INTRODUCTION

There are more than 100,000 dyes commercially available with more than 107 tonnes of dyes produced annually worldwide. These dyes are widely used by several industries such as foods, cosmetics, paper printings, and the textile industries as the largest dye consumers (Benkhaya et al., 2020). Dyes commonly used in industry can be classified as natural and synthetic dyes. According to Rubia & Bhardwaj, (2016), natural dyes have properties that are non-toxic, non-carcinogenic, eco-friendly, biodegradable, and easy to dispose of. However, the use of natural dyes is now starting to be replaced by synthetic dyes. Natural dyes are limited and more expensive than synthetic dyes. On the other hand, synthetic dyes are toxic on aquatic environment because of their non-durable, unstable, and lacking color variations (Zhao et al., 2018). Some of the most abundant synthetic dyes are methyl red (MR) and methyl orange (MO). These dyes have an azo functional group (-N=N-) and are classified as anionic dyes (Shan...
The chemical structure of MR and MO can be seen in Figure 1.

Azo dyes are organic compounds that are difficult to biodegrade due to their high stability to light and resistance to microbial attack (He et al., 2018). According to Hassaan & Nemr (2017), this azo dye was found to be complex and is carcinogenic in reproductive cleavage. These dyes can change the physical and chemical properties of the soil and water and cause damage to the flora and fauna in the environment. The toxic nature of the dye causes the death of soil microorganisms which in turn affect the agricultural productivity. Therefore, a method to deal with the harmful effects caused by dyes is needed. In recent years, biological, chemical, and physical methods, such as aerobic and anaerobic microbial degradation processes, oxidation, membrane filtration, coagulation, flocculation, flotation, precipitation, and adsorption have been developed to address the dyestuff waste from the environment (Semeraro et al., 2017).

According to Vinsiah et al. (2017), adsorption is one of the most efficient methods to remove liquid waste. The treatment of dyestuff waste by the adsorption method has high effectiveness in removing dyestuffs from wastewater (Amelia & Maryudi, 2019). Imron & Said (2017), revealed that adsorption is considered the most effective technique for removing dyes, due to its simple design, high efficiency, easy handling, and low cost. Various natural and synthetic materials such as activated carbon, graphene, carbon nanotubes, zeolites, polymers, clays, and layered double hydroxides (LDH) can be used as adsorbents for dye removal. However, LDH is favored material because it is easy to synthesize, has high stability, reusability and also modification properties.

LDH has a general formula $[\text{M}^{2+}_{1-x}\text{M}^{3+}_x(\text{OH})_2]^{x+}[(\text{A})_{n-}\text{mH}_2\text{O}]^{x-}$, where $\text{M}^{2+}$ and $\text{M}^{3+}$ are divalent ($\text{Cu}^{2+}, \text{Co}^{2+}, \text{Ca}^{2+}, \text{Zn}^{2+}, \text{Mg}^{2+}$, etc.) and trivalent ($\text{Ga}^{3+}, \text{Al}^{3+}, \text{Fe}^{3+}, \text{Cr}^{3+}$, etc.) metal ions, while $\text{A}^{n-}$ is an interlayer anion with charge $n$ (Rathee et al., 2019). One of most interesting properties of LDH is the anion-exchange ability, which can be used to modify the original structure of this material. When the anions in the interlayer are exchanged with other larger anions, the surface area can be increased and the interlayer distances and gallery can be expanded. Some anions that are usually in the interlayer such as nitrate ($\text{NO}_3^-$), sulfate ($\text{SO}_4^{2-}$), chloride ($\text{Cl}^-$), and carbonate ($\text{CO}_3^{2-}$) depending on synthetic conditions (Taher et al., 2019).

Various LDHs have been applied as adsorbent to absorb metal ions or dyes. The results of research Ai et al. (2011), in removing MO dyes using Mg/Al-LDH obtained an adsorption capacity of 0.453 mol/kg. The research conducted by Badri et al. (2021), used intercalated Mg/Cr as adsorbent of Rhodamine B and Methylene blue with the adsorption capacities of 139.526 mg/g and 8.741 mg/g, respectively. The adsorption capacity obtained by (Giscard et al., 2016) in his research to remove nickel ions using intercalated Mg/Cr-oxalate reached 1310 mg/g. Some of these studies prove that modification of LDH has a great ability to remove dye waste.

MATERIALS AND METHODS

Chemicals and instruments

The chemicals used in this experiment, included Mg(NO$_3$)$_2$·6H$_2$O (Merck, 256.41 g/mol), Cr(NO$_3$)$_3$·9H$_2$O (Sigma Aldrich, 400.15 g/mol), C$_3$H$_2$O$_2$·2H$_2$O (Merck, 126.07 g/mol), Na$_2$CO$_3$ (Merck, 105.88 g/mol), NaOH (Merck, 40.00 g/
Desorption and regeneration experiment

The desorption process was conducted with water, sodium hydroxide, hydrochloric acid, and ethanol. As much as 5 g of adsorbent was added into 50 mL MR and MO (100 ppm) and stirred for 120 minutes. The adsorbent dried in an oven at 100°C for 2 hours. The dried adsorbent (0.02 g) was added into 20 mL solvent (water, sodium hydroxide, hydrochloric acid, and ethanol) for 120 minutes. The filtrate was measured by means of a UV-Vis spectrophotometer. The regeneration of adsorbent was performed after the adsorption desorption process. The adsorbent reuse was conducted for three cycles adsorption process.

RESULTS AND DISCUSSION

Characterization of Mg/Cr-LDH and intercalated Mg/Cr LDH with oxalate was carried out using XRD, BET, and FTIR analyses. The XRD characterization results are shown in Figure 2. Figure 2a is the diffraction pattern of Mg/Cr LDH, where there is a 2θ peak at angles 11°(003), 22°(006), 36°(115), and 60°(110) which indicates that the material has a layered structure (Palapa et al., 2020). Intercalated Mg/Cr LDH with oxalate anion has an XRD pattern that resembles Mg/Cr LDH. However, a shift in peak at 11° to 10° indicates an exchange of nitrate anions with oxalate (Giscard et al., 2016). The success of the intercalation process is supported by the data on increasing the interlayer distance from 7.62 Å on Mg/Cr LDH to 11.35 Å on intercalated Mg/Cr LDH.

The N₂ adsorption-desorption curve is presented in Figure 3. On the basis of the IUPAC classification, Mg/Cr LDH and Mg/Cr-oxalate in Figures 3a and b follow the type IV isotherm pattern. According to Mishra et al. (2018), type IV isotherm pattern shows mesoporous material and hysteresis occurs. The data resulting from BET analysis is shown in Table 1 which shows the increase in the surface area of the material after intercalation with oxalate ions. It can be seen from intercalated Mg/Cr LDH which has a surface area of 49.27 m²/g after the intercalation process. However, Mg/Cr LDH has a pore size and pore volume greater than intercalated Mg/Cr LDH. According to Palapa et al. (2020), the decrease in pore size and volume after
intercalation of Mg/Cr LDH is assumed due to oxalate ions covering the pores of the material after the intercalation process.

FTIR spectrum of Mg/Cr LDH and Mg/Cr-oxalate are presented in Figure 4. The vibration peaks of Mg/Cr LDH and Mg/Cr-oxalate are around 3448 cm\(^{-1}\) and 1635 cm\(^{-1}\) indicate the -OH stretching vibrations and bending vibration form water molecules. The vibration peak at wavenumber 1381 cm\(^{-1}\) is assigned as the vibration of the nitrate ion at Mg/Cr LDH. According to Giscard et al. (2016), the existence of an oxalate anion is confirmed by the presence of a vibrational peak around 1550 cm\(^{-1}\) and 1365 cm\(^{-1}\). A decrease in the peak of the vibration at wavenumber 1381 cm\(^{-1}\) indicates that there has been an exchange of nitrate to oxalate ion on the interlayer.

The effect of the adsorption time of MR and MO using Mg/Cr LDH and Mg/Cr-oxalate

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Table 1. BET Surface Area Analysis

| Materials          | Surface area (m\(^2\)/g) | Pore size (nm), BJH | Pore volume (cm\(^3\)/g)\(_{BET}\) |
|--------------------|---------------------------|---------------------|-----------------------------------|
| Mg/Cr LDH          | 21.511                    | 3.20                | 6.564                             |
| Mg/Cr-oxalate      | 49.270                    | 0.158               | 6.511                             |
is presented in Figure 5. The graph in Figure 5 shows that the adsorption process using Mg/Cr-oxalate absorbs higher than Mg/Cr LDH for both MR and MO dyes. This allows that the intercalation material has a large surface area value, thus adsorbent Mg/Cr-oxalate has a high ability to absorb dyes. Figure 5 also shows that the optimum time achieved by Mg/Cr LDH and Mg/Cr-oxalate to adsorb MR and MO was achieved at 100 minutes. The kinetic parameter data of the variation of adsorption time can be seen in Table 2.

The pseudo-first-order (PFO) and pseudo-second-order (PSO) kinetics model are determined from the $R^2$ value which is closer to one (David Kowanga et al., 2016). According to Li et al. (2012), the PFO kinetics model assumes the adsorption rate is influenced by the active site of the adsorbent, while PSO assumes that the reaction process is influenced by the exchange or division of adsorbate and adsorbent. The data in Table 2 shows that the $R^2$ value of the PFO kinetics model for the adsorption process using each adsorbent is closer to 1 than PSO. Thus, the adsorption process takes place following the PFO kinetic model.

The data on the effect of concentration and temperature of MR and MO adsorption using Mg/Cr LDH and Mg/Cr-oxalate are presented in Figures 6 and 7. These figures shows that the increase in concentration is proportional to the increase in adsorption capacity. The MR adsorption process using Mg/Cr-oxalate (Fig. 6b) has a higher adsorption capacity of 63.291 mg/L than pristine adsorbent, while the MR adsorption capacity using Mg/Cr LDH was 53.476 mg/L. The same phenomenon was found for the MO
adsorption process. The adsorption capacity using Mg/Cr-oxalate was up to 53.191 mg/L and for Mg/Cr LDH was 41.841 mg/L. Intercalated Mg/Cr LDH material has a higher adsorption ability than the pristine one. This is supported by the surface area data from intercalated Mg/Cr LDH which is greater than Mg/Cr-LDH, which has been described above. The adsorption isotherm parameter for MR and MO on both adsorbents can be seen in Table 3.

The isotherm parameters studied in this research were the Langmuir and Freundlich models. Adsorption isotherms are used to study the mechanisms that take place during the adsorption process. The adsorption isotherm parameter is determined by an $R^2$ value that is close to one. Table 3 shows that the $R^2$ value of the MR and MO adsorption process using Mg/Cr LDH and Mg/Cr-oxalate follows the Langmuir isotherm. The Langmuir isotherm model assumes that the adsorption process which takes place on the adsorbent surface is homogeneous. The Langmuir isotherm explains that on the surface of the adsorbent there is an active site that is proportional to the surface area. Each active site has only one adsorbable molecule. This allows the adsorption to take place on a monolayer basis (Murthiaprasari et al., 2017). The data in Table 3 shows that at high temperatures, the adsorption capacity increases. The maximum capacity of the adsorption process can be seen from the $Q_{\text{max}}$ value. The Mg/Cr-oxalate adsorbent at a temperature of 333

| Dye | Adsorbent      | $Q_{\text{e,exp}}$ (mg/g) | $Q_{\text{e,calc}}$ (mg/g) | $R^2$ | $k_1$ | $Q_{\text{e,exp}}$ (mg/g) | $R^2$ | $k_2$ |
|-----|----------------|--------------------------|---------------------------|-------|-------|--------------------------|-------|-------|
| MR  | Mg/Cr LDH      | 31.119                   | 31.355                    | 0.998 | 0.045 | 35.971                   | 0.994 | 0.002 |
|     | Mg/Cr-oxalate  | 41.567                   | 36.467                    | 0.999 | 0.046 | 45.455                   | 0.998 | 0.002 |
| MO  | Mg/Cr LDH      | 25.867                   | 25.015                    | 0.998 | 0.043 | 28.409                   | 0.997 | 0.003 |
|     | Mg/Cr-oxalate  | 31.200                   | 33.581                    | 0.999 | 0.046 | 35.336                   | 0.994 | 0.002 |

Table 2. Kinetic parameters of dyes adsorption onto Mg/Cr LDH and Mg/Cr-oxalate

![Figure 6. Effect of concentration and temperature on the adsorption of MR onto Mg/Cr LDH (a) and Mg/Cr-oxalate (b)](image)

![Figure 7. Effect of concentration and temperature on the adsorption of MO onto Mg/Cr LDH (a) and Mg/Cr-oxalate (b)](image)
K has the highest Qmax value for MR and MO absorption. This proves that the intercalated material has a good ability in the adsorption process. Thermodynamic parameter data from the MR and MO adsorption process are presented in Tables 4 and 5, respectively.

The thermodynamic parameters studied in this research include ∆H, ∆S, and ∆G. A positive value on the change in ∆H indicates that the adsorption process is endothermic (Batool et al., 2018). according to Starukh & Levytska (2019), the range of enthalpy values at 40–120 kJ/mol is a chemisorption process. However, if the enthalpy has a value below that range, the adsorption process takes place physically. The thermodynamic parameter data from the MR adsorption process using Mg/Cr LDH and Mg/Cr-oxalate in Table 4 show a positive enthalpy value in the range of 10–60 kJ/mol. These results show that the adsorption process occurs physically.

The ∆G value s is used to determine the spontaneity of the adsorption process. A negative value indicates that the adsorption process was spontaneous while a positive value indicates a non-spontaneous process. The data in Table 4 shows the ∆G value of the MR adsorption process using either Mg/Cr-LDH or intercalated Mg/ Cr LDH gives a negative value. These data indicates that the adsorption process was spontaneous (Ebelgi et al., 2020). Entropy (∆S) is used to describe randomness on the surface of a material. A positive value of ∆S indicates an increase in randomness during the adsorption process (Belhamdi et al., 2016). The data in Table 4 shows a positive ∆S value and decreases as the adsorbate concentration increases.

The ∆H values in Table 5 for the MO adsorption process using Mg/Cr LDH show positive results and are in the range of 14–27 kJ/mol. This indicates that the adsorption process occurs physically. The negative value shown in the MO adsorption process using Mg/Cr LDH and Mg/Cr-oxalate proves that the adsorption process occurs spontaneously. Similar to the MR adsorption process, the MO adsorption process using Mg/Cr LDH and Mg/Cr-oxalate gives a positive Z value and decreases with increasing concentration.

The adsorption capacity of MR and MO in this research is slightly higher than various carbon

| Dye | Adsorbent | Adsorption isotherm | Adsorption constant | T (K) |
|-----|-----------|---------------------|---------------------|-------|
| MR  | Mg/Cr LDH | Langmuir            | Q<sub>max</sub>     | 53.476| 55.556| 60.241| 61.728|
|     |           |                     | k<sub>L</sub>       | 0.110 | 0.235 | 0.373 | 1.906 |
|     |           |                     | R²                  | 0.980 | 0.990 | 0.996 | 0.999 |
|     |           | Freundich           | n                   | 1.132 | 2.941 | 2.381 | 5.650 |
|     |           |                     | k<sub>f</sub>       | 1.417 | 1.462 | 1.474 | 1.041 |
|     |           |                     | R²                  | 0.922 | 0.997 | 0.939 | 0.976 |
| MO  | Mg/Cr LDH | Langmuir            | Q<sub>max</sub>     | 63.291| 68.966| 80.645| 81.235|
|     |           |                     | k<sub>L</sub>       | 0.105 | 0.322 | 0.325 | 0.590 |
|     |           |                     | R²                  | 0.977 | 0.999 | 0.993 | 0.999 |
|     |           | Freundich           | n                   | 0.799 | 1.148 | 1.769 | 2.360 |
|     |           |                     | k<sub>f</sub>       | 1.038 | 1.152 | 1.326 | 1.540 |
|     |           |                     | R²                  | 0.966 | 0.990 | 0.934 | 0.985 |
|     | Mg/Cr-oxalate | Langmuir   | Q<sub>max</sub>     | 41.841| 45.249| 50.251| 54.645|
|     |           |                     | k<sub>L</sub>       | 0.262 | 0.392 | 0.477 | 0.620 |
|     |           |                     | R²                  | 0.999 | 0.999 | 0.999 | 0.999 |
|     |           | Freundich           | n                   | 1.931 | 2.732 | 3.731 | 2.320 |
|     |           |                     | k<sub>f</sub>       | 1.035 | 1.436 | 1.038 | 1.039 |
|     |           |                     | R²                  | 0.941 | 0.996 | 0.997 | 0.965 |
|     | Mg/Cr-oxalate | Langmuir   | Q<sub>max</sub>     | 53.191| 59.524| 64.935| 71.429|
|     |           |                     | k<sub>L</sub>       | 0.125 | 0.193 | 0.390 | 1.296 |
|     |           |                     | R²                  | 0.979 | 0.991 | 0.997 | 0.999 |
|     |           | Freundich           | n                   | 1.098 | 1.193 | 1.464 | 2.415 |
|     |           |                     | k<sub>f</sub>       | 1.408 | 1.443 | 1.472 | 1.507 |
|     |           |                     | R²                  | 0.991 | 0.983 | 0.982 | 0.997 |

Table 3. Isotherms Parameter of Adsorption MR and MO on Mg/CrLDH and Mg/Cr-oxalate
Based adsorbents, as shown in Table 6. Mg/Cr-oxalate after intercalation has higher adsorption capacity than pristine LDH under the same adsorption conditions.

The results of the MR and MO desorption process using Mg/Cr LDH and Mg/Cr-oxalate are presented in Figure 8. Figure 8a is the results of MR and MO desorption using Mg/Cr LDH. These data indicate that the HCl solvent provides the highest percentage of desorption, reaching 80.433% for MR and 97.973% for MO. On the basis of (Badri et al., 2021),

| Concentration (mg/L) | T (K)   | ∆H (kJ/mol) | ∆S (kJ/mol) | ∆G (kJ/mol) | Mg/Cr-LDH | Mg/Cr-oxalate |
|----------------------|---------|--------------|--------------|--------------|-----------|--------------|
|                      | 303     | 52.075       | 0.174        | -0.530       | 59.866    | 0.201        |
|                      | 313     | -2.266       | -4.002       | -5.738       | -2.951    | -4.958       |
|                      | 323     |              |              |              | -4.909    | -6.805       |
|                      | 333     |              |              |              | -6.965    |              |
| 71.642               | 303     | 33.102       | 0.112        | -0.972       | 56.324    | 0.190        |
|                      | 313     | -2.096       | -3.221       | -4.345       | -3.013    | -4.909       |
|                      | 323     |              |              |              | -4.909    | -6.805       |
|                      | 333     |              |              |              | -6.965    |              |
| 81.642               | 303     | 23.983       | 0.081        | -0.435       | 49.798    | 0.168        |
|                      | 313     | -1.214       | -2.047       | -2.853       | -2.807    | -4.487       |
|                      | 323     |              |              |              | -4.487    | -6.168       |
|                      | 333     |              |              |              | -6.168    |              |
| 91.493               | 303     | 20.787       | 0.068        | 0.126        | 42.144    | 0.141        |
|                      | 313     | -0.555       | -1.237       | -1.919       | -0.620    | -2.032       |
|                      | 323     |              |              |              | -2.032    | -3.443       |
|                      | 333     |              |              |              | -3.443    | -4.655       |
| 105.821              | 303     | 16.246       | 0.051        | 0.671        | 33.191    | 0.110        |
|                      | 313     |              |              | 0.157        | -1.104    |              |
|                      | 323     |              |              | -0.357       | -2.000    |              |
|                      | 333     |              |              | -0.871       | -3.296    |              |

| Concentration (mg/L) | T (K)   | ∆H (kJ/mol) | ∆S (kJ/mol) | ∆G (kJ/mol) | Mg/Cr-LDH | Mg/Cr-oxalate |
|----------------------|---------|--------------|--------------|--------------|-----------|--------------|
|                      | 303     | 27.899       | 0.095        | -0.892       | 66.620    | 0.222        |
|                      | 313     | -1.842       | -2.792       | -3.743       | -2.741    | -4.957       |
|                      | 323     |              |              |              | -4.957    | -7.173       |
|                      | 333     |              |              |              | -7.173    |              |
| 71.875               | 303     | 21.534       | 0.072        | -0.276       | 50.322    | 0.169        |
|                      | 313     | -0.996       | -1.716       | -2.436       | -0.796    | -2.483       |
|                      | 323     |              |              |              | -2.483    | -4.170       |
|                      | 333     |              |              |              | -4.170    | -5.858       |
| 80.398               | 303     | 19.541       | 0.064        | 0.271        | 38.363    | 0.128        |
|                      | 313     | -0.365       | -1.001       | -1.637       | -0.434    | -1.714       |
|                      | 323     |              |              |              | -1.714    | -2.995       |
|                      | 333     |              |              |              | -2.995    | -4.275       |
| 90.057               | 303     | 17.072       | 0.054        | 0.729        | 30.915    | 0.102        |
|                      | 313     | 0.189        | 0.579        | 0.151        | 0.012     | -1.007       |
|                      | 323     |              |              |              | -1.007    | -2.027       |
|                      | 333     |              |              |              | -2.027    | -3.047       |
| 108.617              | 303     | 14.412       | 0.043        | 1.436        | 24.914    | 0.079        |
|                      | 313     | 1.007        | 0.579        | 0.151        | 1.054     | 0.266        |
|                      | 323     |              |              |              | 0.266     | -0.521       |
|                      | 333     |              |              |              | -0.521    | -1.309       |
Mg/Cr LDH is easier to exfoliate in acidic solvents. Hence, the adsorbate bound to the surface of Mg/Cr LDH is more easily desorbed. Similar to Mg/Cr LDH, for the desorption of Mg/Cr-oxalate on MR and MO it is more suitable to use HCl as a solvent. The results of this desorption affect the regeneration process, which can be seen in Figure 9.

The results of this desorption affect the regeneration process, which can be seen in Figure 9. Regeneration of the Mg/Cr LDH and Mg/Cr-oxalate materials was carried out in three cycles. The

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**Table 6.** Comparison of the adsorption capacity of MR and MO using several adsorbents.

| Adsorbent                        | Adsorbate         | Adsorption capacity (mg/g) | Reference |
|----------------------------------|-------------------|---------------------------|-----------|
| Carbon from the Annona Squamosa seed (CAS) | MR                | 81.970                    | [24]      |
| Palladium nanoparticles on activated carbon |                  | 60.970                    | [25]      |
| Hydroxyapatite                   |                   | 6.675                     | [26]      |
| Banana pseudostem fibers         |                   | 88.500                    | [27]      |
| White potato peel powder         |                   | 30.480                    | [28]      |
| Modified chitosan                |                   | 61.840                    | [29]      |
| Activated carbon                 |                   | 46.290                    | [25]      |
| Mg/Cr LDH                        |                   | 61.728                    | This research |
| Mg/Cr-oxalate                    |                   | 81.235                    | This research |
| Activated carbon                 |                   | 370.360                   | [30]      |
| Fe-Mg LDH                        |                   | 44.843                    | [31]      |
| Cs-CaCl₂                         |                   | 44.843                    | [31]      |
| CTS/MMT                          |                   | 70.420                    | [32]      |
| Fly ash                          |                   | 0.69                      | [33]      |
| Sugar scum powder                |                   | 15.24                     | [34]      |
| Chitosan                         |                   | 34.830                    | [35]      |
| Mg/Cr LDH                        |                   | 54.645                    | This research |
| Mg/Cr-oxalate                    |                   | 71.429                    | This research |

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![Figure 8. Desorption MR and MO on Mg/Cr LDH (a) and Mg/Cr-oxalate (b)](image)

![Figure 9. Regeneration MR and MO on Mg/Cr LDH (a) and Mg/Cr-oxalate (b)](image)
Mg/Cr-oxalate adsorbent has a higher regeneration ability than Mg/Cr LDH. This phenomenon assumes that intercalated Mg/Cr LDH with oxalate has resistance to acid solvents. The regeneration ability of Mg/Cr LDH decreased drastically because it was exfoliated by the acid solvent.

CONCLUSIONS

The intercalation process of Mg/Cr LDH has been successfully carried out to form Mg/Cr-oxalate. The success of the intercalation process is supported by the XRD data, which shows an increase in the interlayer distance from 7.62 Å to 11.35 Å and a significant increase in the surface area reaching 49.270 m²/g. MR adsorption capacity using Mg/Cr LDH and Mg/Cr-oxalate reached 61.728 mg/g and 81.325 mg/g, respectively, while the MO adsorption capacity reached 54.645 mg/g and 71.429 mg/g for each adsorbent. MR and MO adsorption followed the PFO kinetics model. On the other hand, the thermodynamic parameters of the MR and MO adsorption processes take place endothermic and spontaneously. The regeneration results show that Mg/Cr-oxalate is reusable because it is more resistant to acidic solvents toward a desorption process.

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