ANSF®
APPLIED AND NATURAL SCIENCE FOUNDATION

*Journal of Applied and Natural Science*
14(2), 411 - 417 (2022)
ISSN : 0974-9411 (Print), 2231-5209 (Online)
journals.ansfoundation.org

*Research Article*

# Adsorption potential of *Euphorbia Hirta*'s (leaf and stem) towards methyl red in aqueous systems

**Venkata Kishore Babu Chukka**
Department of Environmental Sciences, University College of Sciences, Acharya Nagarjuna University, Guntur-522510 (Andhra Pradesh), India
**Venkata Ramana Kokkiligadda***
Department of Science and Humanities, Guru Nanak Institutions of Technical Campus, Rangareddy (Telangana), India
**Swamy AVVS**
Department of Environmental Sciences, University College of Sciences, Acharya Nagarjuna University, Guntur-522510 (Andhra Pradesh), India
**Hari Babu Bollikolla**
Department of Chemistry, University College of Sciences, Acharya Nagarjuna University, Guntur-522510 (Andhra Pradesh), India

*Corresponding author. Email: dr.b.haribabu@gmail.com

***Article Info***
https://doi.org/10.31018/jans.v14i2.3346
Received: February 10, 2022
Revised: May 14, 2022
Accepted: May 23, 2022

***How to Cite***
Chukka, V. K. B. *et al.* (2022). Adsorption potential of *Euphorbia Hirta*'s (leaf and stem) towards methyl red in aqueous systems. *Journal of Applied and Natural Science*, 14(2), 411 - 417. https://doi.org/10.31018/jans.v14i2.3346

**Abstract**
Dyes harm both aquatic species and humans in wastewaters, which are poisonous as well as carcinogenic. For decades, the adsorption system technique has been widely used to take out dyes from aqueous solutions since it is a trouble-free and successful process. The present study investigated the use of *Euphorbia hirta*'s leaf powder/stem powder/leaf ash/stem ash for the adsorption of methyl red dye (MRD) from aqueous samples for the first time. MRD aqueous solutions (250 ml, 100 ppm) were incubated for the required contact period with 1.2 gm/l of investigated sorbent with agitation at 100 rpm. The temperature and pH remained maintained at 27 degrees Celsius and 4.0, respectively. The residual amounts of MRD were evaluated by spectrophotometrically measuring MRD absorbance at 464.9 nm. The percent MRD clearance using *E. hirta*'s leaf powder/stem powder/leaf ash/stem ash showed that the optimal condition of MRD clearance happened at pH unit of 4, 100 ppm concentration of MRD, sorbent dose at 1.2 gm/l, ambient temperature, mechanical shaker agitation speed of 100 rpm. The optimal equilibration time for highest percentile MRD clearance was 125 min (*E. hirta* leaf powder), 105 min (*E. hirta* leaf ash powder and *E. hirta* stem powder) and 90 min (*E. hirta* stem ash powder). Negatively charged chemical groups like –COOH, -CHO, -NH, etc. present in the phytochemicals of *E. hirta*'s leaf and stem binds to positively charged ions in MRD, as a result, adsorption occurs. For its significant biosorption potential and cheap cost, *E. hirta*'s leaf powder/stem powder/leaf ash/stem ash can be regarded as alternative biomass for removing MRD from the aqueous solution.

**Keywords:** Aqueous system, Biosorbent, Biosorption, *Euphorbia hirta,* Spectroscopic analysis

## INTRODUCTION

In recent times, accelerated advancement in industrial operations has resulted in the release of an unprecedented volume of wastewater with artificial dyes that contaminate waterways and, as a result, affect humans and other living species (De Luca and Nagy, 2020). A large percentage of the colours utilised are azo reactive dyes (Benkhaya *et al.,* 2020). Because one or more azo groups are coupled with substituted aromatic structures, those dyes have a brilliant colour (Forgacs *et al.*, 2004). Textile, cosmetics, foods processing, leather, paper and dye industry effluents are only a few examples of discharged azo dyes (Bhatnagar and Jain, 2005). Living creatures are poisoned by these colours or their breakdown products (Chung *et al.,* 1981). Colorants in wastewater are very challenging to eliminate since they are light, heat, and oxidising agent resistant. In a nutshell, they are difficult to deteriorate (Jain and Sikarwar, 2008). To accomplish a high degree of removal of dye in wastewater systems, chemical, biological, & physical procedures like coagulation, ultrafiltration, electro-chemical adsorption, & photo-oxidation must be integrated (Kargi and Ozmihci,

This work is licensed under Attribution-Non Commercial 4.0 International (CC BY-NC 4.0). © : Author (s). Publishing rights @ ANSF.

2004). Because of their great effectiveness and capacity to segregate a broad range of chemical components, physical adsorption methods are typically chosen as the ideal approach to removing/purifying organic pollutants (Imamura *et al.,* 2002; Ho *et al.,* 2003; Ofomaja and Ho, 2006; Kokkiligadda *et al.*, 2020).

Owing to the minimal price and broad availability of agricultural residues as starting resources, their use has sparked a lot of research interest. Palm kernel fibres (Ofomaja, 2007), sugarcane bagasse (Azahar *et al.,* 2005), peel of banana (Annadurai *et al.,* 2002), barn of rice and wheat (Xue *et al.,* 2008), rice husk (Lakshmi *et al.,* 2009), tea waste (Tamez *et al.,* 2009; Indolean *et al.,* 2017), shell of coconut (Singh *et al.,* 2008), apple pomace and wheat straw (Robinson *et al.,* 2002), garlic peel (Hameed and Ahmad, 2009), almond shells (Loulidi *et al.,* 2020), Eucalyptus globulus seeds (Renita *et al.,* 2021), flower spikes (Parlayıcı and Pehlivan, 2021) are examples of agro wastes that have been utilised to remove colours.

A pantropical weed, *E. hirta*, occasionally named asthma-plant, originated from tropical regions (Kumar *et al.,* 2010) is a hairy herb growing on roadsides, open grasslands, also in pathways. Several cultures employ it in classic herbal therapy, especially for asthma, skin problems, & hypertension (Xia *et al.,* 2018). It is also used as a folk medicine treating fevers, especially dengue fever & malaria, in the form of herbal tea (Perera *et al.,* 2018; Shah *et al.,* 2019). This herb has never been used to eliminate methyl red dye (MRD) from contaminated water as a biosorbent.

As a result, the primary goal of this research was to determine whether *E. hirta*'s leaves powder, leaves ash, stem powder, and stem ash could be used to build a unique sorbent and also to test its efficacy in eliminating MRD from simulated wastewater. The related factors, including pH, sorbent dose, and contact time, were evaluated systematically.

## MATERIALS AND METHODS

### Sorbent

*Euphorbia hirta,* a member of the Euphorbiaceae family, was available locally. The *E. hirta* plant's leaves and stems were selected, chopped into small pieces, cleaned with double-distilled water, and sun-dried for seven days. The dried leaves/dried stems were pulverised in a high-powered blender and subsequently sieved to get rid of the fibres. The dried leaves/stem were burned in a furnace for a nearly two-hour time period to make the *E. hirta* leaf ash/stem ash.

### Adsorbate-methyl red

"Merck India Ltd, India" provided the methyl red, which was utilised without additional purification. For this investigation, a methyl red dye (MRD) solution with a content value of 100 ppm was prepared. The produced MRD solution was covered using aluminium foil and preserved in the dark to avoid unnecessary light exposures.

### Adsorption experiments

The sorbents (*E. hirta*'s leaf powder/stem powder/ leaf ash/stem ash) were precisely weighed and placed in previously cleansed 500 mL capped bottles holding 250 mL of MRD (100 ppm quantity) solution. The pH of the mixtures (sorbent + MRD solution) was adjusted using HCl of 0.1 M strength or NaOH of 0.1 M strength solutions, depending on their starting pH values. Mechanical mixers were used to vigorously shake the mixtures (sorbent + MRD solution), which were then allowed to equilibrate for the necessary duration of time. However, after the equilibration time, an aliquot of the mixture (sorbent + MRD solution) was collected for the Spectrophotometric measurement of MRD remaining in mixture. The MRD obeys “Beer-Lamberts Law" at trace concentrations and has a maximum wavelength of 464.9 nm. The MRD absorbance measures were recorded at 464.9 nm with a UV-Visible spectrophotometer fabricated by “Systronics” company. From MRD absorbance measures, remaining content (ppm) of MRD can be gauged.

The following formulae were used to compute the percent of MRD removed (%) and the quantity of MRD adsorbed (mg/gm).

Percent of MRD removed (%)= MRD IC-MRD EC/ MRD IC X 100 ………..Eq.1

Quantity of MRD absorbed (qe) = MRD IC-MRD EC/ AS X V ………..Eq.2

Where MRD IC means MRD initial concentration (mg/L); MRD EC means MRD equilibrium concentration (mg/l); AS means sorbents (*E. hirta*'s leaf powder/stem powder/ leaf ash/stem ash) mass; and V means test MRD solution (l).

The % clearance of MRD from simulated water specimens was investigated using the above-mentioned experimental approach regarding time of equilibration, pH values, agitation speed of mechanical shaker, temperature, initial MRD quantity, and sorbent dosage concentration.

## RESULTS AND DISCUSSION

Methyl Red Dye (MRD) is a ubiquitous mono azo dye in use in laboratory assays, textile, as well as other business items. Nevertheless, it can induce eye and skin sensitivities and pharyngeal and digestive system discomfort (Shilpa *et al.,* 2013; Maniyam *et al.,* 2020). MRD is also mutagenic at aerobic conditions, as it biotransforms to 2-aminobenzoic acid & N-N' dimethyl-p-phenylene diamine (Vijaya and Sandhya, 2003; Jadhav *et al.,* 2008). Recently, there has been a surge in interest in devising low-cost methods for lowering, if not totally eliminating, MRD present in wastewater prior to its disposal into receiving water.

Phytochemical investigation of *E. hirta*'s leaves and stems by a number of investigators (Basma *et al.,* 2011; Singh and Kumar, 2013; Kumar *et al.,* 2010) shows the existence of phytochemicals like 1,3,4,6-tetra-*O*-galloyl-β-D-glucose, 24-methylenecycloartenol, 2,4,6-tri-*O*-galloyl-β-D-glucose, 24-methylenecycloartenol, afzelin, alkaloids, camphol, choline, chtolphenolic acid, euphorbins type A – D, flavonoids, gallic acid, heptacosane, kaempferol, myricitrin, *n*nonacosane, protocatechuic acid, quercitrin, reducing sugars, rhamnose, rutin, shikmic acid, steroids, tannins, terpenoids, tinyatoxin, β-amyrin and β-sitosterol. Functional groups like as –COOH, -CHO, -NH, etc. are found in above said phytochemicals. Adsorption occurs when these negatively charged chemical groups in adsorbents bind positively charged ions in MRD.

## Equilibration time

The present study observed that for a given sorbent (*E. hirta*'s leaf powder/stem powder/ leaf ash/stem ash) at a given pH, the % clearance of MRD improves over time, and after a particular period of time, the % clearance of MRD kept static, indicating that an equilibrium point has indeed been established. Fig. 1-4 represent the findings. At a 125-minute equilibration time, the greatest percentile clearance of MRD was achieved with *E. hirta* leaf powder (Fig. 1). The equilibration time was 105 min with *E. hirta* leaf ash powder (Fig. 2) and *E. hirta*'s stem powder (Fig. 3). The greatest percentile clearance of MRD was achieved at an equilibration time of 90 min with *E. hirta*'s stem ash powder (Fig. 4).

As compared to earlier research, Kadam *et al.* (2018) found that plants (*Ammannia baccifera and Fimbristylis dichotoma)* had cleared MRD up to 89% and 91% later 60 h of exposure, respectively. According to Chandanshive *et al.* (2016) *Salvinia molesta* was shown to be capable of degrading azo dye up to 97% in 3 days utilising root biomass.

## Percentage clearance of MRD by sorbents as a function of pH

Owing of its impact on the surface character traits of the sorbents (*E. hirta*'s leaf powder/stem powder/leaf ash/stem ash) and the dissociation/ionization of the MRD molecule, the pH of the reaction has a significant influence on MRD molecule adsorptive uptake. Using a starting concentration of MRD (100 ppm) around 250 mL and 2 g of sorbent (*Euphorbia hirta*'s leaf powder/ stem powder/ leaf ash/stem ash), the impact of pH on % clearance of MRD was evaluated. The pH of the mixtures (sorbent + MRD solution) was adjusted using HCl of 0.1 M strength or NaOH of 0.1 M strength solu-

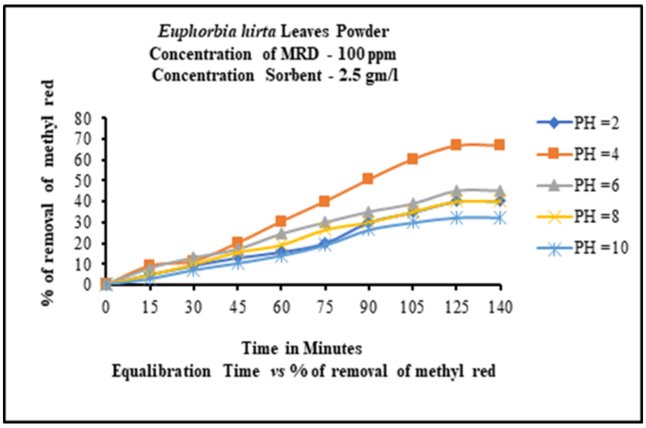


**Fig. 1.** *Equilibration time for Euphorbia hirta leaf powder*

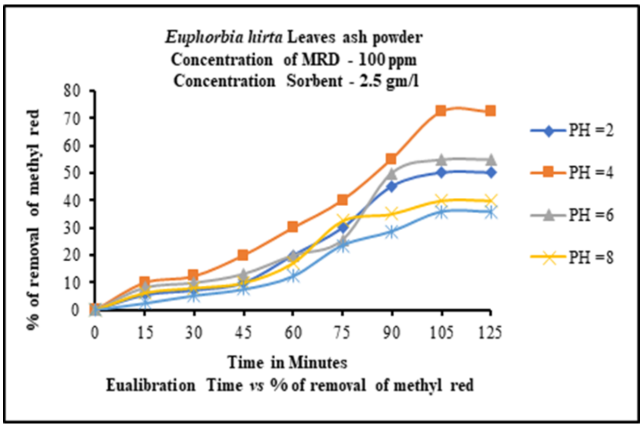


**Fig. 2.** *Equilibration time for Euphorbia hirta leaf ash powder*

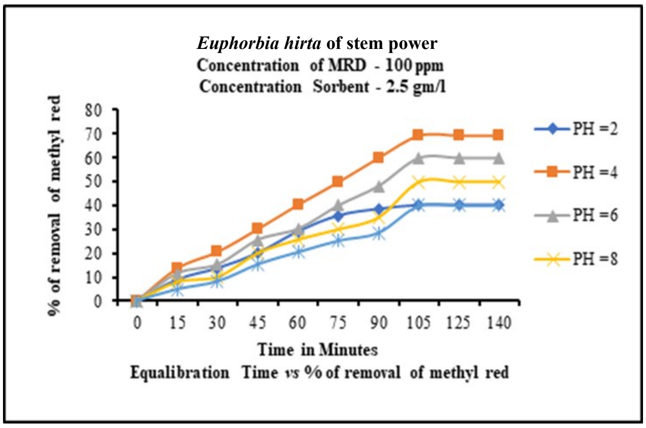


**Fig. 3.** *Equilibration time for Euphorbia hirta stem powder*

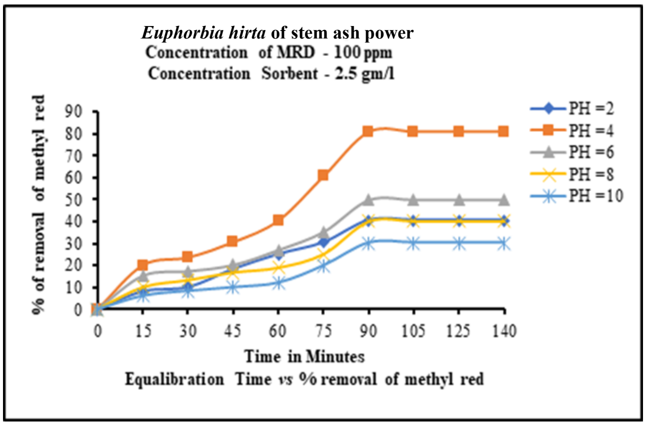


**Fig. 4.** *Equilibration time for Euphorbia hirta stem ash powder*

tions depending on their starting pH units to form a sequence of pH units 2, 4, 6, 8 and 10. Mechanical shakers adopted to agitate the suspensions at ambient temperature showed that the % clearance of MRD in solutions with diverse pH units (2, 4, 6, 8 and 10) is made known in Table 1. The % MRD clearance capacity of investigated sorbents (*E. hirta*'s leaf powder/stem powder/leaf ash/stem ash) improved from pH units 2 to pH 4 and diminished from 6 to 10 pH units. Maximum % MRD clearance was attained at pH unit 4 for all investigated sorbents (*E. hirta*'s leaf powder/stem powder/ leaf ash/stem ash). Low pH (2–4) causes a rise in $H^+$ ions intensity in the chemical system. The surfaces of the sorbents (*E. hirta*'s leaf powder/stem powder/ leaf ash/stem ash) obtained a positive charge by accepting $H^+$ ions. This increases the sorbent's adsorption capability and hence the % MRD clearance. The adsorption efficiency of these sorbents (*E. hirta*'s leaf powder/stem powder/leaf ash/stem ash) was reduced at excessive pH units (6 to 10) because MRD's loss of $H^+$ ions rendered it negatively charged and unable to engage with the investigated sorbents. The current study's findings are comparable to those of Krishna *et al.* (2020). Krishna *et al.,* 2020) reported the optimized pH value of 4 for maximum MRD clearance by Charred Sal sawdust and Xanthated Sal sawdust.

**Effects of considered sorbents dose on percentage MRD clearance**

The effect of investigated sorbents (*E. hirta*'s leaf powder/stem powder/leaf ash/stem ash) dose on the percentage MRD clearance with optimum MRD concentration (100 ppm) at 250 mL was inspected with sorbent doses of 0.2 gm/l, 0.4 gm/l, 0.6 gm/l, 0.8 gm/l, 1.0 gm/l, 1.2 gm/l and 1.4 gm/l. The pH of the mixtures (sorbent + MRD solution) was adjusted using HCl of 0.1 M strength or NaOH of 0.1 M strength solutions to 4 pH. Mechanical shakers were adopted to agitate the suspensions at ambient temperature, and the % clearance of MRD was evaluated at corresponding equilibration times of investigated sorbents. The % clearance of MRD in solutions with diverse dose quantities of investigated sorbents is made known in Table 2. The percentage MRD clearance capacity of investigated sorbents increased from dose quantities 0.1 to 1.2 gm/l at corresponding equilibration times and pH of 4 units. The percentage MRD clearance capacity constantly persisted from 1.2 gm/l dose quantities. As compared to earlier research, Kaya (2017) found that 4 gm dose each of walnut shell and hazelnut shell had cleared 79% and 77% MRD, respectively. Vatsal (2017) reported that 4 gm to 5 gm of orange peel powder is the optimum amount for maximum MRD clearance.

**Percentage clearance of MRD by sorbents as a function of temperature**

Table 3 shows the percentile MRD clearance by researched sorbents (*E. hirta*'s leaf powder/stem powder/ leaf ash/stem ash) versus ambient, 40 °C, 50 °C, and 60 °C temperatures. The quantities of dye adsorbed by the examined sorbents (*E. hirta*'s leaf powder/stem powder/leaf ash/stem ash) remained consistent as the temperature increased, as indicated. As a result, an ideal ambient temperature of 27 °C was chosen. Our findings are consistent with those of Eman's previous research (2020). Whereas Sunil *et al.,* discovered that increasing the temperature from 25°C to 55°C improved the proportion of MRD removed by eggshell waste.

**Table 1.** Percentage clearance of MRD by investigated sorbents as a function of pH

| pH unit | % MRD clearance with *E. hirta*'s | | | |
|---|---|---|---|---|
| | **Leaf powder** | **Stem powder** | **Leaf ash** | **Stem ash** |
| 2 | 40.2 | 40.5 | 50 | 53 |
| 4 | 65.8 | 69.5 | 65 | 60 |
| 6 | 44.8 | 44 | 45 | 48 |
| 8 | 40.1 | 32 | 30 | 40 |
| 10 | 30.4 | 21 | 25 | 35 |

**Table 2.** Percentage clearance of MRD by investigated sorbents as a function of dose quantity

| Dose quantity (gm/l) | % MRD clearance with *E. hirta*'s | | | |
|---|---|---|---|---|
| | **Leaf powder** | **Stem powder** | **Leaf ash** | **Stem ash** |
| 0.2 | 30.5 | 30 | 31 | 28 |
| 0.4 | 40.9 | 40.6 | 48 | 46 |
| 0.6 | 51.2 | 45.8 | 57 | 61 |
| 0.8 | 63.7 | 58.7 | 69 | 68 |
| 1.0 | 72 | 70.2 | 78 | 74 |
| 1.2 | 88.2 | 78.2 | 91 | 90 |
| 1.4 | 88.2 | 78.2 | 91 | 90 |

**Table 3.** Percentile MRD clearance at diverse temperature

| Sorbent | Percentile MRD clearance at temperature of | | | |
|---|---|---|---|---|
| | Ambient | 40 °C | 50 °C | 60 °C |
| Leaf powder | 81.6 | 81.5 | 81.4 | 81.6 |
| Leaf ash | 82.4 | 82.4 | 82.3 | 82.4 |
| Stem powder | 87.2 | 87.1 | 87.1 | 87.1 |
| Stem ash | 82.5 | 82.3 | 82.5 | 82.4 |

**Table 4.** Percentile MRD clearance at diverse initial MRD quantity

| Sorbent | Percentile MRD clearance at initial quantity of MRD at | | | | |
|---|---|---|---|---|---|
| | 100 ppm | 150 ppm | 200 ppm | 250 ppm | 300 ppm |
| Leaf powder | 86.4 | 74.8 | 72.6 | 65.4 | 64.1 |
| Leaf ash | 90.2 | 85.4 | 62.1 | 60.4 | 59.7 |
| Stem powder | 85.6 | 81.2 | 79.6 | 70.5 | 69.7 |
| Stem ash | 88.9 | 79.2 | 75.8 | 69.1 | 66.8 |

**Table 5.** Percentile MRD clearance at diverse agitation speeds

| Sorbent | Percentile MRD clearance at initial quantity of MRD at | | | | |
|---|---|---|---|---|---|
| | 50 rpm | 100 rpm | 150 rpm | 200 rpm | 250 rpm |
| Leaf powder | 87.5 | 91.6 | 90.4 | 85.6 | 71.5 |
| Leaf ash | 83.5 | 96.4 | 95.7 | 92.5 | 84.3 |
| Stem powder | 89.6 | 95.2 | 91.0 | 83.4 | 79.4 |
| Stem ash | 91.6 | 94.8 | 85.2 | 79.5 | 75.4 |

**Effect of MRD initial quantity on percentage MRD clearance by considered sorbents**

A 1.2 gm/l sorbents (*Euphorbia hirta*'s leaf powder/stem powder/leaf ash/stem ash) included in MRD solutions with different dye quantities (100 ppm, 150 ppm, 200 ppm, 250 ppm and 300 ppm) showed that the pH of the solution (sorbent + MRD) was retained at 4 and the solution (sorbent + MRD) was agitated for optimal equilibration time. Table 4 demonstrates the relationship between the MRD amount cleared and the initial quantity of MRD in the solution. The MRD elimination % was shown to be lower the greater the initial MRD concentration. The adsorbent's surface has a substantial percentage of unoccupied sites at the beginning of the adsorption activity (Munir *et al.,* 2020; Sintakindi and Ankamwar, 2020). The proportion of such sites diminishes as the adsorption mechanism progresses. There are plenty of active sites on the sorbent's surface with low initial MRD concentrations. However, there is just not enough empty active sites at high initial MRD concentrations. According to Noha *et al.* (2020), when the starting MRD concentration increased from 10 to 100 ppm, the percentage elimination of MRD dropped with oil shale.

**Effect of agitation speed on percentage MRD clearance by considered sorbents**

The consequence of agitation speediness on the percentage MRD clearance with optimum initial MRD concentration (100 ppm) at 250 mL with sorbents dose of 1.2 gm/l showed that the pH of the solution (sorbent + MRD) was retained at 4. Mechanical shakers were adopted to agitate the suspensions at diverse agitation speeds like 50 rpm, 100 rpm, 150 rpm, 200 rpm, and 250 rpm. The % clearance of MRD was evaluated at corresponding equilibration times (125 min – *E. hirta*'s leaf powder; 105 min – *E. hirta*'s leaf ash powder and *E. hirta*'s stem powder; 90 min – *E. hirta*'s stem ash powder) with sorbents at diverse agitation speeds is mentioned in Table 5. The % MRD clearing improved as the agitation velocity increased from 50 to 100 rpm. As a result, the best agitation rate speed was fixed at 100 rpm. The % MRD removal dropped as the agitation velocity was raised after that. The enduring capability of thin layer sorbent decreased as agitation velocity increased, indicating that the MRD engaged with the sorbent (Potgieter *et al.,* 2021; Giwa *et al.,* 2021). Since the sorbent active regions were saturated with MRD at the best agitation speed, the percentage of MRD clearance fell.

## Conclusion

The biosorption potential of *E. hirta*'s leaf powder/stem powder/leaf ash/stem ash towards MRD was explored for the first time. The impact of pH, sorbent dosage, agitation speed of mechanical shaker, temperature, initial MRD quantity and equilibration time on the biosorption potential of *E. hirta*'s leaf powder/stem powder/leaf ash/stem ash was studied. For all investigated sorbents, maximum percentage MRD clearance was attained at pH unit 4, with a dose quantity of 1.2 gm/l and at ambient temperature of 27 °C. The current analysis concluded that readily accessible *E. hirta*'s might be an effective sorbent for eliminating MRD from aqueous systems.

## ACKNOWLEDGEMENTS

The authors are thankful to Acharya Nagarjuna University (Andhra Pradesh) for constant encouragement.

### Conflict of interest
The authors declare that they have no conflict of interest.

### Erratum
The manuscript was revised post-publication on the author's request to replace "bark" with "stem". The editorial committee reviewed the request and agreed to include the change, which was an oversight on the author's end. The manuscript with the erratum was published on 11-01-2023.

## REFERENCES

1. Annadurai, G., Juang, R. & Lee, D. (2002). Use of cellulose-based wastes for adsorption of dyes from aqueous solutions. *Journal of Hazardous Material*, 92(3), 263-274. DOI: 10.1016/S0304-3894(02)00017-1
2. Azahar, S., Liew, A. G., Suhardy, D., Hafiz, K.F. & Hatim, M. D. I. (2005). Dye Removal from aqueous solution by using adsorption on treated sugarcane bagasse. *American Journal of Applied Science*, 2(11), 1499-1503. DOI: 10.3844/ajassp.2005.1499.1503.
3. Basma, A.A., Zakaria, Z., Latha, L.Y. & Sasidharan, S. (2011). Antioxidant activity and phytochemical screening of the methanol extracts of Euphorbia hirta L. Asian Pacific Journal of Tropical Medicine. 4 (5), 386-390. doi: 10.1016/S1995-7645(11)60109-0.
4. Benkhaya, S., M'rabet, S. & El Harfi, A. (2020). Classifications, properties, recent synthesis and applications of azo dyes. *Heliyon*, 6(1): e03271. DOI:10.1016/j.heli yon.2020.e03271
5. Bhatnagar, A. & Jain, A. K. (2005). A comparative adsorption study with different industrial wastes as adsorbents for the removal of cationic dyes from water. *Journal of Colloid and Interface Science*, 281 (1), 49-55. DOI: 10.1016/j.jcis.2004.08.07
6. Chandanshive, V.V., Rane, N.R., Gholave, A.R., Patil, S.M., Jeon, B.H. & Govindwar, S.P. (2016). Efficient decolorization and detoxification of textile industry effluent by Salvinia molesta in lagoon treatment. *Environmental Research*, 150, 88-96. DOI: 10.1016/j.envres.2016.05.047.
7. Chung, K.T., Fulk, G. E. & Andrews, A. W. (1981). Mutagenicity testing of some commonly used dyes. *Applied Environmental Microbiology*, 42 (4), 641-648. DOI: 10.1128/aem.42.4.641-648.1981
8. De Luca, P. & Nagy, B.J. (2020). Treatment of water contaminated with reactive black-5 dye by carbon nanotubes. *Materials (Basel),* 13(23), 5508. DOI:10.3390/ma13235508
9. Eman, A.A. (2020). Efficient removal of methyl orange from wastewater by polymeric chitosan-iso-vanillin. *Open Chemistry Journal*, 7, 16-25. DOI: 10.2174/1874842202007010016
10. Forgacs, E., Cserhatia, T. & Oros, G. (2004). Removal of synthetic dyes from wastewaters: A review. *Environment International*, 30 (7), 953-971. DOI: 10.1016/j.envint.2004.02.001
11. Giwa, A. A., Bello, I. A., Oladipo, M. A., & Aderibigbe, D. O. (2021). Competitive Adsorption of Congo red in Single and Binary Systems Using a Low-cost Adsorbent. *Journal of Health & Pollution*, 11 (31), 210912. DOI:10.5696/2156-9614-11.31.210912
12. Hameed, B.H. & Ahmad, A. A. (2009). Batch adsorption of methylene blue from aqueous solution by garlic peel, an agricultural waste biomass. *Journal of Hazardous Material*, 164(2-3), 870-875. DOI: 10.1016/j.jhazmat.2008.08.084
13. Ho, Y. S., Chiang, T. H. & Hsueh, Y. M. (2003). Removal of basic dye from aqueous solution using tree fern as a biosorbent. *Process Biochemistry*, 40(1), 119-124. DOI: 10.1016/j.procbio.2003.11.035
14. Imamura, K., Ikeda, E., Nayayasu, T., & Nakanishi, K. (2002). Adsorption behavior of methylene blue and its congeners on a stainless steel surface. *Journal of Colloid and Interface Science*, 245(1), 50-57. DOI:10.1006/jcis.2001.7967
15. Jadhav, S.U., Kalme, S.D. & Govindwar, S.P. (2008). Biodegradation of methyl red by *galactomyces geotrichum* MTCC 1360. *International Biodeterioration* and *Biodegradation,* 62, 135-142. DOI: 10.1016/j.ibiod.2007.12.010
16. Jain, R. & Sikarwar, S. (2008). Removal of hazardous dye congored from waste material. *Journal of Hazardous Material*, 152 (3), 942-948. DOI: 10.1016/j.jhazmat.2007.07.070
17. Kadam, S.K., Chandanshive, V.V., Rane, N.R., Patil, S.M., Gholave, A.R., Khandare, R.V., Bhosale, A.R., Jeon, B.H. & Govindwar, S.P. (2018). Phytobeds with *Fimbristylis dichotoma* and *Ammannia baccifera* for treatment of real textile effluent: An in situ treatment, anatomical studies and toxicity evaluation. *Environmental Research,* 160, 1-11. DOI: 10.1016/j.envres.2017.09.009.
18. Kargi, F. & Ozmihci, S.S. (2004). Biosorption performance of powdered activated sludge for removal of different dyestuffs. *Enzyme and Microbial Technology*, 35(2), 267-271. DOI: 10.1016/j.enzmictec.2004.05.002.
19. Kaya, N. (2017). A comprehensive study on adsorption behavior of some azo dyes from aqueous solution onto different adsorbents. *Water Science Technology*, 76 (2), 478-489. DOI: 10.2166/wst.2017.216.
20. Kokkiligadda, V. R., Pokala, R. K. V., Karumuri, A., & Bollikola, H. B. (2020). Adsorption Potentialities of Bio-Sorbents Derived from Pomegranate in the Removal of Methyl Red Dye from Polluted Waters. *Caribbean Journal of Sciences and Technology (CJST)*, *8*(1), 105–118.
21. Krishna, B.D., Mahesh, B. & Puspa, L.H. (2020). Adsorptive removal of methyl red from aqueous solution using charred and xanthated Sal (Shorea robusta) Sawdust. *Amrita Research Journal*, 1 (1), 37-44.
22. Kumar, S., Malhotra, R., & Kumar, D. (2010). *Euphorbia hirta*: Its chemistry, traditional and medicinal uses, and pharmacological activities. *Pharmacognosy Reviews*, 4(7), 58-61. DOI:10.4103/0973-7847.65327

23. Lakshmi, U.R., Srivastava, V. C., Mall, I. D., & Lataye, D. H. (2009). Rice husk ash as an effective adsorbent: Evaluation of adsorptive characteristics for Indigo Carmine dye. *Journal of Environmental Management*, 90(2), 710-720. DOI: 10.1016/J.JENVMAN.2008.01.002
24. Loulidi, I., Boukhlifi, F., Ouchabi, M., Amar, A., Jabri, M., Kali, A., Chraibi, S., Hadey, C. & Aziz, F. (2020). Adsorption of crystal violet onto an agricultural waste residue: kinetics, isotherm, thermodynamics, and mechanism of adsorption. *The Scientific World Journal,* 2020, article ID 5873521, 9 pages. DOI: 10.1155/2020/5873521
25. Munir, M., Nazar, M. F., Zafar, M. N., Zubair, M., Ashfaq, M., Hosseini-Bandegharaei, A., Khan, S. U., & Ahmad, A. (2020). Effective Adsorptive Removal of Methylene Blue from Water by Didodecyldimethylammonium Bromide-Modified Brown Clay. *ACS omega*, 5(27), 16711–16721. DOI: 10.1021/acsomega.0c01613
26. Maniyam, M. N., Ibrahim, A. L., & Cass, A. E. G. (2020). Decolourization and biodegradation of azo dye methyl red by Rhodococcus strain UCC 0016. *Environmental Technology*, 41(1), 71-85. DOI: 10.1080/09593330.20 18.1491 634.
27. Noha, A.M., Ehssan, N., Mohamed, H. (2020). Use of spent oil shale to remove methyl red dye from aqueous solutions. *AIMS Materials Science*, 7 (3), 338-353. DOI: 10.3934/matersci.2020.3.338
28. Ofomaja, A. E. (2007). Kinetics and mecanisim of methylene blue sorption onto palm kernal fiber. *Process Biochemistry*, 40(1), 16-24. DOI: 10.1016/j.procbio.20 06.07.005
29. Ofomaja, A.E. & Ho, Y.S. (2006). Equilibrium sorption of anionic dye from aqueous solution by palm kiner fiber as sorbent. *Dyes Pigment*, 74(1), 60-66. DOI: 10.1016/ j.dyepig.2006.01.014
30. Parlayıcı, Ş. & Pehlivan, E. (2021). Biosorption of methylene blue and malachite green on biodegradable magnetic Cortaderia selloana flower spikes: modeling and equilibrium study. *International Journal of Phytoremediation,* 23 (1): 26-40. DOI: 10.1080/15226514.2020.1788502.
31. Perera, S. D., Jayawardena, U. A., & Jayasinghe, C. D. (2018). Potential Use of *Euphorbia hirta* for Dengue: A Systematic Review of Scientific Evidence. *Journal* of *Tropical Medicine,* 2018, 2048530. DOI:10.1155/2018/2048530
32. Potgieter, J. H., Pardesi, C., & Pearson, S. (2021). A kinetic and thermodynamic investigation into the removal of methyl orange from wastewater utilizing fly ash in different process configurations. *Environmental Geochemistry and Health*, 43 (7), 2539–2550. DOI:10.1007/s10653-020-00567-6
33. Renita, A.A., Vardhan, K.H., Kumar, P.S., Ngueagni, P.T., Abilarasu, A., Nath, S., Kumari, P. & Saravanan, R. (2021). Effective removal of malachite green dye from aqueous solution in hybrid system utilizing agricultural waste as particle electrodes. *Chemosphere*, 273, 129634. DOI: 10.1016/j.chemosphere.2021.129634.
34. Robinson, T., Chandran, B. & Nigam, P. (2002). Removal of dyes from a synthetic textile dye effluent by biosorption on apple pomace and wheat straw. *Water Research*, 36 (11), 2824-2830. DOI: 10.1016/S0043-1354(01)00521-8
35. Shah, A. P., Parmar, G. R, Sailor, G. U., & Seth, A. K. (2019). Antimalarial Phytochemicals Identification from *Euphorbia Hirta* against Plasmepsin Protease: An *In Silico* Approach. *Folia Medica* (Plovdiv), 61(4), 584-593. DOI: 10.3897/folmed.61.e47965.
36. Shilpa, G., Haresh, K. & Akshaya, G. (2013). Toxicity analysis of azo Red BS and Methyl Red dye solutions on earthworm (*Pheretima phosthuma*), micro-organisms, and plants. *Desalination and Water Treatment*, 51 (22-24), 4556-4565. DOI: 10.1080/19443994.2012.748637
37. Singh, K.P., Malik, A. Sinha, S. & Ojha, P. (2008). Liquid-phase adsorption of phenols using activated carbons derived from agricultural waste material. *Journal of Hazardous Material*, 150(3), 626-641. DOI: 10.1016/j.jhazm at.2007.05.017
38. Singh, G., & Kumar, P. (2013). Phytochemical study and screening for antimicrobial activity of flavonoids of *Euphorbia hirta*. *International Journal Of Applied & Basic Medical Research*, 3(2), 111–116. https://doi.org/10.4103/2229-516X.117082
39. Sintakindi, A. & Ankamwar, B. (2020). Uptake of Methylene Blue from Aqueous Solution by Naturally Grown Daedalea africana and Phellinus adamantinus Fungi. *ACS omega*, 5(22), 12905–12914. DOI: 10.1021/acsomega.0c00673
40. Sunil, R., Virendra, K.S., Avdesh, S.P., Mohit, N. & Kuldeep, R. (2021). Adsorption of methyl red dye from aqueous solution onto eggshell waste material: Kinetics, isotherms and thermodynamic studies*. Current Research in Green and Sustainable Chemistry*, 4, 100180. DOI:10.1016/j.crgsc.2021.100180.
41. Tamez, U. M., Islam, M. A., Mahmud, S. & Rukanuzzaman, M. (2009). Adsorptive removal of methylene blue by tea waste. *Journal of Hazardous Material*, 164(1), 53-60. DOI: 10.1016/j.jhazmat.2008.07.131
42. Vatsal, S. (2017). Removal of methyl red from waste water using orange peels. *International Journal for Scientific Research & Development,* 5 (3), 358-360.
43. Vijaya, P.P. & Sandhya, S. (2003). Decolorization and complete degradation of methyl red by a mixed culture. *Environmentalist*, 23, 145-149. DOI: 10.1023/ A:1024839805387
44. Xia, M., Liu, L. & Qiu, R. (2018). Anti-inflammatory and anxiolytic activities of *Euphorbia hirta* extract in neonatal asthmatic rats. *AMB Express*, 8(1), 179. DOI:10.1186/ s13568-018-0707-z.
45. Xue, S.W., Yin, Z., Yu, J. & Cheng, S. (2008). The removal of basic dyes from aqueous solutions using agricultural by-products. *Journal of Hazardous Material*, 157(2-3), 374 -385. DOI: 10.1016/j.jhazmat.2008.01.004.