

SUSTAINABLE REMEDIATION OF WOOD INDUSTRY WASTEWATER VIA GREEN-TEA-MAGNETIZED DUAL-BIOMASS ADSORBENTS

Ifeanyi-Nze F.O.¹

Scientific Supervisor – Associate Professor Semenova T.S.

¹ITMO University
475130@niuitmo.ru

Abstract

This study develops a sustainable magnetic adsorbent synthesized from a dual-biomass precursor of rice and sunflower husks for chemical oxygen demand removal. To ensure industrial relevance, replica wastewater was formulated by boiling logs of wood in water. Although KOH and KMnO₄ activation yielded varied textural properties, green-tea-mediated magnetization was selected as the optimal pathway (BET=331.47m²/g). This choice prioritizes system reusability over raw surface area. Response surface methodology (RSM) optimization (pH=5.0, 2.0 g/L dose) achieved 91.1 % COD removal. NaOH-mediated desorption facilitated robust reusability, maintaining 85.7% regeneration efficiency over four cycles. The results establish a scalable and circular economy blueprint for industrial wastewater removal.

Keywords

Adsorbent, COD Removal, Green tea mediated adsorbent, Reusability, Desorption, Response Surface Methodology

УСТОЙЧИВАЯ ОЧИСТКА СТОЧНЫХ ВОД ДЕРЕВООБРАБАТЫВАЮЩЕЙ ПРОМЫШЛЕННОСТИ С ПОМОЩЬЮ АДсорбЕНТОВ ИЗ ДВОЙНОЙ БИОМАССЫ, НАМАГНИЧЕННЫХ ЗЕЛЕНЫМ ЧАЕМ

Ифеаньи-Нзе Ф.О.¹

Научный руководитель – к.т.н., доцент Семенова Т.С.

¹Университет ИТМО
475130@niuitmo.ru

Аннотация

В рамках этого исследования был разработан устойчивый магнитный адсорбент, синтезированный из двух видов биомассы - рисовой и подсолнечной лузги, для химического устранения потребности в кислороде. Для обеспечения промышленной актуальности сточные воды replica были получены путем кипячения древесных поленьев в воде. Хотя активация KOH и KMnO₄ приводила к различным структурным свойствам, в качестве оптимального способа было выбрано намагничивание, опосредованное зеленым чаем (BET=331,47 м²/г). При таком выборе предпочтение отдается возможности многократного использования системы, а не площади поверхности. При оптимизации метода обработки поверхности (RSM) (pH=5,0, доза 2,0 г/л) удаление трески составило 91,1 %. Десорбция, опосредованная NaOH, обеспечивает надежное повторное использование, сохраняя эффективность регенерации на уровне 85,7% в течение четырех циклов. Полученные результаты позволяют разработать масштабируемый и экономичный план по удалению промышленных сточных вод.

Ключевые слова

Адсорбент, Удаление ХПК, адсорбент на основе зеленого чая, Возможность повторного использования, Десорбция, Методология определения поверхности отклика

The global wood processing industry faces a critical challenge in managing wastewater characterized by a level of Chemical Oxygen Demand (COD) [1]. If left untreated, the lignins, tannins, and hemicelluloses present in this effluent deplete dissolved oxygen in aquatic ecosystems. Traditional adsorbents (using physical activation method) often lack the structural

diversity required to handle the complex, bulky organic molecules responsible for this COD load. Furthermore, the use of harsh activators like KOH creates a sustainability paradox: they reduce COD but introduce toxic reagents, making adsorbent recovery environmentally risky [2]. The following methodology and innovation was used for this study:

1. **Dual-Biomass Synergy:** By blending rice and sunflower husks, we create a "structural hybrid" adsorbent. The silica-rich rice husk provides a rigid skeleton, while the sunflower husk introduces the fibrous network necessary for a mesoporous structure (3.879 nm) sized for bulky wood-waste pollutant.

2. **Birch-Log Simulation:** Unlike studies using model dyes, to replicate industrial wood waste, a Birch log was boiled in water to produce a concentrated organic matrix. This extract was diluted at a 99:1 ratio to reach a representative industrial COD of 800 mg/L, ensuring the adsorbent was tested against an authentic chemical profile.

3. **Green-Tea Functionalization:** Tea polyphenols were utilized to anchor Fe₃O₄ nanoparticles, facilitating rapid magnetic separation of the adsorbent after it has successfully captured the COD load.

A critical comparison was conducted between traditional physical method, chemical activation (KOH and KMnO₄) and the green-tea-mediated Magnetic adsorbent. While KOH activation reached the highest surface area (552.28 m²/g), it failed the criteria for a circular economy due to its reliance on corrosive synthetic reagents. Though physical activation is also a cleaner production pathway but it recorded a very low surface area (168.09 m²/g), The Magnetic-TEA (surface area: 331.47 m²/g) was selected for its superior Cleaner Production profile because it had an impressive surface area and pore size (3.7 nm) which allows for high-efficiency COD removal without introducing new pollutants into the industrial cycle.

The system was optimized using Response Surface Methodology (RSM) to ensure industrial predictability. The results demonstrated that for an initial COD of 350 mg/L, a specific dosage of 2.0 g/L at pH 5.0 achieved a maximum reduction. The high correlation between the predicted (93.776%) and experimental (91.1%) results proves that this waste-derived material can perform with the same precision as expensive, commercially manufactured carbons.

This study successfully engineered a dual-biomass magnetic adsorbent for high-load COD removal. To replicate authentic industrial conditions, a wood-waste effluent was simulated by boiling Tosnensky Birch timber; following a 99:1 dilution, this produced a rigorous testing matrix with a COD of 800 mg/L. The Magnetic-TEA adsorbent achieved a 91.1% COD reduction, effectively sequestering complex lignins and tannins. Utilizing NaOH for desorption ensured the system's sustainability, maintaining an 85.6% regeneration efficiency over four cycles with a final 92.4% desorption rate. Ultimately, this research provides a scalable, circular economy blueprint for the timber industry, transforming agricultural waste into a high-value tool for managing high-concentration industrial wastewater.

Literature

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