internal layer made up of a thick and mucilaginous liquid: gel. It is a mucilage composed of 99% water, the rest of the products which make up this gel give it its exceptional properties. We find vitamins A, C, E, B1, B2, B3, B4, B6, B9 (folic acid), B12, numerous minerals, enzymes (bradykinase, lipase, peroxidase, tyrosinase, etc.), 7 of the 8 essential amino acids, fatty acids (linoleic acid), saponins, salicylic acid, sterols. It also contains monosaccharides (mostly mannose, glucose, galactose) and

polysaccharides which are essentially glucomannans, the most interesting of which is called acemannan.[5]

Figure 3: Aloe vera leaves
Source: internet

III. Materials used and Methodology

Treatment system design:

In order to determine the choice of the most effective plant and the different optimal concentrations necessary for maximum reduction of water turbidity, we carried out an experimental study. During this study, we carried out a comparison of the effectiveness between industrial flocculants (ferric chloride, FeCl3) and okra and Aloe vera powders.

Materials needed:

1. wastewater sample containing suspended particles

2. Plant powder used (okra and aloe vera)

[5]https://www.dieti-natura.com/plantes-actif/aloe-vera.html

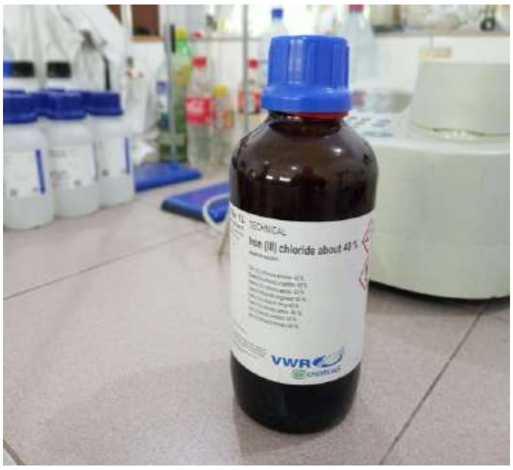
3. The jar test:this is the technique facilitating the optimization of the addition of coagulant and flocculant

4.The turbidimeter: this is the device used to measure the turbidity of water

5.The pH meter: it is a device that allows you to measure the pH of a solution.

6.Magnetic stirrer that allows two solutions to be mixed homogeneously

7.Industrial reagent: ferric chloride



8.beakers

9.Precision scale

Experiment protocol:

1. **Experimentation :**

To effectively conduct our study, we have:

- Use a bucket to draw wastewater. After measuring the turbidity of this water, it was used to fill seven (07) beakers for a quantity of 1 liter each.
- Collected 6.25ml and 7ml of ferric chloride.
- Using the precision balance, we took increasing doses of the natural flocculant (100 mg; 500 mg and 1000 mg);
- Carried out the coagulation-flocculation process using a jar-test with six beakers. The seventh serving as a witness. Increasing doses of industrial flocculant ($FeCl_3$) were introduced into two beakers (numbered 1 and 2). The different doses of natural flocculent were introduced into the four (04) remaining beakers (numbered 3 to 6). All under rapid stirring of 150 rpm for 5 minutes. Following this phase, slow stirring of 35 rpm for 15 minutes followed.
- Using the pH meter, we measured the PH of the treated solutions.
- Measured the turbidity of the samples after 30 minutes to quantify the effectiveness of the settling.

IV. **Analysis and interpretation of results**

	Used water	Ferric chloride		Natural flocculant			
Volume	1 liter	6.25ml	7ml	100 mg	500 mg	1000 mg	
Turbidity (NTU)	64.3	1.68	3.26	69.9	57.5	62.5	Okra
				11.78	10.35	5.24	Aloe vera
Rate (%) = ((tf - ti) / ti) x 100		97.39	94.93	+8.70	-10.57	-2.80	Okra
				- 81.68	-83.9	-91.85	Aloe vera

After the various results presented above, we note that the okra powder did not act effectively on the settling. This is not the case for aloe vera powder. We also note that the optimal dose of aloe vera is 1000 mg/l with a reduction rate of 91.85%.

7. Conclusion

Conducting experiments is a hands-on approach that strengthens learners' understanding of scientific principles and helps them internalize concepts in meaningful ways. It allows young people to put their scientific knowledge into practice by handling equipment, carrying out measurements and observing real phenomena, encourages the development of their practical and technical skills and promotes the development of critical thinking and scientific curiosity. But unfortunately 66.67% of secondary schools in Benin do not even have the means to carry out these different experiences.

Using local plants (okra and aloe vera) as natural reagents, this research explores environmentally friendly and cost-effective solutions for water treatment, while providing students with an opportunity for hands-on learning and technical skills development.

After the various experiments carried out in the laboratory of the Coulibaly technical high school, we noted that the aloe vera powder is the one which acted effectively on the decantation with a reduction rate of 91.82% at an optimal dose of 1000 mg/l.

References

1. https://enseignementsecondaire.gouv.bj/volet-enseignements/enseignement-secondaire-genera
2. Master's thesis on: Exploration of solid-liquid separation concepts for ammonia water in a mining context
3. http://gombolfbpgr7.canalblog.com/archives/2014/01/13/28943560.html
4. https://www.dieti-natura.com/plantes-actif/aloe-vera.html