Indonesian Journal of Material Research
*e*-ISSN: 2987-1654
Vol. 3, No. 1, March 2025

Research Paper

# Enhanced Selectivity of Ni/Al LDH for Cationic Dye Adsorption via Gambier Leaf Extract Modification

Jefri Jefri[1], Najma Annuria Fithri[2*], Navinda Ramadhan[1]

[1] *Master Program of Material Science, Graduate School, Universitas Sriwijaya, Palembang, 30139, Indonesia*
[2] *Department of Pharmacy, Faculty of Mathematics and Natural Sciences, Universitas Sriwijaya, Ogan Ilir, 30862, Indonesia*
[*] **Corresponding author**: najma.fithri@mipa.unsri.ac.id

**Abstract**

The adsorption capability of Ni/Al LDH modified with gambier leaf extract was evaluated for the removal of Rhodamine B (RhB), Malachite Green (MG), and Methylene Blue (MB) dyes from aqueous solutions. UV-Vis spectroscopy analysis revealed that Ni/Al-Gambier Leaf Extract exhibited a higher efficiency in cationic dye removal compared to unmodified Ni/Al LDH. The removal percentages of RhB, MG, and MB using unmodified Ni/Al LDH were 6.00%, 40.05%, and 14.73%, respectively. However, after modification with Gambier Leaf Extract, these values significantly improved to 25.62%, 39.48%, and 31.06%, respectively. This enhancement was attributed to the polyphenolic functional groups present in the gambier leaf extract, which strengthened electrostatic interactions and promoted dye adsorption. These findings indicate that incorporating gambier leaf extract into Ni/Al LDH enhances its adsorption performance, making it a promising material for improving dye removal in wastewater treatment.

**Keywords**

Selectivity, Adsorption, Ni/Al LDH, Gambier Leaf Extract, Cationic Dyes

Received: 10 December 2024, Accepted: 15 March 2025
https://doi.org/10.26554/ijmr.20253148

## 1. INTRODUCTION

Environmental pollution due to textile industry effluents containing synthetic dyes is a serious concern because they are toxic and difficult to degrade naturally (Azanaw et al., 2022; Kumari, 2024; Slama et al., 2021). Cationic dyes, such as rhodamine B (RhB), malachite green (MG), and methylene blue (MB), are often found in industrial effluents and can have negative impacts on aquatic ecosystems (Oladoye et al., 2022; Priya et al., 2024; Sharma et al., 2023). The presence of these dyes in water can inhibit the penetration of sunlight, thereby disrupting the photosynthesis process of marine organisms, reducing dissolved oxygen levels, and impacting the balance of the ecosystem (Alsukaibi, 2022; Al-Tohamy et al., 2022). In addition, some dyes are known to be carcinogenic and mutagenic, which may pose health risks to humans through bioaccumulation in the food chain (You et al., 2021). Therefore, effective methods are needed to remove these dyes from the environment. One promising technique is adsorption, as it is easy to implement. The adsorption process requires porous materials such as carbon-based (Jagadeesh and Sundaram, 2023; Mohadi et al., 2022), zeolite (Abbas and Trari, 2023; Bezerra et al., 2019), bentonite (Bessaha et al., 2023; Potgieter et al., 2019), and layered double hydroxides (LDH) (Jefri et al., 2024; Lee et al., 2024; Lesbani et al., 2021).

LDH is a layered inorganic material composed of divalent and trivalent metal cations forming positively charged sheets, with exchangeable anions between the layers (Abd El-Monaem et al., 2023; Ahmad et al., 2024a; Milos et al., 2024; Wibiyan et al., 2024b). It is widely used in various applications, including catalysis, energy storage, and adsorption, due to their large surface area, good chemical stability, and high ion exchangeability (Hu et al., 2023; Wang et al., 2023). However, despite its many advantages, LDH also has some limitations. Its stability in aqueous environments still needs to be improved due to its tendency to undergo structural degradation or anion dissolution under certain conditions (Lu et al., 2024; Zehra et al., 2025). In addition, LDH also tends to agglomerate, which can reduce its effective surface area in the adsorption process. Therefore, there is a need to modify LDH with another material, such as organic materials, to improve its structural stability, expand its active surface, and enhance its selectivity and adsorption efficiency toward certain pollutants (Ahmad et al., 2024b; Wibiyan et al., 2024a; Yang et al., 2022).

Several previous studies have shown the effectiveness of combining LDH with organic materials in improving adsorption performance. For example, Lesbani et al. (2024) reported that the modification of Ni/Al LDH and Zn/Al LDH with *Spirulina platensis* significantly enhanced the adsorption capacity of MG

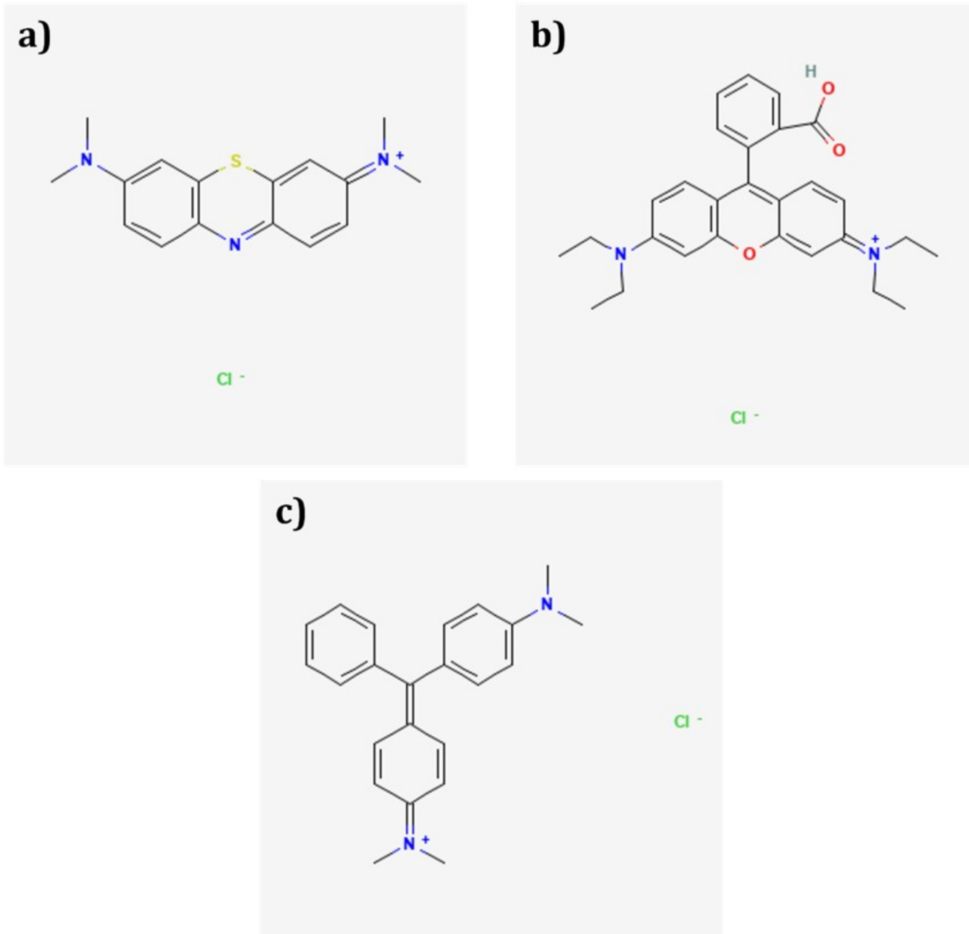


**Figure 1.** Cationic Dyes Structure, a) MB, b) MG, and c) RhB

through increased surface area, electrostatic interactions, as well as additional contributions from hydrogen bonding and $\pi$-$\pi$ interactions, thereby improving the stability and reuse efficiency of the materials. Wijaya et al. (2024) developed Ni/Al LDH modified with cellulose, which showed an increase in surface area from 3.29 to 5.09 $m^2/g$, thus increasing the adsorption capacity of MG to 107.527 mg/g with a removal efficiency of 71%. The material also demonstrated good stability, maintaining 54% of its adsorption capacity after six reuse cycles. Ahmad et al. (2025) investigated the selective adsorption of MG, MB, and RhB using Ni/Al-Lignin, emphasizing the crucial role of functional group interactions in determining dye selectivity. Ni/Al-Lignin exhibited a high adsorption capacity for MG, with a maximum uptake of 175.44 mg/g. Abdel-Hady et al. (2024) reported the results of modifying Zn/Co/Fe LDH with chitosan increased removal efficiency to more than 90%. Another study involved synthesizing Zn/Al LDH modified with phenyl pyruvate (PPA) via the co-precipitation method, enhancing its functionality in organic dye adsorption (Zahid et al., 2024).

Although various modifications have been shown to increase the adsorption capacity, further understanding of the material's selectivity to specific dyes is still needed (Wibiyan et al., 2024a). Not all adsorbents can specifically remove one type of dye from a complex mixture, making selectivity an important factor in effluent treatment efficiency. In this study, we explored the selectivity of Ni/Al LDH-gambier leaf extract to cationic dyes by comparing the removal efficiency of MB, MG, and RhB (Figure 1) in the adsorption method. The results of this study are expected to provide new insights into the potential of Ni/Al LDH- gambier leaf extract as a more environmentally friendly and selective adsorbent for certain pollutants, as well as contribute to developing more efficient and sustainable waste treatment methods.

## 2. EXPERIMENTAL SECTION

### 2.1 Materials and Instrumentation

The materials employed in this study consist of commercial MB, MG, and RhB from RofaLab, gambier leaf extract (Jefri et al., 2024). Additionally, nickel nitrate hexahydrate ($Ni(NO_3)_2.6H_2O$), aluminum nitrate nonahydrate ($Al(NO_3)_3.9H_2O$), sodium hydroxide (NaOH), hydrochloric acid (HCl), and sodium carbonate ($Na_2CO_3$) were used, all of which were procured from MERCK. Distilled water was supplied by Bratachem.

For characterization, the instruments utilized included a

 

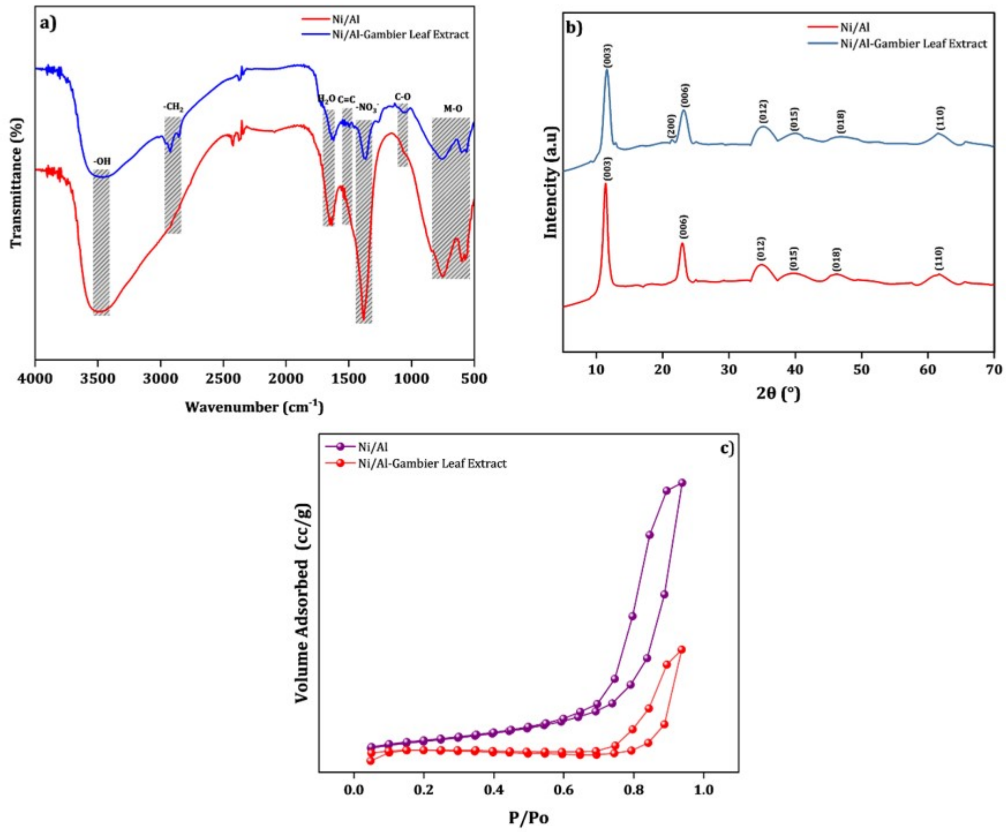


**Figure 2.** a) FTIR Spectra, b) Difractogram, and c) BET Isotherm of Ni/Al and Ni/Al-Gambier Leaf Extract

Rigaku MiniFlex 600 X-Ray Diffractometer (XRD), a Shimadzu Prestige-21 FT-IR Spectrophotometer, a BELSORP-miniX Brunauer-Emmett-Teller analyzer, and an EMC 18 series UV-Vis Spectrophotometer.

### 2.2 Synthesis of Ni/Al LDH

The synthesis of Ni/Al LDH was carried out by the co-precipitation method adapted from the procedure of Rahayu Palapa et al. (2021), in which 50 mL of nickel nitrate hexahydrate was reacted with 50 mL of aluminum nitrate nonahydrate in a 3:1 molar ratio. This mixture was stirred for 30 minutes before gradually adding NaOH and $Na_2CO_3$ until it reached pH 10. Next, the suspension was stirred for 15 hours at 80°C, then filtered, washed with distilled water, and dried. The LDH materials obtained were characterized using XRD, FTIR, and BET surface area analysis.

### 2.3 Synthesis of Ni/Al-Gambier Leaf Extract

A total of 3 g of Ni/Al LDH was dispersed in 50 mL of distilled water and then subjected to ultrasonication for 20 minutes to increase viscosity. Subsequently, 3 g of gambier leaf extract was incorporated, followed by stirring the mixture using a magnetic stirrer at 75°C and 250 rpm for 24 hours. The resulting solid (Ni/Al-Gambier Leaf Extract) underwent rinsing with distilled water, drying at 60°C, and pulverization.

### 2.4 Selectivity of Cationic Dyes

MB, MG, and RhB were each prepared at a 20 mg/L concentration and thoroughly mixed. The mixture of cationic dyes was analyzed using a UV-Vis spectrophotometer. Afterward, 20 mg of Ni/Al-Gambier Leaf Extract was added and left to react for 2 hours before separation. The mixture was subsequently re-scanned, and a comparison was made using Ni/Al LDH alone.

## 3. RESULTS AND DISCUSSION

### 3.1 Characterization of Materials

FTIR spectra of Ni/Al LDH and Ni/Al LDH modified with gambier leaf extract exhibited distinct features indicative of successful modification (Figure 2a). The absorption band at 3474 $cm^{-1}$ corresponds to stretching vibrations of hydroxyl (−OH) groups, originating from both the LDH structure and adsorbed water (Abdelrahman et al., 2023). The band at 2928 $cm^{-1}$ is linked to ($-CH_2$) stretching vibrations from organic compounds in gambier leaf extract, highlighting the interaction between LDH and organic species (Jefri et al., 2024). Additionally, the absorption band at 1633 $cm^{-1}$ is associated with trapped water molecules. The characteristic band at 1513 $cm^{-1}$ is a C=C vibration of aromatic compound (Wongsa et al., 2022), derived from phenolic compounds in gambier leaf extract, suggesting the possibility of interaction through surface adsorption processes. Meanwhile, the band at 1367 $cm^{-1}$ is associated with nitrate ($NO_3^-$) stretching vibrations, indicating the presence of anions in the LDH interlayer (Singha Roy et al., 2023). Meanwhile, the band at 1056 $cm^{-1}$ is assigned to C—O stretching vibrations, indicative of organic compounds interacting with LDH. Moreover, absorption bands at 738 $cm^{-1}$ and 561 $cm^{-1}$ are linked to M—O stretching vibrations, affirming the structural integrity of LDH after modification (Hanifah et al., 2022; Intachai et al., 2019).

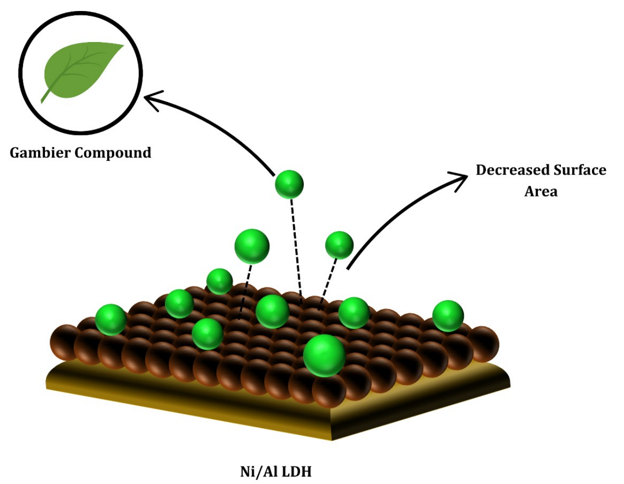


**Figure 3.** Decreasing Surface Area of Ni/Al LDH Illustration

The XRD patterns in Figure 2b show the comparison between Ni/Al LDH before and after modification with gambier leaf extract. The Ni/Al LDH diffractogram (red line) shows typical LDH diffraction peaks at $2\theta$ around 11.37°, 22.99°, 35.03°, 39.80°, 46.44°, and 61.48°, which correspond to the (003), (006), (012), (015), (018), and (110) crystal planes, confirming the hydrotalcite structure under JCPDS standard No. 15-0087 (Foruzin et al., 2025; Luo et al., 2022). After modification with gambier leaf extract (blue line), there was a change in the intensity and width of the diffraction peaks, indicating an interaction between the organic molecules of the extract and the LDH layer (Jefri et al., 2024). The broadening of the peaks in the diffraction pattern indicates a possible decrease in crystallinity due to the presence of extracted molecules that disrupt the order of the layer. In addition, the absence of new crystalline phases indicates that the main structure of LDH is maintained after the modification process. These XRD results support the findings from the FTIR spectra, where the interaction of organic molecules with LDH is confirmed through the shift and appearance of characteristic absorption bands.

Figure 2c shows the adsorption-desorption isotherms for Ni/Al and Ni/Al-Gambier Leaf Extract (GLE). Based on BET analysis, the specific surface area of pure Ni/Al is 31.73 $m^2/g$, while after modification with gambier leaf extract, the surface area decreases dramatically to 4.13 $m^2/g$. This decrease indicates that the organic compounds from the gambier leaf extract likely covered most of the active surface of the material, as illustrated in Figure 3. In addition, the total pore volume also decreased significantly, from 0.08 cc/g in pure Ni/Al to only 0.0018 cc/g in the composite, indicating pore filling by the extracted molecules (Jefri et al., 2024). The average pore size also changed from 4.91 nm (mesopore category) to 0.89 nm (micropore category) (Fukumori et al., 2018), indicating that the modification caused pore narrowing. Overall, these changes may reduce the physical adsorption capacity but increase the selectivity of interaction with the target substance through chemical or electrostatic effects.

### 3.2 Selectivity of Cationic Dyes

Figure 4a shows the UV-Vis spectra of the dye solution before and after the adsorption process by Ni/Al LDH and Ni/Al-Gambier Leaf Extract materials. In the initial spectrum (yellow curve), there are three main absorbance peaks, namely RhB ($\lambda$ = 554 nm), MG ($\lambda$ = 618 nm), and M ($\lambda$ = 664 nm). After adsorption by Ni/Al LDH (red curve), the intensity of the three peaks decreased, indicating the absorption of dye by the material. A more significant decrease was seen in the spectrum after adsorption by Ni/Al-GLE (blue curve), indicating that modification with gambier leaf extract increased the adsorption capacity of this material (Jefri et al., 2024).

**Table 1.** Comparison with Another Study of Cationic Dye Adsorption

| Adsorbent | Dyes | Removal (%) | Reference |
|---|---|---|---|
| Ni/Al | RhB | 6.00 | This Study |
| | MG | 40.05 | |
| | MB | 14.73 | |
| Ni/Al-Gambier Leaf Extract | RhB | 25.62 | This Study |
| | MG | 39.48 | |
| | MB | 31.06 | |
| Rape Straw Activated Carbon | RhB | 12.57 | (Du et al., 2024) |
| Acid-Base-Activated Silica | RhB | 12.11 | (Wahyuningsih et al., 2018) |
| Oyster Shell Powder | MG | 6.57 | (Lin et al., 2022) |
| MOF-5 | MG | 30.00 | (Mohammadi et al., 2022) |
| *Anona squmosa* Seed | MB | 24.33 | (Santhi et al., 2016) |
| Powder Activated Carbon (0.1) | MB | 21.00 | (Nizam et al., 2021) |

Further adsorption effectiveness is shown in Figure 4b, which shows the percentage removal of each dye. Ni/Al LDH showed the highest efficiency in adsorbing MG (40.05%), while RhB and MB only reached 6.00% and 14.73%, respectively. After modification with gambier leaf extract, the adsorption effectiveness

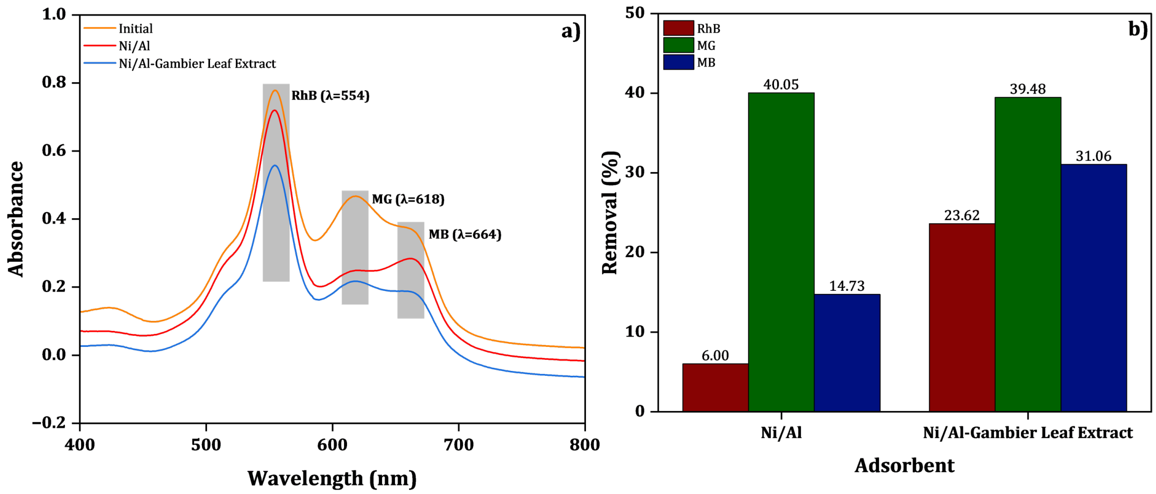


**Figure 4.** UV-Vis Spectra of RhB, MG, and MB Before and After Adsorption (t = 2 hours) and (b) RhB, MG, and MB Removal Efficiency (%) of Ni/Al and Ni/Al-Gambier Leaf Extract

increased significantly, especially for RhB and MB, which increased to 25.62% and 31.06%, respectively. MG still showed a high removal rate (39.48%), although it was slightly lower than before modification. This increase suggests that the gambier leaf extract contributed to enhancing the interaction between the adsorbent and the dye, which is most likely due to the presence of additional active groups from the polyphenolic compounds in the extract (Sadegh et al., 2022; Septiningrum et al., 2024). MG showed the highest adsorption rate compared to RhB and MB on these two adsorbent materials. This can be explained by the stronger electrostatic interactions between MG and the adsorbent material compared to RhB and MB (Lesbani et al., 2024). In addition, the smaller molecular size of MG allows for easier diffusion into the pores of the adsorbent material. Overall, modification with gambier leaf extract was shown to improve the performance of the material in dye adsorption, especially for RhB and MB. To further emphasize the impact of gambier leaf extract modification, a comparison with previous studies is provided in Table 1.

## 4. CONCLUSIONS

This study showed that the modification of Ni/Al LDH with Gambier Leaf Extract significantly improved its adsorption capacity towards RhB, MG, and MB dyes. UV-Vis spectroscopy results showed a decrease in dye concentration after the adsorption process, confirming the improved performance of Ni/Al-Gambier Leaf Extract compared to unmodified Ni/Al LDH. The increase in removal efficiency, especially for RhB and MB, indicated that the polyphenolic compounds in the extract contributed to enhancing the interaction between the adsorbent and the dye molecules. Therefore, Ni/Al-Gambier Leaf Extract is a promising material for wastewater treatment applications, offering an environmentally friendly and effective solution for dye removal.

## 5. ACKNOWLEDGEMENT

The authors would like to express their gratitude to the Research Center of Inorganic Materials and Coordination Complexes, Sriwijaya University, which has supported the authors in completing this research.

## REFERENCES

Abbas, M. and M. Trari (2023). Contribution of Zeolite to Remove Malachite Green in Aqueous Solution by Adsorption Processes: Kinetics, Isotherms and Thermodynamic Studies. *Textile Research Journal*, **93**(15–16); 3765–3776

Abd El-Monaem, E. M., H. M. Elshishini, S. S. Bakr, H. G. El-Aqapa, M. Hosny, G. Andaluri, G. M. El-Subruiti, A. M. Omer, and A. S. Eltaweil (2023). A Comprehensive Review on LDH-Based Catalysts to Activate Persulfates for the Degradation of Organic Pollutants. *npj Clean Water*, **6**(34); 1–24

Abdel-Hady, E. E., S. H. M. Hafez, H. F. M. Mohamed, and M. R. M. Elsharkawy (2024). Characterization and Application of LDH with Chitosan Composites Investigated by Positron Annihilation Lifetime Spectroscopy and Surface Texture for the Adsorption of Methyl Orange. *Scientific Reports*, **14**(1); 16501

Abdelrahman, A. A., S. H. Bendary, and S. A. Mahmoud (2023). Synthesis and Electrochemical Properties of NiAl LDH@RGO Hierarchical Nanocomposite as a Potential Counter Electrode in Dye Sensitized Solar Cells. *Diamond and Related Materials*, **134**; 109738

Ahmad, N., F. S. Arsyad, I. Royani, Y. Hanifah, and A. Lesbani (2025). Lignin-NiAl Layered Double Hydroxide Composite Adsorbent for Selective Removal of Malachite Green from Aqueous Solutions of Cationic Dyes. *Chemistry Africa*; 1–11

 

Ahmad, N., A. R. Marlan, and S. P. J. Negara (2024a). Insight of Anionic Dyes Adsorption from Their Aqueous Solutions onto MgAl LDH/Lignin: Characterization and Isotherm Studies. *Indonesian Journal of Material Research*, **2**(2); 40–46

Ahmad, N., Rohmatullaili, A. Wijaya, and A. Lesbani (2024b). Magnetite Humic Acid-Decorated MgAl Layered Double Hydroxide and Its Application in Procion Red Adsorption. *Colloids and Surfaces A: Physicochemical and Engineering Aspects*, **684**; 133042

Al-Tohamy, R., S. S. Ali, F. Li, K. M. Okasha, Y. A. G. Mahmoud, T. Elsamahy, H. Jiao, Y. Fu, and J. Sun (2022). A Critical Review on the Treatment of Dye-Containing Wastewater: Ecotoxicological and Health Concerns of Textile Dyes and Possible Remediation Approaches for Environmental Safety. *Ecotoxicology and Environmental Safety*, **231**; 113160

Alsukaibi, A. K. D. (2022). Various Approaches for the Detoxification of Toxic Dyes in Wastewater. *Processes*, **10**(10); 1968

Azanaw, A., B. Birlie, B. Teshome, and M. Jemberie (2022). Textile Effluent Treatment Methods and Eco-Friendly Resolution of Textile Wastewater. *Case Studies in Chemical and Environmental Engineering*, **6**; 100230

Bessaha, F., G. Bessaha, S. Ziane, and A. Khelifa (2023). Adsorption of Methyl Orange on Bentonite: Design, Modeling, and Analysis of Experiments. *Iranian Journal of Chemistry and Chemical Engineering*, **42**(10); 3306–3323

Bezerra, B. G. P., L. Bieseki, D. R. da Silva, and S. B. C. Pergher (2019). Development of a Zeolite A/LDH Composite for Simultaneous Cation and Anion Removal. *Materials*, **12**; 661

Du, C., T. Hu, C. Tang, Y. Liu, J. Deng, S. Wang, S. Yan, and X. Hu (2024). Rapid Removal of Rhodamine B by Phosphoric Acid-Modified Activated Carbon Derived from Rape Straw. *Environmental Technology*, **45**(27); 5855–5864

Foruzin, L. J., F. Nasirpouri, and H. Dai (2025). Electrochemically-Deposited NiAl-Layered Double Hydroxide/Ni Electrocatalysts for Enhanced Magnetic Water Oxidation. *Applied Clay Science*, **269**; 107770

Fukumori, Y., H. Takeuchi, and Y. Ando (2018). Structural Control of Nanoparticles. In *Nanoparticle Technology Handbook*. pages 49–107

Hanifah, Y., R. Mohadi, M. Mardiyanto, and A. Lesbani (2022). Photocatalytic Degradation of Malachite Green by NiAl-LDH Intercalated Polyoxometalate Compound. *Bulletin of Chemical Reaction Engineering and Catalysis*, **17**(3); 627–637

Hu, X., W. Zheng, M. Wu, L. Chen, and S. Chen (2023). Composites of Metal-Organic Frameworks (MOFs) and LDHs for Energy Storage and Environmental Applications: Fundamentals, Progress, and Perspectives. *Sustainable Materials and Technologies*, **37**; e00691

Intachai, S., P. Pimchan, and P. Sumanatrakul (2019). Synthesis of NiAl-Layered Double Oxide as Inorganic Adsorbent for Eliminating Dye from Solution. *Naresuan University Journal: Science and Technology*, **27**(4); 66–74

Jagadeesh, N. and B. Sundaram (2023). Adsorption of Pollutants from Wastewater by Biochar: A Review. *Journal of Hazardous Materials Advances*, **9**; 100226

Jefri, J., N. A. Fithri, and A. Lesbani (2024). Enhanced Removal Efficiency of Malachite Green Dye Using Gambir Leaf Extract-Modified NiFe LDH Composites: A Study of Cationic Dye Adsorption. *Bulletin of Chemical Reaction Engineering & Catalysis*, **19**(4); 573–584

Kumari, U. (2024). Textile Dyes and Their Impact on the Natural Environment. In P. Singh, editor, *Dye Pollution from Textile Industry: Challenges and Opportunities for Sustainable Development*. Springer Nature Singapore, pages 17–30

Lee, H., S. Fiore, and F. Berruti (2024). Adsorption of Methyl Orange and Methylene Blue on Activated Biocarbon Derived from Birchwood Pellets. *Biomass and Bioenergy*, **191**; 107446

Lesbani, A., N. Ahmad, R. Mohadi, I. Royani, S. Wibiyan, Amri, and Y. Hanifah (2024). Selective Adsorption of Cationic Dyes by Layered Double Hydroxide with Assist Algae (*Spirulina platensis*) to Enrich Functional Groups. *JCIS Open*, **15**; 100118

Lesbani, A., N. R. Palapa, R. J. Sayeri, T. Taher, and N. Hidayati (2021). High Reusability of NiAl LDH/Biochar Composite in the Removal Methylene Blue from Aqueous Solution. *Indonesian Journal of Chemistry*, **21**(2); 421–434

Lin, Y. R., Y. F. Hu, C. Y. Huang, H. T. Huang, Z. H. Liao, A. T. Lee, Y. S. Wu, and F. H. Nan (2022). Removing Malachite Green and Leucomalachite Green From Freshwater and Seawater With Four Water Treatment Agents. *Frontiers in Environmental Science*, **10**; 906886

Lu, Y., X. Li, X. Jing, Y. Huang, Y. Qiang, G. Cao, R. Qin, Q. Cao, J. Cao, and S. C. Lee (2024). Applications of Layered Double Hydroxide Nanomaterials in Environmental Remediation: Synthesis, Structural Modification and Performance Enhancement. *Surfaces and Interfaces*, **52**; 104902

Luo, Y., Y. Han, Y. Hua, M. Xue, S. Yu, L. Zhang, Z. Yin, X. Li, X. Ma, H. Wu, T. Liu, Y. Shen, and B. Gao (2022). Step Scheme Nickel-Aluminium Layered Double Hydroxides/Biochar Heterostructure Photocatalyst for Synergistic Adsorption and Photodegradation of Tetracycline. *Chemosphere*, **309**; 136802

Milos, E., L. Cocheci, A. Popa, L. Lupa, and A. Filimon (2024). Hybrid Materials $Mg_3Al-LDH$ /Ionic Liquids/Chitosan Used in the Recovery Process of Pd Ions from Aqueous Solutions. *Molecules*, **29**(24)

Mohadi, R., Normah, N. R. Palapa, and A. Lesbani (2022). M2+(Ni, Cu, Zn)/Al-LDH Composites with Hydrochar from Rambutan Peel and Study the Adsorption Efficiency for Organic Dyes. *Environment and Natural Resources Journal*, **20**(2); 221–233

Mohammadi, A. A., S. Moghanlo, M. S. Kazemi, S. Nazari, S. K. Ghadiri, H. N. Saleh, and M. Sillanpää (2022). Comparative Removal of Hazardous Cationic Dyes by MOF-5 and Modified Graphene Oxide. *Scientific Reports*, **12**(1); 15314

Nizam, N. U. M., M. M. Hanafiah, E. Mahmoudi, A. A. Halim, and A. W. Mohammad (2021). The Removal of Anionic and Cationic Dyes from an Aqueous Solution Using Biomass-Based Activated Carbon. *Scientific Reports*, **11**(1); 1–17

Oladoye, P. O., T. O. Ajiboye, E. O. Omotola, and O. J. Oyewola (2022). Methylene Blue Dye: Toxicity and Potential Elimination Technology from Wastewater. *Results in Engineering*, **16**; 100678

 

Potgieter, J., F. B. Waanders, and E. Fosso-Kankeu (2019). Removal of Malachite Green and Toluidine Blue Dyes from Aqueous Solution Using a Clay-Biochar Composite of Bentonite and Sweet Sorghum Bagasse. *International Journal of Applied Engineering Research*, **14**(6); 1324–1333

Priya, P. S., P. Pratiksha Nandhini, S. Vaishnavi, V. Pavithra, M. H. Almutairi, B. O. Almutairi, S. Arokiyaraj, R. Pachaiappan, and J. Arockiaraj (2024). Rhodamine B, an Organic Environmental Pollutant Induces Reproductive Toxicity in Parental and Teratogenicity in F1 Generation in Vivo. *Comparative Biochemistry and Physiology Part C: Toxicology & Pharmacology*, **280**; 109898

Rahayu Palapa, N., T. Taher, R. Mohadi, H. Paluta Utami, and A. Lesbani (2021). The Ability of Composite Ni/Al-Carbon Based Material Toward Readsorption of Iron(II) in Aqueous Solution. *Science and Technology Indonesia*, **6**(3); 156–165

Sadegh, N., H. Haddadi, F. Sadegh, and A. Asfaram (2022). Recent Advances and Perspectives of Tannin-Based Adsorbents for Wastewater Pollutants Elimination: A Review. *Environmental Nanotechnology, Monitoring & Management*, **19**; 100763

Santhi, T., S. Manonmani, V. S. Vasantha, and Y. T. Chang (2016). A New Alternative Adsorbent for the Removal of Cationic Dyes from Aqueous Solution. *Arabian Journal of Chemistry*, **9**; S466–S474

Septiningrum, F., A. H. Yuwono, F. A. Maulana, E. Nurhidayah, D. Dhaneswara, N. Sofyan, H. Hermansyah, and W. W. Purwanto (2024). Mangosteen Pericarp Extract Mediated Synthesis of Ag/TiO2 Nanocomposite and Its Application on Organic Pollutant Degradation by Adsorption-Photocatalytic Activity. *Current Research in Green and Sustainable Chemistry*, **8**; 100394

Sharma, J., S. Sharma, and V. Soni (2023). Toxicity of Malachite Green on Plants and Its Phytoremediation: A Review. *Regional Studies in Marine Science*, **62**; 102911

Singha Roy, A., S. Kesavan Pillai, and S. S. Ray (2023). A Comparison of Nitrate Release from Zn/Al-, Mg/Al-, and Mg–Zn/Al Layered Double Hydroxides and Composite Beads: Utilization as Slow-Release Fertilizers. *ACS Omega*, **8**(9); 8427–8440

Slama, H. B., A. Chenari Bouket, Z. Pourhassan, F. N. Alenezi, A. Silini, H. Cherif-Silini, T. Oszako, L. Luptakova, P. Golińska, and L. Belbahri (2021). Diversity of Synthetic Dyes from Textile Industries, Discharge Impacts and Treatment Methods. *Applied Sciences*, **11**(14); 6255

Wahyuningsih, S., V. Anjani, H. Munawaroh, and C. Purnawan (2018). Optimization of Rhodamine B Decolorization by Adsorption and Photoelectrodegradation Combination System. *ALCHEMY Jurnal Penelitian Kimia*, **14**(2); 276

Wang, P., X. Zhang, B. Zhou, F. Meng, Y. Wang, and G. Wen (2023). Recent Advance of Layered Double Hydroxides Materials: Structure, Properties, Synthesis, Modification and Applications of Wastewater Treatment. *Journal of Environmental Chemical Engineering*, **11**(6); 111191

Wibiyan, S., I. Royani, N. Ahmad, and A. Lesbani (2024a). Assessing the Efficiency, Selectivity, and Reusability of ZnAl-Layered Double Hydroxide and Eucheuma cottonii Composite in Removing Anionic Dyes from Wastewater. *Inorganic Chemistry Communications*, **170**; 113347

Wibiyan, S., I. Royani, A. Lesbani, et al. (2024b). Selective Adsorption of Cationic and Anionic Dyes Using Ni/Al Layered Double Hydroxide Modified with Eucheuma cottonii. *Indonesian Journal of Material Research*, **2**(1); 1–6

Wijaya, A., Z. A. Zahara, P. M. S. B. N. Siregar, N. Ahmad, A. Amri, N. R. Palapa, R. Mohadi, and A. Lesbani (2024). Cellulose-Supported Ni/Al Layered Double Hydroxide (LDH) as Unique Adsorbents for Malachite Green Dye Removal in Aqueous Solutions. *Iranian Journal of Chemistry and Chemical Engineering*, **43**(4); 1566–1578

Wongsa, P., P. Phatikulrungsun, and S. Prathumthong (2022). FT-IR Characteristics, Phenolic Profiles and Inhibitory Potential Against Digestive Enzymes of 25 Herbal Infusions. *Scientific Reports*, **12**(1); 6631

Yang, J., G. Gao, Z. Zhu, and X. Yu (2022). Biochar Modified Co–Al LDH for Enhancing Photocatalytic Reduction CO2 Performance and Mechanism Insight. *Research on Chemical Intermediates*, **48**(6); 2313–2323

You, H., B. Huang, C. Cao, X. Liu, X. Sun, L. Xiao, J. Qiu, Y. Luo, Q. Qian, and Q. Chen (2021). Adsorption–Desorption Behavior of Methylene Blue onto Aged Polyethylene Microplastics in Aqueous Environments. *Marine Pollution Bulletin*, **167**; 112287

Zahid, S., W. Jamil, D. Q.-U.-N. Shumaila, and J. Shaikh (2024). Sorption of Methylene Blue Dye Through Synthesized and Modified Phenyl Pyruvate Zn Al Layered Double. *Journal of Population Therapeutics & Clinical Pharmacology*; 1625–1641

Zehra, T., A. R. Safira, A. Fattah-alhosseini, M. Alkaseem, and M. Kaseem (2025). Decoration of CoFe-LDH/porous MgO Composite with $ZrO_2$ Nanoparticles for Efficient Photocatalytic Removal of Indigo Carmine. *Journal of Magnesium and Alloys*, **(in press)**

 