Measurement and Quality of Wool Mordant Effluent

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Background and Purpose. Potassium aluminum sulfate (PAS) is one of the most commonly used mordants for animal fibers and is considered relatively non-toxic (Cardon, 2007; Sigma-Aldrich, 2015). However, there is concern regarding the toxicity of residual metal ions from the mordant effluent, which in high concentrations can harm aquatic life and human health (Rosseland et al., 1990; Shahid & Mohammad, 2013). Thus, the purpose of the study was to determine the amount of Al ions being disposed from mordanting procedure of two substrates, wool challis fabric and wool yarn. Three mordant concentrations, 7%, 12%, and 17% by the weight of fiber (wof) were examined. The effluent characteristics of chemical oxygen demand (COD) and total organic carbon (TOC) were also measured. Findings were compared to against disposal, discharge, and output standards and regulations.

Methods and Analysis. ASTM D5673-16 Inductively Coupled Plasma Mass Spectrometry was used to measure the Al ions in the treated liquors and in the substrates (American Society for Testing and Materials, 2016). COD and TOC were measured using the COD 8000 method from Hach (2019) and the Shimadzu TOC analyzer (Shimadzu Corporation, 2018). To determine the amount and distribution of Al ions in total liquor (400 ml) across the pre-mordanting process, the following equation was used: Control Liquor = Treated Liquor + Treated Substrate + Rinse Water + Environmental Loss. Two sample t-test and one way analysis of variance were used for statistical analysis.

Results and Discussion. For the wool fabric, the percentage of Al remaining in the substrate decreased with an increase in PAS, that is 62%, 39%, and 30% Al respective of the PAS concentration owf at 7%, 12%, and 17%. See Table 1. The wool yarn had a similar trend but also had more Al distribution in the treated liquor, rinse water, and environmental loss. The results are similar to Chan et al., (2002). In contrast, the amounts of Al being disposed are much lower than other research reporting over 90% of Al in the wastewater (Glover & Pierce, 1993; Koestler et al., 1985; Saha et al., 2019; Smith & Wagner, 1991).The wool yarn absorbed a significantly lower ($p<0.050$) percentage of Al than the wool challis. This unexpected result may have been due to the sport yarn density and the challis crimped and wavy structure. With the increase of the PAS mordant concentration, the percentage of Al ions detected in the substrates decreased significantly and the Al ions percentage significantly increased in the treated liquors. Thus, the 7% owf PAS concentration was significantly more efficient ($p<0.050$) compared to the often recommended 12% concentration.

Table 1. *Aluminum Distribution across the Mordant Conditions for Wool Challis and Kona Sport Yarn (8000 mg samples)*

PAS	Mean AL mg									
mg (% wof)	Control liquor[a]	Treated liquor[b] (percentage)[d]		Treated Substrate (percentage)[d]		Rinse Water[c]		Environmental Loss	
		Fabric	Yarn	Fabric	Yarn	Fabric	Yarn	Fabric	Yarn
560 (7)	32.14	11.52 (35.84)	8.52 (26.51)	19.93 (62.01)	13.90 (43.25)	0.00	4.08	2.07	5.71
960 (12)	73.35	39.85 (54.33)	42.65 (58.15)	28.52 (38.88)	14.53 (19.91)	0.00	8.0	4.98	8.17
1360 (17)	100.02	65.32 (65.30)	68.44 (68.43)	29.95 (29.94)	16.99 (16.99)	0.00	8.08	2.76	6.52

Note. [a] Control liquors are mg/315 ml. [b] Treated liquors are mg/310 ml. [c] Rinse water are in mg/400 ml. [d] Percentage was calculated as dividing the treatment by the control.

The COD and TOC values are reported in (Table 2). While the results meet disposal standards and regulations, the pH does not.

Table 2. *COD, TOC and pH Values in PAS Mordant Treated Liquors*

PAS % wof	COD values (mg/L)		TOC values (mg/L)		pH value	
	Fabric treated liquors	Yarn treated liquors	Fabric treated liquors	Yarn treated liquors	Before mordant treatment	After mordant treatment
7	53.00	95.13	26.01	41.78	3.70	3.50
12	70.37	94.63	30.92	36.17		
17	66.67	80.8	38.83	35.12		

Conclusions and Implications. Without any further dilution, the Al amounts in the effluent are below the U.S. EPA 2017 Aquatic Life Ambient Water Quality Criteria for Aluminum in Freshwater's acute limit of 1,400 mg/L and chronic limit of 390 mg/L. The findings suggest that a lower PAS mordant concentration than the commonly used 12% wof can be used for mordanting wool fibers. The TOC and COD values of the effluents met the Code of Federal Regulations (2014) for textile mill effluent discharge and the Global Organic Textile Standard (2017) limits as output; however, dilution and neutralization are required before disposing of the effluents. In addition, the pH did not meet the US EPA 2017 Aquatic Life Ambient Water Quality Criteria (pH=7.0) for Aluminum in Freshwater. Thus, natural dyers should not dispose of the effluent to the ground or in standing water. However, the effluent can be drained through the sink after neutralizing as the COD is below the discharge limit to U.S. sewage systems. Overall, this research supports the use of PAS as a mordant for the selected wool substrates, when the effluent is neutralized. Further studies could investigate lower concentrations of PAS, the feasibility of reusing the treated liquors, and the impact of PAS amount to dye color parameters.

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