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**19. BLEACHING**

Oxidation or reduction of discoloration within paper supports.

**19.1 Purpose**

Primarily one of restoration i.e., generally a cosmetic procedure used to diminish discoloration which severely interferes with the visual integrity or original tone of the object, but which cannot be diminished in any other relatively safe manner. Less frequently, bleaching might be used to remove staining material which is contributing to accelerated deterioration of the object (e.g., stains containing iron, oils, etc.). In this second instance, bleaching may in some ways improve the relative permanence of the paper.

**19.2 Factors to Consider****19.2.1 Extent to Which the Same Effect can be Achieved with Another Method Believed to be Safer**

(Note: Since the potential for damage varies with the bleach, alternate treatment method and object under consideration, it is important to evaluate each combination separately.)

- A. Extent to which the object can be subjected to washing, alkaline baths, solvent treatment, enzyme treatment, etc.; for example, some stains such as foxing and mat burns can be lessened visually with alkaline solutions, like calcium hydroxide or ammonium hydroxide, which solubilize components of discoloration or swell fibers to allow greater diffusion through washing.
- B. Effectiveness of prior washing, alkaline baths, solvent treatment, enzyme treatment, etc. in diminishing discolorations. (Often a stain does not need to be entirely eliminated to return a sense of visual integrity to the object.)

**19.2.2 Appropriateness of Bleaching for the Object**

- A. Nature of the image/object (historical, archival, fine art); historical relevance of the stain under consideration.
- B. Determination of original color, surface, or character of paper; it may be impossible to return an object uniformly to selected "original color", resulting in the balance of color being thrown off.
- C. Composition of paper (e.g., presence of lignin which can react with bleaches to alter tonality, etc.); sizings, fillers, colorants, or optical brighteners added to fibers which may also react with bleaches in undesired ways, etc.
- D. Degree of penetration or superficiality of discoloration.

- E. Location of discoloration (overall, local, etc.); it is often preferable to mask edge discolorations with overmatting, rather than subject object to bleaching procedure.
- F. Type of staining material. (Is it bleachable?)
- G. Effect of previous stain reduction treatment on bleaching material (e.g., residual alkalinity, enzymes, solvents).
- H. Extent to which object can withstand bleaching process, including washing, alkaline baths, and possible extreme shifts in pH.
- I. Extent to which media can withstand bleaching and subsequent washing.

### 19.2.3 Selection of Appropriate Bleach

- A. Risk to the object (i.e., change, degradation, etc.) and the conservator (i.e., health and safety); many bleaches are toxic to the conservator or may have a vigorous bubbling action which could disrupt paper surfaces.
- B. Compatibility of bleach with object.
- C. Appropriateness of bleach for a particular stain; not all bleaches work on all stains; there may even be variations with the same bleach and stain on different papers, or from spot to spot.
- D. Probable result on paper type and impact on original color, surface character, and physical and chemical properties of the substrate.

### 19.2.4 Control of Bleaching Process

- A. Rate of bleaching as a function of time and concentration; increase in chemical concentration reduces time of bleaching but increases risk of loss of control of treatment.
- B. Control of bleaching during bleaching process; removal of bleaching solution does not automatically halt bleaching action, sometimes secondary agents are required to stop or neutralize bleaching, followed by washing to remove all bleach residues.
- C. Disadvantages of differential bleaching when object is unevenly degraded, when masking out, or during local bleaching; this could lead to differential aging, color reversion and mottling.

- D. Recognition of the way the wetting of the paper affects the color of the stain; a wet stain often looks darker while wet than it does after drying, and this can lead to over-whitening or halos; similarly, colored solutions (whether due to solubilized colored materials or to the bleach itself) can mask the lightened color of an area during spot bleaching; frequent spot rinsing (in the case of local treatments) or lifting out of the bleach bath (in the case of immersion treatments) may be necessary to check on progress of stain removal.
- E. Consideration of bleaching action (due to chemical residues) during the washing process.
- F. Removal of chemically modified staining material by washing.
- G. Safety hazards of bleaching chemicals and methods; some bleaches are toxic or explosive and must be disposed of properly.

#### **19.2.5 Effects of Bleach on Paper Support and Media**

- A. Rate and amount of color reversion (yellowing) of the paper after bleaching, this may be difficult to ascertain.
- B. Rate and amount of return of discoloration to specific stained area.
- C. Effect or damage to fibers, media, color balance, or sizing by bleaching.
- D. Type and degree of change to the chemistry of the paper and image components.
- E. Effects of residual bleaching chemicals and staining materials left in paper, which can continue to interact.
- F. Effect of pH of bleach on paper and media.

#### **19.2.6 Bleach Disposal**

- A. Procedures for the safe disposal of bleaches are outlined in Manufacturer's Safety Data Sheets (MSDS). Each sheet is numbered by the manufacturer. The sheet number and procedural information may vary according to manufacturer or supplier. Examples of MSDS numbers and some manufacturers have been provided for each bleach listed.

### 19.3 Materials and Equipment

(Description of oxidizing and reducing bleaches and chemicals to eliminate bleach residues.)

#### 19.3.1 Oxidizing Bleaches

Oxidizing bleaches are chemicals which increase the oxidation state of staining materials and support, thereby increasing the solubility of stains and decreasing color intensity. The pH of the bleach (and consequently that of the artifact) has great influence on working properties of the bleach and on the chemical and physical effects of the treatment on the object.

##### A. Hydrogen Peroxide

Formula:  $\text{H}_2\text{O}_2$  (HOOH/HOO-).

Mechanism: Oxidation by active species HOO-.

Preparation: Reagent grade hydrogen peroxide is preferred; commercial hydrogen peroxide is acidic and usually too strong for use as a conservation bleach; it must be diluted and alkali added to increase the pH and obtain the concentration of HOO- which is sufficient to produce the desired bleaching effect; buffers may be added to the bleach solution in order to control the pH and stabilizers should be added to guard against the evolution of oxygen gas. Although many conservators prefer to make up fresh solutions periodically during the course of the treatment, this is not sufficient to guard against oxygen gas evolution and oxidation of the paper fibers; the decomposition occurs very rapidly and the stabilizers added by the manufacturer to the stock solutions is not sufficient to prevent decomposition of the alkalized, diluted working solution.

Disposal: MSDS #44B.

Application: Treatment of an object with  $\text{H}_2\text{O}_2$  can be aqueous, non-aqueous, or gaseous; application can be by immersion, suction table, floating, wet-blotter, spray, poultice, or brush techniques.  
 General:  $\text{H}_2\text{O}_2$  is sold in 30 or 50% solutions in  $\text{H}_2\text{O}$  which are very caustic and which should be stored in the refrigerator; 30% stock solutions can be diluted with water or an aqueous solution like  $\text{Mg}(\text{HCO}_3)_2$ ; opened bottles of peroxide should have a vent hole opened in bottle top to allow dissipation of  $\text{O}_2$  generated.

Working Conditions: Usually safest at concentrations of 3% or less. Solutions usually made up at pH of 10, 9, or 8 using the following buffer system to maintain pH hydroxide/carbonate/bicarbonate (pH 10), borate (pH 9), or phosphate buffer (pH 8); ammonia is often used to raise pH (especially for ether/peroxide

bleaching) but due to its volatile nature, pH may not be stable; bleaching action increases with increasing pH as does rate of degradation.

**Stabilization:** Can be fully stabilized with magnesium sulphate and silicates to avoid decomposition of the solution; chelating agents such as EDTA may also be used; some stabilization may also be observed when magnesium bicarbonate is used to dilute stock solution.

**Advantages:** Can decolorize wood pulp stains and mat burn; can convert darkened lead white to white lead sulfate (see **3. Media Problems**); only oxidizing bleach which can be used with lignin containing papers; bleaching action is more controllable than that obtained with chlorine bleaches; least reversion of all oxidizing bleaches (i.e., less yellowing after bleaching) although with ligneous papers reversion can still be rapid; fume hood not required unless used with ether.

**Disadvantages:** Should not be used on paper with conspicuous traces or stains of heavy metals (e.g., iron, copper) or their salts or oxides (can promote decomposition of bleach and increase mechanical and oxidative deterioration of paper); can degrade paper if improperly used or stabilized since  $H_2O_2$  may decompose to release oxygen gas; in some cases darkening of paper may occur and stain may return in a very short time, as little as a few months; oxygen gas evolution during immersion can blister short fibered, degraded, mold damaged, or thick, laminated papers; can sensitize paper to light if residues not removed; can bleach iron gall ink; hydrogen peroxide (or its by-products) and ether can be explosive, even at room temperature. This is a moderate to weak bleach which is not always effective on severe stains like foxing or mold stains.

## **B. Hypochlorites**

### **1. Calcium Hypochlorite**

Formula:  $CaOCl_2$ .

Mechanism: Chlorination and oxidation.

Preparation: Usually used in aqueous solutions; must be buffered to maintain alkaline pH during bleaching; do not mix with ammonia since chlorine gas is formed as a by-product.

Disposal: MSDS #68.

**Application:** Treatments are aqueous and can include immersion, suction table, floating, wet-blotter, spray, poultice, or brush application.

**General:** First used for bleaching discolored paper in 1789; working solutions are usually made directly by dissolving solid chemical in water; concentrated stock solutions can be made up, stored in the refrigerator, and diluted later; should be used in a fumehood; bulk chemical is stored as dry powder and has longer shelf life than sodium hypochlorite.

**Working Conditions:** Concentration should be no greater than 0.5%; a bath of pH 9.0 represents the best compromise between safety to object and bleaching power; buffer by chosen method (e.g., add boric acid and adjust pH with the addition of calcium hydroxide); paper degradation most rapid at near neutral pH and so bleach solutions near pH 7 must never be used; acidic objects must be neutralized or made alkaline (brought to above pH 7) before being placed in an alkaline bleach bath in order to prevent paper from passing through pH 7; a bleach bath should be kept at chosen pH during use; monitor with pH meter and combination electrode (alternatively, periodically replace bath with fresh solution).

**Advantages:** Hypochlorites are very effective stain removers and are especially effective for foxing; presence of calcium may protect against oxidation, especially in comparison with sodium salt.

**Disadvantages:** Commercial product contaminated with varying amounts of calcium carbonate and hydroxide; difficult to know exact concentration being used unless one has access to chemical analysis data; the extent of bleaching is difficult to control and may result in a paper looking greyer, cooler, or unnaturally white; should not be used if transition metal stains (e.g., iron or copper) are present since fiber damage is accelerated; the fast bleaching action can be difficult to control; proteins (albumin, gelatin, glues, etc., in sizes, consolidants, media and adhesives) react to form chloramines which are difficult to wash out with water; may dissolve carbohydrates such as starch sizes; may decrease strength of most papers, especially highly purified wood pulp; may oxidize certain media; can cause yellowing from oxidation; alkaline pH can effect image and/or paper; extensive washing after bleaching is required; cannot be used with ligneous papers; color reversion is a frequent problem.

**2. Sodium Hypochlorite**

Formula: NaOCl.

Mechanism: Chlorination and oxidation.

Preparation: Sold as liquid stock solutions which should be stored in refrigerator; dilute and buffer as for calcium hypochlorite stock solutions; do not mix with ammonia since chlorine gas is formed as a by-product.

Disposal: See **19.3.1 B. Calcium Hypochlorite.**

Application: Treatments are aqueous and can include immersion, suction table, floating, wet-blotter, spray, poultice, or brush application.

General: Buffering to maintain alkaline pH is especially important, since diluted working solutions will not contain enough buffering power to maintain desired pH; similar to calcium hypochlorite with respect to pH of working solution (usually around 9), type of buffer (borate), and concentration of bleach (see notes above).

Advantage: Very effective stain removers; able to remove foxing; it is easier to make up solutions because it is sold as a liquid.

Disadvantages: Stock solution has much shorter shelf life than solid calcium hypochlorite; has faster rate of reaction than calcium hypochlorite at same weight percent; otherwise, has similar disadvantages as calcium hypochlorite; rarely used because of presence of sodium salt and rapid bleaching and degradation of paper.

**C. Chloramine-T (N-chloro-p-toluenesulphonamide)**

Chloramine-B (N-chlorobenzenesulfonamido)

Formula:  $C_7H_7ClNNaO_2S$  (chloramine-T) $C_6H_5ClNNaO_2S$  (chloramine-B)

Mechanism: Solvent (water or alcohol) reacts with chloramine-T to release hypochlorite;  $OCl^-$  works by chlorination and oxidation.

Preparation: Solid chemical is dissolved in water or alcohol, preferably ethanol; no buffers or stabilizers required; do not mix with ammonia since chlorine gas is formed as a by-product.

Disposal: MSDS #23270 (Fluka).

**Application:** Treatment can be aqueous or non-aqueous; can use immersion, suction table, floating, wet-blotter, spray, poultice, or brush.

**General:** Introduced for bleaching paper in 1937; has fallen into almost complete disuse because of problems removing residues; concentration should not exceed 4% (traditionally used at 2%); self-buffers at around pH 9.0; active bleach concentration much less than same weight percent solution of pH 9 calcium or sodium hypochlorite; methanol should not be used as a solvent because of its toxicity; chloramine-B has similar action.

**Advantages:** Very controllable bleach; can be used in non-aqueous solvent with water sensitive media; solutions are easy to make up; self buffers to pH 9 (the safest pH for a "hypochlorite" type bleach); slowest and most controllable of the chlorine bleaches (therefore much less able to decolorize stains); can bleach mild oxidation stains and some mold stains.

**Disadvantages:** Has fallen into disuse after previous popularity because bleach complexes with inorganic salts (e.g., alum) and residues cannot be removed, even with extensive washing; bleaching can continue for months after treatment; bleaching action is not strong (e.g., foxing may be difficult to remove); similar problems as with other hypochlorite type bleaches with respect to degradation, although the problems are not as severe as with hypochlorites; alkaline pH can affect paper and image; paper may grey less than with hypochlorites; may cause lignin containing stains to go yellow-green.

#### **D. Chlorine Dioxide**

**Formula:**  $\text{ClO}_2$

**Mechanism:** Chlorination and oxidation.

**Preparation:** Solid sodium chlorite is dissolved in water; the solution is activated and chlorine dioxide gas liberated by the addition of formaldehyde (gas phase or immersion treatments), or hypochlorite and oxalic acid (gas phase treatment only); activation by heating and the addition of sulfuric acid is not recommended for safety reasons.

**Disposal:** See 19.3.1 D. Chlorine Dioxide.

**Application:** Treatment can be aqueous or gaseous; can include immersion, suction table, floating, wet-blotter, suspension of object over liquid, spray, poultice, or brush.

**General:** Introduced in 1951; used in concentrations of less than 2%; fumehood is mandatory; respirators are advised; minimize potential for explosion by keeping temperature below 25°C (77°F); hypochlorite/oxalic acid activation method requires special chamber and knowledge of handling methods; formaldehyde method safest (although formaldehyde is a carcinogen) and has minimal requirements for equipment; alkalinity may impede bleaching and so prior deacidification is not recommended (initial pH of 6 to 7 drops over the 15-20 minute time period after activation to approximately pH 5 to 6); washing is required after gas phase treatments as well as after immersion treatments; anti-chlors are used in cases where there is any doubt that all chlorine is removed from paper by washing; recommended that washing be performed in a fumehood; after treatment is complete, active chemicals in bath must be eliminated by reaction with reducing agent such as sodium thiosulphate.

**Advantages:** Affective bleach which will often decolorize severe foxing (without as much degradation or color reversion as the hypochlorites); gaseous or immersion techniques possible with basic lab safety equipment; not as sensitive to trace metal impurities as other chlorine bleaches.

**Disadvantages:** Use with extreme caution because extremely toxic and explosive; ligneous papers should not be treated; reacts with lignin to form chlorinated compounds which cannot be washed out without use of very strong alkali; presence of lignins, metal centers, gelatin, or other proteinaceous materials, such as animal glues and other impurities may result in pink or orange tone changes in paper (reducing agents like dithionite or borohydride occasionally correct this); some report yellowing when used on papers which had been exposed to thymol; can bleach image colors; can cause an unacceptable degradation of paper; can result in rapid color reversion, especially with ligneous papers or when paper oxidized during treatment; formaldehyde is a cross-linking agent for gelatin and might possibly permanently set in pink discoloration; extensive washing required after treatment; can decolorize organic colors in media or colored paper; can cause yellowing of plastics (trays, etc.); do not mix with ammonia since chlorine gas is formed as a by-product.

#### **E. Potassium Permanganate**

Formula:  $\text{KMnO}_4$

Mechanism: Oxidation.

Preparation: Solid chemical is dissolved in water (0.2%-0.5%).

Disposal: MSDS #95.

Application: Treatments are aqueous and use immersion.

General: Various concentrations used (2-3%); has fallen into almost complete disuse since even very low concentrations are believed to be very damaging to the paper.

Advantages: Decolorizes almost any stain, good with ink stains.

Disadvantages: Damage to fibers is extreme; potential for irreparable damage to image; color reversion potential extreme; difficult to control amount of bleaching because purple color of solution impairs visibility (leads to a tendency to over bleach); manganese salt residues may lead to stains after treatment.

### 19.3.2 Anti-chlors (Also called Bleach Eliminators.)

Term applies to chemical commonly used to remove residual active bleach after treatment; usually is a reducing agent and is used only with oxidizing bleaches; in order to avoid using more chemicals than absolutely necessary when bleaching, anti-chlors should be used only when bleaching action should be interrupted, with chloramine-T, and/or when the thickness of the paper or fragility of the artifact suggests that the washing period will not be sufficient to remove all bleach.

#### A. Borohydrides (See 19.3.3 A.)

#### B. Sodium Formaldehyde Sulfoxylate

Formula:  $\text{CH}_3\text{NaO}_3\text{S}$ .

Mechanism: Reducing agent.

Preparation: Solid chemical in powder form is dissolved in water.

Disposal: MSDS #71534 (Fluka).

Application: Treatments are aqueous and use immersion or spraying on suction table.

General: 2-5% solution, fumehood mandatory; has never had wide use because of its odor.

Advantages: Some research suggests that paper strength may increase on ageing.

Disadvantages: Has a noxious odor; formaldehyde is a hazard to conservator and proteinaceous materials; may decolorize blues and greens (indigo, prussian blue, or azo dyes); extreme alkalinity can cause some carbon inks to transfer to blotter (probably by affecting oil binder in ink).

**C. Sodium Sulfite**

Formula:  $\text{NaSO}_3$

Mechanism: Reducing agent.

Preparation: Solid chemical is dissolved in water.

Disposal: MSDS #7233 (Conservation Materials Supply).

Application: Treatments are aqueous and use immersion or spraying on suction table.

General: Concentration of 1-6% with a pH of 6-7.5; use of fumehood advised; must remove completely by washing.

Advantages: Soluble in glycerol as well as water.

Disadvantages: Causes some bleaching of paper (poorest of the sulphur reducing agents); brightening effect not stable, i.e., color reversion will occur; may not reduce all bleach residues (especially with chloramine-T); solutions have a sulphur odor.

**D. Sodium Thiosulfate**

Formula:  $\text{Na}_2\text{S}_2\text{O}_4$

Mechanism: Reducing agent.

Preparation: Solid chemical is dissolved in water.

Disposal: MSDS #72049 (Fluka).

Application: Treatments are aqueous and use immersion or sprayed on suction table.

General: Concentration of around 2% (up to 5% has been used); must be completely washed out (test with potassium iodide/iodine test); best choice for anti-chlor of the sulfur-based reducing agents; should wash object well after use to remove residues.

Advantages: No odor; more effective than sulfite.

Disadvantages: If not removed, residues may cause problems; some bleaching of paper; brightening effect is not stable and therefore use increases color reversion; may not reduce all bleach residues (especially chloramine-T).

### 19.3.3 Reducing Bleaches

Reducing bleaches work by chemically reducing stains and/or oxidized sites on cellulose thereby making them colorless and/or increasing their solubility; can be used with ligneous fibers, unlike the chlorine based oxidizing bleaches.

#### A. Borohydrides

Chemicals in this group are effective bleaches, anti-chlors (the only anti-chlor which reliably removes chloramine-T and hypochlorites), and chemical stabilizers of cellulose.

##### 1. Sodium Borohydride

Formula:  $\text{NaBH}_4$

Mechanism: Reducing agent.

Preparation: Solid chemical is dissolved in water or alcohol, preferably ethanol for reasons of its lower toxicity.

Disposal: MSDS #93.

Application: Treatment can be aqueous or non-aqueous (i.e., in ethanol); can include immersion, suction table, floating, wet-blotter, spray, poultice, or brush.

General: Introduced in 1970s; use at concentrations of 0.01% to 1% (up to 2% for anti-chlor for chloramine-T); moderate to mild bleaching properties, depending on concentration; more soluble in water than alcohol; majority of bleaching effect occurs in first ten minutes (immersion), longer for suction table or local methods; paper must be neutralized before bleaching; trace transition metals (e.g., iron stains) should be removed with dithionite; fumehood not mandatory; gloves should be used; buy bleach in small quantities and store bottles in desiccator; keep bulk chemical cool and away from moisture.

Advantages: Can be used in alcohol with water-sensitive media; borohydrides more stable in alcohol; the permanence of paper is improved by the removal of ketone and aldehyde carbonyls by borohydride bleaches; alkalinity (around pH 9 in water) promotes solubilization of many stains; some color reversion but not excessive; bleaching action can be controlled easily by

concentration and method of application; seldom leads to over-bleached appearance; slow-acting and seems to have definite end-point.

Disadvantages: During immersion treatment, sodium salt rapidly gives off hydrogen gas which could physically damage fragile papers or media, particularly in highly oxidized or mold damaged areas; metal centers (e.g., iron and copper) promote decomposition of bleach; some color change of colorants possible (but can often be reversed with ethereal peroxide); alkaline pH may speed solubilization and/or degradation of some media, sizes, coatings and oil-based inks; spot-bleaching can lead to great solubilization of stains and possible over-bleaching; shelf life of chemical is limited and requires special storage conditions; should be rinsed in bath or on suction table; sodium cation must be completely removed after bleaching- displacement with calcium or magnesium salt recommended. A moderate to weak bleach, reduces mild stains but with partial action on more severe staining; if washing not complete, borate residues may remain and increase fluorescence under UV light.

## 2. **Tetramethylammonium Borohydride**

Formula:  $\text{N}(\text{CH}_3)_4\text{BH}_4$

Mechanism: Reducing agent.

Preparation: See 19.3.3 A. 1. Sodium Borohydride.

Disposal: See 19.3.3 A. 1. Sodium Borohydride.

Application: See 19.3.3 A. 1. Sodium Borohydride.

General: Recently tested and proposed derivative; higher molecular weight requires slightly higher concentrations for same effective bleach concentration as sodium salt; much more stable than sodium salt solutions, otherwise very similar in use and working properties.

Advantages: Less decomposition in solution than the sodium salt; sodium cation replaced with tetramethyl ammonium cation.

Disadvantages: See 19.3.3 A. 1. Sodium Borohydride; solubility in alcohol significantly less, relative to water solubility; expensive.

**3. Tetraethylammonium Borohydride**

Formula:  $N(CH_2CH_3)_4BH_4$

Mechanism: Reducing agent.

Preparation: See 19.3.3 A. 1. Sodium Borohydride.

Disposal: See 19.3.3 A. 1. Sodium Borohydride.

Application: See 19.3.3 A. 1. Sodium Borohydride.

General: See 19.3.3 A. 2. Tetramethylammonium Borohydride, except stability and molecular weight slightly higher.

Advantages: The most stable of the three borohydrides; decomposition of bleach is minimal in ethanol; other advantages as outlined for sodium and tetraethylammonium borohydride.

Disadvantages: See 19.3.3 A. 2. Tetramethylammonium Borohydride.

**B. Sodium Dithionite (Hydrosulfite)**

Formula:  $Na_2S_2O_4$

Mechanism: Reducing agent, used to reduce ferric oxide stains to ferrous oxide.

Preparation: Solid chemical is dissolved in water; ammonia may be added to stabilize solution; use of fume-hood advised.

Disposal:

Application: Treatments are aqueous and can use immersion, suction table, floating, wet-blotter, spray, poultice, or brush.

General: Used in the past as a brightening agent, but use has declined due to poor color reversion properties and availability of other bleaching methods; concentration of 1-6% with a pH of 6-7.5; if ammonia is added, pH should be in range of 8 to 9; best known as a treatment for removing iron; not usually used as general bleach and stain remover; object must be washed thoroughly to ensure complete solubilization of ferrous cations.

Advantages: Safe method for the effective removal of iron; not known to degrade cellulose.

Disadvantages: Extremely mild brightening agent (less bleaching action than thiosulphate); rapid reversion properties if used as brightening agent; iron stains will revert if ferrous iron is not completely washed out; strong sulphur odor.

#### 19.3.4 Light

##### A. Natural Light

Mechanism: Most likely photo-oxidation; free radical pathways, like  $H_2O_2$

Preparation: Access to daylight; pure water with or without the addition of chemicals to obtain alkaline pH; ethanol:water (e.g., 9:1 solution has been used in tests).

Disposal: Procedure may vary depending upon what chemicals (if any) are added to alkalize bath; solutions may usually be poured down sink with addition of copious tap water.

Application: Treatments can be aqueous or non-aqueous; can use immersion, floating, wet-blotter, spray, masking, and sandwich techniques.

General: Used in the eighteenth century for paper bleaching, referred to more in the nineteenth century; done in aqueous baths, alkaline baths (e.g., dilute deacidification solutions or ammonium hydroxide), or a combination of these with alcohol; filters to screen out some ultraviolet light must be used; should not be used with alum sized or lignin containing paper; rate of bleaching seems to increase with increase in alkalinity and intensity of sunlight; rate of bleaching decreases with increase in time; effective wavelengths include the short wave-length end of the visible spectrum, i.e., 400-550nm; effective time frame is 2-4 hours, depending on intensity and pH (many treat longer, up to 20 hours - but extra time causes little extra bleaching); washing in fresh bath afterwards may reduce tendency toward color reversion.

Advantages: Works on many types of stains; subtle action easy to control; no fumehood required; no major pH adjustments; can use with other bleaches; gives a good paper tone after treatment, similar to that obtained with  $H_2O_2$  bleaching.

Disadvantages: May cause photo-oxidation of paper and media and increase their solubility (in alkaline or neutral water); free radicals may initiate degradation; post-radiation effect may occur (i.e., free-radical reactions which continue in the dark); intensity of light may be inconsistent or uneven and difficult to measure; difficult to exactly

replicate bleaching conditions; bleaching difficult to control if done outdoors; with alum sized or lignin containing paper yellowing or darkening could occur; paper must be rinsed after final bleach; size may be solubilized during treatment and paper may require resizing after sunbleaching; alkaline baths lead to more rapid color reversion; temperature inside tray may be high and speed up degradation; information on best working conditions (wavelengths, temperature, pH, etc.) not currently available; free radical continues in dark; light reflected from sides and bottom of immersion tub contributes to bleaching edges and reverse of object; may not be suitable for certain papers and design materials.

**B. Artificial Light**

Mechanism: See 19.3.4 A.

Preparation: Access to suitable lamps; water baths as outlined for natural light bleaching.

Disposal: See 19.3.4 A.

Application: Treatments can be aqueous or non-aqueous (e.g., 9:1 ethanol:water has been used in tests); can use immersion, floating, wet-blotter, or sandwich techniques.

General: Types of lights tested include banks of GE spectra tubes (40-100 watts), Sylvania cool light, and Norelco daylight; tungsten and halogen sources have been used, as well as fiber optics for spot work; ultraviolet screening filters must be used with light sources which contain significant UV radiation.

Advantages: See 19.3.4 A; easier to monitor and reproduce bleaching conditions; better control of wavelengths and intensity used; object does not have to be left outside; can minimize bleaching time with double sided bleaching.

Disadvantages: See 19.3.4 A; potential heat build up, leading to degradation of paper or image components; procedures require significantly more time than natural light bleaching; long immersion times for the object (18-70 hours) may damage some objects; although most bleaching levels off at 4 hrs; bleaching dependent on bulbs and pH used; some tests have shown drops in folding endurance following long artificial light bleaching.

**19.3.5 Equipment for Mixing Chemicals**

- A. Beakers, graduated cylinders, funnels, chemical scoops, pipets (for small quantities formaldehyde used in chlorine dioxide bleaching)
- B. Magnetic stirrers and stirring plate and/or glass stirring rods
- C. Balance
- D. pH meter, combination pH electrode, and calibration buffers (for making up buffers and adjusting pH of bleaches)
- E. Filters, pH strips, potassium iodide strips.

**19.3.6 Equipment for Testing**

- A. For detecting residual chloride: silver nitrate, ion-selective quant strips (from Thomas Scientific), or chloride detecting electrode. Silver nitrate test: put rinse water in small beaker (10 ml), add 1/8 - 1/4 tsp silver nitrate crystals. Cloudy precipitate indicates residual chlorine. Rinse until test solution is clear.
- B. For detecting residual peroxide: potassium iodine or Peroxide-Test; "Test strips for the detection and semi-quantitative determination of peroxides."; detects as little as 1 ppm peroxide in aqueous solution; from Merckoquant 10011, Lab Safety Supply Co.
- C. KI-Starch test strips. Oxidizing agent (i.e., residual oxidizing bleach) converts iodide to iodine which reacts with starch to form blue color; works with oxidizing bleaches such as chloramine-T, hypochlorites, peroxides.
- D. Compact tristimulus color analyzer to monitor and qualify shifts in paper value, hue and chroma. Compact tristimulus color analyzers (such as a Minolta Chroma Meter) can be used to monitor color shifts in paper as a result of bleaching. Such investigations into the Chroma Meter's use are currently underway in several paper labs, including the Palace of the Legion of Honor (San Francisco), the Conservation Analytical Lab (Smithsonian), and the Canadian Conservation Institute.
- E. For monitoring change in acidity, pH meter; combination electrode (flat-head electrode required for determining surface pH of object before and after treatment), and calibration buffers.

**19.3.7 Drying Equipment (See 28. Drying and Flattening.)**

**19.3.8 Tools for Application**

- A. Synthetic brushes
- B. Swabs
- C. Cotton wads
- D. Poultices
- E. Airbrush or spray equipment

**19.3.9 Washing Supports, Moisture Barriers, etc.**

- A. Trays (inert material construction)
- B. Polyester web and film
- C. Floating screens
- D. Suction table
- E. Masking materials (e.g., aluminum foil)
- F. UF3 Plexi
- G. Hair dryer

**19.3.10 Safety Equipment**

- A. Gloves
- B. Respirator
- C. Fumehood
- D. Goggles
- E.  $\text{ClO}_2$  tolerance indicator badges

**19.3.11 Light Bleaching Apparatus**

- A. Ultraviolet filtering plexiglas, polyester film, or polycarbonate plastic sheeting
- B. Light meter measuring device

- C. Lamp and equipment for artificial light
- D. Thermometer
- E. pH meter, combination electrode and calibration buffer solutions
- F. Shield to stop light bleaching action

## 19.4 Treatment Variations

### 19.4.1 Aqueous Treatments

**General Procedures:** Standard drycleaning, washing, solvent cleaning, etc. should have been performed to remove all water or solvent soluble discoloration products. Solvent (water-based), bleach and anti-chlor to be used should be tested inconspicuously on the stain, paper, and media. In some cases deacidification of the paper before and/or after bleaching may be appropriate, particularly to prepare a neutral support which will not alter the pH of the solutions during bleaching. See discussion of individual bleaches. In many cases bleaching should be terminated before the desired effect is perceived since lightening may continue during washing and drying. For oxidizing bleaching a bath of 2% thiosulfate should be prepared for use if bleaching must be halted quickly. For borohydride and dithionite bleaches a water bath should be available. Full immersion treatments provide a more even, overall action; they are also more rapid and difficult to control and may cause blistering with certain bleaches (especially borohydride and peroxide). Local procedures provide more control but there can be problems with "halo effects" and the solubilization and removal of reaction products; the rate and extent of bleaching will often be diminished.

Suction table treatments offer a tremendous improvement in control because it prevents haloing along fine lines or around foxing, etc., but bleaching action may be considerably slower than immersion; many disadvantages of certain bleaches may be eliminated (e.g., tendency of peroxide to cause bubbles in paper, physical damage to degraded papers by hydrogen gas evolution from borohydrides, etc.); degraded paper and friable media are less likely to be damaged. Disadvantages of suction table treatment are the length of time for treatments and need for specialized equipment; problems obtaining a thorough rinse with some paper types; and reaction of suction table materials to bleach solution. (For more detailed procedural information see **16. Washing** and **27. Suction Table Treatments**, both to be published.)

**A. Hydrogen Peroxide****1. Immersion**

1) Wash and neutralize paper and allow it to dry 2) make up the solution by adding peroxide (enough for final concentration of 0.3-2.0%) to a solution adjusted to a pH of over 7 with alkaline agents, such as ammonium hydroxide, calcium, or magnesium hydroxide or bicarbonate; or buffer salts such as phosphate (pH 8), borate (pH 9), or carbonate (pH 10); addition of stabilizers such as magnesium sulphate, sodium silicate, and EDTA are recommended in order to keep the solution from decomposing. The concentration of stabilizers added at the time of manufacture (e.g., strontium chloride) is not high enough to stabilize the diluted bleach solution. Any sulfuric acid (from a manufacturer's stabilizer such as strontium chloride) added to slow down decomposition will be neutralized by the alkalization of the bleach solution. Likewise, the periodic replacement of unstabilized solution with fresh solution throughout the treatment will not be sufficient to adequately guard against oxygen evolution and oxidation of the paper fibers. 3) immerse and bleach the object, taking care to keep stabilizer suspended if a colloidal silicate type is used 4) wash and allow to dry 5) take surface pH of paper and deacidify only if necessary and appropriate for specific object. Has been combined with light bleaching to speed up the bleaching process.

**2. Suction Table**

Repeat steps 1 and 2, above. 3) place object on table and wet with water; allow the stabilizer to settle, if a colloidal silicate type is used in bleach (for suction table work the addition of EDTA (about 0.1 M) to bleach solution is preferred); spray clear supernatant from settled solution (alternatively, use a clear solution containing EDTA) on object to bleach object; if bleaching is proceeding too rapidly in any area, selectively spray with distilled, recalcified, or deionized water; wash extensively by spraying with water; dry object; take surface pH and deacidify only if necessary and appropriate for specific object.

**3. Local****a. Float Bleaching:**

(Similar to float washing, see 16. **Washing**, to be published.) Place relaxed paper on a support (screen, web, or Plexiglas) and allow it to float on the meniscus of the water or of the bleaching solution. If desired, and possible, stained edges can be sunk, up to about one-half the surface area of the paper, depending on its weight, absorbency, etc. Spot bleaching can be done with a soft fine brush, spray, or cotton wad poultice. Caution must be exercised when removing the item from the

bath to ensure that solution does not trickle over unwanted areas. One manner of removing an item which has been partially sunk is to place a rigid support (plexiglas or floating screen) on the bottom of the bath and raise it slowly at a slight angle until it makes contact with the floating object and is able to lift the object slowly off the surface of the water. If all edges are sunk, insert a polyester web support under the object, slide in a glass rod under a web support to the location of the water meniscus on the surface of the object, and slowly lift the rod, web, and object slightly in such a manner as to encourage solution to run outward into the bath, until the object can be properly supported on a rigid support and drained.

**b. Blotter Bleaching:**

This is good for objects too fragile for immersion or floating but which need even bleaching, but may not adequately remove materials solubilized during bleaching process. It can also substitute for a suction table if one is not available. The technique is especially good for removing stains on the verso of the object. A blotter is saturated with the bleaching solution and the object, relaxed with moisture, is placed upon it, and monitored until desired effect is achieved.

**c. Spot Bleaching:**

1. Suction table: (see 27. Suction Table Treatments, to be published).
2. Spray: various spray devices may be used (see 22. Humidification). Must mask off areas not to be bleached, and rinse thoroughly.
3. Poultice: cotton, cellulose ether, or diethyl ether emulsion, etc.
4. Brush: subtle results can be achieved by cross-hatching; apply sparingly with brush; natural bristol brushes can be consumed by bleaches.

**B. Hypochlorites**

**1. Calcium Hypochlorite**

Applications are generally by immersion, but can be applied locally or overall by many of the techniques already described above. An example of one aqueous immersion technique is as follows: 1) neutralize object before bleaching if it is acidic, and prepare three baths: an alkaline water bath (pH 9); a bleach bath of 0.05% to 0.5% calcium hypochlorite; and an anti-chlor of a 1-

2% sodium thiosulfate. (It is preferable to remove all chlorine by extensive washing rather than immersion in an anti-chlor if possible.) 2) immerse object in alkaline water bath, then in the bleach bath until desired effect is achieved, rinse in alkaline  $H_2O$ , then immerse in alkaline anti-chlor and rinse again; 3) test for residual chlorine; exceedingly important that paper be alkaline (around pH 9) during bleaching; an alkaline water rinse after bleaching will promote removal of bleach residues and modified stain materials.

## 2. Sodium Hypochlorite

Application is generally by immersion, but can be applied locally or overall by many of the techniques previously described.

### C. Chloramine-T (No longer in general use.)

Application is generally by immersion, but can be applied locally or overall by many of the techniques previously described. The only anti-chlor which can remove all chlorine is one of the borohydrides, although they will (like all reducing agent anti-chlors) continue to brighten the paper during anti-chlor treatment.

### D. Chlorine Dioxide

Fumehood is mandatory for health and safety of the conservator. Aqueous applications are generally by immersion. A typical immersion technique is as follows: 1) pretreat paper as necessary; 2) prepare a 2% solution of sodium chlorite for every liter of solution and add 15 ml to 25 ml of formalin solution (40% formaldehyde in water for every liter of solution); 3) wearing respirator, immerse wet object into bleach until just before desired effect is achieved; 4) remove paper and rinse extensively in water (use of fumehood recommended for washing procedure); 5) dry object and take surface pH; 6) following bleaching deacidify in calcium hydroxide for 30 minutes if necessary and appropriate for object; 7) neutralize bleach bath prior to disposal with 2-7% thiosulfate to eliminate any active chemicals which may remain; test for chlorine residues with KI/I<sub>2</sub> strips.

### E. Permanganate (No longer in general use.)

Usually immersion or local (see 19.4.1 B.); turns area wetted brownish-red; after one minute, treat area wetted with 1% sulfur dioxide or 5% sodium hydrosulfide, or 1-5% oxalic acid to rid brownish-red color; repeat as needed; wash in water thoroughly. (If Na hydrosulfide is used, 0.5% ammonia should be added to the wash water.)

**F. Sodium Formaldehyde Sulfoxylate**

Usually used as an anti-chlor by immersing object in solution; may also be sprayed on object; usually done immediately after bleaching and before washing.

**G. Sodium Sulfite (See 19.4.1 F.)****H. Sodium Thiosulfate (See 19.4.1 F.)****I. Borohydrides**

As an anti-chlor, see 19.3.2 A.

As a bleach and local treatments. A typical treatment for any of the three borohydride salts is as follows: 1) wash and neutralize object; perform alkalization treatment if this is the only way pH can be raised to 7; 2) make up solution by dissolving chemical; wait for evolution of hydrogen gas to slow down (note: for sodium salt in water, bubbling will not completely stop); 3) immerse object and bleach; 4) wash extensively (if using sodium borohydride, consider adding calcium or magnesium salt to wash water in order to displace any residual sodium); 5) dry and take surface pH; 6) deacidify only if necessary and appropriate for object.

**J. Sodium Dithionite (Hydrosulfite)**

Useful for iron stains only, wash extensively before and after, use a 2% concentration; can add a chelating agent like polyphosphate; addition of alkali like ammonia will slow down the procedure but will also decrease rate of decomposition of bleach; fumehood required when handling large volumes of solutions.

**K. Natural Light**

Pretreat object as necessary (surface cleaning, washing, etc.); immerse in purified water made alkaline with ammonium hydroxide (no precipitate), magnesium or calcium bicarbonate; mask from sun where necessary (e.g., cover with aluminum foil or polyester film with white-out to block specific areas from sun; light-sensitive areas such as signatures can be masked with starch paste or appropriate fixative); cover with UF3 plexiglas or UV-stabilized Lexan, position over top of tray at least one inch, with air space to avoid condensation, and set in sunlight; additional bleaching will occur from light reflected off the sides of white tubs; during 2-4 hours of exposure, set-up should be monitored for changes in cast shadows, temperature, or bath evaporation; blue wool standards may be placed beside tray and/or under glass to monitor light intensity; rinse in fresh bath after bleaching.

**L. Artificial Light**

Pretreat object as necessary (surface cleaning, washing, etc.); immerse in purified, buffered water; expose to appropriate artificial lights (i.e., 8 Sylvania cool white bulbs, 34 watts; 8 GE spectra bulbs, 40-100 watts; Norelco daylight, 34 watts, etc.); mask if necessary; turn object over if necessary; expose anywhere from 2-12 hours (safest).

Bleaching can be done simultaneously on both sides of the object using top and bottom light banks and a tray made of UV-stabilized Lexan.

**19.4.2 Non-Aqueous Treatments - Organic Solvents**

All of the currently available treatments with organic solvents use either alcohol or ether which can be safer for the object by diminishing bubbling or ink solubility etc.; frequently the only variation from the aqueous method is that a different solvent is used. If alcohol is the solvent, ethanol is the best choice for reasons of lower toxicity; always test paper and image for sensitivity to solvent (color changes and/or solubilization are possible); a fumehood is usually mandatory; proper safety precautions should be observed in disposing of bleach and rinse baths.

**A. Hydrogen Peroxide****1. Immersion**

1) Dilute reagent grade 30 or 50% hydrogen peroxide to 10% with water and adjust solution to alkaline pH with ammonium hydroxide (or other hydroxides),  $\text{Na}_4\text{EDTA}$ , or carbonates of magnesium or calcium; dilute with ethanol to desired concentration of about 2.0-3.0%; 2) immerse solvent-safe object and allow bleaching to proceed; 3) rinse object with alcohol.

**2. Local**

Spot bleaching, see 19.4.1 A.

**B. Chloramine-T (No longer recommended.)**

Treatment is as for aqueous chloramine-T except that chemical is dissolved in ethanol (note: if object is water sensitive, no water washing is done before bleaching but dry-cleaning and solvent cleaning should be carried out as required); anti-chlor of borohydride dissolved in ethanol may be necessary for complete removal of bleach residues; rinse with ethanol after bleaching; it may be difficult to remove all anti-chlor residues unless extensive washing with alcohol is possible.

**C. Borohydrides (See 19.4.2 B. for procedure.)**

Non-aqueous borohydride treatments are frequently performed in order to take advantage of the greater stability of the bleach solution as well as object sensitivity to water; in the case of objects which are

not water sensitive: 1) water wash and neutralize; 2) spray or immerse the object in ethanol; treat object with bleach made up in ethanol; 3) rinse in ethanol; 4) wash in water and dry; 5) take surface pH and deacidify only if necessary and appropriate for object. Caution: Using borohydride in ethanol may mask the fact that borohydride may change sizings or coatings to be water-soluble; check before proceeding with any aqueous procedure; it may be necessary to wash by rinsing in ethanol bath(s).

#### D. Light

See 19.4.1 K.; bleaching efficiency seems to be approximately the same regardless of percent of ethanol added to buffered water. Certain amount of water should be tolerable as paper should be rinsed in water to increase solubilization of acids produced during bleaching.

### 19.4.3 Non-Aqueous Treatments - Gaseous

General Procedures: Object is pre-treated as appropriate; gaseous treatments have the advantage of being over-all treatments that do not physically endanger the object to the same extent as immersion treatments; however, it may be impossible to remove residual chemicals and the treatments may be difficult to control; they often require specialized equipment and handling techniques.

#### A. Hydrogen Peroxide

1) Mix 10 ml of 30% hydrogen peroxide with 100 ml diethyl or dipropyl ether in a glass container and cover (ether is toxic and explosive); 2) let stand until the ether/peroxide portion starts to rise (no more than 2-3 hr); 3) suspend the object on a screen over a tray of the solution; 4) long term stability of object will be less if washing cannot be carried out after bleaching.

#### B. Chlorine Dioxide

Gaseous chlorine dioxide was previously thought to be suitable for water or solvent sensitive objects which cannot be washed; current recommendation is that washing after bleaching is important to avoid serious degradation and reversion of cellulose; gaseous methods have been used for objects in which it was necessary to minimize exposure to water and which had design elements which were likely to be solubilized in the bleach bath. The chemical proportions given below are from Gettens 1952 (smaller quantities of formaldehyde may suffice): 1) dampen or humidify object (necessary for bleaching action; also, ensures more even penetration); 2) mix 60 g sodium chlorite in 3 liters water with 75 ml of 37% formaldehyde and pour in deep tray; solution should turn yellow-green in less than 15 min; 3) test stains with a swab moistened with solution; rinse test spot; 4) wearing respirator place damp object on a screen suspended over the

rising gas; place a templet of polyester film on object if any blocking is desired; place a sheet of glass or plexiglas over the tray, being careful to leave an adequate vent for gas to escape; be sure to move the object periodically on the screen in order to prevent the appearance of a grid pattern; 5) after bleaching is complete wash object extensively on suction table or in immersion wash; let dry; eliminate active bleach in tray by pouring in 2% sodium thiosulphate until yellow color has disappeared; 6) take surface pH and deacidify only if appropriate for specific object.

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## 19.6 Special Considerations

The following was compiled from comments by contributors, whose initials follow each entry.

### 19.6.1 History of Bleaching

- A. "Historically, developments in paper bleaching have followed the progress of the bleaching of textiles. Some early books on spot and stain removal from cloth (the first was printed in 1532) contain directions for the removal of stains from paper as well. In other cases, procedures for cleaning cloth are later published with the directions applied to paper. Although the written evidence is scant, it is reasonable to assume that sunbleaching is the earliest method of bleaching. Cleaning reagents which were widely published by the end of the sixteenth century include mixtures of salt and lemon juice to generate hydrochloric acid and the use of weak acids such as citric and oxalic (from sources such as oranges and wood sorrel respectively) to remove iron gall ink.

"There was little technological development of bleaches until the experiments of Scheele resulted in the discovery of chlorine in the mid-eighteenth century. Then in 1788, Chaptal published his observation that oxygenated hydrochloric acid could be used to bleach time-darkened engravings. Other methods of bleaching art on paper soon followed, with Eau de Javelle (potassium hypochlorite) and calcium or sodium chlorate being the most common. In addition to those mentioned thus far, in the nineteenth century instructions were published for generating chlorine and ozone for the purpose of bleaching prints. Hydrogen peroxide seems not to have come into common use as a general bleach for paper until rather late in the nineteenth century although its ability to whiten darkened lead white was by then widely employed.

"Prior to the early nineteenth century, published instructions for bleaching works of art on paper are rare. When placed in comparison, most authors are unanimous in their praise of sunbleaching over the newer group of reagent bleaches. This attitude continued well into the third quarter of the nineteenth century. Then, perhaps due to their availability and efficacy, reagent bleaches gain ascendancy, until by the first quarter of this century no mention of sunbleaching is made in published discussions of stain removal from works of art on paper." (MS)

- B. The history of reagent bleaches used since the middle of the twentieth century include the "use of Chlorox in 1940s (Fogg) used locally with cotton held in tweezers. Gettens introduced Sodium Chloride and Chlorine Dioxide in 1952 (Museum, Vol, V, No. 2,

1952, "Bleaching of Stained and Discolored Pictures on Paper with Sodium Chlorite and Chlorine Dioxide, 1950-70".) There was "general use of Na and Ca hypochlorite and chloramine-T." With a "general switch to Ca over Na...It was first thought that chloramine-T was mild and didn't need to be washed out. Then it was decided it should be washed and an anti-chlor used as well. It then fell out of favor due to the fear of inability to wash it out." There was a "general shift in the 80's to use H<sub>2</sub>O<sub>2</sub> and borohydrides." (DM)

#### 19.6.2 Philosophy Concerning the Current Usage of Bleaching as a Treatment for Paper

- A. "Bleaching is considered a last resort. I have rarely bleached an object overall. Most institutions are interested in the longevity of the work and realize bleaching will shorten the life of paper in terms of inherent strength even though the sheet may look brighter for awhile. Winterthur, in particular, treats its objects as historical artifacts as opposed to fine artworks and therefore is not bothered by stains. Fine art museums, on the other hand, often will not accept a stain that hinders the appearance of the object.

"Stains that I have locally bleached include: mat burns that impinged on the design, especially in modern works; oily stains that inhibited the enjoyment of old master works; foxing stains in fine art in prominent locations on the sheet; discoloration from [wooden] backing shingles that created sharp contrasts between general sheet tone and severe discoloration.

"Bleaches tend to alter the [presumed] original tone of the paper - shifting to a slightly yellower or greyer cast than hoped for. There do seem to be some trends in types of paper and bleach combinations to produce characteristic tonalities even though the sheet may be brighter. After bleaching there also seems to be some color shifts in light and dark storage." (DM)

- B. "We try to bleach as infrequently as possible. We view bleaching as "cosmetic" treatment which may improve the artwork's appearance tremendously, but is not essential to its preservation. We will bleach artworks with very disfiguring stains that are to be exhibited. Bleaching is obviously only done if it can be undertaken safely. Stains, [for example] foxing in blank margins/edges are frequently not bleached but overmatted." (TF)
- C. "I believe strongly in the value of stain removal, using a bleach only as a last resort. Bleaching is relative, and it should be contemplated only if the media are sound and if the paper, especially the texture,

will not be affected. Too many bleached objects are cold white, soft and wooly after treatment because too many conservators have focused on the stain and ignored the lustrous, hard, creamy areas of undamaged paper. The sacrifice of the latter in the service of removal of the former can never be justified. These judgments are made through experience, which often provides its surprises. I have tried to learn from these. Nothing in my experience matches sunbleaching, for ease of control and for aesthetic quality of result. These two criteria, plus the subjective satisfaction derived from not putting chemicals into the paper, have made me reject almost all other bleaches. I retain hydrogen peroxide because of its ease for local application and its apparent relative safety. I would never bleach anything which cannot be rinsed; fortunately the suction disk permits local rinsing." (MC)

- D. "The overriding philosophical guideline I use in determining whether or not to bleach is the degree of visual interference with the artwork the offending damage presents. A tape stain in the margin that is to be covered with a mat is not as likely a candidate for major treatment as one in the middle of the image. Subtle foxing stains in unobtrusive areas would be less likely candidates for spot bleaching than a dark stain in the middle of the forehead. I have found my general approach to treatment recommendations has progressively moved from what can be done with a given damage to what should be done. I find I rely heavily on the appropriate curator's eye for determining whether a stain or overall discoloration interferes enough to warrant treatment. In such cases I try to provide information on the expected effectiveness and safety of a given treatment as well as any long term deleterious effects, if known. Any type of bleaching operation is viewed as a major step and the frequency of its application steadily declines in my studio. That is not to say that I am working towards total elimination, as I feel bleaching has its place. I just try to avoid falling into the trap of solely basing my decision of to bleach or not to bleach (or any other treatment for that matter) on the safety and expected effectiveness of said bleach." (HK)
- E. "Of all conservation treatments, bleaching reminds us most directly that our decisions about when and how to treat an art object are subjective, and fallible. In chemical bleaching we put our own immediate aesthetic needs ahead of the future needs of the object, or the possibility of changing aesthetic judgments since we effect a permanent change in the object based on the judgement of the present state of scholarship and taste. I believe bleaching should always be considered the treatment of last resort, and the aim should be the reduction, not the elimination of any particular stain. (See my essay in "Special Conservation Problems for Collectors: The Cleaning of Drawings." Drawing, Vol. 8, #1, May/June, 1986.)" (JW)

### 19.6.3 Treatments

- A. "I have noticed that residue from Na Borohydride bleaching may be detectable with ultra-violet light. I saw a whitish fluorescence when examining a drawing on green paper with U.V. after matline reduction. Repeated rinsing with water removed fluorescing residues. With light white or off-white papers this fluorescence may not be detectable." (NA)
- B. "I have had difficulty in removing chlorine dioxide bleach by washing alone. To remove the bleach I have had to also use anti-chlor baths. I prefer Helen [Burgess's] most recent stabilizer (with hydrogen peroxide) EDTA, because it involves fewer chemicals, is faster to prepare and stays in solution." (TF)
- C. "The most common stains I bleach are pressure sensitive tape stains, mat burns and foxing stains. Overall sunstaining and cardboard burns are also candidates for light bleaching if washing has not satisfactorily reduced the offending discoloration.

"I generally light bleach in a plain water bath. I have had bad experiences with carbonates forming on the surface of the art works during light bleaching so I have shied away from incorporating them in the bleaching bath. In addition, the water in my area [Fort Worth, Texas] is relatively high in carbonates. This may explain why I have noticed no difference in effectiveness of bleaching since I started using plain water.

"I am loath to expose any colored inks to the light and will commonly mask off colored areas. Effective masks can be constructed of Mylar and water insoluble markers or blotter cutouts. Tape stains are commonly treated in this manner, masking the entire object and creating only a small "window of vulnerability" (to quote Keiko Keyes) that is exposed to the light.

"One technique I've developed which is very effective combines light and Hydrogen Peroxide bleaching. After immersion and exposure to the lights for a time (approximately 30 minutes) the object is removed and placed on a screen. The offending stain (tape and mat burns especially) are painted with a strong Hydrogen Peroxide solution (5-10% in pH 9 water). This may be repeated two or three times before the object is returned to the light bleaching bath. The

combination seems to accelerate both types of bleaching. The exposure times are significantly shortened since bleaching of the worse staining is hastened with the hydrogen peroxide. The light bank also seems to even out any problems inherent with spot bleaching."  
(HK)

- D. "If a tablespoon of Hydrogen Peroxide is added as a catalyst to a full tray of alkaline water, the rate of [light] bleaching is markedly increased. Stains which are otherwise quite tenacious can be reduced (rubber cement, terrible mat burns, foxing, etc.) in a few hours of exposure to sunlight, although the paper does whiten quite a bit more.

"Preferred bleaches: I use sun bleaching and hydrogen peroxide only. I am reluctant to use chlorine-based bleaches since they leave residues in the paper, require extra chemical treatments to render them safe, and are more likely to give the stark white sheet of so called "over bleached" objects. If I can't remove a stain with peroxide or light, I leave it. I try to encourage my clients to live with reduced rather than eliminated staining, and most often we are both satisfied with results.

"Stains I bleach: Severely disfiguring foxing, mat burn, some resinous stains (rubber cement [and] tapes respond to sunbleaching if solvents aren't effective). Overall discoloration from poor backings or light damage.

"To minimize bleaching: Here are some of the things I do to avoid bleaching: alkaline washing; localized treatment with ammoniated water, solvents, enzymes, or citric and oxalic acids on metal stains; even use of paper pulp to cover a stain; and JUDICIOUS MATTING of an object sometimes means no bleaching is necessary (either over matting the stain in the margin, or the use of a white backing sheet with a cream throw mat with translucent sheets to give the effect of a brighter sheet). Also: education of clients and curators so they don't expect perfect objects." (JW)

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