

5) 洋紙作品の安定化処理および修理

はじめに

東京国立博物館は陸前高田市立博物館が所蔵する絵画作品の安定化処理と修理を行っています。対象作品は東北地方太平洋沖地震による大津波で被災したもので、その中の洋紙作品（版画、水彩画、アクリル画等）作業に従事しました。2013年から、効果的な安定化方法を模索して様々な実験を行ってきました。そして現在、その結果に基づき少しずつ作品の処置をしています。ここではこれまでの実験で得られた情報を中心に現段階での安定化処理状況を報告します。

作品の状況

対象となる洋紙作品はすべて、2011年3月11日に被災後、同年8～9月にかけて全国美術館会議の主導でエタノール、TBZによる殺菌、ドライクリーニング等の応急処置が施されています。それから約3年間は岩手県立美術館収蔵庫内の安定した環境で保管されていたため、状態に大きな変化はなかったと思われます。作品群に共通してみられる損傷は海水、汚水に浸水したことによる黴、シミ、変形です。特に黴の発生により、黒、茶色、薄いピンク色や黄色など様々な色素が固着しました。シミは主に泥水や錆、テープ痕、他の作品から溶解した色材の付着などです。

安定化処理のための実験

5) Stabilization and Repair of Artworks on Modern Paper

Introduction

The Tokyo National Museum has been working on stabilizing and repairing the RTCM's collection of artwork damaged by the tsunami in 2011. We are engaged in the treatment of artwork on modern paper (prints, watercolor paintings, and acrylic paintings). Researching for effective stabilization methods, we have been conducting various experiments since 2013. Based on the results of these experiments, we are currently treating the artwork carefully. Focusing on the data obtained from the experiments, our current stabilization treatment is described in this section.

Artwork condition

For all damaged artwork on modern paper involved in this project, temporary treatments, including sterilization with ethanol or TBZ and dry cleaning, were performed from August through September 2011 under the guidance of the Japanese Council of Art Museums. Since they were stored in a stable environment at the repository of the Iwate Museum of Art for approximately three years after treatment, it is assumed that no significant change has occurred in the condition of the artwork. Common damage to the artwork was mold, stains and deformation caused by being soaked in seawater and contaminated water. Pigments of various colors such as black, brown, light pink, and yellow have affixed to the drawings because of mold. The stains include those caused by muddy water and rust, tape marks, and the attachment of colored material that dissolved from other works of art.

Experiments conducted in preparation for stabilization

One of the most effective methods for stabilizing artwork on modern paper is washing with water. By running water through the artwork, contaminants remaining in the fibers of the paper are washed away. This method was employed to remove

水を用いた洗浄は洋紙作品修理の最も有効な方法の1つで水を通して紙の繊維内に残留した汚れを洗い流すことができます。残留した塩分を除去するためにこの方法を用いました。脱塩後の廃液に残留する塩化物イオン濃度の目標値は6ppmに設定しました。作品自体に残留する塩分の計測は蛍光X線分析及び塩化物試験紙を用いました。塩化物試験紙の目盛りは0.2刻みで1～10まであります。測定可能な最小値は1.2(ppmに換算するとNaClは50ppm、Cl⁻は30ppm)です。水道水を測定すると目盛り1以下に設定しました。実験の手順は以下のとおりです。

実験の手順

- ①オリジナル作品中に残留した塩素を蛍光X線分析装置で分析。
- ②作品と同じ種類の紙（紙：BBケント紙）を入手し、人工海水（人工海水マリンソルト200L用・株式会社カイスイマレン）に浸漬後乾燥させてテストピースを作成。
- ③実験前のテストピースの塩素を蛍光X線分析装置で分析。塩化物試験紙（Chloride QuanTab® Test Strips, 30-600mg/L, Titrators for Chloride Low Range・HACH社）でも計測（画面側の9ヶ所）。
- ④上記のテストピースを使用し、以下のa.～g.の方法で各々実験。繰り返す度に塩化物試験紙で塩化物イオン濃度を測定。
- ⑤実験後のテストピースを蛍光X線で分析。
 - a. サクション法：画面側を上にし、サクシオンテーブルで5分間吸引しつつ3分間水300mlを全体に噴霧するこ

residual salt. The target value for the concentration of residual chloride ions in the discharged liquid from the desalination process was set at 6 ppm. Salt remaining in the artwork itself was measured by employing fluorescent X-ray analysis and chloride test strips. The scale of the chloride test strip ranges from 1 to 10 with increments of 0.2. The minimum value that can be measured is 1.2 (50 ppm for NaCl and 30 ppm for Cl⁻). The chloride test strip indicated scale 1 for tap water. Thus, the target value on the test strip was set at scale 1 or less. The experimental procedure is explained below.

Experiment procedure

- (1) Chlorine remaining in the artwork was analyzed by an X-ray fluorescence analyzer.
- (2) The same type of paper used for the original artwork (BB Kent paper) was obtained. Sheets of this paper were soaked in artificial seawater ("Marine-Salt for 200L"; Kaisuimaren Co., Ltd.) and then dried to create test pieces.
- (3) Chlorine in the pre-experiment test pieces was analyzed using an X-ray fluorescence analyzer. It was also measured by chloride test strips (Chloride QuanTab® Test Strips, 30-600 mg/L, Titrators for Chloride Low Range; Hack Company) at 9 points on the front side of the test pieces.
- (4) Experiments were conducted using these test pieces by employing the following methods a. through g. Each time a treatment was repeated, the chloride ion concentration was measured using chloride test strips.
- (5) Post-experiment test pieces were analyzed by fluorescent X-ray.

a. Suction Method: A test piece was placed on a suction table with its front side facing up. While suctioning for five minutes, the entire test piece was misted with 300 ml of water for three minutes. This process was performed repeatedly.

b. Blotting Method: A test piece was placed on a piece of blotting paper, which had been soaked with a considerable amount of water, with its front side facing up, and left for 10 minutes. This process was performed repeatedly (the blotting

表1 洗浄法の比較実験結果 Table 1 Results of a comparative experiment of washing methods

方法 Test name	実験前の噴霧 処理 ¹⁾ Misting prior to the experiment ¹⁾	備考 Remark	実験回数 Number of experiments	所要時間 (分) Experiment time (min.)	塩分濃度 (単位: 目盛数) ²⁾ Salinity concentration ²⁾ (unit: strip scale)	
					実験前 Pre-experiment	最終回 Last measurement
a サククション法 Suction Method	W	4回で0に近くなる。 Came close to 0 after 4 treatments.	4	20	10	0.02
	E	2回で0に近くなる。 Came close to 0 after 2 treatments.	2	10	7	0.02
b ブロットイング法 Blotting Method	W	4回である程度減少しその後横ばい。 Concentration was reduced to a certain extent after 4 treatments and then the values leveled out.	6	60	9	1.1
	E	3回である程度減少しその後横ばい。 Concentration was reduced to a certain extent after 3 treatments and then the values leveled out.	7	70	9	1.24
c 浸漬法 (10分間) Soaking Method (10 min.)	W	4回で0になる。 Reached 0 after 4 treatments.	4	40	2.8	0
	E	2回で0になる。 Reached 0 after 2 treatments.	2	20	2.11	0
d 短時間浸漬法 (3分間) Short Duration Soaking Method (3 min.)	E	4回で0に近くなる。 Came close to 0 after 4 treatments.	4	12	10	0.26
e 温水浸漬法 Warm Water Soaking Method (25°C, 30°C, 35°C and 40°C)	E	2回で微量になり、その後横ばい。温度による差はほとんど見られない。 Concentration was reduced considerably after 2 treatments and then the values leveled out. Differences in temperature had little effect on the outcome.	2	20-30	9.53	0.86
f 温水噴霧+サククション法 Warm Water Misting + Suction Method (25°C, 30°C, 35°C and 40°C)	E	3回で0に近くなる。温度による差はほとんど見られない。 Came close to 0 after 3 treatments. Differences in temperature had little effect on the outcome.	3	15	9.85	0.12
g 流水法 Running Water Method	W	2回である程度減少するがそれ以降横ばい。 Concentration was reduced by a certain extent after 2 treatments and then the values leveled out.	3	15	10	0.55
	E	2回である程度減少するがそれ以降横ばい。 Concentration was reduced by a certain extent after 2 treatments and then the values leveled out.	4	20	10	0.93

- 1) E: 実験前に40%のエタノール水溶液を噴霧。 W: 実験前に純水を噴霧。
 2) 塩化物試験紙による塩分濃度測定結果 (数字は目盛数の測定箇所全体での平均値)。
 1) E: 40% ethanol was sprayed prior to the experiment. W: Deionized water was sprayed prior to the experiment.
 2) Results of salinity concentration measurement using chloride test strips (values are the average of the results of the entire area measured).

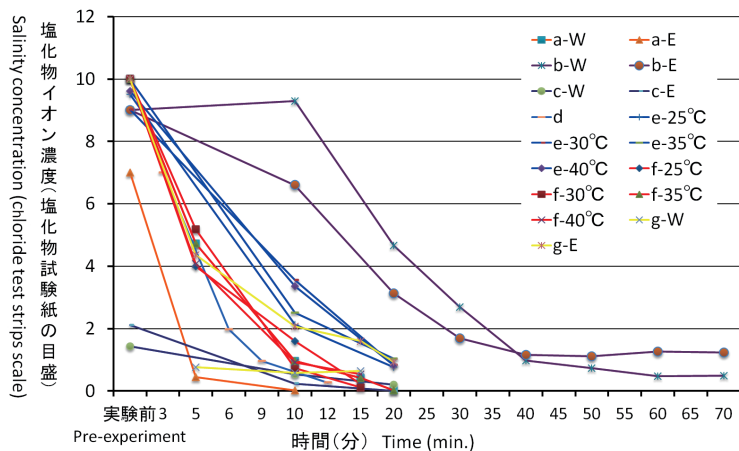


図1 塩化物イオン濃度と脱塩時間の関係
 Fig. 1 Relationship between chloride ion concentration and desalination time

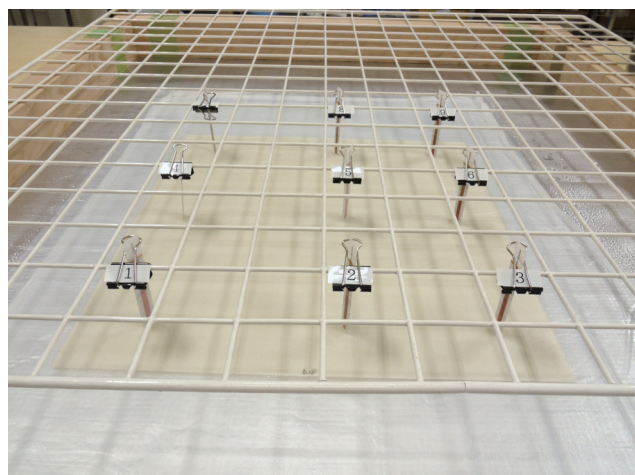


図2 塩化物試験紙による計測実験
 Fig. 2 Experiment using chloride test strips



図3 ハンディイオンメータで塩化物イオン濃度を計測
 Fig. 3 Measuring chloride ion concentration using a Handy Ion Meter

とを繰り返す。 b. プロットイング法：十分な量の水で濡らした吸取紙の上に画面側を上にしてのせ、10分間おくことを繰り返す（吸取紙は毎回交換）。 c. 浸漬法（10分間）：3Lの水に10分間浸漬を繰り返す。 d. 短時間浸漬法（3分間）：3Lの水に3分間浸漬を繰り返す。 e. 温水浸漬法：25℃・30℃・35℃・40℃の温水3Lに各々10分間浸漬を繰り返す。 f. 温水噴霧＋サクション法：4枚のテストピース各々に25℃・30℃・35℃・40℃の温水を噴霧し、各々サクションテーブルで5分間吸引しつつ3分間水300mlを全体に噴霧することを繰り返す。 g. 流水法：バットに20L水を貯めた中にテストピースを浸漬し、その中に1分間に100mlの勢いで水を流し続け5分ごとに引き上げる。

なお、いずれの方法も処理前にエタノール40%水溶液を噴霧しました。また、a～cおよびgについては処理前に純水を噴霧する方法でも実験を行いました。

実験結果

実験の結果、「短時間浸漬法」が最も早く確実に脱塩できることがわかりました(表1)。また、浸漬の前にエタノール水溶液を噴霧すると紙の繊維の中まで水が入り、脱塩効果が高まると同時に時間を短縮できました。

実際の安定化処理と修理

作品はリトグラフで、水に溶解しないインクだったため短時間浸漬法で安定化処理を行いました。手順は次の

paper was replaced each time).

c. Soaking Method (10 minutes): A test piece was soaked in 3 L of water for 10 minutes. This process was performed repeatedly.

d. Short Duration Soaking Method (3 minutes): The process of soaking a test piece in 3 L of water for three minutes was performed repeatedly.

e. Warm Water Soaking Method: Test pieces were soaked in 3 L of water at temperatures of 25, 30, 35, and 40°C for 10 minutes, respectively. This process was performed repeatedly.

f. Warm Water Misting + Suction Method: Four test pieces were misted with warm water at temperatures of 25, 30, 35, or 40°C. Then, while suctioning for five minutes using a suction table, the entire area of test pieces was misted with 300 ml of water for three minutes. This process was performed repeatedly.

g. Running Water Method: A test piece was placed in a tray filled with 20 L of water. Then water was continuously supplied to this tray at a speed of 100 ml per minute. The test piece was removed every 5 minutes.

A 40% ethanol solution or deionized water was misted before each method.

Results of the experiment

The results of these experiments showed that the Short Duration Soaking Method was the fastest and most reliable method for desalination of the test pieces (Table 1). It was also found that desalination efficiency improved and the required time is reduced when the test pieces were sprayed with a 40% ethanol solution prior to soaking.

Actual stabilization and repair

A disaster-damaged lithograph was treated. Since ink that is insoluble in water had been used, the drawing was stabilized using the Short Duration Soaking Method. The following procedure was employed: (1) the drawing was cleaned in a dry

とおりです。①練り消しゴムで乾式洗浄 ②作品裏面からエタノール水溶液を噴霧し水の浸透性を高め、短時間浸漬法を5回繰り返す ③pH9に調整した水酸化カルシウムで脱酸処置（フロート法）④過酸化水素水、水素化ホウ素ナトリウムで黴とシミを漂白 ⑤水洗後上記と同様の方法で脱酸 ⑥加圧乾燥で変形修正

安定化処理および修理の結果と効果

短時間浸漬法では1回ごとに、脱塩時の廃液の塩化物イオン濃度を測定器（ハンディ塩素イオンメータTiN-5102I・株式会社東興化学研究所）で計測しました。1回目は117ppmでしたが、5回目は0.69ppmに下がりました。塩化物試験紙では目盛0でした。実験をふまえた実践でも十分な効果があることがわかりました。

黴の漂白では、黒色部位は完全には除去できませんでしたが、部分的に薄くなるものもありました。薄い茶色や黄色、ピンク色などの色素には有効でした。全体に波打つような変形は加湿後加圧乾燥することにより、本来の自然な形状に戻りました。シミは今回の作品には見られなかったため、今後の作業で研究を進める予定です。

本実験には西原紀恵氏（絵画修復家）、土屋裕子氏、和田浩氏、神庭信幸氏（東京国立博物館）、山領まり氏（絵画修復家）が参加しました。

米倉乙世（紙・書籍保存修復技術者）

state using a kneaded eraser; (2) the drawing was sprayed from the back with an ethanol solution to enhance water permeability, and then treated with the Short Duration Soaking Method. This was repeated five times; (3) deoxidation (float method) was performed using calcium hydroxide adjusted to pH9; (4) mold and stains were bleached using a hydrogen peroxide solution and sodium borohydride; (5) after washing with water, the drawing was deoxidized using the above described method; and (6) deformation was corrected by press drying.

Results and outcome of stabilization and repair work

While performing the Short Duration Soaking Method, the concentration of chloride ion in the desalination discharged liquid was measured after each treatment using Handy Chlorine Ion Meter TiN-5102i (TOKO Kagaku Co., Ltd.). The concentration level was 117 ppm at the first measurement, and was reduced to 0.69 ppm at the fifth measurement. The chloride test strip indicated a scale reading of 0. Thus, it was found that this method was also sufficiently effective on the original artwork.

After bleaching the mold, the black stains could not be removed completely, but the color partially faded. The bleaching treatment was effective for removing light brown, yellow, pink, and stains of other colors too.

The wave-like deformation of the entire artwork was returned to its original, natural form by press drying after dampening it. Although stains were not observed in this artwork, experiments for removing stains will be required for future treatment.

The experiments were performed by the author Ootoyo Yonekura, Norie Nishihara (painting conservator), Yuko Tsuchiya, Hiroshi Wada, Nobuyuki Kamba (Tokyo National Museum) and Mari Yamaryo (painting conservator).

Ootoyo Yonekura (Paper & Book Conservator)



図4 短時間浸漬法：水を張ったバットに順に浸漬する
Fig. 4 Short Duration Soaking Method: The artifacts are soaked one by one in a series of water-filled trays

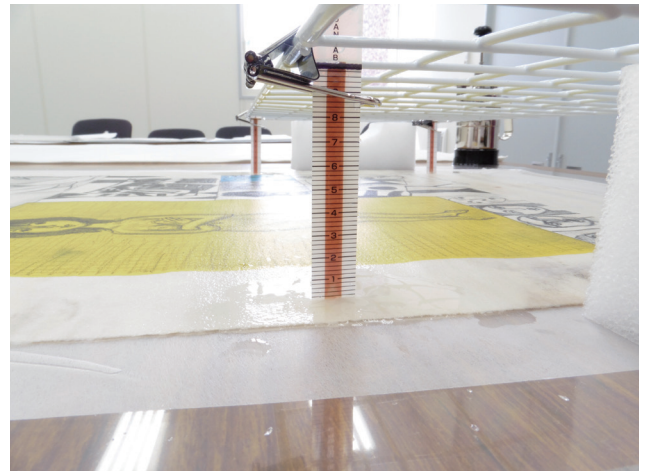


図5 塩化物試験紙で、作品に残留した塩化物イオン濃度を測定する
Fig. 5 Concentration of chloride ions remaining in the artifact is measured using chloride test strips

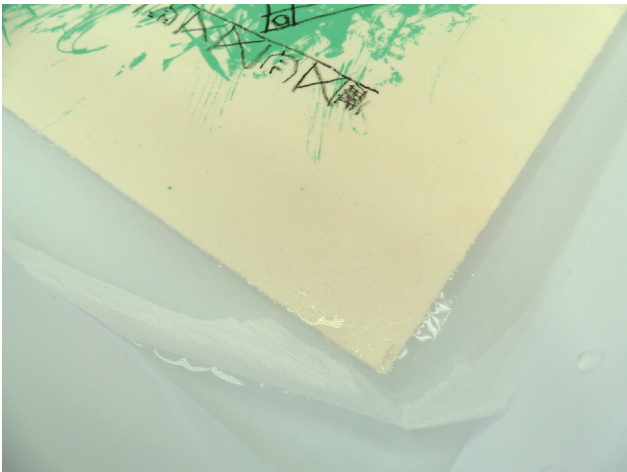


図6 フロート法で脱酸処置する
Fig. 6 Deoxidation using the float method



図7 漂白作業
Fig. 7 Bleaching process



図8 漂白前の黴（部分）
Fig. 8 Pre-bleaching mold on artwork (partial)



図9 漂白後の黴（図8と同じ部分）
Fig. 9 Post-bleaching mold on artwork (same area as Fig. 8)