NANO ENHANCED ADSORBENTS FOR CONTAMINANT REMOVAL

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Introduction:

Water is vital for human life, but growing populations generate large volumes of wastewater from domestic, industrial, and agricultural activities. Although 70% of Earth is water, only 3% is freshwater, and much of it is under threat due to pollution and overuse. A major cause of water pollution is the discharge of untreated wastewater into rivers and lakes, stemming from industrial waste, urban growth, poor sewage systems, and agricultural chemicals.

This pollution poses serious risks to health and ecosystems. To combat this, many developed nations have enforced stricter wastewater regulations. For example, the EU's Water Framework Directive of 2000 sets standards for protecting water resources. In response, numerous treatment technologies have been developed, including filtration, oxidation, biodegradation, and electrochemical processes.

This review highlights recent advancements in treating dairy industry wastewater, focusing on integrated methods that enhance both resource recovery and environmental protection.

Objectives:

1. Investigate the effectiveness of carbon nanotubes (CNTs) in removing pollutants from dairy effluent.
2. Evaluate the adsorption capacity of CNTs for various dairy effluent.
3. Optimize CNT dosage and treatment conditions (e.g., contact time, pH, temperature) for maximum pollutant removal.
4. Assess the reusability and regeneration of CNTs for repeated treatment cycles.
5. Investigate the mechanisms of pollutant removal by CNTs (e.g., adsorption, absorption, chemical reactions).

Material and Methodology:

For the current study, Coconut Husk was chosen as a cost-effective, Sustainable alternative material to Carbon nanotubes. The lab-based synthesis of carbon nanotubes (CNTs) from coconut husk involves a step-by-step process focusing on pre-treatment. The process begins with gathering the necessary materials, which include dried coconut husk, hydrochloric acid (HCl), or sodium hydroxide (NaOH) for optional pre-treatment, deionized water to be used.

The first step is the pre-treatment of the coconut husk. Begin by collecting the husks and ensuring they are free from contaminants like dirt or oil. Wash them thoroughly with water to remove any impurities. Soak the ground coconut husk in a 1M solution of HCl or NaOH for about 12 hours. After this, wash the treated husk thoroughly with deionized water until the pH reaches neutral, ensuring the removal of excess acid or base. Finally, dry the material again in a vacuum oven at 100°C for 12-24 hours. Once dried, grind the husks into small pieces or powder using either a mechanical grinder or a mortar.

Figure 1: Synthesis of Coconut Husk as Carbon Nanotubes

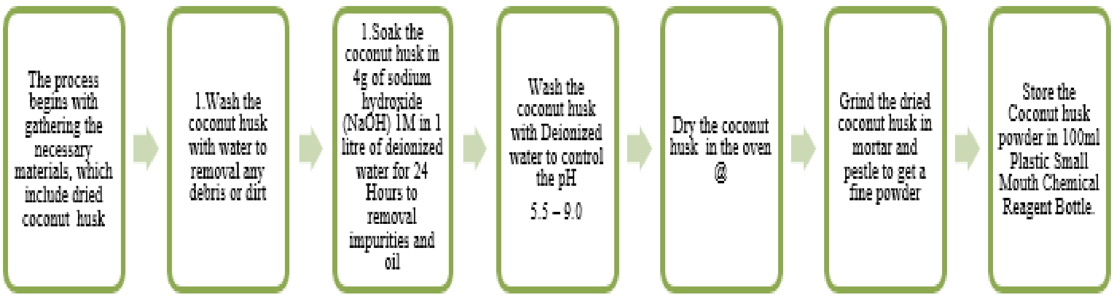

Figure 2: Experimental Process of Synthesis of Coconut Husk Powder

Result and Discussions:

Table 1: Comparision and Results with Variation of Coconut husk Powder & CNT for various parameter Removal Efficiency

EXPERIMENTS		PRE ANALYSIS	POST ANALYSIS										CPCB Std for effluent discharge
			0.5 mg		1 mg		1.5 mg		2 mg		2.5mg		
			CNT	CH	CNT	CH	CNT	CH	CNT	CH	CNT	CH	
pH		7.79	7.61	7.65	7.34	7.11	7.21	7.10	7.10	7.07	7.05	7.02	5.5 – 9.0
TDS (mg/L)		20.59	18.33	18.87	11.18	12.74	10.99	12.34	9.88	10.65	8.43	9.24	-
CHLORIDE (mg/L)		68.48	39.70	29.77	35.43	28.48	31.33	27.21	28.42	25.58	24.75	22.46	-
COD (mg/L)		704	560	608	512	592	368	432	284	321	210	270	≤ 250 mg/L
BOD (mg/L)		1440	810	450	670	220	480	110	244	54	96	25	≤ 20 mg/L
NITRATE (mg/L)	FILTERED	95.05	88.26	74.54	78.55	70.21	61.25	65.82	53.43	53.28	38.10	23.75	-
	UNFILTERED	111.2	106.6	81.28	92.86	80.58	83.25	75.63	71.21	61.67	52.11	41.78	
SOLIDS (mg/L)	FILTERED	2280	1870	1935	1145	1325	775	978	310	440	123	160	≤ 100 mg/ L
	UNFILTERED	2115	2035	1224	1345	805	955	484	456	271	148	96	

Discussion of Results obtained: (Mustapha et.al "Preparation and characterization of Bio-Adsorbent from coconut husk for remazol red dye removal." Biointerface Research in Applied Chemistry 11, no. 3 (2020): 10006-10015.), (Shankar et.al "Colour removal in a textile industry wastewater using coconut coir pith." Pollution Research 33, no. 3 (2014): 499-503.)

The results from the chemical tests reveal the progressive improvement in pollutant removal efficiency with increasing dosages of carbon nanotubes (CNTs) and coconut husk powder over a 30-minute treatment period. A comparative analysis of the experimental parameters highlights distinct atrends across pH levels, Total Dissolved Solids (TDS), chlorides, Chemical Oxygen Demand (COD), Biochemical Oxygen Demand (BOD), nitrates, and suspended solids.

pH:

Both carbon nanotubes and coconut husk powder maintained the pH close to neutral across all dosages, with values ranging from 7.61–7.05 for CNTs and 7.65–7.02 for coconut husk powder.

The slight decline in pH with increasing adsorbent dosage suggests enhanced adsorption of ionic pollutants, which helps stabilize the water's pH.

Total Dissolved Solids (TDS):

CNTs consistently achieved lower TDS values compared to coconut husk powder. At 2.5 g dosage, TDS was reduced to 8.43 mg/L for CNTs versus 9.24 mg/L for coconut husk powder.

The improved performance of CNTs is attributed to their higher surface area and adsorption efficiency. Coconut husk powder, while slightly less effective, still exhibited significant reductions in TDS, demonstrating its potential as a cost-effective alternative.

Chlorides:

Chloride removal improved with increasing adsorbent dosage. At 2.5 g, chloride levels were reduced to 24.75 mg/L (CNTs) and 22.46 mg/L (coconut husk powder).

Coconut husk powder outperformed CNTs in chloride removal across all dosages, likely due to its affinity for ionic compounds in solution.

Chemical Oxygen Demand (COD):

CNTs achieved greater COD reduction, decreasing from 560 mg/L at 0.5 g to 210 mg/L at 2.5 g. Coconut husk powder also showed significant COD removal, lowering values from 608 mg/L to 270 mg/L over the same dosage range.

The superior performance of CNTs reflects their advanced adsorption capabilities, though coconut husk powder also provides substantial COD removal as a sustainable option.

Biochemical Oxygen Demand (BOD):

Both adsorbents demonstrated significant reductions in BOD, with CNTs reducing it from 810 mg/L to 96 mg/L and coconut husk powder from 450 mg/L to 25 mg/L at 2.5 g.Coconut husk powder exhibited excellent BOD reduction efficiency, potentially due to its ability to adsorb organic pollutants effectively at higher dosages.

Nitrates:

Nitrate removal was effective for both adsorbents, with CNTs reducing levels from 88.26 mg/L to 38.10 mg/L and coconut husk powder from 74.54 mg/L to 23.75 mg/L at 2.5 g dosage.

Coconut husk powder slightly outperformed CNTs in nitrate removal at higher dosages, making it a promising solution for reducing nutrient pollution.

Suspended Solids:

CNTs and coconut husk powder showed significant reductions in suspended solids, with final levels of 52.11 mg/L and 41.78 mg/L, respectively, at 2.5 g dosage.

The better performance of coconut husk powder in reducing suspended solids highlights its potential to address turbidity and particulate matter in wastewater.

Conclusions:

1. Carbon Nanotubes (CNTs) as a sustainable and effective solution for dairy effluent treatment. This research underscores the viability of CNTs in removing pollutants efficiently, presenting a cost-effective and environmentally friendly alternative to traditional treatment methods. The implications of this study extend beyond immediate wastewater management, offering valuable insights into advancing sustainable development and promoting environmental stewardship.
2. The results emphasize the transformative role of CNTs in improving dairy effluent quality. By effectively adsorbing a wide range of pollutants, including organic matter and nutrients, CNTs deliver a comprehensive approach to wastewater treatment. The optimization of treatment parameters such as dosage, pH, and contact time further enhances their efficiency, making CNTs a versatile solution for tackling diverse water quality challenges faced by dairy industries.
3. The application of CNTs aligns with sustainability principles, as they are reusable, generable, and capable of maintaining efficiency over multiple cycles. This minimizes material waste and operational costs, addressing both economic and environmental concerns. By adopting CNT-based technologies, communities and industries can reduce reliance on chemical-intensive methods, mitigating their ecological footprint while ensuring effective wastewater management.
4. Beyond wastewater treatment, CNTs hold promise for broader environmental and industrial applications, contributing to a more sustainable future. By embracing innovative materials like CNTs, industries can align their practices with global goals for environmental preservation and sustainable development, paving the way for a cleaner and healthier ecosystem.

5. The findings demonstrate that both carbon nanotubes and coconut husk powder are effective adsorbents for dairy wastewater treatment. CNTs consistently achieved higher reductions in TDS, COD, and BOD due to their superior adsorption properties. However, coconut husk powder showed comparable or better performance in reducing chlorides, nitrates, and suspended solids.
6. Coconut husk powder's cost-effectiveness, sustainability, and significant pollutant removal efficiency position it as an eco-friendly alternative for large-scale applications. Scaling up this approach offers a dual benefit of addressing wastewater challenges and repurposing agricultural waste, contributing to sustainable environmental management.

Future Scope:

The future scope of this project includes:

1. Advanced nanomaterials such as metal-organic frameworks (MOFs), bio-inspired nanomaterials, and 2D materials (e.g., MXenes, graphene derivatives) hold promise for even greater adsorption efficiency and selectivity.
2. Combining Nano-enhanced adsorption with other water treatment technologies (e.g., photocatalysis, membrane filtration, or biological treatment) may offer synergistic benefits for complex water matrices.
3. Computational modeling and artificial intelligence (AI)-based tools can be employed to predict adsorption behaviour, optimize design, and accelerate material discovery.