Eco-Friendly Silver Nanoparticles for Wastewater Remediation: Degradation of Para-Nitrophenol and Azo Dyes Using Rice Husk-Derived Silver Nanoparticles

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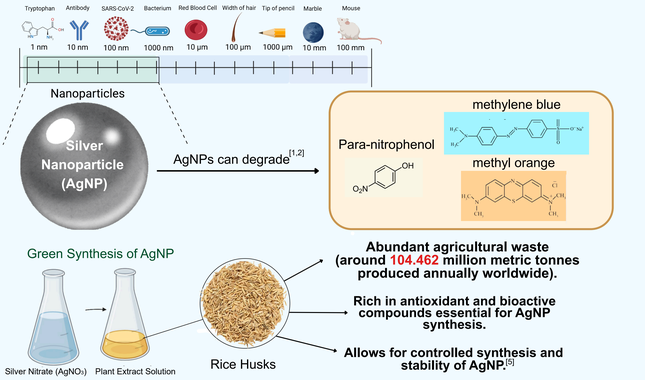
Background



Research Problem

Azo dyes and para nitrophenols are often discharged untreated into water by industries.

Azo dyes
Widely used in textiles, food, and cosmetics industries.

Para-nitrophenol (PNP)
Widely used in drugs, pesticides, rubber, resins etc.

Problems with conventional methods of removing them from water.

Traditional methods are expensive, produces secondary waste and/or produces harmful byproducts.[4]

Traditional methods are inefficient and expensive.[1]

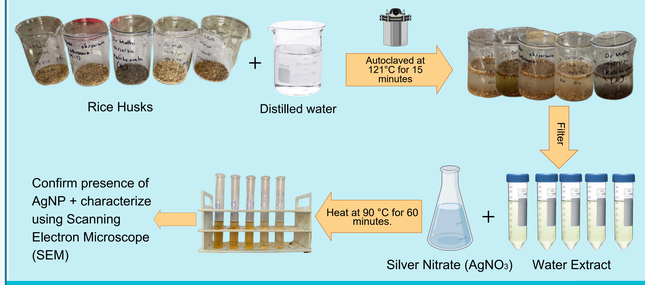
When left untreated in water, these chemicals causes **harm to aquatic environment as well as other organisms including humans**. Makes water **unsafe** for consumption if left untreated.[5]

Objectives

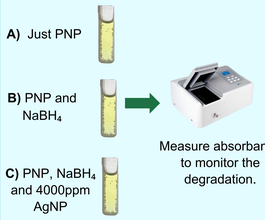
- To assess the suitability of rice husks (RH) from five Sri Lankan rice varieties - Suwadel (S), Kaluheenati (K), Madathalawalu (M), Bg375 (B5) and Bg374 (B4) as sustainable precursors and natural stabilizing agents for the green synthesis of AgNPs.
- To evaluate the catalytic and photocatalytic efficiency of RH-AgNPs in degrading major wastewater pollutants, azo dyes (methylene blue and methyl orange) and para-nitrophenol, and to establish their potential as a cost-effective nanomaterial for sustainable wastewater treatment in line with Sustainable Development Goal 6.

Methodology

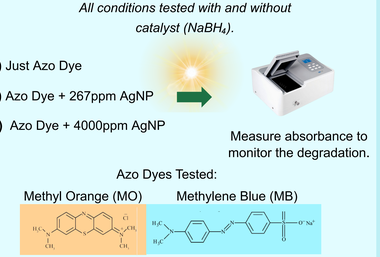
Subcritical Extraction of Rice Husk Water + AgNP Synthesis



Photocatalytic and Catalytic Degradation of Azo Dyes and PNP

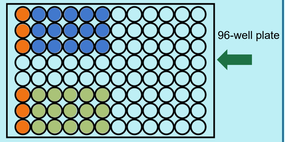


All conditions tested with and without catalyst ($NaBH_4$).



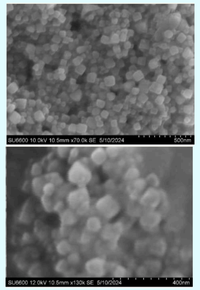
Cytotoxicity Testing of AgNPs

Brine Shrimps used to assess cytotoxicity of AgNPs to determine its safety in using it as a wastewater treatment



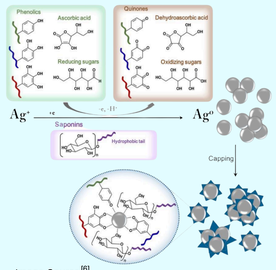
Results & Discussion

SEM Pictures of AgNP



Average Diameter of each NP: ~50 nm

Synthesis Mechanism of AgNP



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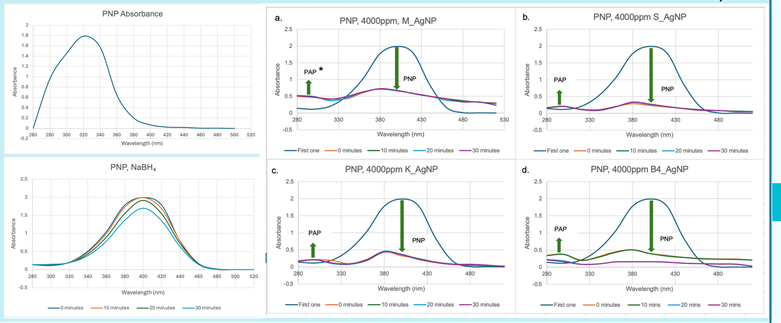
PNP Degradation

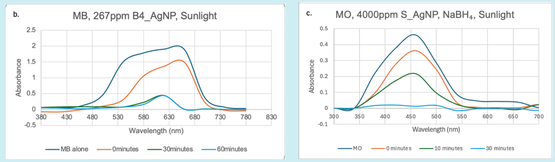
PAP = Para-aminophenol



Azo Dye Degradation

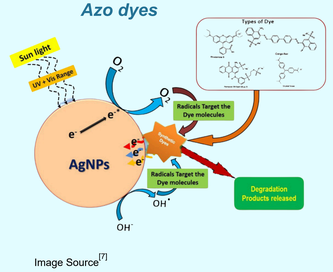
Sample ID	MB Degradation Rate Constant (k) (min^{-1})			
	267ppm AgNP		4000ppm AgNP	
	Sunlight, $NaBH_4$	Sunlight	Sunlight, $NaBH_4$	Sunlight
M_AgNP	0.361	0.416	0.085	0.138
S_AgNP	0.725	0.947	0.159	0.271
K_AgNP	0.343	0.367	0.075	0.152
B4_AgNP	0.33	1.21	0.321	0.114

Sample ID	MO Degradation Rate Constant (k) (min^{-1})			
	267ppm AgNP		4000ppm AgNP	
	Sunlight, $NaBH_4$	Sunlight	Sunlight, $NaBH_4$	Sunlight
M_AgNP	0.072	0.051	0.134	0.257
S_AgNP	0.110	0.079	0.739	0.278
K_AgNP	0.106	0.086	0.659	0.329
B4_AgNP	0.090	0.085	0.270	0.247



Mechanisms of Degradation

Azo dyes



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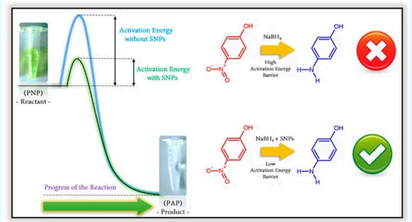
Paranitrophenol



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Results & Discussion (Continued)

Cytotoxicity Test Results

Results of Cytotoxicity Analysis of 200ppm AgNP Solution.

Sample	Well 1	Well 2	Well 3	Viability
Control	2/2	2/2	2/2	100%
M_AgNP	2/2	2/2	2/2	100%
S_AgNP	2/2	2/2	2/2	100%
K_AgNP	2/2	2/2	2/2	100%
B4_AgNP	2/2	2/2	2/2	100%

Results of Cytotoxicity Analysis of 800ppm AgNP Solution.

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M_AgNP	2/2	2/2	2/2	100%
S_AgNP	2/2	2/2	2/2	100%
K_AgNP	2/2	2/2	2/2	100%
B4_AgNP	2/2	2/2	2/2	100%

Conclusion

Rice husks (RH) from all Sri Lankan varieties were successfully used as green precursors for AgNP synthesis except for Bg375 (B5).

RH-AgNPs demonstrated strong catalytic and photocatalytic activity in degrading PNP and azo dyes, respectively. This contributes to improved water quality and safer water resources for ecosystems and communities, aligning with SDG 6.1 and 6.3.

Concentration-Dependent Performance for photocatalytic degradation of azo dye:

- For MB, maximum efficiency occurred at lower concentration (267 ppm) under sunlight.
- For MO, higher concentration (4000 ppm) with $NaBH_4$ gave the fastest degradation.

Future Work

Toxicity assessments could be expanded to include zebrafish embryos (*Danio rerio*) for developmental toxicity studies and mammalian cell lines to evaluate human cell compatibility.

Test photocatalytic degradation against other widely used azo dyes such as congo red, reactive black 5, Direct Blue 1, etc.

References

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