Enzyme, Bleaching, & Solvent Treatments for Removing Oxidized Linseed Oil from Paper

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INTRODUCTION

Many contemporary works of art on paper have the problem of oil stains halting the image. The prints that initiated this project are located at the National Gallery of Canada (NGC) in the Prints and Drawings collection. All of the Warhol Mao series (1972) collected at the NGC have severe stains that disrupt the visual image. This staining is believed to be from oil migration from paint to paper since the purchase of each series in 1973. The degradation is most likely linseed oil, the drying oil used in screen printing inks. This project reproduced the artworks’ degradation by saturating 20 samples with cold-pressed linseed oil, then were artificially aged until the oil oxidized. Three treatments (bleaching, solvent, and enzyme) were evaluated on their effectiveness of reducing the oil staining. Previous research suggests that oil saturated paper does not degrade once the oil has oxidized. This research project, however, has concluded that non-oxidized and oxidized oil are both degrade paper while visually disrupting the image. A bleaching treatment with sodium borohydride was successful in reducing the linseed oil and staining.

EXPERIMENTAL: MATERIALS

- 20 Samples (11.0 cm x 5.0 cm)
- Beckett Expressions Radiance (120c)
- Gamblin Cold-Pressed Linseed Oil
- Heat & Thermal Artificial Aging for 64 Hours
- Analysis Conducted:
  - Before Aging, After Aging, and After Treatment
  1) Digital Photography
  2) Fourier Transform Infrared Spectroscopy (FTIR)
  3) Colorimetry
  4) Microscopy
  5) Fold Endurance
  6) Phloroglucinol

- Treatments:
  Bleaching
  1) 11% Sodium Borohydride (NaBH₄) in 1:1 Ethanol (EtOH)/Water (H₂O)
  2) 5% NaBH₄ in H₂O Solvent
  3) Trichloroethylene (C₂HCl₃) + 0.1% Sodium Hydroxide (NaOH)
  4) Enzyme
  5) Lipase in 1% Methylcellulose Poulitce (pH 7.0)

RESULTS OF FTIR

- The decreasing spectra between 1900 cm⁻¹ and 1200 cm⁻¹ shows a decline in intensity of cis-trans isomerization, a result of polymerization and oxidation.
- Oxidation occurred at 64 hours under the conditions of 450 nm at 45°C and 65 W/m² in the O-Sun Test Chamber.

RESULTS OF MICROSCOPY

- Bleaching reduced the amount of linseed oil on the fibers without physically damaging the fibers better than enzyme or solvent treatments.

RESULTS OF COLOREIMETRY

- Lightness (L*) bleaching treatment at 5% was closest to original paper; although, all three treatments would be successful.
- Bleaching treatment reduced the yellow (b*) of the treated sample.
- Aged linseed oil sample was closer to original color than the non-aged.

RESULTS OF FOLD ENDURANCE

- The control sample had a paper strength 2106% more than the saturated samples.
- The blank non-aged samples had an average fold of 3.
- Aging the blank samples reduced the average fold count to 5.
- The saturated sample had an average fold of 15.
- The saturated and aged samples had an average fold of 2.
- Treatment with 5% sodium borohydride did not reduce the paper strength.
- Lipase did not reduce the paper strength significantly.
- Fold endurance tests could not be conducted on the solvent treated samples because of swelling and planar deformation.

CONCLUSIONS

Cold-pressed linseed oil oxidizes over a long period of time; unless, it is not kept in a controlled environment. Heat and UV light will expedite the oxidation of linseed oil. This research has shown that cold-pressed linseed oil saturated in paper is harmful whether it is oxidized or not. There was no method found to fully remove the oxidized linseed oil from the paper; but, the staining and oil can be reduced by bleaching with sodium borohydride in concentrations of 0.5% to 5%. (The higher the concentration the more effective the treatment.) The application of the bleach should be conducted on a suction table to reduce planar deformation of the paper substrate. The solvent and enzyme treatments were not effective; although, lipase did remove superficial oxidized linseed oil. Further research needs to be conducted such as: analysis on the actual artwork, different concentrations of successful treatments, and more scientific analysis on the successful treatments (scanning electron microscopy, degree of polymerization, and gas chromatography).