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Simultaneous Adsorption of Rhodamine B, Malachite Green, and Congo Red Dyes Through Aluminium Oxide Modified Natural Clay: A Comprehensive Study

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ABSTRACT:

The main point of this study is to find out how well a mixture of natural clay and aluminium oxide can get rid of manufactured colours in water. The synthetic colours that companies dump into their wastewater are bad for both people and the earth. Adding aluminium oxide to clay changes it so that it can accept things better than clay that has not been changed. Longer contact times, higher dye concentrations, and higher adsorbent doses led to higher outputs. This was shown by batch adsorption tests and spectrophotometric analysis, which shows that adsorption depends on concentration. The results show that modified clay might be a better way to get rid of dyes than the usual methods, which are bad for the environment and people. As suggested, a lot of research should be done into how adsorption works, how it can be regenerated and used again, what the best conditions are for adsorption, and how to put the suggested solutions into action with the help of important business players. This study shows how important it is to keep dye pollution under control in wastewater treatment in order to keep communities healthy and the environment clean.

1. Introduction

There are a lot of factories in the world that try to provide advanced products that are full of benefits. Apart from the benefits of the products, the carbon smoke and waste materials of factories are harmful to the environment. Particularly, the wastewater that is released from the factories is full of synthetic dyes. The synthetic dye is very dangerous for the ecosystem and human health. The wastewater of the factories directly destroyed the whole ecosystem of the rivers and lakes. Adsorption is useful method to take up these harmful dyes from the water to protect the environment. This method effectively working like a sponge to absorb the harmful synthetic dyes. This study is all about a comprehensive utilization of the natural clay by adding aluminium oxide into it to remove the synthetic dyes from the water. By utilizing the modified natural clay, it is possible to protect the environment from synthetic dyes.

The significance of the study is focusing to overcome the robust problems which are related to aquatic life and as well as human health. The synthetic dyes that are included in the wastewater of factories can harm the aquatic life and also human health by getting into the poisonous water or drinking the poisonous water [1]. The use of natural clay for absorbing the harmful synthetic dies is exceptionally an innovative idea in the matter of protecting the environment. Natural clay is easily available everywhere in the earth and it is an eco-friendly and natural element. The addition of aluminium oxide builds the clay a modified option for adsorbing the synthetic dyes in the water with a lot of efficiency. In this study here are mainly aiming bat three types of synthetic dyes such as Rhodamine B, Malachite green, and Congo Red. These three types of dyes are most common synthetic dyes among all which are used in factories. These dyes can easily destroy the whole environment and human health. Hence, the study represents the importance of adding aluminium oxide in the natural clay to remove the synthetic dyes from the wastewater of the factories [2]. The application of the modified natural clay help to safeguard the whole ecosystem and keep people healthier by providing the environment clean and safe water to use. The main objective of the study is to evaluate the benefits and experimental outcomes of the adsorption capability of aluminium oxide modified natural clay and thereafter analysing the influential factors of the adsorption procedure to realize the benefits of the dye removal technique by using the improved clay.

2. Methodology and materials

The addition of aluminium oxide turns the natural clay into a dynamic one. The aluminium oxide coating over the clay to enhances the capability of absorption of it. The increased surface area and reactivity that come out from the modification of the natural clay represent a sustainable bond between the improved clay and the molecules that are present in the dyes. The aluminium oxide added to natural clay will represent improved efficiency and quick kinetics in adsorbing the synthetic dyes from the aqueous solutions [3]. Adsorption capacity expansion will help influence the initial conditions. Enhancement in the adsorption capability will be pronounced at the higher initiatives in dye concentrations, acidic pH conditions, and the contact time. The modification of natural clay with aluminium oxide will create a more effective adsorbent for dye adsorption in the concept of improving the water treatment process [4].

Sample Selection:

Natural clay sample was gathered from a pond in ghat village, Meerut. The selection of the clay is evolving around some basic demands. The demands are generally purity of the clay, absence of contaminants in the clay, and stability in particle size distribution to mitigate the variations in the results of the experiments. The natural clay samples is collected from trustable geological source and is recognized by its mineral composition, surface area, and exceptional quality for experimentation [5].

Preparation of Modified Clay using Aluminium Oxide :

The aluminium oxide addition in natural clay has represented the usage of a well-established process. For this process, at first, the natural clay samples were completely dried to remove the moisture content. Then 10g of aluminium oxide is melted to make a suitable solution and then the solution is added to the dried clay [6]. After that ensuring the solution of aluminium oxide is evenly spread in the clay is mandatory thing for this experiment. The solution was heated to 500°C to build a coating of the aluminium oxide on the surface of the clay.

Selection of Dyes and Experimental Conditions:

In this study, Rhodamine B, Malachite Green, and Congo Red were the selected dyes as synthetic pollutants for successfully implementing the experiment. These three synthetic dyes are renowned for their broader usage among the several industries and various chemical properties [7]. A 30 mg/l solution is made with each of these three dyes in water to replicate the findings in polluted water.

Adsorption Experiments:

The batch adsorption experiment compares the capability of adsorption of the dyes between the regular clay and modified clay. Each experiment is carried out using a series of Erlenmeyer flask of 250 ml capacity. An absorbent dosage of 5 g in 50 ml of 30 mg/l dye solution is used to calculate the effect of various factors on the adsorption capacity. For this experiment, the temperature and pH level must be steady and ensure the modified clay have enough time to adsorb the dyes present into the solution to finish the experiment successfully. At particular time intervals the solutions are filtered. For 30 minutes the mixture is centrifuged at 10,000 rpm for 30 minutes to separate the dye solution from the adsorbent. UV spectrophotometer is used for checking the quantity of remaining dyes in the supernatant [8]. This tool is very useful for checking the adsorbing ability of clay.

Moreover, following these steps effectively helps to see the capability of the modified clay in the matter of

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removing the dyes Rhodamine B, Malachite Green, and Congo Red dyes from water in the entire experiment.

3. Experimental

3.1 Adsorption Experiments:

Batch adsorption experiments were performed to understand the impact of different parameters on the adsorption capacity of modified adsorbent for all the three dyes Rhodamine B, Malachite Green and Congo Red. Systematically, measured the effect of change of pH value, contact time, and adsorbent dosage on adsorption percentage with accuracy and reliability [9].

3.2 Spectrophotometric Analysis:

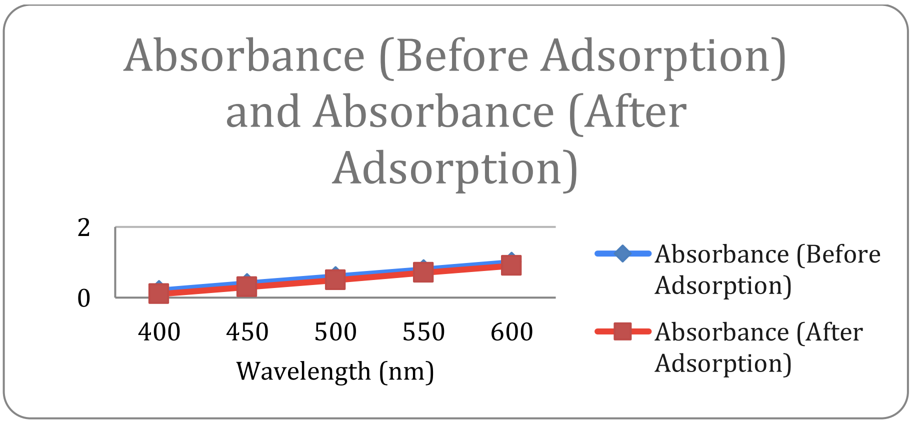

Fig 1: Absorbance Spectra Before and After Adsorption
(Source: Self Made)

This illustrates approximate absorbance values on this desk at distinct wavelengths earlier than and after adsorption of the dyes.

Spectrophotometric analysis has been used to decide the quantity of dye adsorbed over the adsorbent. To decide the extent of dye, adsorbed from the modified clay, the absorbance of the dye at a selected wavelength has to be measured [10]. Calibration of the spectrophotometer and adherence to standardized protocols ensure accuracy and reproducibility.

3.3 Effect of changing pH :

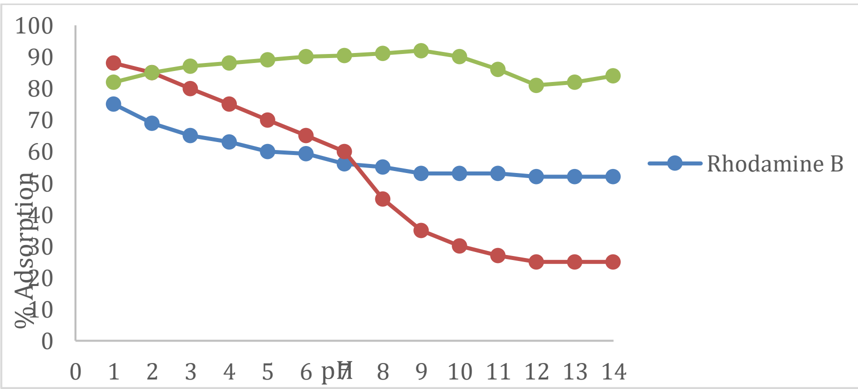

Fig 2: Change in adsorption with pH Variation

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The adsorption process of an adsorbate is significantly influenced by the pH level of the solution. The pH of a system plays a crucial role in controlling the adsorption capacity of a biosorbent, as it is affected by both the surface properties of the biosorbent and the ionic state of the dye solution. The approximate percentage of adsorption change with change in pH of Rhodamine B, Malachite Green, and Congo Red dye. Each line in the graph represents an change in adsorption with the pH of a selected dye, which varies in step with unique colourings. The pH has been changed accordingly to evaluate its effect on the adsorption process [11]. An effective pH meter has been used for accurate measurements in all experiments, and maintain consistency of measurements to reduce fluctuations.

3.4 Contact Time Studies:

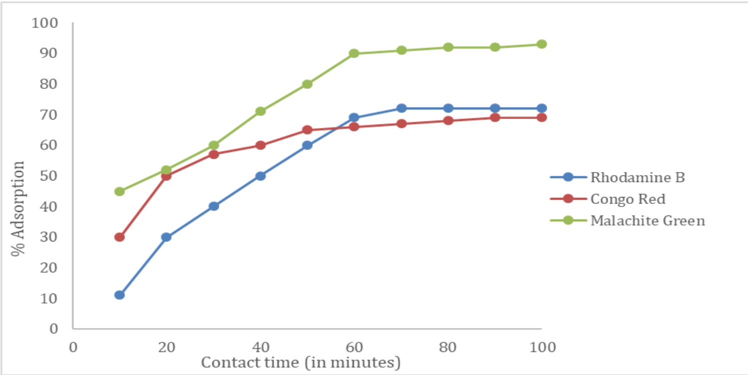

Fig 3: Effect of Contact Time on Adsorption
(Source: Self Made)

It is widely recognized that the contact time serves as a valuable metric for investigating the features of biosorbent adsorbates. The investigation of the adsorption behaviour of different dyes has been conducted by examining the influence of contact time. The study investigated the impact of several contact durations, ranging from 10 to 100 minutes, on the adsorption of dyes over aluminium oxide modified clay. The effect of contact time on the adsorption ability is investigated by sampling the solutions at periodic intervals. [12] The efficiency of adsorption values for Rhodamine B, Malachite Green, and Congo Red has been found to be positively correlated with the contact time. Rec

3.5 Adsorbent Dosage Variation:

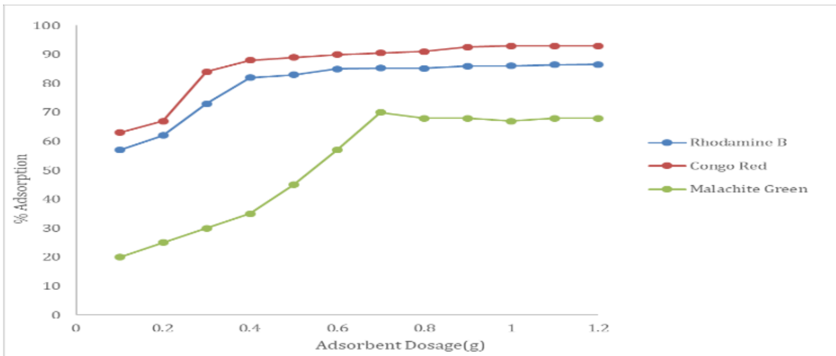

Fig 4: Adsorption Capacity vs. Adsorbent Dosage
(Source: Self Made)

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Use the calculated leaching capacities of soils modified for rhodamine B, malachite inexperienced, Congo Red and many others. At exceptional drainage tiers in this table. Each line or bar within the graph represents the connection between the quantity of dye absorbed and the absorption charge of a specific dye, with special colours or patterns.

In drying exams, the quantity of clay was amended to test the effect of dryer quantity on dye removal [13]. Record adsorption capacity information at one-of-a-kind concentrations to establish the connection between adsorbent awareness and elimination efficiency, and to ensure consistency in instruction and dosing strategies.

3.6 Change in Initial Dye Concentration

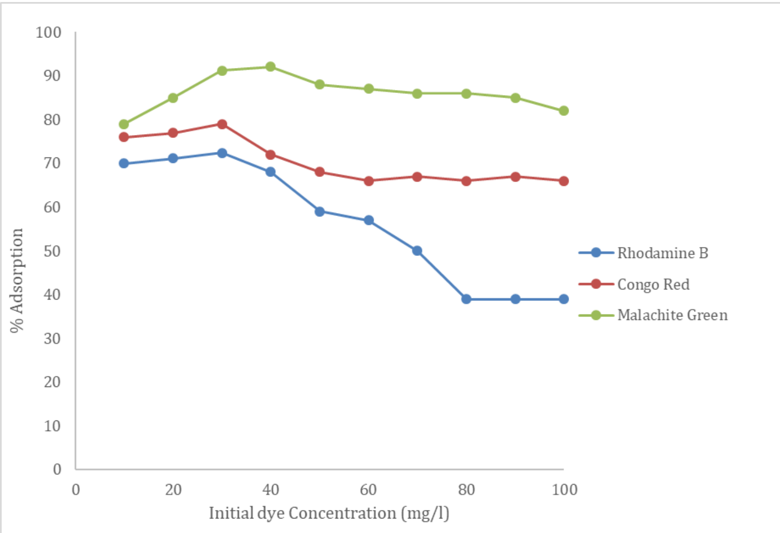

Fig 5: Adsorption Efficiency of Aluminium Oxide Modified Natural Clay for Different Dye Concentrations (Source: Self Made)

The adsorption efficiency vs. Dye concentration graph illustrates the increasing adsorption performance of the modified clay with better dye concentrations and thereafter it become almost constant, showing little fluctuations for each dye [14]. Absorbance spectra earlier than and after adsorption reveal the difference in dye concentrations adsorption, validating the efficacy of the modified clay as an adsorbent.

4. Analysis of the Data

The outcomes of the data tables display the effectiveness of the adsorption of clay with aluminium oxide for the removal of rhodamine B, malachite green experienced and Congo red dyes from the aqueous solutions.

In the adsorption experiments, it was observed that as concentration of adsorbent elevated, the adsorption performance of the modified clay also expanded [15]. For Rhodamine B, the adsorption efficiency at exclusive concentrations ranged from 39% to 71%. Malachite Green showed adsorption efficiencies between 85% and 91%, and Congo Red confirmed adsorption efficiencies between 66% and 77 %.

Spectrophotometric research shown in Figure 1. illustrates approximate absorbance values on this desk at distinct wavelengths earlier than and after adsorption of the dyes.

Figure 2 shows the tracking of pH modifications. Consequently it can be inferred that adsorption of Rhodamine-B, Congo Red and Malachite Green has an inverse relation with pH change. The pH alteration graph shows decrease in adsorption efficiency or constant adsorption with changing pH values [16]. Correlation time evaluation shows the mechanism of adsorption, with growing contact time growing the adsorption potential, as a characteristic of time primarily based on adsorption curves.

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Figure 3 shows that contact time research confirmed that longer contact time led to higher adsorption capacity, wherein equilibrium changed into reached after a sure time. The time-structured adsorption curves showed the kinetics of dye adsorption-modified clay, indicating speedy preliminary adsorption accompanied by way of slow saturation.

Moreover, the correlation between adsorbent dose and adsorption potential turned obvious, and growing dosage accelerated the adsorption potential of all the studied dyes, as proven in Figure 4. Overall, those consequences affirm the effectiveness of aluminium oxide-modified natural clays in the elimination of dyes from aqueous solutions. Furthermore, the graph of adsorption capacity as opposed to adsorbent dosage indicates the connection between dosage and adsorption and shows the effectiveness of higher dosages in growing adsorption performance.

The analysis of the data uncovered various significant outcomes related to the adsorption of Rhodamine B, Malachite Green, and Congo Red dyes by using aluminium oxide-modified natural clay. The adsorption efficiency of the modified clay is enhanced with higher dye concentrations, pointing out that the adsorption procedure is fully dependent on concentration [17].

Spectrophotometric tools help to analyze the demonstration of a remarkable reduction in dye concentrations after the adsorption onto the modified clay. The spectrophotometric analysis established the impact of the adsorption process in cleaning the dyes from aqueous solutions.

Moreover, observing the pH differentiation over time uncovered some imbalances in the pH levels of the dye solutions at the time of the adsorption [18]. The imbalances may be contributing to the come-outs of ions during the adsorption procedure. The ions are often responsible for the probable transformations in the chemical composition of the solutions.

Contact time suggests that the adsorption procedure follows a kinetics-dependent mechanism, with continuous adsorption initially followed by gradual saturation over time. However, the relationship between the adsorbent dosage and adsorption capacity marked the significance of dosage optimization for intensifying adsorption efficiency.

5. Results and Discussion :

The study found sudden information on the adsorption of Rhodamine B, malachite green and Congo Red dyes using natural clay modified with aluminium oxide [19]. The results showed a concentration structured adsorption performance, with growing dye concentration and increasing adsorption within the modified clay similar to of them exhibited adsorption efficiencies as much as 71%, at the same time as Malachite Green and Congo Red showed efficiencies of 85% to 91% and 66% to 77%, respectively.

The spectrophotometric analysis confirmed that the dye concentration reduced notably after adsorption, assisting the effectiveness of the modified clay as an adsorbent. Monitoring the pH changes at some stage in drying revealed adjustments in pH levels, indicating that chemical adjustments can arise in dye solutions due to the drying process.

Contact time research has proven that longer contacting time outcomes in better adsorption capacity, which reaches equilibrium after a certain time [20]. The time-structured adsorption curves showed the kinetics of dye adsorption on the changed clay surface, showing initial speedy adsorption observed by using gradual saturation.

Furthermore, the correlation between adsorbent concentration and adsorption ability changed into evident, with increasing concentrations increasing the adsorption potential of all of the studied dyes. This highlights the importance of dose optimization to adsorption efficiency has been highlighted.

Overall, the examined findings spotlight the effectiveness of aluminium oxide-modified natural clay as a promising adsorbent for adsorption of harmful dyes.

The results prove that aluminium oxide-modified natural clay grasps the commitment as an effective adsorbent for cleaning up the dyes from aqueous solutions. The concentration-dependent adsorption process is crucial in the mitigation of dye concentrations post-adsorption, and the impact of contact time and adsorbent dosage on adsorption capability. The concentration-dependent adsorption process highlighted the expected sequences of this material for addressing the wastewater treatment concept [21]. Further studies are required to improve the conditions and evaluate the benefit of scale-up for practical execution. The outcomes of the experiment

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address modifying the sustainable solutions for dye removal and environmental progress.

6. Conclusion

In this study, the experiment of adding aluminium oxide to the natural clay is demonstrated properly. The result of the experiment showcases the benefits of the modified clay compared to the regular clay. This means the modified clay is a helpful way to remove the synthetic dyes from the water and clean up the water ecosystem in the future. This technique of removing the dyes from the water can step forward to protect our environment and keep the balance between ecosystem and human health.

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