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Two-Stage Batch Adsorber Optimisation for Malachite Green Removal Using Activated Waste Biomass

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Outline

- Introduction and Objectives
- Experimental Systems
- Modeling Theory and Models
- Results
- Conclusion

INTRODUCTION

Waste Biomass

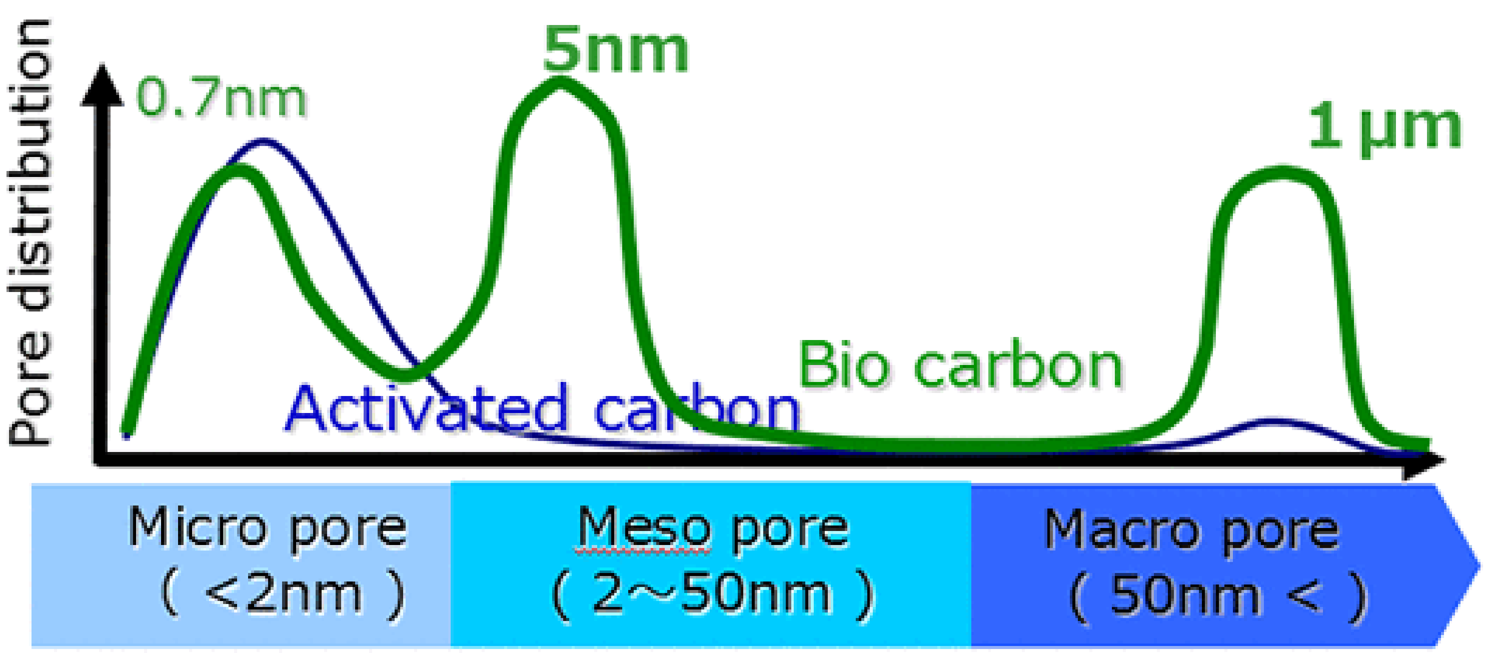
Sources:
- Straws (wheat, rice husk…)
- Shells (coconut, pistachio, palm kernel, walnut…)
- Fruit stones (olive, dates, peaches, mango…)
- Pine, wood, bamboo, lignin….

Source: filtrasystems

Activated Carbons

- Activation: controlled oxidation of carbon atoms in the raw material – expanding the internal surface area
- Physical and chemical activation
- Strong physical adsorption and chemical reactions
- Low density
- High porosity: pore volume (0.2 to 0.6 cm^3/g)
- Brunauer- Emmett- Teller (BET): surface area (500 to 1500 m^2/g)

Source: carbon-filter

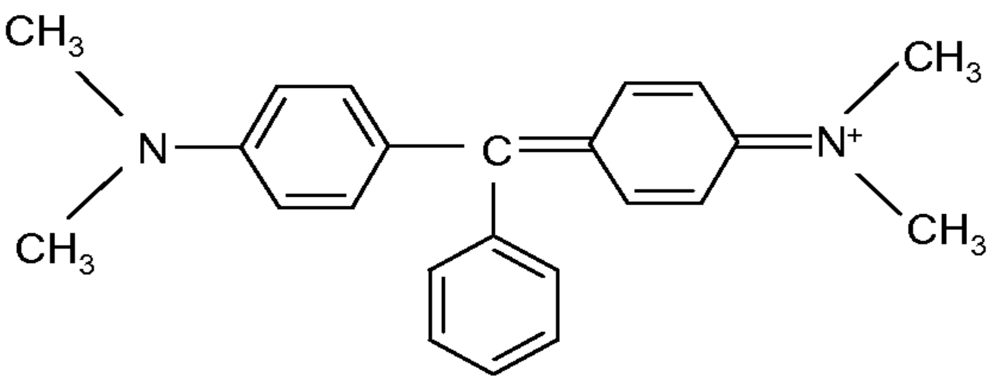


Source:yet2.com marketplace

Dyes (Malachite Green)

- Dyes are applied to textiles, paper, leather, food, drugs, cosmetics and other products.
- More than 2000 dyes are currently used (reactive orange, congo red, methylene blue, malachite green)
- Major environmental problems (increase in COD, decrease in DO, toxic, carcinogenic, mutagenic, prevent light penetration into water)

Malachite Green



$C_{23}H_{25}ClN_2$

Source: Alibaba.com

Adsorption

Factors affecting adsorption

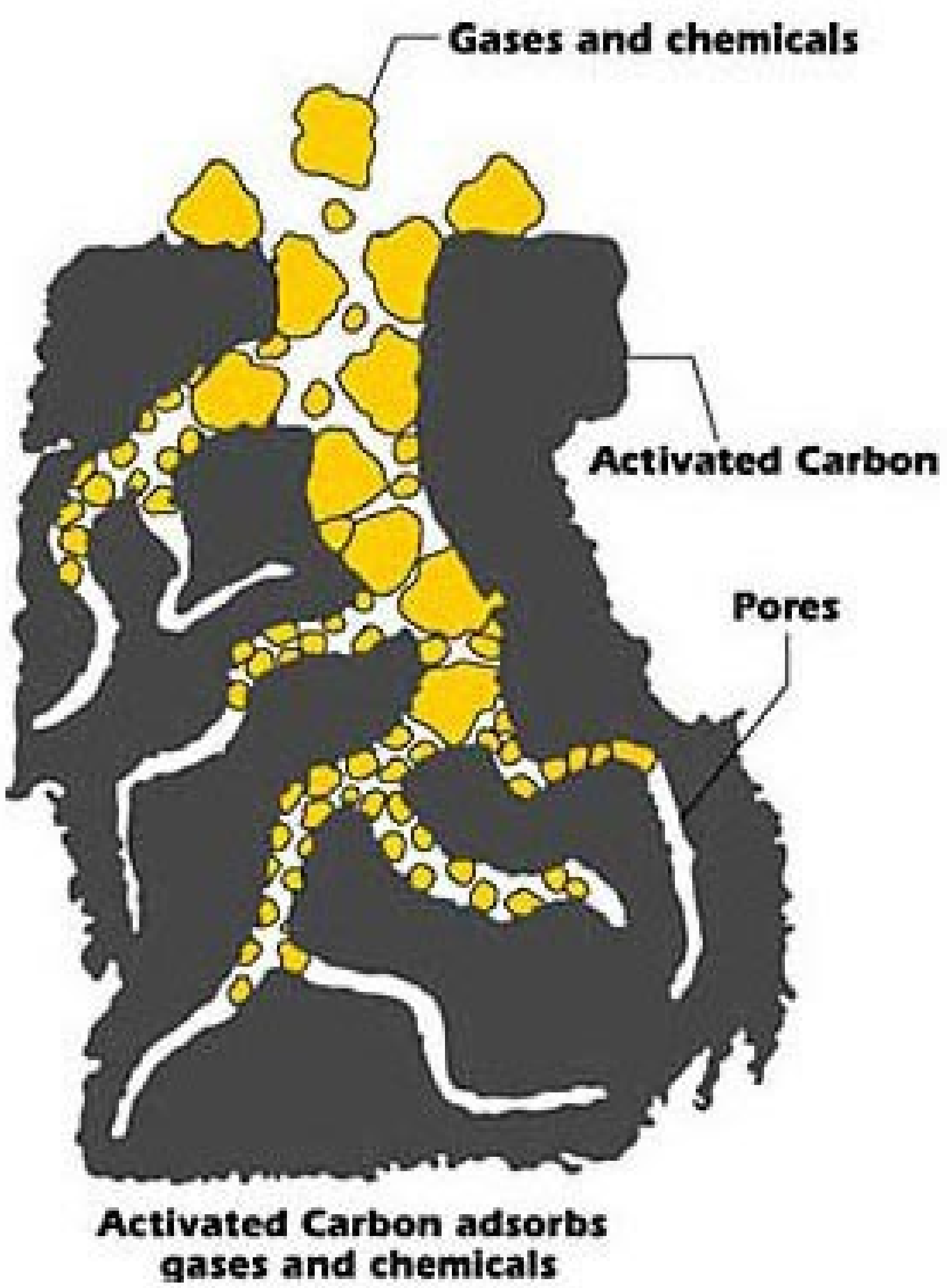
pH and Temperature

Time

Adsorption

Initial concentration

Porosity (pore size, volume, and distribution)



Low cost

Low energy

Eco-friendly

Sustainable

Objectives

- Characterize date stones
- Develop suitable activation methods
- Test and compare the performance of the activated date pits adsorbents on the target pollutant of Malachite Green
- Understand the adsorption mechanisms
- Design a two stage adsorption system

The waste product of the seedless date products industry is the date “pit” or date “stone” which is a sustainable and economical resource that can be used to enhance the treatment of water.

EXPERIMENTAL SYSTEMS

Experimental Systems

Experimental Systems (Cont.)

Properties of the date stones

Date stone	Total volume of pore (cm^3/g)	Mean pore diameter (nm)	BET surface area (m^2/g)
NDS	0.21	2.31	85.74
PADS	0.55	2.48	908.6

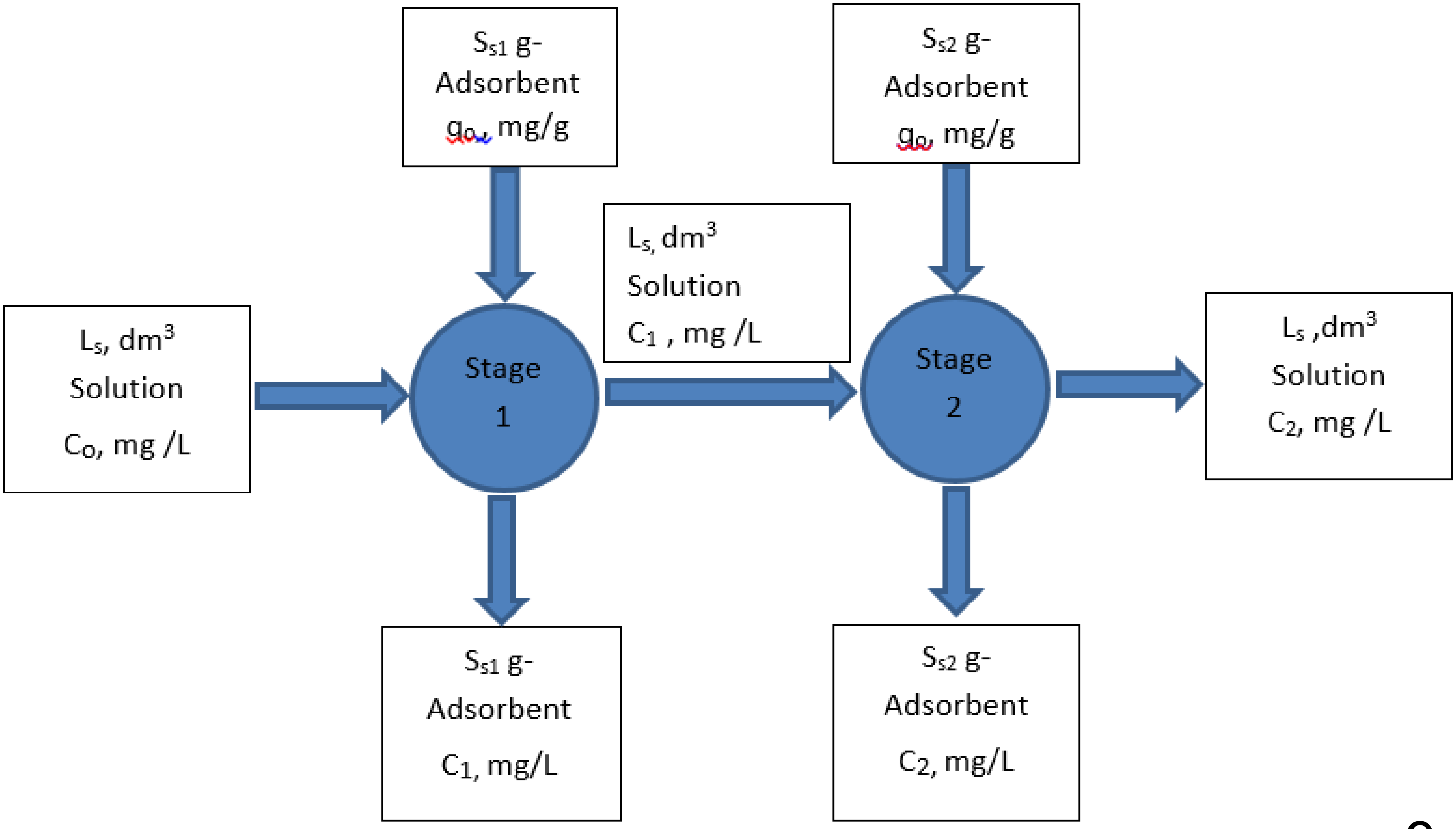
Adsorption Tests

- Carried out at 20°C
- 3g of adsorbent with MG
- Shaking at 250 rpm
- Measuring initial and final concentr

- Mass balance

(amount of dye adsorbed = amount of dye removed)

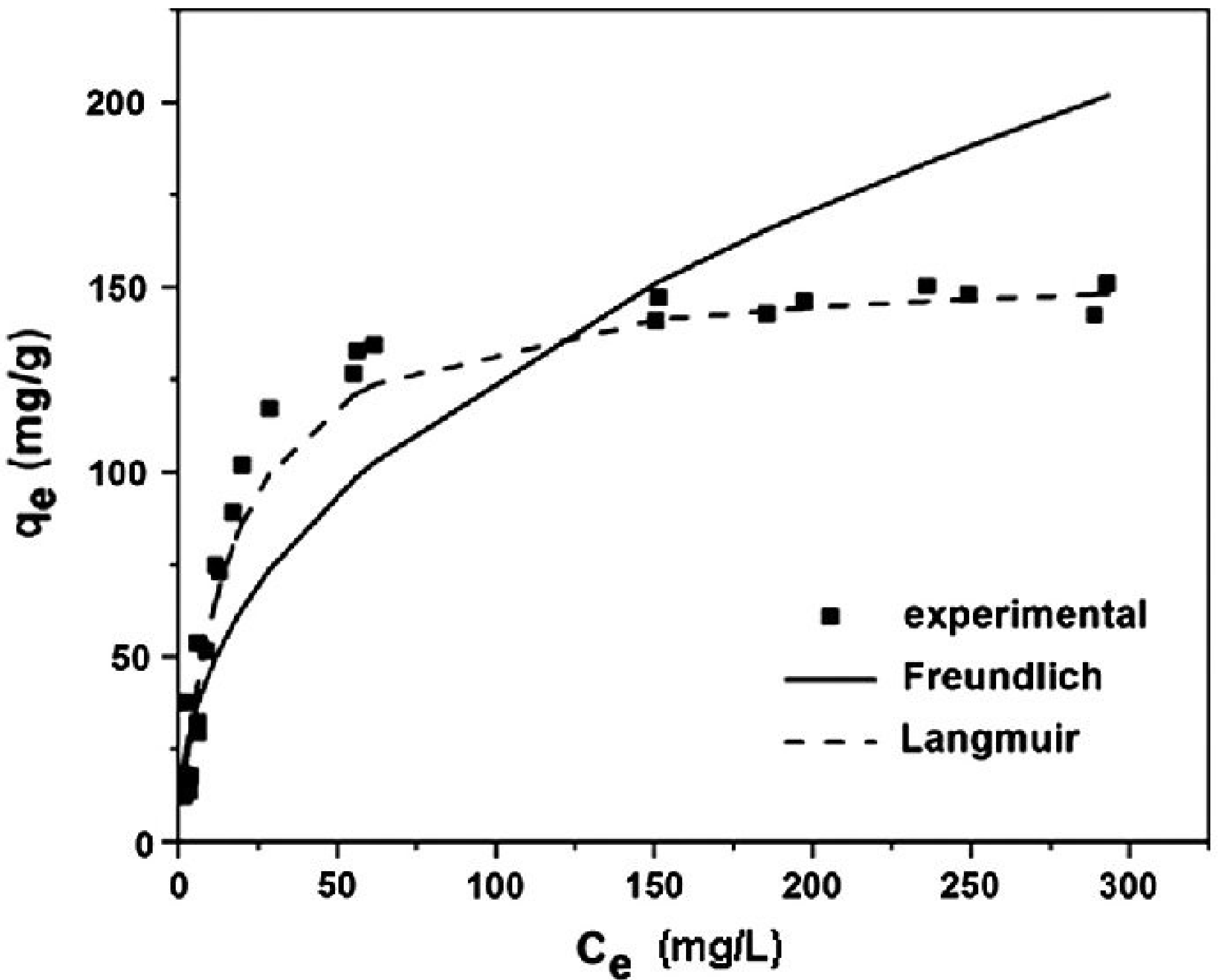
Two-Stage Batch Adsorber Optimisation



MODELING THEORY AND MODELS

Isotherms

- qe :amount of contaminant adsorbed
- Ce: equilibrium concentration of the contaminant



Source: researchgate

Models:

- Langmuir
- Freundlich
- SIPS

Model information:

- Prediction
- Type of adsorption
- Molecular interaction

Errors:

SSE, chi-square statistic, g-square statistic, relative errors, absolute errors, percentage errors, and fractional errors, etc.

Isotherms (Cont.)

Langmuir isotherm

$$q_e = \frac{q_m\, b\, C_e}{1 + bC_e}$$

- q_m (mg/g): adsorption capacity constant
- b (L/mg): energy constant

Assumptions:
- Ideal gas behavior of adsorbate
- Molecules do not interact among each other
- Uniform monolayer adsorption

Freundlich isotherm

$$q_e = k_F C_e^{\frac{1}{n}}$$

- k_F: adsorption capacity constant
- n: constant (surface heterogeneity)

Assumptions:
- Empirical equation
- Multilayer adsorption
- Heterogeneous system

SIPS isotherm

$$q_e = \frac{q_m\, K_{LF}\, C_e^{1/n_{LF}}}{1 + K_{LF}\, C_e^{1/n_{LF}}}$$

- K_{LF}: LF constant
- n_{LF}: isotherm exponent

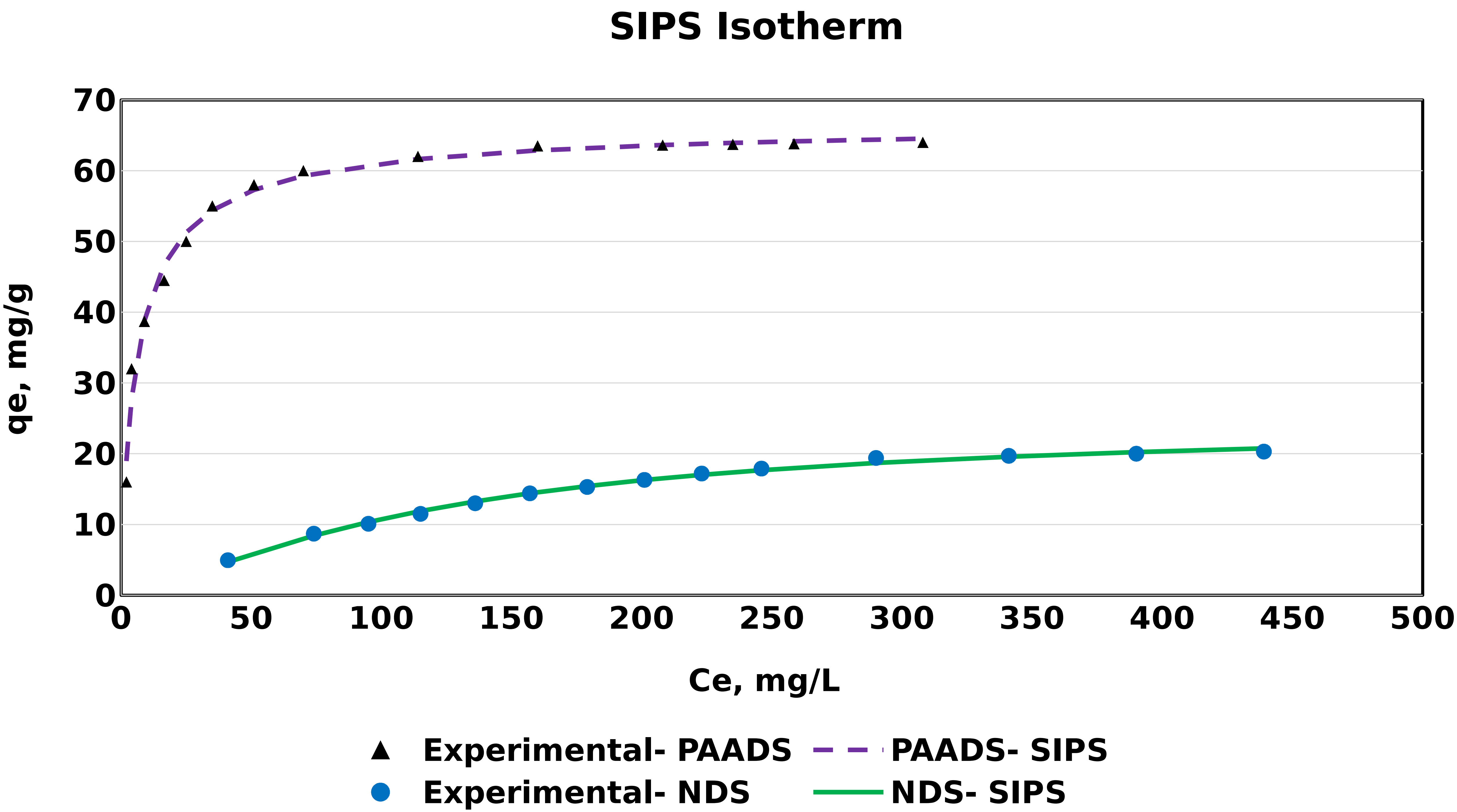
Assumptions:
- Combination of Langmuir and Freundlich
- High concentrations ~ Langmuir

RESULTS

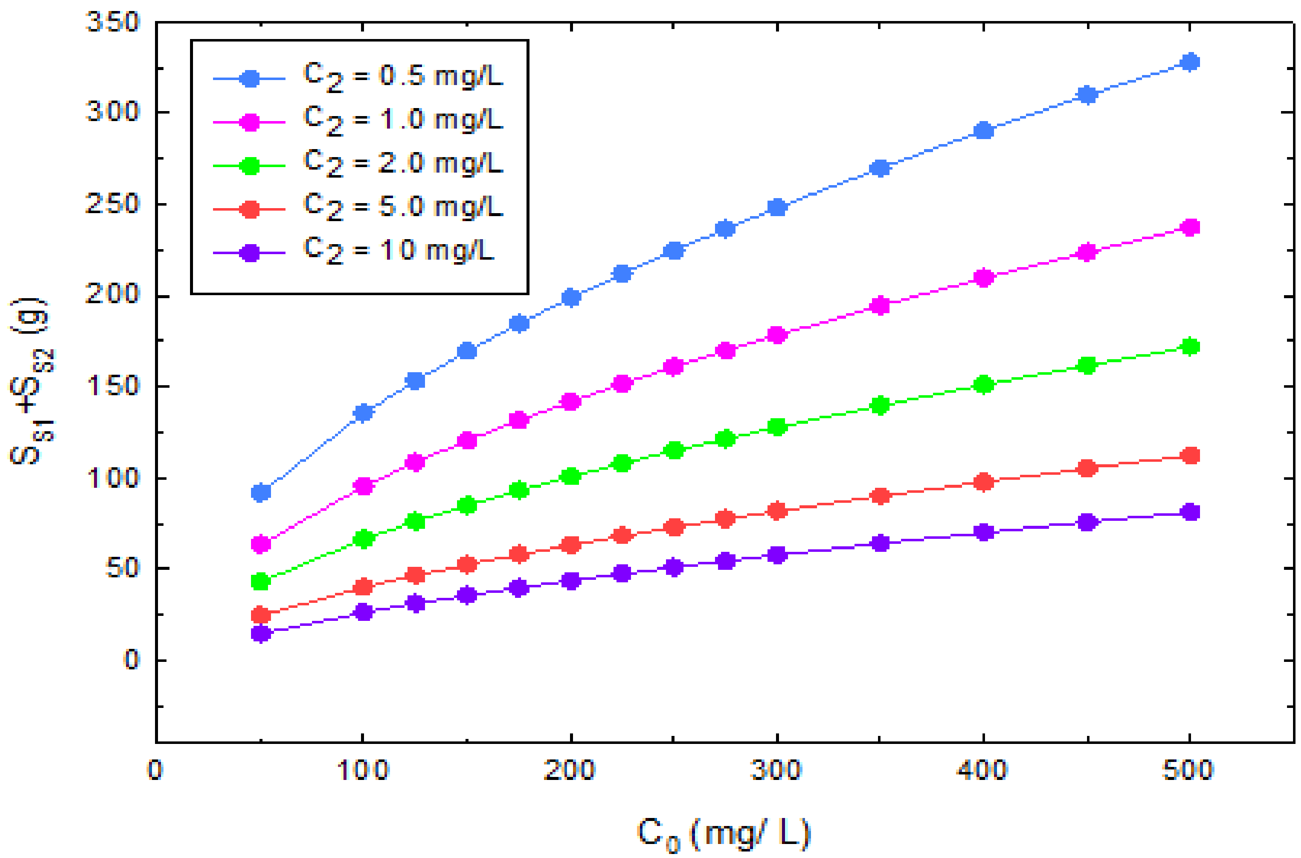
Isotherm Study Parameters

Isotherms		PADS	RDS
Langmuir Model	b	0.174	0.00583
	q_m	64.7	29.5
	SSE	52.4	3.53
Freundlich Model	k_F	26.7	1.22
	1/n	0.165	0.476
	SSE	404	16.8
SIPS Model	K_{LF}	14.8	0.203
	a_{LF}	0.221	0.0016
	b_{LF}	0.840	1.34
	SSE	36.2	1.30

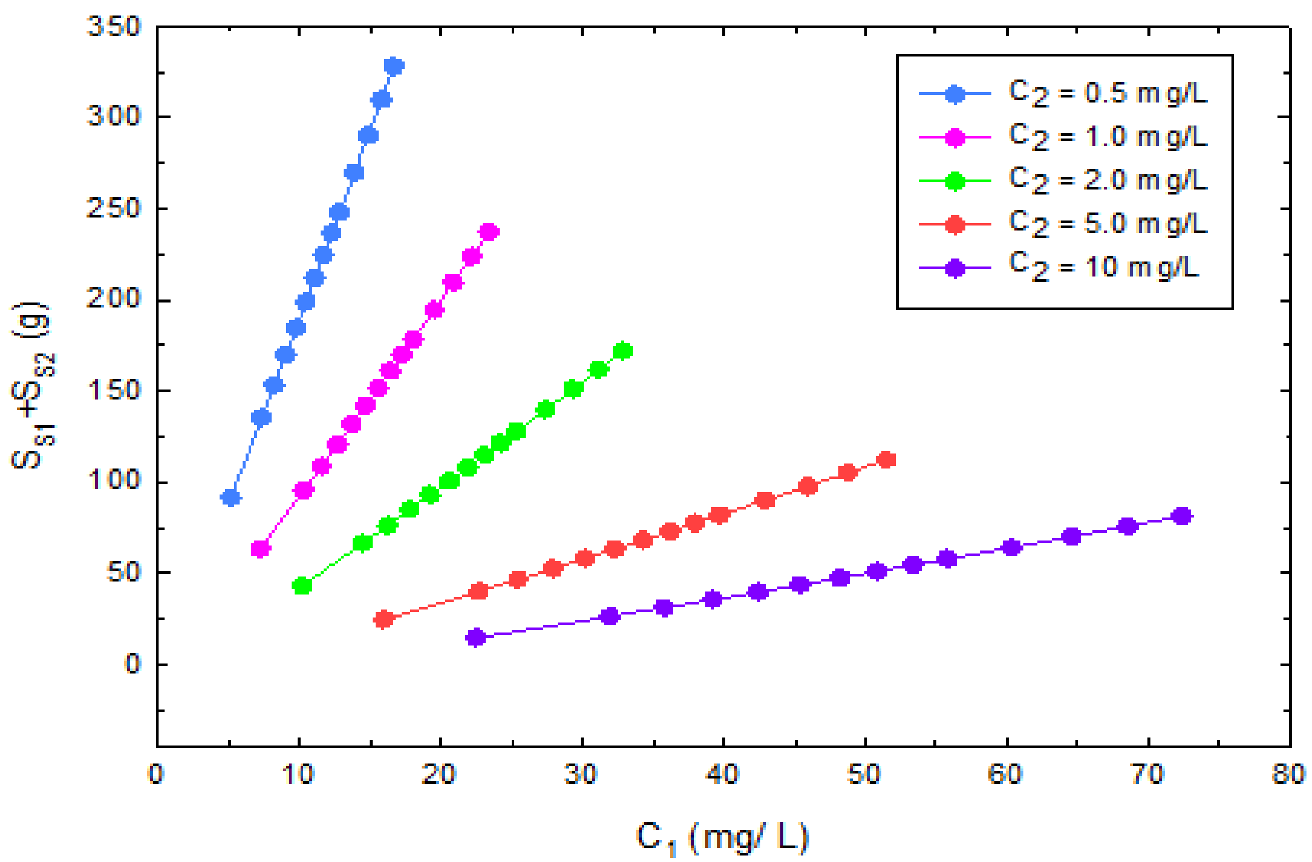
Isotherm Study Results (Cont.)



NDS



C2 = 0.5 mg/L
C2 = 1.0 mg/L
C2 = 2.0 mg/L
C2 = 5.0 mg/L
C2 = 10 mg/L
Ss1+Ss2 (g)
C0 (mg/ L)



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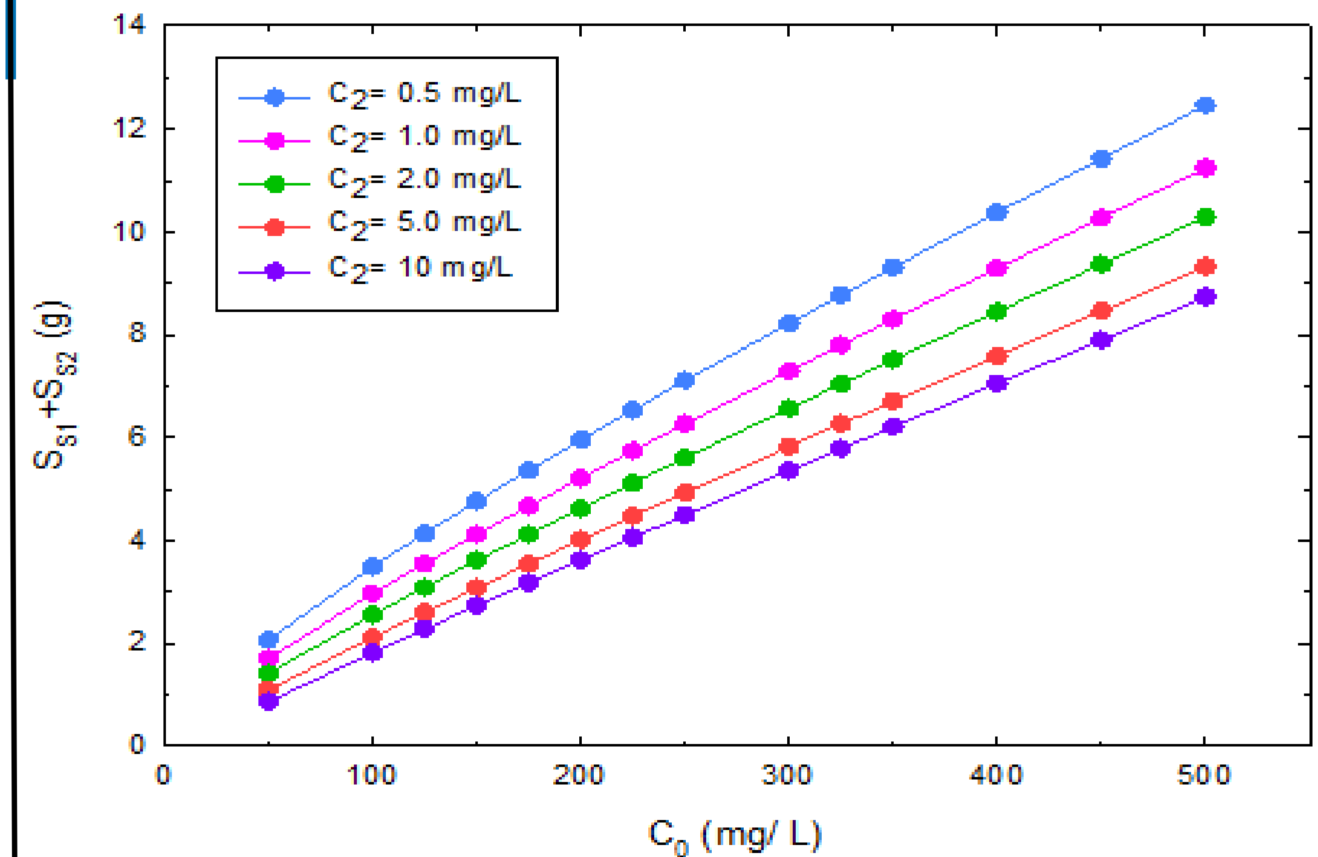
C2 = 2.0 m g/L
C2 = 5.0 m g/L
C2 = 10 m g/L
Ss1+Ss2 (g)
C1 (mg/ L)

PADS



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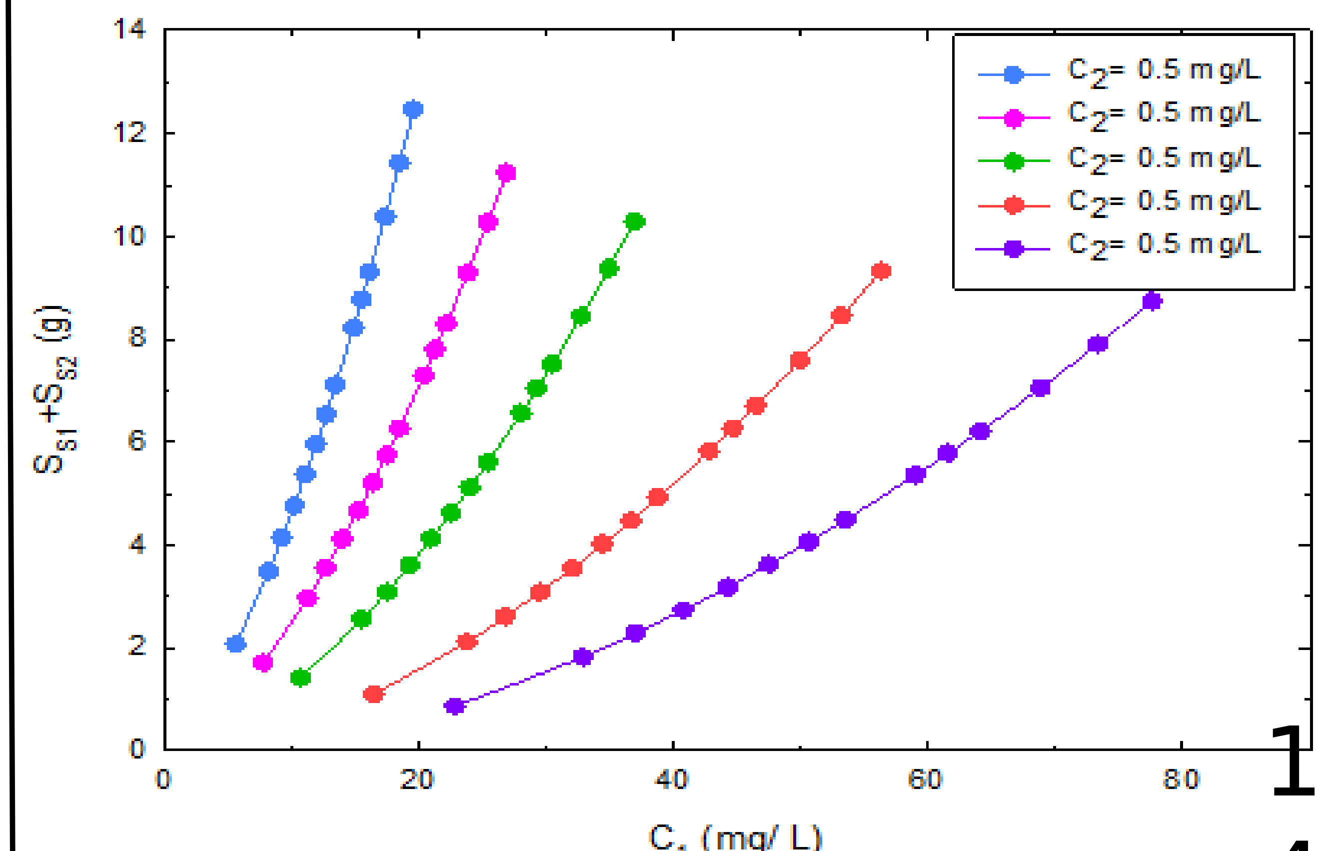

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Ss1+Ss2 (g)
C1 (mg/ L)

Single Stage vs Two Stage Adsorption

Amount of PADS adsorbent required

Removal %	99.50%		95%	
C_0 (mg/L)	S (g)	S1+S2 (g)	S (g)	S1+S2 (g)
50	11.5	2.5	2.2	1.2
100	13.5	3.5	3.1	2.1
150	15.1	4.2	3.9	2.8
200	16.4	5.0	4.7	3.6
250	17.7	5.9	5.5	4.2
300	18.8	6.4	6.2	5.0
350	19.9	7.5	7.0	5.5
400	21.0	8.3	7.7	6.2
450	22.0	9.2	8.5	7.0
500	23.0	10.0	9.2	7.5

CONCLUSION

Conclusion

- Date pits are hard lignocellulosic materials with high carbon content and low impurities, and are excellent precursors for the production of activated carbons
- Langmuir-Freundlich (SIPS) isotherm is the best fit among the studied isotherms for both adsorbents and should be used for design purposes
- The total amount of adsorbent increases with increasing initial concentration of malachite green dye, higher removal rate, and with an increase in the dye solution volume
- The two-stage system resulted in a decrease of around 33% of the total adsorbent requirement compared to the one-stage system to remove the same amount of MG
- For a commercial treatment process, the economic comparison between the adsorbent saving versus the increased cost of the two-stage adsorber over the single-stage adsorber needs to be investigated

Thank You
Any Questions?