Cationized Cotton: Opportunities and Challenges

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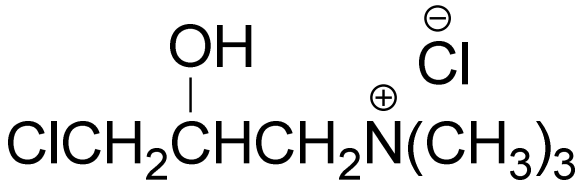
What is Cationized Cotton and Why Is It needed?

- Cotton chemically modified with permanent cationic charges
  - Cationic dye sites to attract anionic dyes
- Dyeing cotton (especially with fiber reactive dyes)
  - Salt needed (efficient exhaustion)
  - Large amounts of water and energy required (afterwash)
  - Color in effluent (hydrolyzed dye)

Cationization Methods

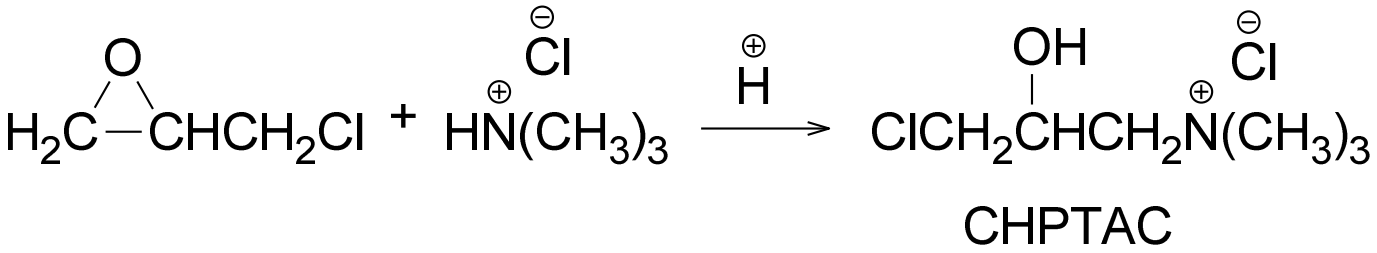
- Cationic Polymers
  - Ring dyeing and poor lightfastness
- Cationic Reagents
  - Uniform dyeing with minimal effect on lightfastness
  - 3-chloro-2-hydroxypropyltrimethylammonium chloride (CHPTAC) promising approach



CHPTAC

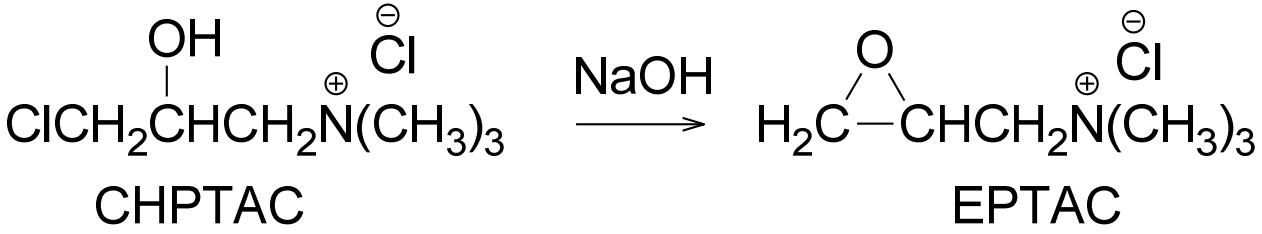
CHPTAC Reactions

- Synthesis



CHPTAC

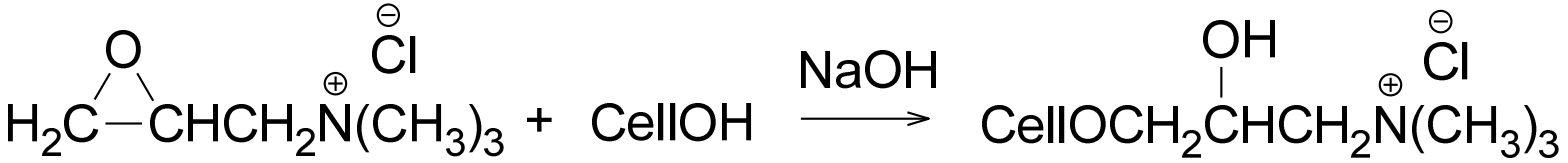
- Reactive Intermediate



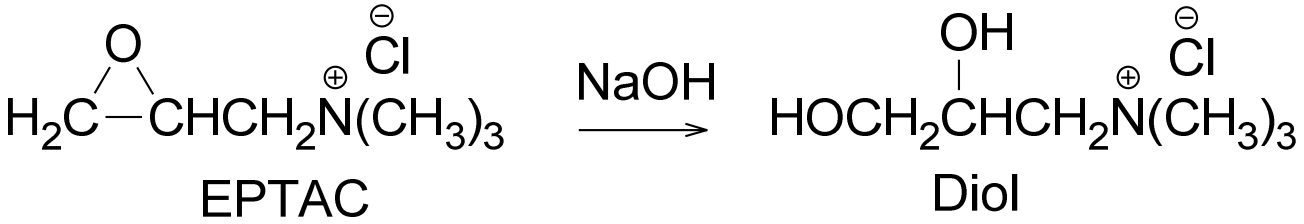
CHPTAC EPTAC

CHPTAC Reactions

- Cotton Cationization



- EPTAC Hydrolysis



Application of CHPTAC

- Cold pad batch most efficient
  - CHPTAC available as 65% active solution
  - Pad 5 – 10% CHPTAC owf with ~ 2 moles of NaOH/mole CHPTAC
  - Batch 16 – 24 hours, rinse and neutralize
  - ~50% yield (higher with mercerized cotton)
- Cationizing during preparation is preferred

Dyeing Cationized Cotton

- Modified conventional procedures
  - Follow recommendations for alkali, time, and temperature
  - Remove salt
  - Reduce afterwashing

Benefits of Dyeing Cationized Cotton

- Reduced water, energy, and time
- Higher color yields

Substrate	Water Usage (L/kg)	Energy Usage (MJ/kg)	Process Time (min)	% Dye Exhaustion	K/S
Cotton	130	45.9	230	87.5	23.8
Cationized Cotton	23	18.9	105	99.1	26.2

Fiber reactive Blue 225 (5% CHPTAC owf, 3% dye owf, 10:1 LR)

Benefits of Dyeing Cationized Cotton

- More efficient use of dye

Benefits of Dyeing Cationized Cotton

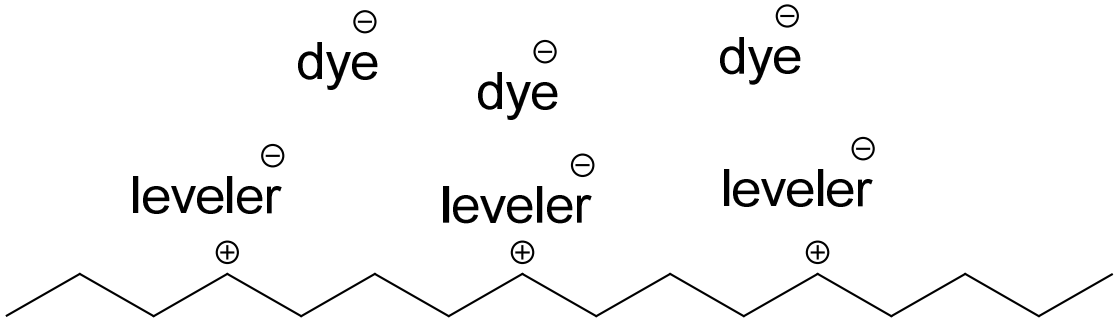
- Lower total cost
  - Pilot plant dyeing comparisons
    - 55 pound tubular knit dye lots
    - 4.3% owf CHPTAC application
    - 33% less dye at matched shades
    - 19% overall cost savings

What Could Possibly Go Wrong?

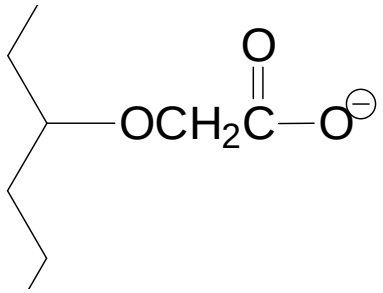
- Rapid dye strike → unlevel dyeings
- Conventional dye formulas give different shades → shades rematched
- More dye sites than dye → dye pickup during laundering

Improving Dye Levelness

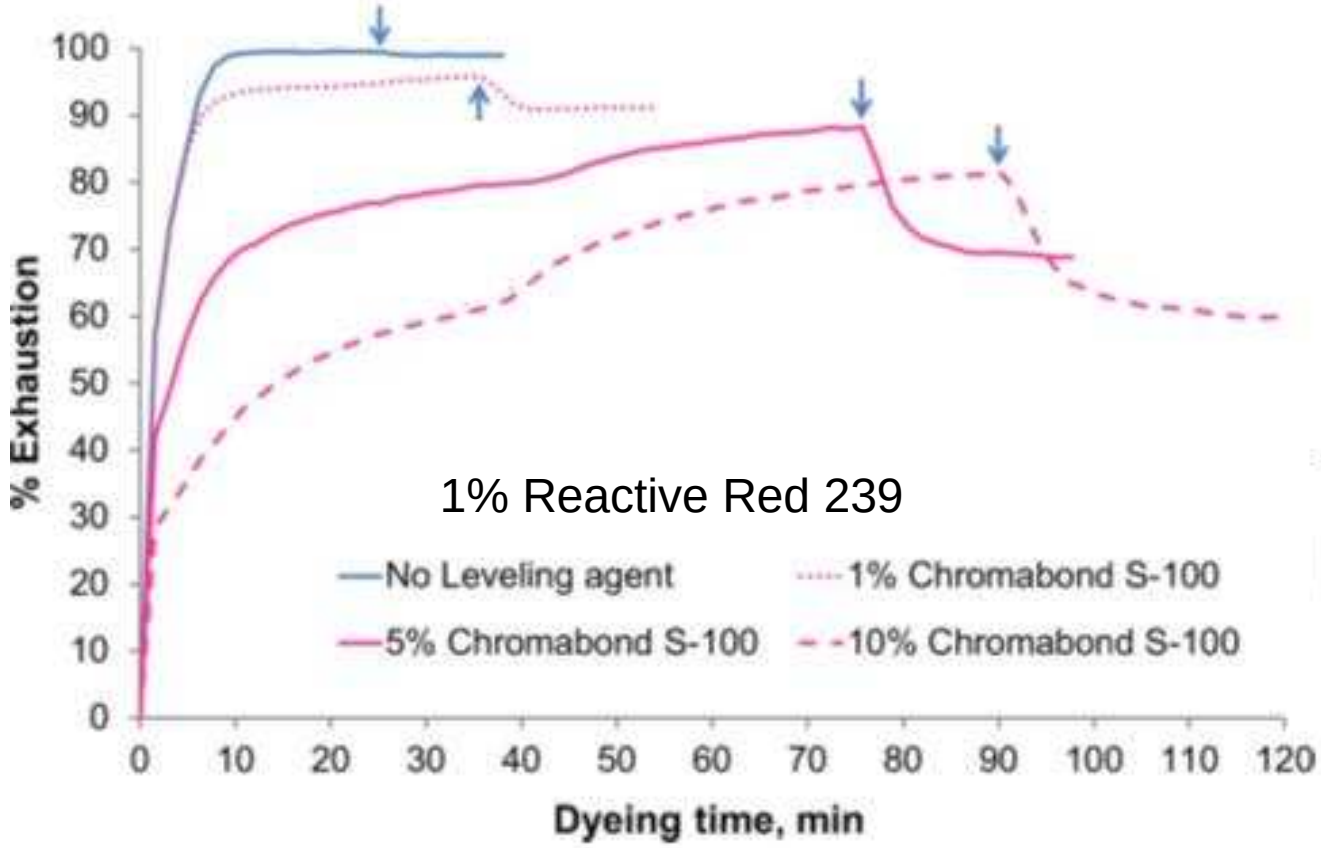
- Anionic leveling agents

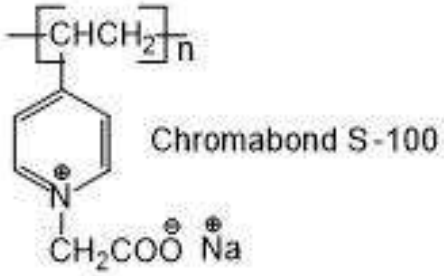


- Carboxymethyl cellulose effective

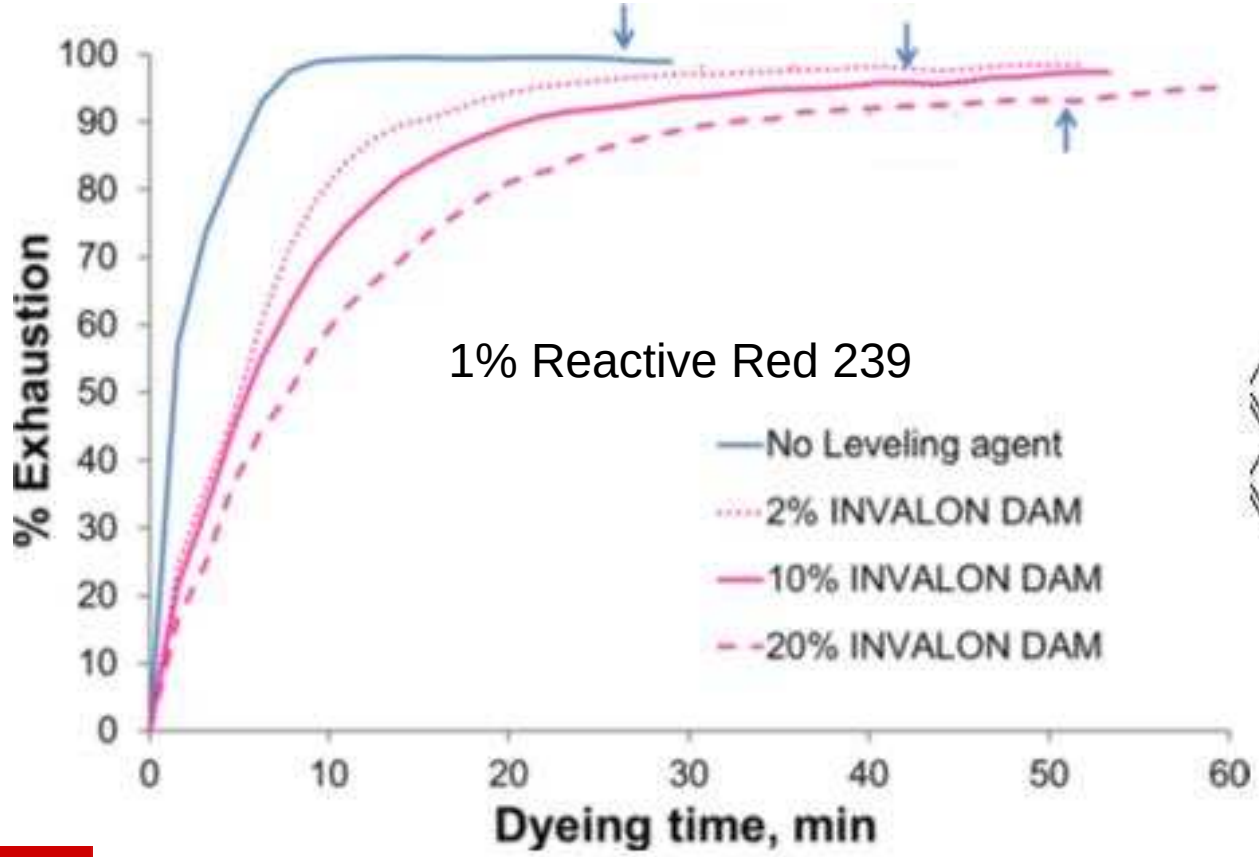


Improving Dye Levelness

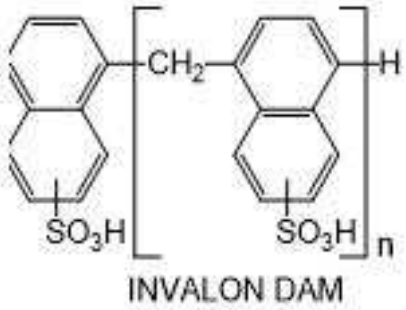




Improving Dye Levelness



1% Reactive Red 239



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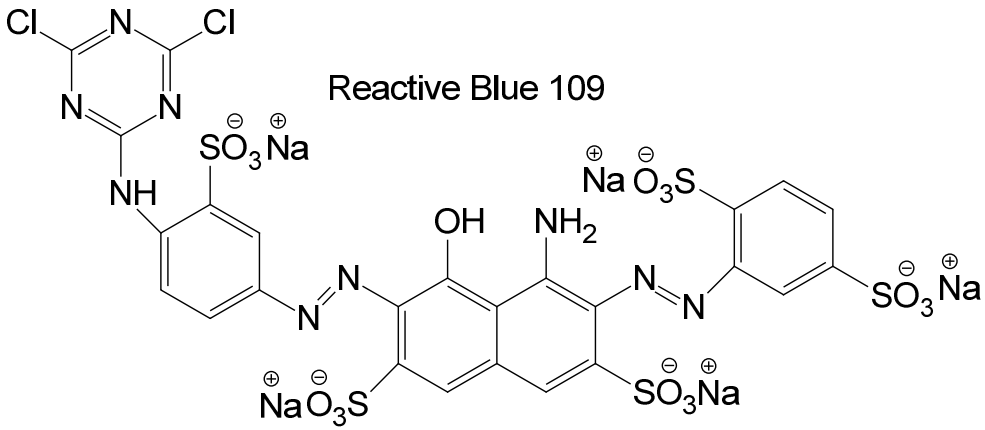
Effect of Dye Structures on Adsorption and Exhaustion Rates

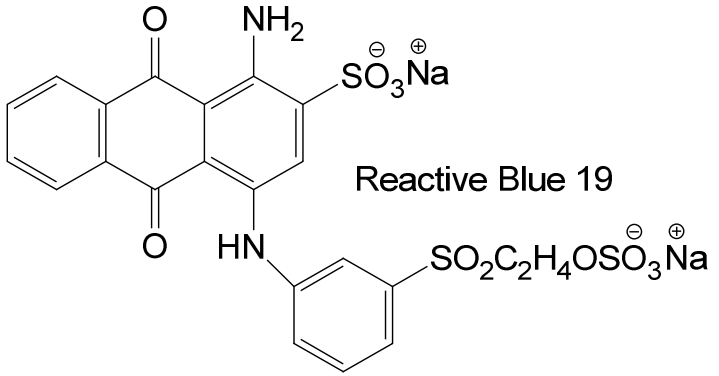
- Five dyes with different structures
  - Molecular weights
  - Number of anionic groups

	Reactive Blue 19	Reactive Violet 5	Reactive Red 11	Reactive Red 198	Reactive Blue 109
MW g/mole	627	736	767	968	1040
# SO_3^- *	2	3	3	4	5

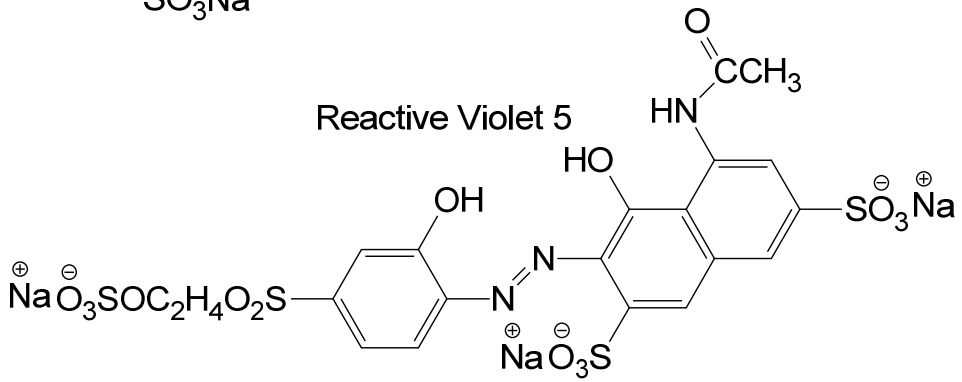
* includes SO_3^- from sulfatoethyl sulfone groups



Reactive Blue 109

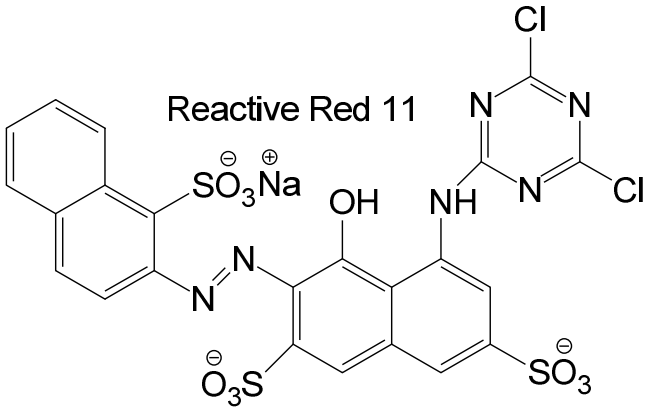


Reactive Blue 19

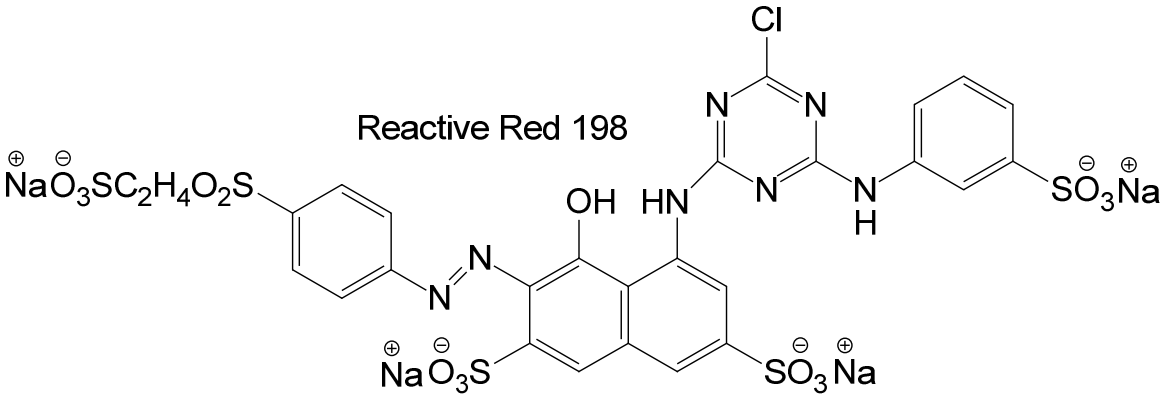


Reactive Violet 5

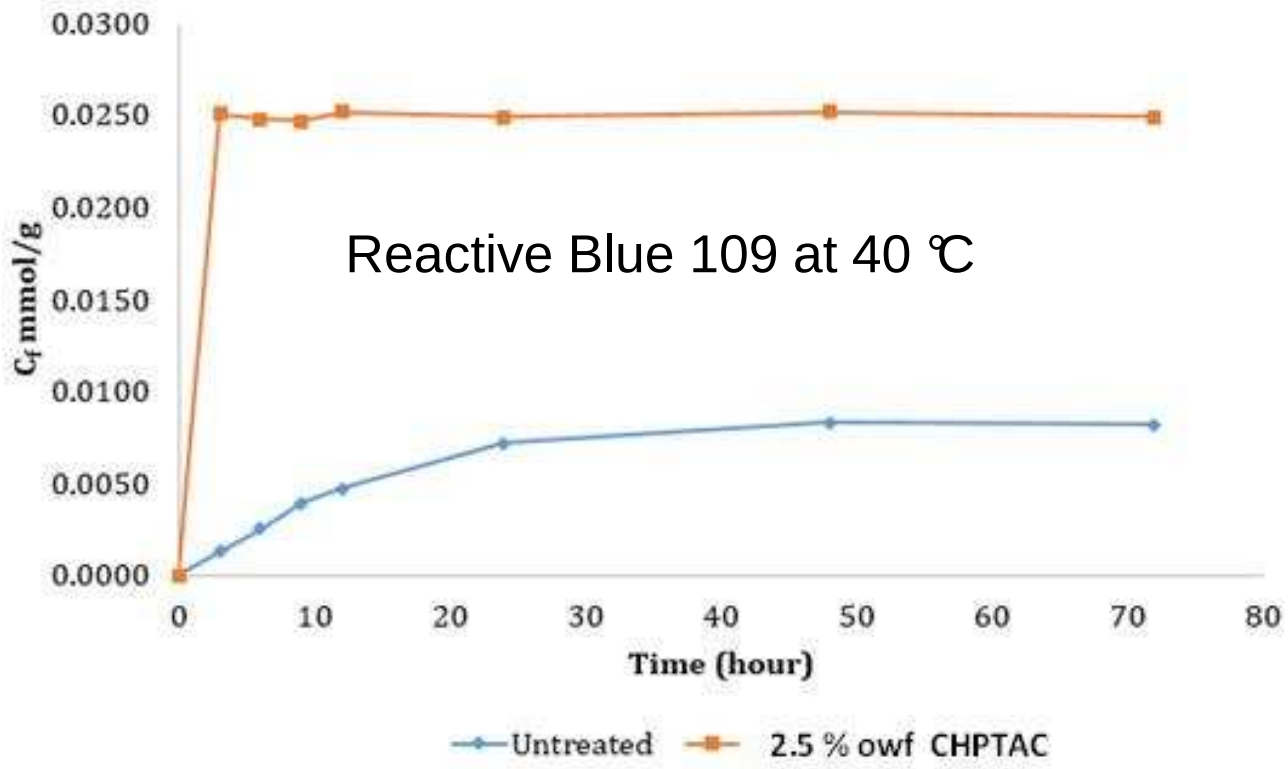
Reactive Red 11



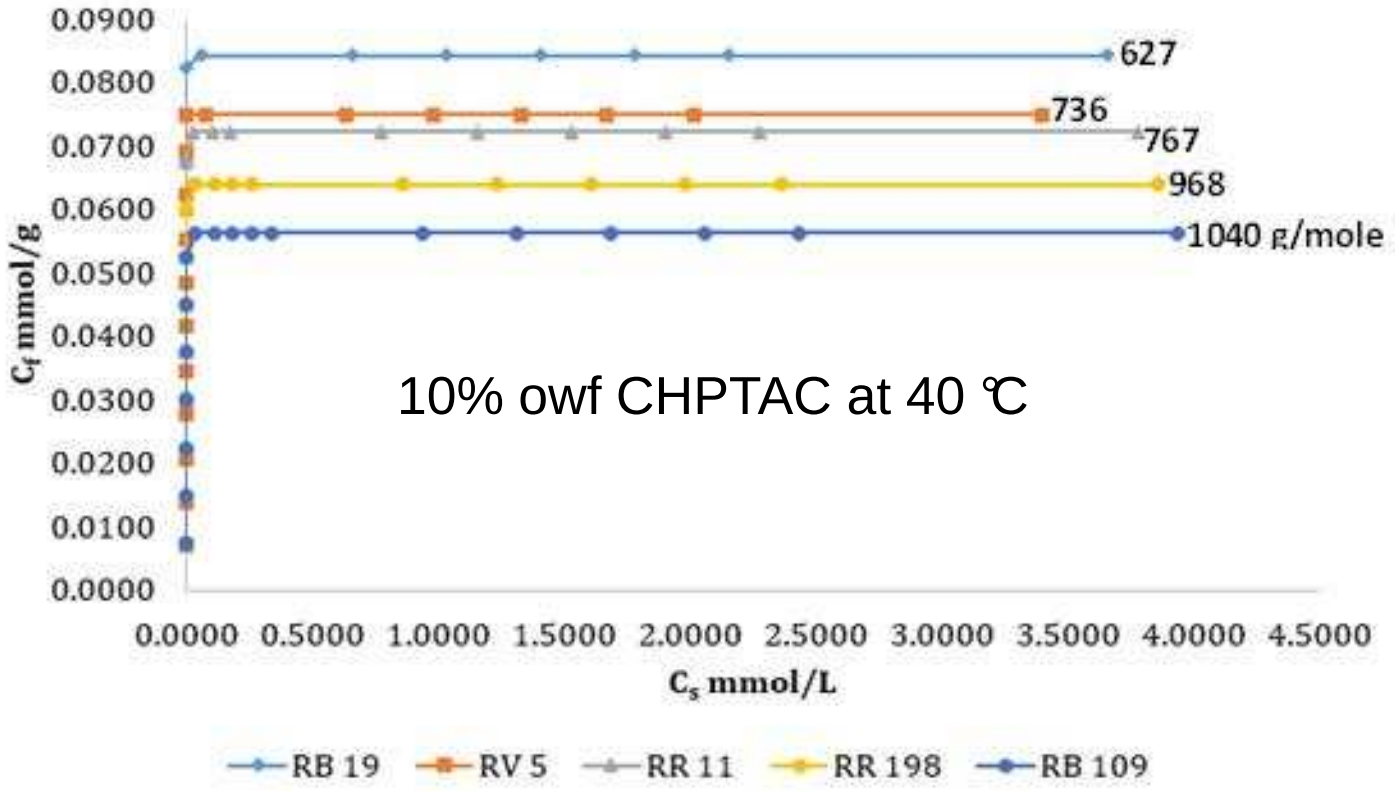
Reactive Red 198



Equilibrium Adsorption Results



Equilibrium Adsorption Results



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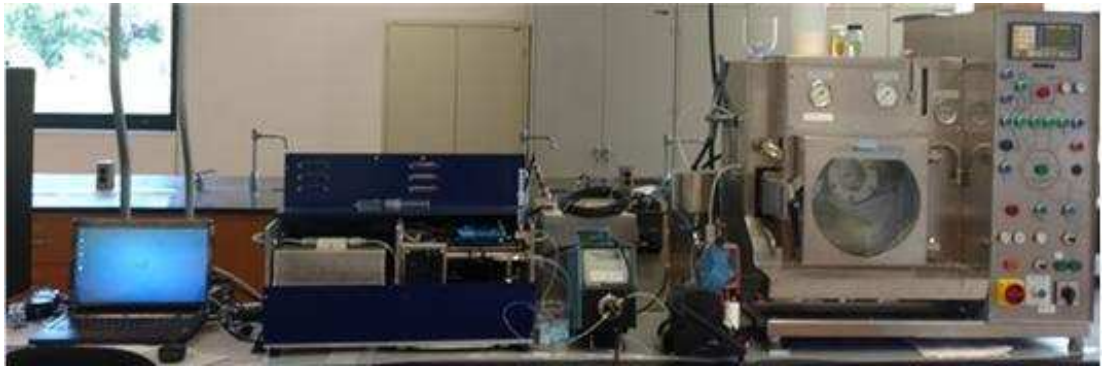
Dye Exhaustion

- Mathis JFL dyeing machine with HueMetrix monitoring system



  - Dye concentrations adjusted to give equimolar dyeings
  - No salt with cationized dyeings
  - Recommended alkali amounts

Dye Exhaustion Results

	% Exhaustion				
Cotton Fabric	1.81 % owf Reactive Blue 19 627 g/mole	2.12 % owf Reactive Violet 5 736 g/mole	2.21% owf Reactive Red 11 767 g/mole	2.79 % owf Reactive Red 198 968 g/mole	3.00 % owf Reactive Blue 109 1040 g/mole
Untreated Cotton	82.6	69.6	70.4	65.9	61.2
2.5 % owf CHPTAC Cotton	66.2	59.0	61.3	53.2	50.3
5.0 % owf CHPTAC Cotton	90.8	81.7	83.2	70.4	58.7
10.0 % owf CHPTAC Cotton	98.1	94.2	92.4	89.6	85.2

Color Matching with Cationized Cotton

- Existing color primaries give poor matches on cationized cotton

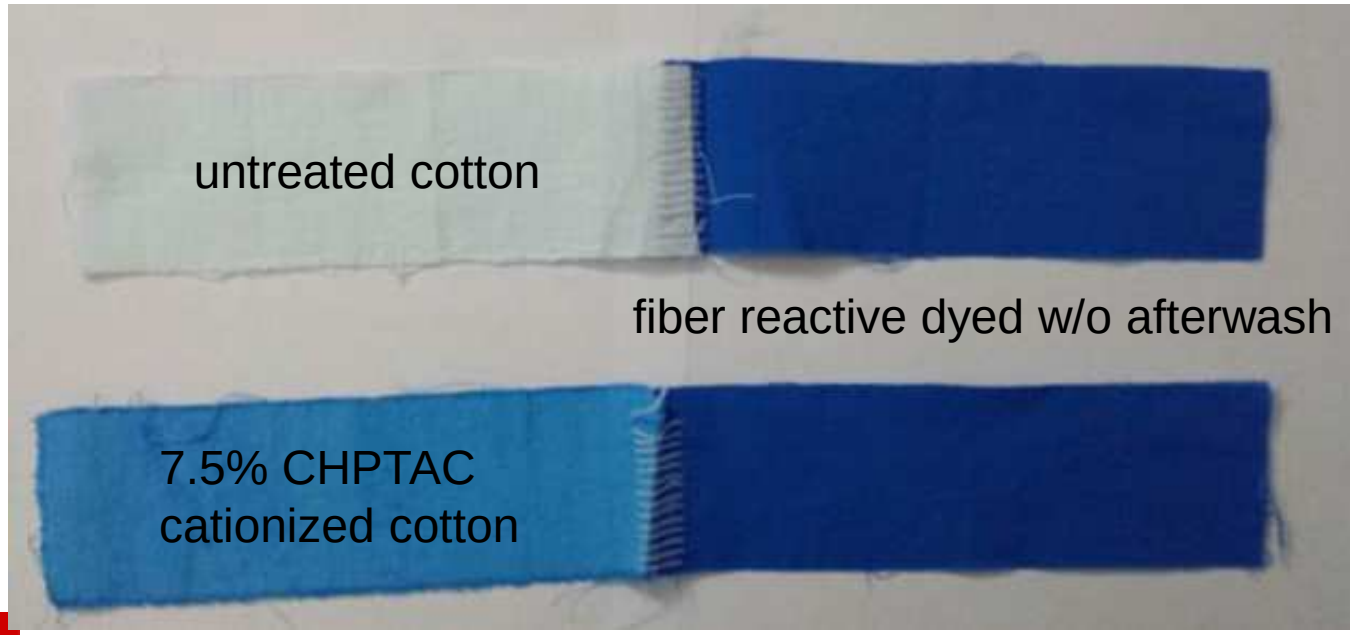
- Color primaries developed with cationized cotton provide closer matches on cationized cotton

Color Matching with Cationized Cotton

	Shade One		Shade Two		Shade Three	
	Conventional Primaries	Cationized Primaries	Conventional Primaries	Cationized Primaries	Conventional Primaries	Cationized Primaries
% dye	0.324	0.315	0.814	0.718	2.43	1.18
ΔEcmc	4.22	1.20	2.06	0.68	4.70	2.09

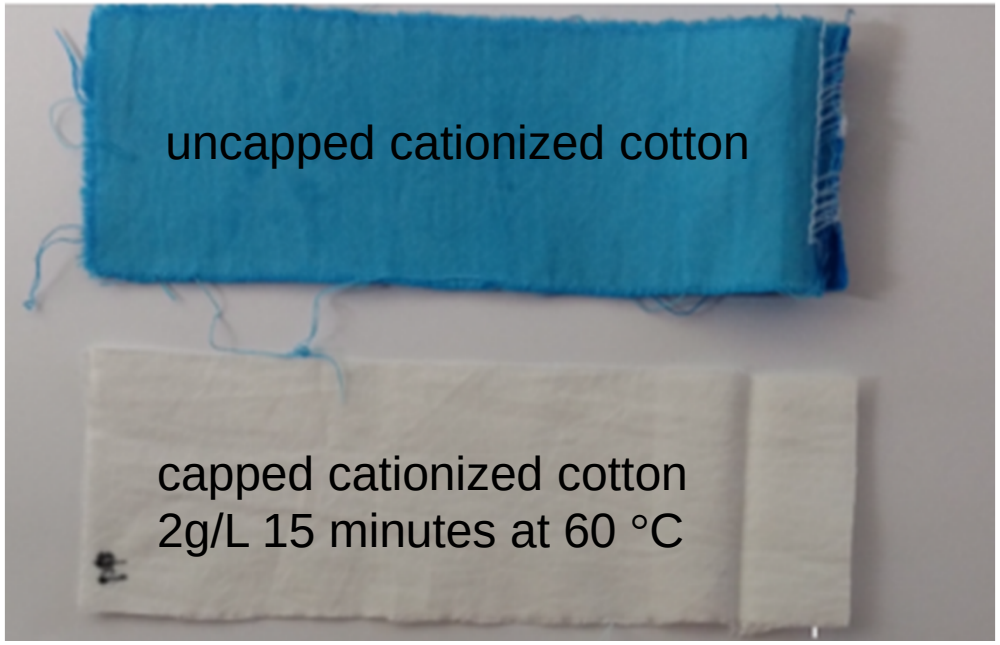
Capping Excess Dye Sites

- Dye transfer during AATCC TM 61-2A



Capping Excess Dye Sites

- Sera Fast N-HF-01 (high molecular sulfonic acid)



Printing Cationized Cotton

- Screen printing of pigments
  - Improved wash fastness
- Screen printing of direct dyes
  - Excellent wash fastness
- Inkjet printing of fiber reactive dyes
  - Increased color yield and outline sharpness
  - Reduced steaming and wash off time
- Concerns with white ground staining

Commercially Viable Cationized Cotton

- Lower cost approach to more sustainable cotton dyeing
- Leveling concerns
  - Leveling agents available
  - Match dye sites and dye concentrations
- Color matching
  - New color primaries
  - Select dyes with similar exhaustion rates
- Color transfer
  - Capping agents available

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Thank you for your attention.

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