JIPS 6 (2) (2025)

Jurnal Inovasi Pendidikan dan Sains

E-ISSN 2721-9119

https://ejournal.unwmataram.ac.id/index.php/JIPS

Utilization of Non-Filter Cigarette Butt Extract as a Natural Inhibitor of Carbon Steel Using Extraction and Microwave-Assisted Extraction Methods

Micha Mahardika[1*], Nabila Anas Tasyia[2], Dina Alva Prastiwi[3]

[1]Chemical Analyst Study Program, Sekolah Tinggi Analis Kimia Cilegon, Indonesia
[2,3]Chemistry Study Program, Sekolah Tinggi Analis Kimia Cilegon, Indonesia

----
Corresponding Author:
Author Name*: Micha Mahardika
Email*: micha.mahardika@gmail.com

Accepted: June 13th 2025. Approved: August 23th 2025. Published: August 30th 2025

ABSTRACT

Corrosion is one of the destructive processes that primarily affects metals through chemical or electrochemical reactions with their environment. An inhibitor is one of the methods used in corrosion control. A corrosion inhibitor functions to reduce the corrosion rate of a material. In 2024, 28.6% of the Indonesian population were reported as active smokers, which causes an increase in cigarette butt waste. Kretek cigarettes, whose main ingredient is tobacco, can be utilized as corrosion inhibitors due to their tannin content. This study aims to determine the corrosion rate, evaluate efficiency, and compare two extraction methods: maceration and Microwave-Assisted Extraction (MAE). MAE is an extraction method that uses microwave irradiation to accelerate selective extraction through rapid and efficient solvent heating. The extract obtained through maceration produced corrosion rates of 4.3, 4.8, 6.9, and 11.31 MPY. By comparison, the extract obtained using the MAE method showed corrosion rates of 0.7, 0.4, 0.3, and 0.15 MPY. In this study, the optimal results were observed at an acid concentration of 150 ppm, where the maceration method produced the lowest corrosion rate of 4.3 MPY, while the MAE method yielded the lowest corrosion rate of 0.15 MPY.

Keywords: inhibitor, corrosion rate, MAE, maceration, non-filter cigarette

INTRODUCTION

In 2024, 28.6% of the population in Indonesia was reported as active smokers, which causes an increase in cigarette butt waste [1]. Cigarette butt waste still contains toxic substances such as carcinogens, nicotine, chromium, arsenic, lead, and other hazardous chemicals that pose a threat to human life, particularly children, as well as animals [2].

In general, cigarettes are categorized into non-filter cigarettes, filter cigarettes, and electronic cigarettes. Non-filter cigarettes (kretek), whose main ingredient is tobacco, can be utilized as corrosion inhibitors due to their tannin content [3]. Generally, metal corrosion is caused by electrochemical processes that occur on the metal surface or at the interface between the metal and the solution. Consequently, the corrosion reaction is a heterogeneous reaction governed by diffusion processes [4]. Based on their raw materials, inhibitors can be classified into two types, namely synthetic and natural inhibitors. Synthetic-based inhibitors are quite effective in slowing down the corrosion rate; however, they are toxic. In contrast, natural inhibitors not only reduce the corrosion rate but are also non-toxic, inexpensive, naturally available, renewable, and environmentally friendly [5]. Natural corrosion inhibitors are obtained through the extraction of various naturally occurring substances. Several examples of natural materials that can be used as corrosion inhibitors include guava leaves, tea leaves, soybeans, coffee, tobacco, and others. Each material contains different compounds. Various plant extracts have been shown to contain organic compounds that can reduce the corrosion rate of different metals, including tannins, alkaloids, pigments, saponins, carbohydrates, and amino acids [6].

The Microwave-Assisted Extraction (MAE) method is an extraction technique that utilizes microwave irradiation to enhance the rate of extraction through rapid and efficient solvent heating. This occurs because electromagnetic waves penetrate the cell walls of simplicia and uniformly excite water and fat molecules [7]. The efficiency of the MAE method depends on several factors, such as the properties of the solvent, the sample material, and the extracted components, particularly the dielectric constant. Extraction using MAE requires optimization of several parameters, including the polarity and volume of the extraction solvent, sample size, extraction time, temperature, and microwave power [8]. Tobacco leaf extraction using the MAE method yielded a corrosion rate of 0.009268 mpy with an efficiency of 98.50% in a NaOH solution corrosion medium [9]. Cigarette butt waste can be extracted using the MAE method under optimum conditions at a power of 150 watts and a duration of 15 minutes. The extract produced a corrosion inhibition efficiency of 71.53% in a 3.56% NaCl medium [10]. This study aims to extract non-filter cigarette butt waste using maceration and Microwave-Assisted Extraction (MAE) methods with ethanol as the solvent. Then, the extract is used as a corrosion inhibitor in a 1 M H_2SO_4 medium, and the corrosion rate, as well as the efficiency of the non-filter cigarette butt extract, is calculated.

RESEARCH METHODS

This study used the maceration method, using a 70% ethanol solution, for 3 days to extract tannin compounds from non-filter cigarette (kretek) waste. The maceration product was then filtered using filter paper and evaporated at 80°C for 1 hour. The corrosion medium was subsequently prepared at concentrations of 0, 50, 100, and 150 ppm by mixing the evaporated extract with a 1 M H_2SO_4 solution.

For comparison, 30.2 g of non-filter cigarette butt waste in 181.2 mL of ethanol solution was processed using the MAE method for 2 minutes and 15 seconds. The pulse method was applied during the MAE process. The corrosion medium was then prepared at concentrations of 0, 50, 100, and 150 ppm by mixing the MAE extract with a 1 M H_2SO_4 solution.

Both extracts obtained from the maceration and MAE processes were then analyzed using Fourier Transform Infrared Spectroscopy (FTIR) to determine their functional groups. The corrosion rate test was subsequently conducted by preparing steel specimens and immersing them in each corrosion medium for a period of three days. After three days, the weight loss was measured to calculate the corrosion rate using the following equation:

$$CR = \frac{K.W}{\rho.A.T}$$

Description:
CR : Corrosion Rate
K : Constant
W : Weight loss (g)
ρ : Density (g/cm^3)
A : Surface area (cm^2)
T : Time

The research flowchart is presented in Figure 1.

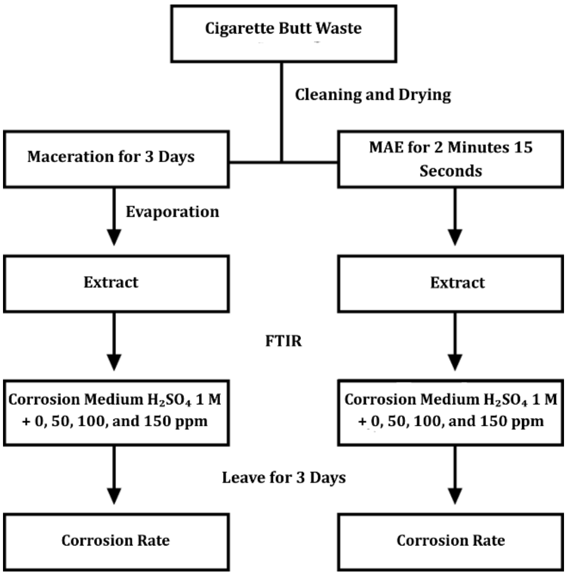

Figure 1. Research Flowchart

RESULTS AND DISCUSSION

In this study, the corrosion inhibitor was produced from the extract of non-filter cigarette butt waste. To reduce the water content, the cigarette butt waste was first dried and then soaked in 70% ethanol to help disrupt the cell membranes. This study used two extraction methods: maceration, in which the sample was left for three days, then filtered and evaporated; and Microwave-Assisted Extraction (MAE), in which 70% ethanol was added to the sample and the mixture was subjected to microwave irradiation for 2 minutes and 15 seconds. The pulse method was applied to prevent the extract temperature from rising excessively, thereby preserving the tannin compounds in the cigarette butt waste sample.

The following is a comparison of the extraction yields obtained using the maceration method and the Microwave-Assisted Extraction (MAE) method:

Table 1. Yield Results Using Maceration and MAE

Sample	Sample Weight (g)	Solvent (mL)	Extract Weight (g)	Method	Yield (%)
Cigarette butt waste	50	300	11.24	Maceration	22.48
Cigarette butt waste	30.2	181.2	22.34	MAE	73.94

Based on Table 1, the extract yield from cigarette butt waste using the MAE method was 73.97%, whereas the extract obtained with the maceration method was 22.48%. Therefore, the results obtained from the MAE method are better than those obtained from the maceration method. The purpose of using the MAE method is to shorten the extraction time, since MAE generates heat through microwave irradiation. Microwave irradiation is converted into heat through ionic conduction or dipole rotation. The MAE method can increase the recovery of organic chemical compounds from plants and shows more optimal process efficiency [8].

Ionic conduction refers to the effect of changes in the electric field generated by microwaves, which heats the solution. Meanwhile, dipole rotation is the reorientation of molecular dipoles caused by rapid changes in the electric field, which leads to collisions between dipole molecules and surrounding molecules, thereby producing heat [11].

Heating in the MAE method is carried out in a closed system, which causes the solvent to evaporate more rapidly. The MAE method has been widely studied by researchers because of its advantages in producing higher yield percentages [12]. Additionally, MAE enhances efficiency and effectiveness in extracting polar active compounds by providing even heating, thereby preventing damage to the active substances in natural materials.

1. Functional Group Identification

To strengthen the assumption of tannin presence, FT-IR analysis was performed to determine the chemical functional groups of organic and inorganic compounds. In general, compounds exhibit characteristic absorption or emission in the IR spectral region. The FT-IR readings of the two samples obtained using the maceration and MAE methods can be seen in Figure 2 below;

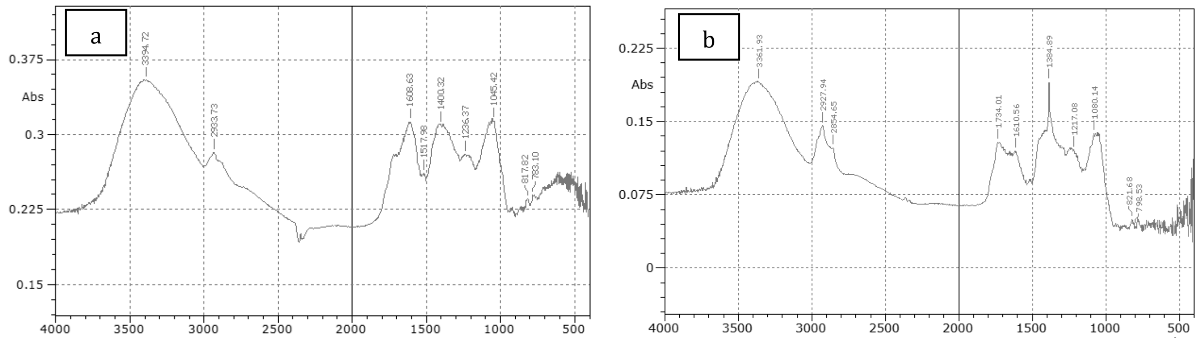

Figure 2. (a) IR Spectrum of the extract obtained by maceration, (b) IR Spectrum of the extract obtained by MAE

In Figures 2a and 2b, absorption bands were observed in the range of 1600–1700 cm^{-1}, which are presumed to be associated with the carbonyl C=O group; at 700–800 cm^{-1}, which are likely due to aromatic C–H bonds; and around 3300 cm^{-1}, which are associated with the OH group. These findings support the hypothesis that non-filter cigarette butt waste containing tobacco includes tannin compounds [13] with the chemical formula $C_{27}H_{52}O_{46}$

2. Corrosion Rate

Variations in concentration result in differences in corrosion rates and efficiencies. The corrosion rate results are presented in Table 2.

Table 2. Corrosion rate at various concentrations

Method	Concentration (ppm)	Initial weight (g)	Final weight (g)	Weight loss (g)	Corrosion rate (mpy)	Efficiency (%)
Maceration	0	6.71	5.98	0.73	11.31	–
	50	6.71	6.25	0.46	6.9	38
	100	6.61	6.29	0.32	4.8	57
	150	6.79	6.50	0.29	4.3	61
MAE	0	4.33	3.63	0.70	10.5	–
	50	5.05	5.03	0.02	0.4	42
	100	4.90	4.89	0.01	0.3	57
	150	4.88	4.87	0.01	0.15	78

Based on Table 2, it can be seen that the higher the inhibitor concentration applied, the lower the reaction rate, thereby reducing the likelihood of corrosion. Cigarette butt waste can maintain the formed passivation layer, which functions as a protective layer to inhibit the corrosion process. After calculation, an extract concentration of 50 ppm from the maceration method produced the highest corrosion rate value of 6.9 mm/year, whereas at a concentration of 150 ppm, it decreased to 4.3 mm/year. Therefore, the greater the inhibitor concentration added, the lower the corrosion rate, because the tannin compounds in the extract can form complexes with Fe (III) on the steel surface [14].

The best corrosion rate was obtained from the extract of cigarette butt waste, which was extracted using the MAE (Microwave-Assisted Extraction) method, with a corrosion rate value of 0.4 mm/year at a concentration of 50 ppm. However, at a concentration of 150 ppm, the corrosion rate decreased to 0.15 mm/year. This finding is consistent with a study that reported a corrosion rate of 0.009268 mpy, achieved with an efficiency of 98.50% using the MAE method in a NaOH solution corrosion medium [9]. A low corrosion rate indicates the inhibitor's ability to protect the metal surface by suppressing oxidation and reduction reactions occurring on the metal surface. The greater the flavonoid content, the more effective the protection of the metal will be, thereby significantly reducing the corrosion rate [15].

Figure 3 illustrates the correlation between the efficiency and corrosion rate of the extract obtained through maceration.

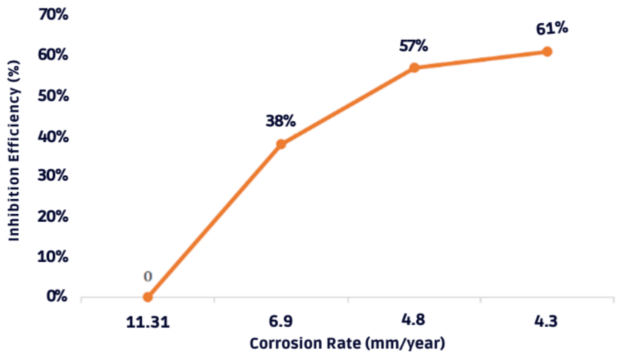

Figure 3. Correlation between corrosion rate and efficiency (maceration extract)

Based on Figure 3, the lowest efficiency value was obtained at a corrosion rate of 6.9 mm/year, with an efficiency of 38%. In contrast, the highest efficiency was achieved at a corrosion rate of 4.3 mm/year, with an efficiency of 61%. This shows a correlation between corrosion rate and efficiency, where the lower the corrosion rate, the higher the inhibition efficiency produced [16]. The increase in efficiency occurs because the inhibition layer formed can prevent the corrosion medium solution from penetrating the carbon steel surface [17].

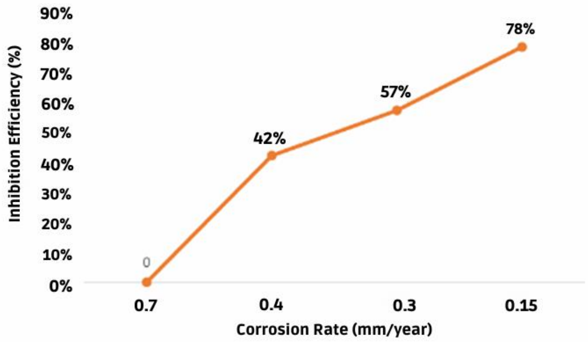

Figure 4. Correlation between corrosion rate and efficiency (MAE extract)

Based on Figure 4, it is shown that the lowest inhibition efficiency occurred at a corrosion rate of 0.4 mm/year, with an inhibition efficiency of 42%, whereas at a corrosion rate of 0.15 mm/year, the inhibition efficiency reached 78%. The increasing trend in the graph at various corrosion rates indicates that the corrosion rate affects inhibition efficiency [18]. The higher the inhibition efficiency, the more effective the suppression of the corrosion rate that occurs.

In aqueous solution, H_2SO_4 and HCl dissociate into H^+, HSO_4^-, SO_4^{2-}, and Cl^- ions. Corrosion of steel in acidic solution is considered localized corrosion in the form of pitting, with hydrogen at the cathodic area and Fe at the anodic area, where HSO_4^-, SO_4^{2-}, and Cl^- ions react and form corrosion products such as $FeCl_2$, $FeSO_4$, and $Fe(HSO_4)_2$ [19]. Reaksi yang terjadi adalah $Fe_{(s)} + H_2SO_{4(aq)} \rightarrow H_{2(g)} + FeSO_{4(aq)}$

In this corrosion reaction, iron (Fe) releases electrons and reacts with H^+ ions from H_2SO_4, forming hydrogen gas (H_2) and Fe^{2+} ions, which can subsequently be oxidized to Fe^{3+}. These ions then react with SO_4^{2-} to form $Fe_2(SO_4)_3$, which dissolves in water and accelerates the corrosion process. The addition of an inhibitor forms a complex with H^+ ions, thereby reducing their concentration and slowing down the corrosion rate [20].

$FeSO_4$ is commonly known as rust. From this reaction, it can be seen that corrosion involves H_2SO_4, producing rust that appears red and gray in color, while the gas bubbles formed on the surface of mild steel are hydrogen gas (H_2). Corrosion of iron can be accelerated by several factors, such as acidity level (pH), contact with electrolytes, and the condition of the metal itself (such as density, as well as the smoothness or roughness of its surface) [21].

CONCLUSION

Using the MAE method, the highest inhibition efficiency was 78% at a corrosion rate of 0.15 mm/year, while the lowest efficiency was 42% at a corrosion rate of 0.4 mm/year. In the maceration method, the lowest inhibition efficiency was 38% at a corrosion rate of 6.9 mm/year, whereas the highest efficiency reached 61% at a corrosion rate of 4.3 mm/year.

ACKNOWLEDGMENTS

We want to express our gratitude to Sekolah Tinggi Analis Kimia Cilegon, the Fish and Environmental Health Testing Center, and PT. MC PET Film.

REFERENCES

[1] D. R. Utami and M. Romzi, *badan pusat statistik-indonesia-2025*, vol. 53. BPS-Statistics Indonesia.

[2] J. Torkashvand, M. Farzadkia, H. R. Sobhi, and A. Esrafili, "Littered cigarette butt as a well-known hazardous waste: A comprehensive systematic review," *J Hazard Mater*, vol. 383, p. 121242, Feb. 2020, doi: 10.1016/j.jhazmat.2019.121242.

[3] H. Devianto, I. Nurdin, P. Widiatmoko, D. Silvia, and C. Prakarsa, "Tobacco Extract for Inhibition of Carbon Steel Corrosion in H2S-contained NaCl Solution," *International Journal of Technology*, vol. 14, no. 5, pp. 1167–1176, 2023, doi: 10.14716/ijtech.v14i5.5272.

[4] A. P. Yanuar, H. Pratikno, and H. S. Titah, "Pengaruh Penambahan Inhibitor Alami terhadap Laju Korosi pada Material Pipa dalam Larutan Air Laut Buatan," *JURNAL TEKNIK ITS*, vol. 5, no. 2, 16AD.

[5] A. A. Al-Amiery, W. N. R. W. Isahak, and W. K. Al-Azzawi, "Corrosion Inhibitors: Natural and Synthetic Organic Inhibitors," Apr. 01, 2023, *MDPI*. doi: 10.3390/lubricants11040174.

[6] R. Manurung, Y. Simanungkalit, and F. Amelia, "Extraction of tannin from guava leaves (Psidium Guajava L) by soxhletation method and application as iron corrosion inhibitor in sea water medium," in *IOP Conference Series: Earth and Environmental Science*, Institute of Physics, 2025. doi: 10.1088/1755-1315/1445/1/012050.

[7] L. A. Setiani, B. L. Sari, L. Indriani, and J. Jupersio, "PENENTUAN KADAR FLAVONOID EKSTRAK ETANOL 70% KULITBAWANG MERAH (Allium cepa L.) DENGAN METODE MASERASI DAN MAE (Microwave Assisted Extraction)," *FITOFARMAKA: Jurnal Ilmiah Farmasi*, vol. 7, no. 2, pp. 15–22, Dec. 2017, doi: 10.33751/jf.v7i2.772.

[8] H. López-Salazar, B. H. Camacho-Díaz, M. L. A. Ocampo, and A. R. Jiménez-Aparicio, "Microwave-assisted extraction of functional compounds from plants: A Review," *Bioresources*, vol. 18, no. 3, Jun. 2023, doi: 10.15376/biores.18.3.Lopez-Salazar.

[9] C. Fattriot Tama, F. Anindita, R. Adji Alif Asyari, M. Rizal, and R. Pasonang Sihombing, "INHIBITOR KOROSI DARI EKSTRAKSI DAUN TEMBAKAU DENGAN METODE MICROWAVE ASSISTED EXTRACTION (MAE) PADA BERBAGAI LINGKUNGAN," *PROSIDING SNAST*, pp. D10-15, Nov. 2022, doi: 10.34151/prosidingsnast.v8i1.4146.

[10] I. A. Alatif *et al.*, "Pemanfaatan Limbah Puntung Rokok sebagai Inhibitor Korosi pada Baja St40 Menggunakan Metode Microwave Assisted Extraction (MAE) di Lingkungan NaCl 3,56%," *KOVALEN: Jurnal Riset Kimia*, vol. 10, no. 3, pp. 244–250, Jan. 2025, doi: 10.22487/kovalen.2024.v10.i3.17394.

[11] "OPTIMASI PROSES EKSTRAKSI KULIT BATANG BAKAU DENGAN METODE MICROWAVE ASSISTED EXTRACTION TERHADAP KADAR ANTOSIANIN TOTAL MENGGUNAKAN SPEKTROFOTOMETRI UV-VIS OPTIMATION PROCESS EXTRACTION MANGROVE BARK WITH METHODS MICROWAVE ASSISTED EXTRACTION ON ANTHOCYANIN TOTAL CONTENT USING UV-VIS SPECTROPHOTOMETRY HAS JUNITA N011 18 1302 PROGRAM STUDI FARMASI FAKULTAS FARMASI UNIVERSITAS HASANUDDIN MAKASSAR 2022."

[12] D. Silsia, M. Febreini, and L. Susanti, "RENDEMEN AND CHARACTERISTICS OF PEKTINS RED DRAGON FRUIT LEATHER (Hylocereus costaricensis) WITH THE DIFFERENCE IN EXTRACTION METHOD AND TIME," *Jurnal Agroindustri*, vol. 11, no. 2, pp. 120–132, Dec. 2021, doi: 10.31186/j.agroindustri.11.2.120-132.

[13] R. N. Faizah *et al.*, "Efektifitas Ekstrak Daun Nicotiana tabacum L. var. Virginia dan Carica papaya L. var Thailand Sebagai Bioinsektisida Terhadap Mortalitas Spodoptera litura F. Effectiveness of Nicotiana tabacum L. var. Virginia Leaf Extract and Carica papaya L. var Thailand as Bioinsecticides towards Mortality of Spodoptera litura F," vol. 13, no. 1, pp. 141–149, 2024, [Online]. Available: https://journal.unesa.ac.id/index.php/lenterabio/index

[14] M. Pramudita, H. Juliansyah, M. Andre Rizki Jurusan Teknik Kimia, F. Teknik, U. K. Sultan Ageng Tirtayasa Jln Jendral Sudirman, and C. Banten Telepon, "Ekstrak Kulit Manggis (Garcinia Mangostana L) Sebagai Inhibitor Korosi Baja Lunak (Mild Steel) Dalam Larutan H 2 SO 4 1 M."

[15] S. Pudjiwati, Y. Sanusi, and I. G. A. Arwati, "Use of Hibiscus rosa-sinensis as a Green Corrosion Inhibitor for Valve Materials in RO Water," *International Journal of Innovation in Mechanical Engineering and Advanced Materials*, vol. 7, no. 2, p. 88, Apr. 2025, doi: 10.22441/ijimeam.v7i2.32806.

[16] Sri Hermawan, Yuli Rizky Ananda Nasution, and Rosdanelli Hasibuan, "PENENTUAN EFISIENSI INHIBISI KOROSI BAJA MENGGUNAKAN EKSTRAK KULIT BUAH KAKAO (Theobroma cacao)," *Jurnal Teknik Kimia USU*, vol. 1, no. 2, pp. 31–33, Dec. 2012, doi: 10.32734/jtk.v1i2.1415.

[17] J. Hasil, K. Ilmiah, S. Mubarak, S. Jokosiswor, and P. Mulyatno, "JURNAL TEKNIK PERKAPALAN Pengaruh Penambahan Inhibitor CaCO3 Terhadap Laju Korosi Baja SS 400 dalam Larutan Air Laut Buatan," *Jurnal Teknik Perkapalan*, vol. 8, no. 3,

2020, [Online]. Available: https://ejournal3.undip.ac.id/index.php/naval
[18] "PROSES EKSTRAKSI DAUN KETAPANG (Terminalia Catappa) DENGAN METODE MICROWAVE ASSISTED EXTRACTION (MAE) SEBAGAI PENGHAMBAT LAJU KOROSI BAJA SKRIPSI Oleh: ADI RENIE HAPPY NIM. 19640004 PROGRAM STUDI FISIKA FAKULTAS SAINS DAN TEKNOLOGI UNIVERSITAS ISLAM NEGERI MAULANA MALIK IBRAHIM MALANG 2023."
[19] Alketa Lame *et al.*, "Walnut (Juglans regia L.) fruit septum alcoholic extract as corrosion inhibitor for Fe B500B steel bars in mixed acidic solution," *Journal of Electrochemical Science and Engineering*, vol. 14, no. 3, pp. 297–320, Jul. 2024, doi: 10.5599/jese.2303.
[20] M. Mahardika, N. T. Susparini, I. Lailatusholihah, and I. Syahrial, "EKSTRAK DAUN TEMBAKAU (NICOTIANA TABACUM) SEBAGAI INHIBITOR KOROSI ALAMI BAJA KARBON," *Jurnal Inovasi Pendidikan dan Sains*, vol. 5, no. 3, pp. 82–87, 2024.
[21] T. N. R, S. Sulistijono, A. Mahiri, and M. R. Pambudi, "PERANCANGAN PROTEKSI ARUS PAKSA PADA PIPA BAJA API 5L DENGAN COATING DAN TANPA COATING DI DALAM TANAH," in *PROSIDING SEMINAR NASIONAL FISIKA (E-JOURNAL) SNF2016 UNJ*, Pendidikan Fisika dan Fisika FMIPA UNJ, 2016, pp. SNF2016-CIP-95-SNF2016-CIP-102. doi: 10.21009/0305020119.