



Project : BIOPUR



**Algerian Democratic and Popular Republic
Ministry of Higher Education and Scientific
Research**

University AUGUST 20, 1955 Skikda

A project to obtain a start-up certificate within the framework of

**Ministerial Resolution 1275
Speciality : Materials Chemistry**

Title:

**Enhancing and evaluating the value of waste biomass by producing
high-value products: Moving toward zero-waste**

Faculty of Sciences
Department of Chemistry



Commercial Name.

BIOPUR

Information card

About the workgroup management team.

Supervisory team :

Specialty	
Senior supervisor: Dr. BENACHOUR NAIMA	Chemistry
Co-supervisor: Dr. FERKOUS HANA	Process Engineering
Co-supervisor: Phd. GHOUAFRIA IMANE	Environmental Process Engineering

Project team

Specialty	
Student 01: ZITOUNI RAZIKA	Materials Chemistry

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Introduction

In the last few decades, natural extracts have been widely applied as corrosion inhibitors, a problem that constantly affects the entire industry, causing economic losses and, in some cases, loss of product quality. Mild steel (MS) is frequently used in industry due to its cost-effectiveness, impressive mechanical characteristics, high mechanical properties, and the possibility of forming pipes without changing their properties. Nevertheless, it exhibits poor resistance in acidic environments (widely used in various industry sectors), which limits the use of MS in many applications. Problems caused by corrosion often lead to production stoppages or even the breakdown of equipment and/or pipes, which can cause damage to workers and the environment and lead to astronomical financial losses for the industry.

First axis:
Presentation of the project

First axis: Presentation of the project

1. The project idea

Environmental issues have been the focus of the discussion in scientific, industrial, and social circles. Since the beginning of human development, the environment has been directly affected by industrial and population growth. The increase in population consequently increases food consumption, and to meet demand, the industry has increasingly deforested virgin areas to have a larger production area and used chemical products, such as pesticides, to increase production. These actions taken by the industry end up directly harming the environment, often generating irreversible problems in the ecosystem. Biotechnology came as an alternative to try to mitigate, eliminate, and compensate for the damage caused by man. The reuse of biomass for industrial application has become very promising in several sectors where it is possible to solve problems in the industry through renewable sources and add value to a product that initially would not have an intended use, in the case of biowaste.

2. Proposed values

- Enhancing and evaluating the value of waste biomass.
- Modernity: Relying on a completely new and effective method for treating waste water.
- Performance: Low production cost by adopting a new product.
- Enhance risk management and ensure customer protection.
- Ease of use: allowing more convenience, by making products easier and simpler to use.

The work team

	Specialty
Student 01: ZITOUNI RAZIKA	Materials Chemistry

Project objectives

Enhancing and evaluating the value of waste biomass by producing high-value products paves the way toward a zero-waste strategy, transforming trash into cash.

Our goal is to become the leading competitor in the industrial polymers market in Algeria within, aiming to capture a market share of the total Algerian production capacity.

A timetable for project realization

Here's a general timetable for a project that involves the use of *Corchorus olitorius* leaves as a corrosion inhibitor for carbon steel and its waste as an adsorbent for methylene blue dye. This timetable assumes a research project of about **6 months** duration. Adjust based on the specifics of your resources and scope.

Month 1: Planning and Preparations

1. Week 1–2:

- Conduct a literature review on corrosion inhibitors and adsorbents using *Corchorus olitorius*.
- Define project objectives and methodologies.

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- Procure materials: *Corchorus olitorius* leaves, carbon steel samples, methylene blue dye, chemicals, and equipment.

2. Week 3–4:

- Develop a detailed experimental plan.
- Perform preliminary tests for leaf extraction and waste processing.

Month 2: Extraction and Characterization

1. Week 1–2:

- Prepare extracts from *Corchorus olitorius* leaves using methods like maceration, Soxhlet extraction, or ultrasonication.
- Characterize the extract using techniques like FTIR, UV-Vis spectroscopy, and GC-MS.

2. Week 3–4:

- Process *Corchorus olitorius* waste into adsorbent material (e.g., drying, grinding, and activation if needed).
- Characterize the adsorbent (e.g., SEM, BET analysis, and FTIR).

Month 3: Corrosion Inhibition Study

1. Week 1–2:

- Prepare carbon steel samples (e.g., polishing, degreasing).
- Conduct weight loss experiments in corrosive media (e.g., acidic environment) with varying concentrations of the leaf extract.
- Perform electrochemical studies (e.g., potentiodynamic polarization and EIS).

2. Week 3–4:

- Analyze data to determine inhibition efficiency and the mode of action.
- Optimize extract concentration and conditions for maximum inhibition.

Month 4: Adsorption Study

1. Week 1–2:

- Conduct batch adsorption experiments using the prepared adsorbent.
- Study parameters like PH, initial dye concentration, contact time, and adsorbent dosage.

2. Week 3–4:

- Determine adsorption capacity and evaluate the material's efficiency.

Month 5: Synergistic Applications and Optimization

1. Week 1–2:

- Explore combined applications or integrated systems using *Corchorus olitorius* derivatives.
- Investigate recycling or regeneration potential of the adsorbent.

2. Week 3–4:

- Optimize both processes (corrosion inhibition and dye adsorption) based on experimental results.

Month 6: Data Analysis and Reporting

1. Week 1–2:

- Perform comprehensive data analysis and statistical validation.
- Compare results with existing literature to highlight contributions.

2. Week 3–4:

Prepare the final report, including results, discussions, and conclusions

Second axis
Innovative aspects

Second axis: Innovative aspects

- **Bio-based Alternatives:** Utilizing *Corchorus olitorius* agricultural waste as a corrosion inhibitor aligns with the global shift toward sustainable and environmentally friendly solutions.
- **Phytochemical Potential:** The waste of *C. olitorius* is rich in bioactive compounds such as flavonoids, tannins, and saponins, which are known to adsorb on metal surfaces and create protective films, preventing corrosion.
- **Cost-Effectiveness:** Agricultural waste is abundant and inexpensive, making it an economically viable alternative to synthetic corrosion inhibitors.
- **Eco-friendly Approach:** Unlike traditional inhibitors, which may release toxic by products, *C. olitorius* waste provides a biodegradable and non-toxic option
- **Circular Economy:** Using agricultural waste for both corrosion mitigation and water adsorption embodies the principles of waste valorization and resource efficiency.
- **Reduced Waste:** This approach helps manage agricultural residues effectively, reducing environmental pollution caused by waste disposal.

4. Technological and Scientific Contributions

- **Advanced Material Science:** The study of how *C. olitorius* waste interacts with metals (adsorption isotherms, thermodynamics, and surface characterization) could lead to innovations in materials engineering.
- **Biochar and Nanotechnology Integration:** Converting *C. olitorius* waste into biochar or nanomaterials could enhance its efficacy in

corrosion mitigation and water adsorption, opening doors for novel applications.

- **Plant Physiology Insights:** Studying how these waste materials influence water uptake by plants can contribute to a deeper understanding of plant-soil interactions and drought resistance.

5. Socio-Economic and Environmental Impact

- **Sustainable Agriculture:** The dual-use of *C. olitorius* waste supports sustainable farming practices by reducing reliance on chemical inputs and improving resource efficiency.
- **Empowering Rural Communities:** Farmers could generate additional income streams by valorizing agricultural waste.
- **Mitigating Climate Change:** Reduced chemical usage and improved water management contribute to a lower environmental footprint.

**Third axis:
Strategic market analysis**

Third axis: Strategic market analysis

A strategic market analysis for products derived from *Corchorus olitorius* leaves as corrosion inhibitors for carbon steel and its waste as adsorbents for methylene blue dye can be structured as follows:

1. Market Overview

Corchorus olitorius is widely grown in tropical and subtropical regions. Its natural phytochemical components make it useful in corrosion inhibition and environmental cleanup.

- **Corrosion Inhibition:** Phytochemicals such as polyphenols, flavonoids, and alkaloids have been identified as effective corrosion inhibitors for carbon steel in acidic environments.
- **Adsorption Applications:** Agricultural waste from *Corchorus olitorius*, including stems and leaves, contains lignin and cellulose, making it a low-cost, sustainable adsorbent for removing dyes like methylene blue from wastewater.

2. Industry Trends

Corrosion Inhibitors Market:

- Shift toward **green corrosion inhibitors** due to environmental regulations.
- Growing demand in **oil and gas, chemical, and construction industries** to protect pipelines and equipment from acid corrosion.
- Emerging markets in Asia-Pacific are driving growth, especially in infrastructure development

Adsorbent Market:

- Rising concerns over water pollution and increasing regulations on industrial wastewater treatment.
- Growing demand for cost-effective and biodegradable adsorbents in textile and dyeing industries.

3. SWOT Analysis

Corchorus Olitorius as a Corrosion Inhibitor:

Strengths:

- Sustainable and eco-friendly alternative to synthetic inhibitors.
- Abundant availability in agricultural regions.

Weaknesses:

- Limited awareness of its efficacy compared to commercial inhibitors.
- Variability in performance due to differences in plant composition.

Opportunities:

- Increased adoption in emerging markets with high industrial corrosion challenges.
- Potential for integration into multi-functional coatings.

Threats:

- Competition from other natural inhibitors like neem and green tea extracts.
- Market dominance by synthetic inhibitors.

Corchorus Olitorius Waste as an Adsorbent:

Strengths:

- Low cost and biodegradable.
- High adsorption capacity due to natural porosity and functional groups.

Weaknesses:

- Requires pre-treatment or modification to enhance efficiency.
- Limited scalability for industrial use without process optimization.

Opportunities:

- Application in textile wastewater treatment and municipal wastewater plants.
- Potential for combining with nanomaterials for improved performance.

Threats:

- Competing technologies like activated carbon and synthetic adsorbents.
- Resistance from industries relying on traditional methods.

4. Market Size and Growth Potential

- **Corrosion Inhibitor Market:** Valued at USD 7 billion in 2023, expected to grow at a CAGR of 4-5% by 2030.
- **Adsorbent Market:** Estimated to grow at a CAGR of 6-7% from 2023 to 2030, driven by rising wastewater treatment needs.

5. Target Customers and Applications

Corrosion Inhibitor:

- Industries: Oil & gas, chemical processing, and marine industries.
- Specific Applications: Acid cleaning, pickling processes, and protective coatings.

Adsorbent:

- Industries: Textile, paper, and dye manufacturing industries.
- Specific Applications: Removal of methylene blue and other synthetic dyes from industrial effluents.

6. Competitive Landscape

Corrosion Inhibitors:

- Key Players: Cortec Corporation, BASF, and Henkel.
- Differentiation: Focus on eco-friendly solutions and cost-effectiveness.

Adsorbents:

- Key Players: Calgon Carbon Corporation, Cabot Corporation.
- Differentiation: Emphasis on sustainability and adsorption efficiency.

7. Strategic Recommendations

Research and Development:

- Optimize extraction methods to enhance corrosion inhibition efficiency.

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- Improve the adsorption performance of *Corchorus olitorius* waste via chemical or physical activation.

Market Penetration:

- Collaborate with industries to demonstrate the effectiveness of these solutions in real-world applications.
- Develop educational campaigns to highlight the benefits of green inhibitors and adsorbents.

Cost Optimization:

- Utilize agricultural by-products to reduce production costs.
- Leverage government subsidies for eco-friendly initiatives.

Partnerships and Collaborations:

- Work with wastewater treatment companies and industrial players for large-scale adoption.
- Engage in joint ventures with academic institutions for technology validation.

The fourth axis
Production planning and organization

The fourth axis: Production planning and organization

1. The production process

The objective of this framework is to create eco-friendly solutions utilizing *Corchorus olitorius* for corrosion inhibition and adsorption. The production planning and organization are display in figure 1.

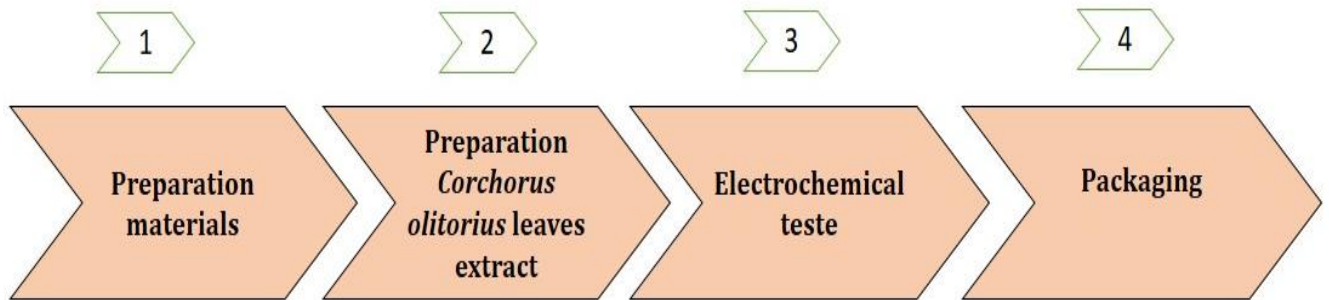


Fig 1. Diagram showing the production *Corchorus olitorius* for corrosion inhibition

Fifth axis
Financial plan

Fifth axis: Financial plan

1. Balance sheet (Bilan financier):

1.1. Bilan Actif:

En milliers DZD	PREVISIONS	
	2025	2026
ACTIF NON COURANT		
Ecart de réévaluation ou goodwill)		
Immobilisation Incorporelles		
Immobilisation Corporelles	1 791 000	1 791 000
Terrain		
Bâtiment		
Autres Immobilisations Corporelles		
Immobilisations en concession		
Amortissements	179 000	358 000
Montants nets	1 612 000	1 433 000
Impôts différés actif		
ACTIF NON COURANT	1 612 000	1 433 000
ACTIF COURANT		
Stocks et encours	888 528	1 332 792
Autres créances et emplois assimilés		
Disponibilités et assimilés		
Placements et autres actifs financiers courants		
Trésorerie	3 148 902	8 163 740
ACTIF COURANT	4 037 430	9 496 532
TOTAL ACTIF	5 649 430	10 929 532

1.2 Bilan Passif :

En milliers DZD	PREVISIONS	
	2025	2026
<u>CAPITAUX PROPRES</u>		
Capital émis	1 791 000	1 791 000
Capital non appelé		
Ecart de réévaluation		
Primes et réserves- Réserves Consolidées		
Résultat net- RN part du groupe	3 256 300	4 244 060
Autres capitaux propres- report à nouveau		4 012 327
Part de la société consolidante (1)		
CAPITAUX PROPRES	5 047 300	10 047 387
<u>PASSIFS NON-COURANTS</u>		
Provisions et produits constatés d'avance		
PASSIFS NON-COURANTS		0
<u>PASSIFS COURANTS</u>		
Fournisseurs et comptes rattachés	555 330	832 995
Impôts	0	0
Autres dettes	46 800	49 140
Trésorerie passif		
PASSIFS COURANTS	602 130	882 135
TOTAL PASSIF	5 649 430	10 929 522
Vérification de l'équilibre Actif/Passif	-	

2. Tableau des Comptes de Résultat :

En Milliers DZD		PREVISIONS	
		2025	2026
VENTES DE MARCHANDISES			
Production vendue	Produits fabriqués	11 106 600	16 659 900
	Prestations de services		
	Vente de travaux		
Subvention d'exploitation			
Production de l'exercice		11 106 600	16 659 900
Achats consommés		6 064 000	9 995 940
Services Extérieurs et autres consommations		700 000	880 000
Consommation de l'exercice		6 764 000	10 875 940
Valeur ajoutée d'exploitation		4 342 600	5 783 960
Charges de personnel		907 200	1 360 800
Impôts et taxes et versement assimilés		0	0
Excédent Brut d'Exploitation		3 435 400	4 423 160
Dotations aux amortissements, Provisions		179 100	179 100
Reprise sur pertes de valeurs et provisions			
Résultat opérationnel		3 256 300	4 244 060
Résultat financier		0	0
Résultat Ordinaire avant impôt		3 256 300	4 244 060
Impôt exigible sur résultat ordinaire			
Impôt différé (variation) sur résultat ordinaire			
RESULTAT NET DE L'EXERCICE		3 256 300	4 244 060

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Application	CA mensuel DA	CA annuel DA
Première année	925500	11 106 000
Deuxième année	1 388 325	16 659 900

Tableau des détails des amortissements des investissements :

	montant	%	2025	2026
Equipm ent	1 791 000	10 et 5	179 000	358 000
Total			179 000	358 000

Chiffre d'affaires optimiste

Indice de croissance 50 %

Produit à destiné client	2025	2026
Produit	100	150
Prix HT	9 255	9 255
CA mensuel total DA	925 000	1 388 325
CA annuelles DA	11 106 000	16 659 900

Chiffre d'affaire pessimiste

Indice de croissance 37.5%

Produit à destiné client	2025	2026
Produit	50	75
Prix HT	9 255	9 255
CA mensuel total DA	462 750	694 125
CA annuelles DA	5 553 000	8 329 500

Tableau 01 : coûts des services nécessaires pour le projet

Déclaration	Services requis pour le projet
Electricité	60 000
L'eau	10 000
L'internet	12 000
Publicité	100 000
total	182 000

3. The Business Model Canvas (BMC):

<p>5. الشراكات الرئيسية (Key Partnerships)</p> <ul style="list-style-type: none"> Agricultural suppliers: Ensuring consistent and sustainable sourcing of Jew's mallow. Research institutions: Collaborating on advanced extraction techniques. Industrial validation partners: Testing inhibitors in real-world applications. Distributors: Expanding market reach through established networks- 	<p>4. الأنشطة الرئيسية (Key Activities)</p> <ul style="list-style-type: none"> - Plant cultivation and sourcing: Ensuring consistent supply of Jew's mallow. - Extraction and processing: Developing inhibitors from plant components. - Quality control: Maintaining high standards of product efficacy. - Marketing and outreach: Promoting the product to target industries 	<p>3. القيمة المضافة المقترحة (Value Propositions)</p> <ul style="list-style-type: none"> - Eco-friendly innovation: Extracted from Jew's mallow, reducing reliance on synthetic chemicals. - Cost-effective: Utilizes a widely available and inexpensive plant resource. - High efficacy: Provides excellent corrosion inhibition properties. - Sustainable production: Promotes natural resource utilization and reduces environmental impact. 	<p>2. العلاقات العملاء (Customer Relationships).</p> <ul style="list-style-type: none"> - Technical support: Providing expertise on application and performance. - Custom solutions: Adapting the inhibitor formulation to meet specific needs. - Sustainability engagement: Aligning with customers' environmental goals. - Regular feedback loops: Continuous improvement based on client input. 	<p>1. شرائح العملاء (Customer Segments)</p> <ul style="list-style-type: none"> - Oil and gas industries: For pipeline and equipment corrosion protection. - Chemical plants: Corrosion prevention in chemical storage and processing units. - Marine industries: Anti-corrosion solutions for ships and offshore structures. - Construction and infrastructure: Protection of steel reinforcements in concrete structures. - Industrial suppliers: Distributors and maintenance companies
<p>9. هيكل التكاليف (Cost Structure)</p> <ul style="list-style-type: none"> - Fixed costs: <ul style="list-style-type: none"> ○ Setup and maintenance of production facilities. ○ Salaries for technical and R&D staff. ○ Investment in research and product development. - Variable costs: <ul style="list-style-type: none"> ○ Sourcing and transportation of Jew's mallow. ○ Energy and processing expenses. ○ Packaging and distribution costs. 	<p>8. مصادر الإيرادات (Revenue Streams)</p> <ul style="list-style-type: none"> - Sales of corrosion inhibitors: Primary revenue source. - Licensing technology: Offering extraction and formulation methods to other producers. - Consultancy services: Assisting industries with customized anti-corrosion solutions 	<p>7. الموارد الأساسية (Key Resources)</p> <ul style="list-style-type: none"> - Jew's mallow supply: Reliable and sustainable plant sourcing. - Processing facilities: Equipment to extract and formulate the inhibitor. - R&D team: Innovating and enhancing product performance. - Industry partnerships: Collaborations for testing and validation. 	<p>6. التوزيع (Channels)</p> <ul style="list-style-type: none"> - Direct sales: Selling directly to industrial users. - Partnerships: Collaborating with distributors and equipment suppliers. - Online channels: E-commerce platforms targeting specialized industries. - Expos and trade shows: Participating in industry events to showcase the product. 	

**Sixth axis Experimental
prototype**

Sixth axis: Experimental prototype

Introduction

This study is composed of two parts. In the first, we will describe the green inhibitor extraction method based on *Corchorus Olitorius* leaf extract. It brings together the electrochemical and characterization methods used to study the different parameters, which influence the inhibition of corrosion of steel in the acidic environment. The second part, we will present the different techniques used in its characterization.

Materials and methods

Preparation of plant material used as inhibitor

The *Corchorus olitorius* leaves, collected from the Guelma region in July 2024, were initially separated from the rest upon arrival at the laboratory. The leaves were thoroughly washed with tap water to remove any impurities. Following the washing process, the leaves were dried in a well-ventilated area, shielded from direct sunlight, for a duration of three weeks. After drying, the leaves were finely ground using a coffee grinder to obtain a fine powder. This powder was then stored for further use



Fig 2: Corchorus Olitorius.

Glassware and small equipment

The glassware and small equipment used in the experiment are summarized below.

Laboratory glassware	small equipment
-volumetric flasks - vacuum flasks - funnels - beakers - pipettes - test tube - test tubes - vials	- Precision balance - PH meter - Mortar - sonicator - Vacuum pump - Muffle furnace - Crucible

Materials

For the characterization of our product, we used the following techniques:

- Quattro model scanning electron microscope.
- Sigma centrifuge brand
- UV-Visible Spectrophotometer

Reagents and chemical compounds

All chemicals, solvents, and reagents used in this work are described in the table below:

Table.1 : Produits chimiques utilisés.

solvents and reagents	Chemical formula	Purity%	M (g/mol)
Methanol	CH ₃ OH	99,6	32.04
Acide chlorhydrique	HCl	37	36,461
Zinc Chloride	ZnCl ₂	-	163,28
Methylene blue	<u>C₁₆H₁₈ClN₃S</u>	-	319.9
Hydroxyde de sodium	NaOH	97	40

Inhibitor extraction

Fifty grams of *Corchorus Olitorius* leaf powder were weighed and extracted with 500 mL of a methanol mixture at ambient temperature, with stirring, for 24 hours in the dark. After 24 hours, the mixture was placed in an ultrasonic bath (sonicator) at room temperature, where the extraction continued for 30 minutes. The power used during the sonication was 720 W. The extract was then filtered, and the filtrate was evaporated using a rotary evaporator (rotovap) to recover the solvent. The collected filtrate was stored in a small opaque bottle until further use.

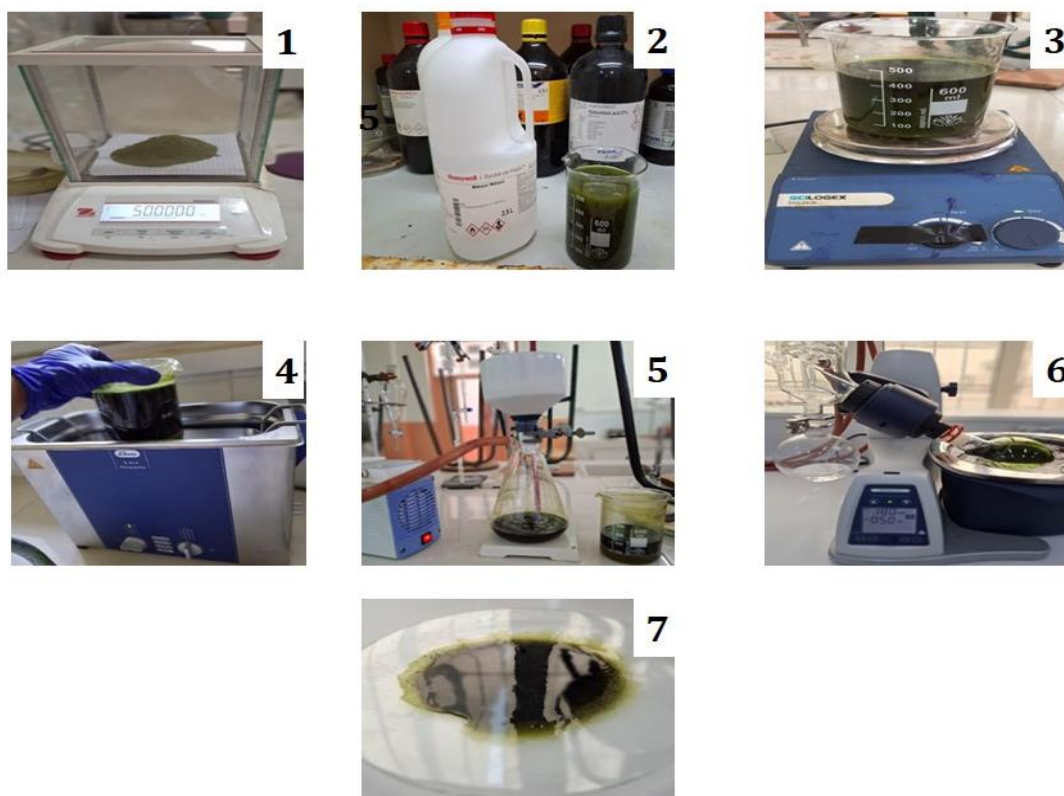


Fig 3: Extract preparation steps

Activated carbon preparation

Corchorus Olitorius waste was dried in an oven at 105C° for 24 h. Then, the ZnCl₂ solutions were dissolved in a 2:1 wt ratio by adding *Corchorus Olitorius* waste. The impregnation step lasted 24 h at room temperature. The mixtures were first dried at 110C° for the impregnated sample. The precursor is then pyrolyzed for three hour in a 700 C° oven with a linear temperature increase of 10 C° /min1 under airflow. After being cooled to room temperature, it is rinsed with NaOH, HCl and hot distilled water until neutral. After drying overnight at 105 C°, the powder is ground to a fine powder with a 200 mm diameter and stored in an airtight container for future use.

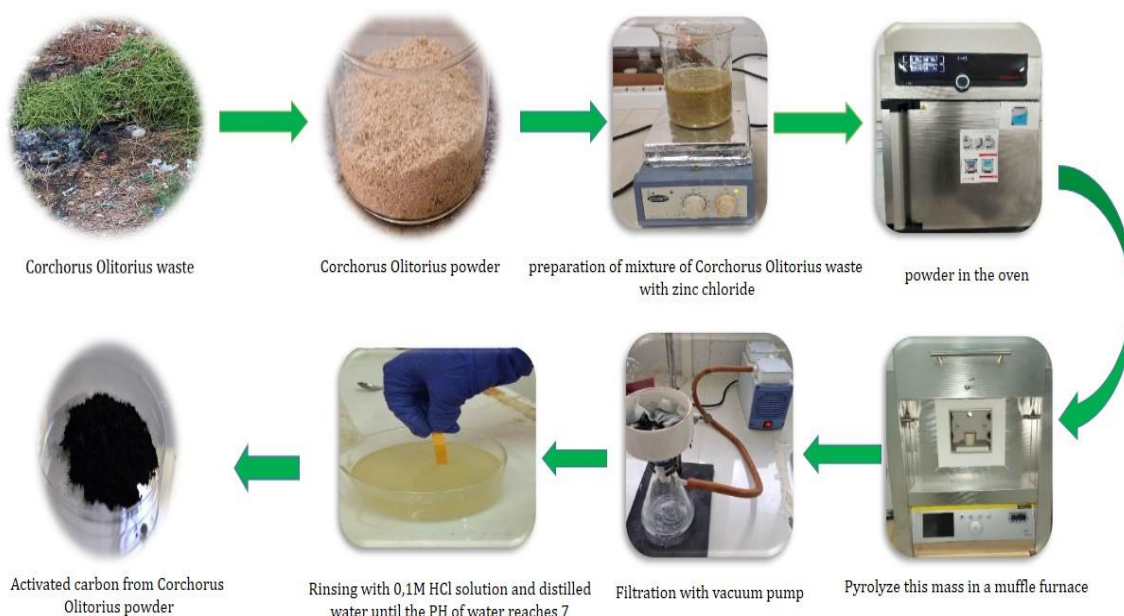


Fig 4: Activated carbon preparation steps

Extraction yield

After extraction we calculated the yield according to the following formula :

$$R\% = \frac{M_f}{M_i} \times 100$$

R (%): Extraction yield.

M_f : Final mass in g of the extract after evaporation of the solvent.

M_i : Initial mass in g of the leaf powder.

Specimens Preparation

Tests were performed on X52Q steel specimen cut into a rectangular shape of 1×1 cm² for electrochemical tests, as the working electrode (WE). The samples were prepared in inert resin and polished with different grades of emery papers from 400-2500 then cleaned with double distilled water, degreased with acetone and dried Fig 5.



Fig 5: Working electrode (WE)

Corrosive solutions

By diluting 37% weight grade reagent in deionized water, a corrosive solution of 1 M hydrochloric acid produced. The corrosive medium solutions were made with varying doses of Corchorus Olitorius leaves inhibitor (50, 100, 200, 300, and 400 ppm).

Electrochemical measurement

Polarization curves

The electrochemical study was conducted at the Science Department laboratory of the University of Skikda, using a POTENTIOSTAT/GALVANOSTAT/ZRA GAMRY Reference 600+ Fig 6. This device is connected to a PC running the Gamry Instruments FRAMEWORK software. The obtained curves are then exported to EC-Lab software. This method allows for the determination of the following parameters: instantaneous corrosion rate (I_{corr}), corrosion potential (E_{corr}), Tafel slopes, polarization resistance (R_p), and diffusion-limited currents



Fig 6: Instrument for measuring electrochemistry

Electrochemical cell

The electrochemical tests were conducted in a three-electrode electrochemical cell, consisting of Fig 8:A platinum counter electrode.

1. A silver/silver chloride (Ag/AgCl) reference electrode.
2. A working electrode made of the steel under study.



Fig 7: Electrochemical cell used

Preparation of methylene blue

To prepare the stock solution of methylene blue, 0.1 g of the compound is dissolved in 1 L of distilled water at ambient temperature. This stock solution, with a concentration of 3.13×10^{-4} mol/l, is then used to prepare a series of diluted solutions by successive dilution in volumetric flasks. The concentrations of the diluted solutions are determined using the dilution law, expressed as $C_1 \cdot V_1 = C_2 \cdot V_2$, where C_1 and V_1 are the concentration and volume of the stock solution, and C_2 and V_2 are the concentration and volume of the diluted solution. To measure the methylene blue concentration in these solutions, the absorbance is determined using a spectrophotometer at a wavelength of 665 nm.

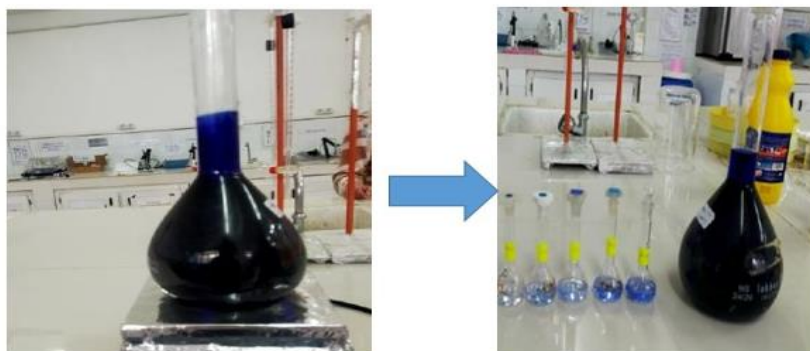


Fig 9: Standard solution

Characterization techniques

This section is dedicated to the various physicochemical characterization methods employed in this study. For some of these methods, a more detailed description is provided to facilitate understanding and to support subsequent discussions of the results.

SEM and EDS analyses.

The X52Q steel surface morphology was analysed by scanning electron microscopy (SEM) (FEI thermoscientific Quattros model equipment) **Fig 10** for samples immersed in 1 M hydrochloric acid without and with 400 ppm of *Corchorus olitorius* leaves extract and activated carbons inhibitor at 298 K for 24 h. EDS analysis allowed to evaluate the chemical composition of the obtained film.

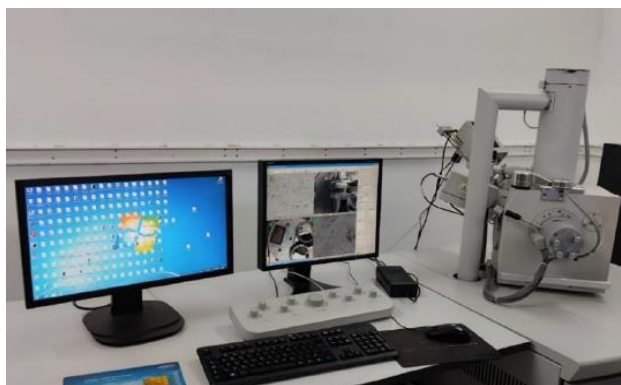


Fig 10: Scanning electron microscopy

Results and discussion:

Introduction

In this study, all the experimental results obtained are presented and discussed. As mentioned earlier, the experimental program focused on the study of corrosion mitigation and the adsorption of water by plants, specifically using the agricultural waste of *Corchorus olitorius*.

Extraction yield

The yield of *Corchorus olitorius* leaves extract and activated carbon is summarized in the table below:

R %	
<i>Corchorus olitorius</i> leaves extract	7.3
activated carbon	9.04

Table 2 : The yield of *Corchorus olitorius* leaves and activated carbon.

Electrochemical studies

Polarization measurements (PDP)

Potentiodynamic polarization experiments were undertaken to evaluate the kinetics of cathodic and anodic processes. **Fig. 11** illustrates the potentiodynamic polarization curves for mild steel in the absence and presence of various inhibitor concentrations. The obtained curves indicate that the extract acts as a mixed-type inhibitor, effectively inhibiting both the release of cathodic hydrogen and the dissolution of anodic mild steel. The

electrochemical kinetic measurements, including the corrosion potential E_{corr} , I_{corr} , cathodic Tafel slope (β_c), and anodic Tafel slope (β_a), were determined through extrapolation of the polarization curves and are listed in **Table 3**. Notably, as the inhibitor concentration rises, the I_{corr} values demonstrate a significant decrease, signifying a reduced corrosion reaction due to the presence of the inhibitor. Moreover, the more negative E_{corr} values observed in the presence of the inhibitor indicate that it functions primarily as a cathodic inhibitor. The β_a and β_c values do not correspond to a regular pattern, suggesting the mixed mode of inhibition. Although, the inhibitor exhibits a higher degree of cathodic inhibition compared to anodic inhibition.

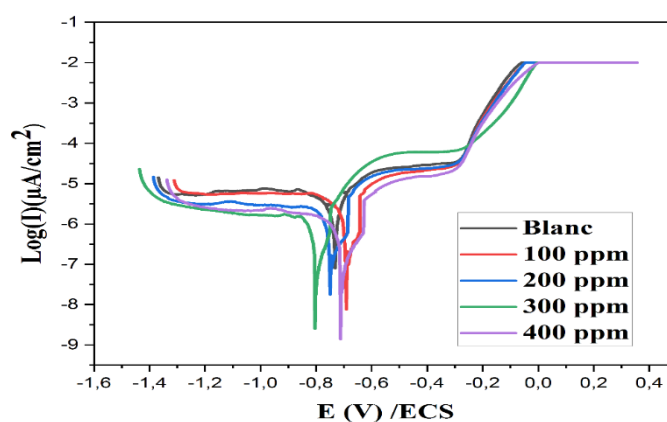


Fig. 11 Variation of Tafel curves recorded for carbon steel X52Q in 1 M HCl solutions containing various concentration of *Corchorus olitorius* leaves extract at 298 K.

Concentration (ppm)	E_{corr} (mV)	I_{corr} (mA/cm ²)	β_a (mV)	β_c (mV)	R_p (Ohm)	IE R_p %
Blanc	-493.90	232.686	74	84.4	59.3	-
100	- 490.98	105.82	77.7	114.4	166	64.27
200	- 493.73	59.807	79.1	109.5	317	81.29
300	- 487.71	18.826	82.3	93	970	93.88
400	- 481.21	14.878	78.6	97.7	1 230	95.17

Table 3 Polarization parameters for X52Q steel corrosion in 1 M HCl in the absence and presence of

Corchorus olitorius leaves extract

Electrochemical impedance spectroscopy (EIS)

EIS is a very sensitive technique that can be used to study electrochemical systems like corrosion without damaging them. Electrochemical impedance spectroscopy (EIS) was also utilized to examine the activities that take place at the metal/solution interface, the creation of the films, and their effectiveness as a protective measure. This measurement is a useful non-destructive instrument for comparing the behavior of shielded and unprotected corrosive metal materials. The EIS findings for *Corchorus olitorius* leaves extract - containing steel/HCl (1 M) solution interactions are shown in **Fig. 12**. The Nyquist plots have a single capacitive depressed semicircle, indicating that the charge transfer process regulated the corrosion mechanism in the systems under study. The depressed semicircles are often caused by inhomogeneity of the electrode surface, impurities, and the distribution of active sites on solid surfaces. The width of the capacitive loop increased compared to a system without the inhibitor, and the intensity of the inhibition grew as the quantity of *Corchorus olitorius* leaves extract was diluted. This molecule showed that the inhibitor coating on the metal surface increased compact, improving carbon steel protection at low concentrations. The experimental data are shown in [Table 3](#).

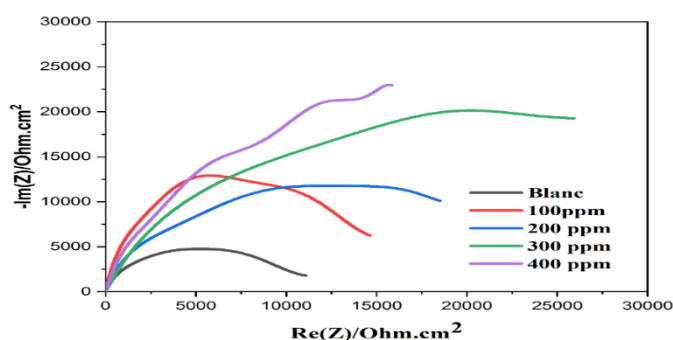


Fig. 12. Nyquist plot of X52Q steel immersed in 1 M HCl solution without (Blank) and with different concentrations of *Corchorus olitorius* leaves extract

	Rs (cm²)	Rct (cm²)	n_{dl}	Qdl(mF.snd 1.cm⁻²)	Rad (cm²)	n_{ad}	Qad (mF.snf⁻¹. cm⁻²)	IEZ (%)
Blanc	5.14	53.22	0.93	90.4	-	-	-	-
100	8.36	284.07	0.71	51.8	94.28	0.94	11.0	81.26
200	8.02	474.30	0.75	54.0	53.47	0.92	11.5	88.78
300	8.76	829.20	0.72	25.2	49.55	0.98	6.03	93.58
400	7.92	899.56	0.73	26.4	43.27	0.99	5.78	94.08

Table 4 EIS parameters for X52Q steel corrosion in 1 M HCL without and with different concentrations of *Corchorus olitorius* leaves extract

Scanning electron microscope (SEM)

The surface morphology of X52Q carbon steel is represented in **Fig. 13.a**, 13.b and 13.c before and after immersing in 1 M HCl acidic solution in presence and absence of inhibitor. An aggressive attack is noted (**Fig. 13.b**) in carbon steel surface's micrographs after immersion in the absence of inhibitor (Solution of 1 M HCl for 24 h). The cracks and pits on the metal surface indicate that the solution's corrosive attack considerably damaged it. Meanwhile, adding 400 ppm of the inhibitor to the system (**Fig. 13.c**) shows a smooth and more compact surface, with very few notable cracks and pits; showing that the metal was indeed protected from the corrosive attack. The difference could easily be interpreted as the working electrode's steel surface was protected by the adsorbed *Corchorus Olitorius* leaf extract molecules. This demonstrates that an efficient protective layer of the tested inhibitor was adsorbed on the metal surface, and played a useful role in protecting the surface steel against corrosion.

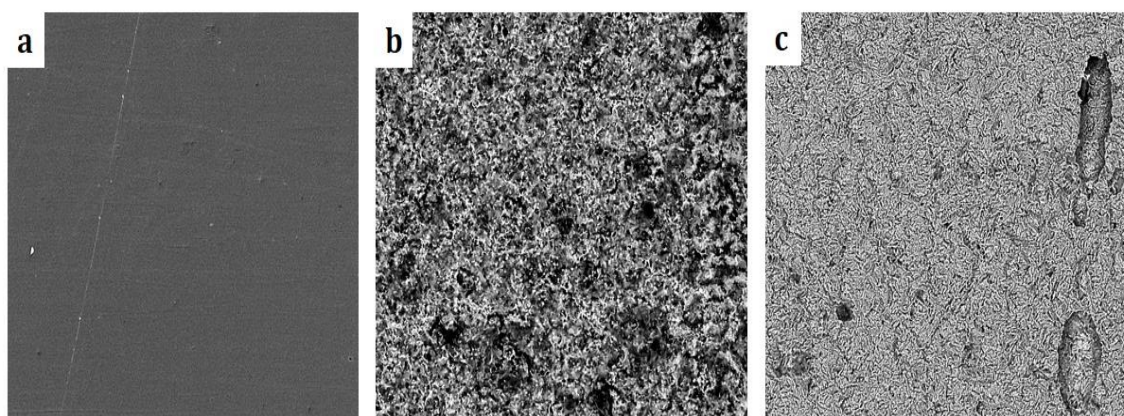
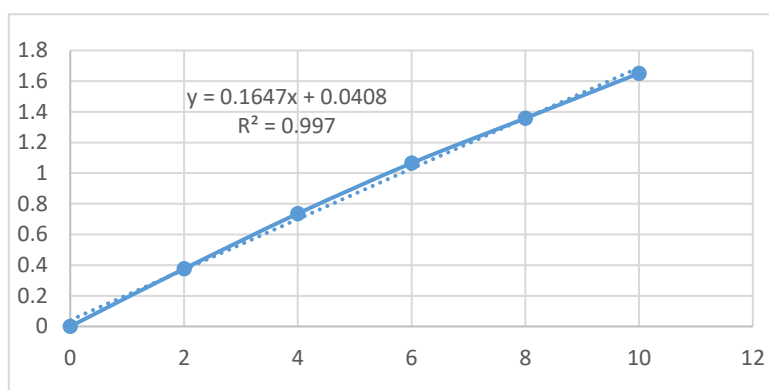


Fig 13. SEM images of the X52Q steel a) Before immersion. b) After immersion in acidic solution without *Corchorus Olitorius* leaf extract. c) After immersion in acidic solution with *Corchorus Olitorius* leaf extract (400 ppm).

Calibration results:

To establish the calibration curve of methylene blue, solutions are prepared within a concentration range of 1 to 10 mg/L, and the absorbance is measured as a function of concentration.

C (mg/L)	0	2	4	6	8	10
Absorbance	0	0,376	0,736	1,065	1,358	1,651

Table 5: Calibration results table**Fig 14 :** Calibration curve of methylene blue MB $\lambda_{\max} = 665\text{nm}$ **Study of elimination (adsorption) of methylene blue**

- **PH effect**

Prepare a series of daughter solutions from a stock solution of methylene blue, ensuring a concentration of 20 mg/L and a volume of 50 mL for each solution. Adjust the PH of the solutions incrementally from PH 3 to PH 12 by carefully adding drops of HCl or NaOH. After PH adjustment, introduce 0.15 g of activated carbon into each solution. Place all solutions on a magnetic stirrer and allow them to stir continuously for 2 hours.



Fig 15:The tests of the PH effect

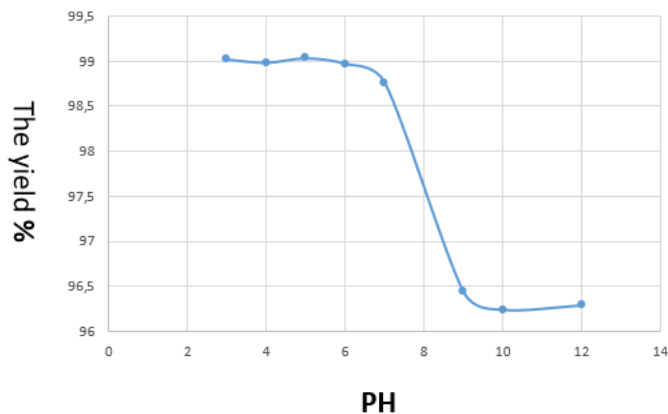


Fig 16: The influence of PH on the removal efficiency of MB ($C_0= 10$ ppm)

The curves illustrate the study of dye adsorption using MB, showing how the removal efficiency (percentage yield) and adsorption capacity vary with PH. **In Figure**, the yield remains consistently high (approximately 98%) at specific PH levels, highlighting the optimal performance of the activated carbon under these conditions. However, notable variations are observed, with a decline in yield at certain PH levels, particularly between 5 and 10. These fluctuations may result from changes in the activated carbon's surface properties or specific interactions between H^+ ions and the active sites, which influence the chemical adsorption process. This indicates that PH plays a critical role in the adsorption efficiency of activated carbon, emphasizing the presence of an optimal PH range for maximizing its effectiveness.

Mass effect

The effect of adsorbent mass was evaluated using varying amounts (0.05, 0.1, 0.15, 0.2, and 0.25 g) mixed with 50 mL of MB solution at an initial methylene blue concentration of 20 mg/L, a PH of 3, and a contact time of 2 hours. **In Figure 18** the increase in yield can be attributed to improved efficiency as the adsorbent mass increases, up to the point of saturation where further increases in mass no longer affect the yield.

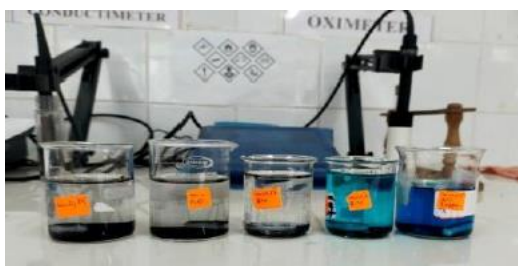


Fig 17: The tests of mass effect

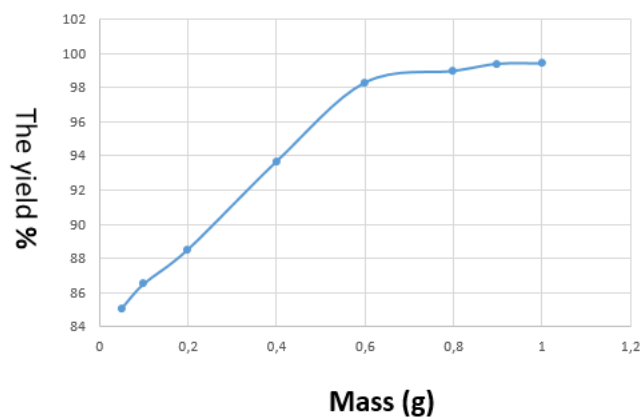


Fig 18: The influence of the mass of the coal on the removal efficiency of MB

Time effect

To evaluate the effect of contact time on the adsorption of MB onto activated carbon, 50 mL MB solutions were exposed to 10 ppm of activated carbon for various time intervals (5, 10,15,20 and 25 minutes). The experiments were conducted with an initial adsorbate concentration of 10 ppm and a solution PH of 3. The results are shown in the figure below.

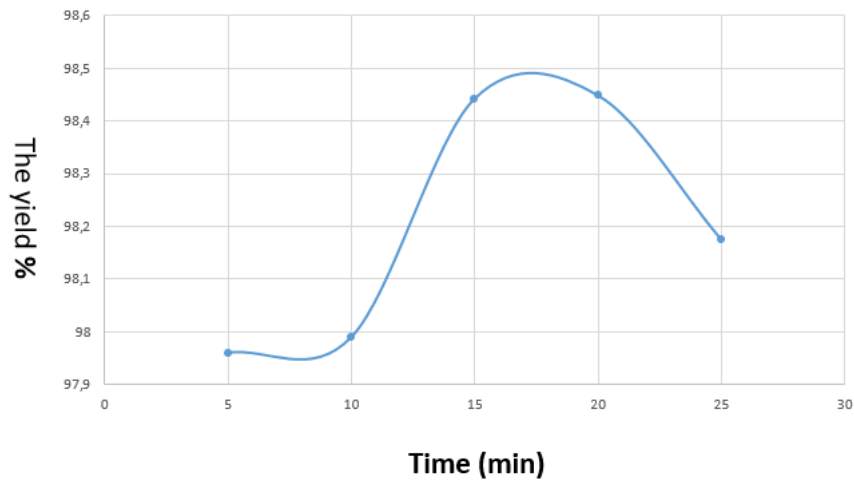


Fig 19: The influence of the time on the removal efficiency of MB

Conclusion

The inhibition efficiency of *Corchorus Olitorius* leaf extract as green corrosion inhibitor for carbon steel has been evaluated by electrochemical impedance spectroscopy (EIS) study, Potentiodynamic polarization (PDP) measurement in 1M HCl solution. the inhibition efficiency of *Corchorus Olitorius* leaf extract at a concentration of 400 ppm was as high as 95.17 % and have effectively removing dyes like MB from wastewater. This not only reduces manufacturing costs but also promotes renewable energy sources, enhancing energy security and reducing environmental impacts. This approach promotes circular economy principles and environmental stewardship.