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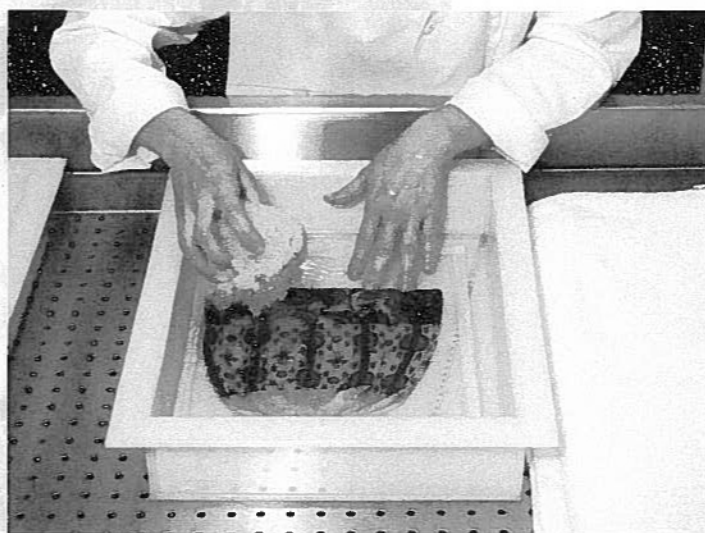
Technical Bulletin 24

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Water Quality for Treatment of Paper and Textiles



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Water Quality for Treatment of Paper and Textiles

by Season Tse

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Abstract

The installation of water purification systems in conservation treatment laboratories has become standard practice in recent years. Choosing a suitable system within a given budget requires knowledge of the way the systems work, the factors that influence the quality of water, and the water quality requirements for treatment. This bulletin provides basic information about water purification methods, and guidelines for water quality requirements for treatment of paper and textile artifacts.

Author

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Introduction

The unpredictable quality of tap water (i.e. the possible presence of heavy metal cations, chlorine, and particulates) has made water purification systems an essential part of conservation laboratories (Textile Conservation Group Newsletter 1996). Water treatment and purification is a complex science and a multi-million dollar industry, and a great deal of information is readily available (see "Further Reading" and "Web Sites" at the end of this bulletin). The American Society for Testing and Materials (ASTM) has devoted two entire volumes to standards for water (ASTM 2000).¹

This bulletin will focus only on the aspects of water quality that are relevant to the conservation treatment of paper and textiles.

Water Quality

There is a tendency to think of water quality in simple terms of 'good' or 'bad'. In practice, however, quality must be measured by what is in the water, how the water is to be used, and what problems may arise if the water is the 'wrong' type. For example, water that is appropriate for chemical analyses may not be suitable for drinking; likewise drinking water may not be suitable for electronics industry or medical/pharmaceutical applications.

What is in water?

All natural sources of water (i.e. those that are unpolluted) contain the following substances in various concentrations:

- dissolved ionized inorganic compounds (e.g. calcium, magnesium, sodium, heavy metal salts)
- dissolved gases (e.g. carbon dioxide)
- particulates (e.g. sand, rust, debris) and colloids
- organic compounds (from pollution or natural decomposition)
- bacteria and pyrogens (bacteria by-products that, if present in blood, may trigger an immune response that results in fever)
- other microbiological contaminants (e.g. algae, protozoa, toxins)

The purpose of water purification is to remove some or all of these components. Different materials require different methods of purification for their removal, and no method of purification can remove all materials.

Types of water

Potable water

The most common measure of water quality is whether or not it is potable, i.e. is it fit for human consumption. The standards for potable water are stringent with respect to microbiological quality, disinfection products, heavy metals, and pesticides or other industrial wastes. Most Canadian tap water is potable, although many people opt

to use water purification systems such as carbon filters to improve taste and colour, or UV light disinfection devices or simple boiling to remove biological contaminants. Potable water may or may not be acceptable for other applications, e.g. medicine, certain industries, scientific analyses, or conservation treatments.

Softened water

Water softening refers to the removal of hardness ions (calcium and magnesium) which is usually accomplished by ion-exchange with sodium chloride. Water is softened to improve the performance of soaps and laundry detergents and to reduce scaling.

Reagent-grade water

Reagent-grade water is required for most analytical and medical applications. There are many classifications of reagent-grade water, the standards for which are specified by organizations such as the ASTM, the College of American Pathologists, and the National Committee for Clinical Laboratory Standards. The water quality standard most often referred to by manufacturers of water purification systems is the ASTM standard (ASTM 2000, "D1193. Standard Specification for Reagent Water"), where water quality is classified as Type I, II, III, or IV according to its content (Table 1).

Water analysis

When designing water purification systems suitable for specific purposes, or determining levels of pollutants for environmental control purposes, it is usually necessary to analyse the quality of feedwater (water prior to purification). Water analysis usually assesses the following:

Resistivity and conductivity

Conductivity is a measure of the ability of water to conduct electricity. It depends on the amount or concentration of dissolved soluble salts and gases (e.g. carbon dioxide). The higher the concentration of dissolved ionized materials, the higher the conductivity. Conductivity is normally expressed as micromhos per centimetre ($\mu\text{mhos/cm}$) or micro-siemens per centimetre ($\mu\text{S/cm}$).

Resistivity is the reciprocal of conductivity, and is a measure of the inability of water to conduct electricity. It is measured in ohm-centimetres ($\Omega\text{-cm}$). The higher the purity of the water, the higher the resistivity. Absolutely pure water has a resistivity of 18 million $\Omega\text{-cm}$ (18 M $\Omega\text{-cm}$) at 25°C. This value increases with decreasing temperature, and decreases with increasing temperature.

Conductivity and resistivity indicate the ionic content of the water; they provide no information about non-ionic contaminants such as particulates, non-ionics, organics, or biological agents.

Most deionizers have a permanent built-in meter that allows resistivity or conductivity to be monitored

continuously. These built-in meters are usually more reliable than dip/portable meters, as dissolved carbon dioxide in exposed water can influence measurements and errors can also occur when measuring still water.

Total matter, total dissolved solids, and total ionized solids

The following definitions are useful [in the context of water purity, the unit for all of these quantities is milligrams per litre (mg/L)]:

- total matter is the sum of particulates and dissolved matter
- total dissolved solids (TDS) includes both ionized and non-ionized soluble organic and inorganic solutes in the water; disinfection can increase the TDS of water (Lorch 1987, p. 90); dissolved hardness ions (calcium and magnesium) make up a large proportion of TDS

- total ionized solids is the sum of ionizable materials only and is related to the conductivity of water; typical values range from 50 to 350 mg/L, good raw water is about 50 mg/L, average value is about 170 mg/L (Barnstead 1989)

Particulates can be effectively removed by membrane filtration; ionized solids can be removed by deionization, distillation, and reverse osmosis (RO).

Total organic carbon

Measured in milligrams of carbon per litre of water (mg/L), total organic carbon (TOC) indicates the amount of organic contamination in the water. In 1990, the TOC of CCI's tap water (Barnstead 1990) was 3.15 mg/L (as carbon); ASTM requires the TOC of Types I, II, and III water to be 0.2 parts per million (ppm) or less. Organics can be effectively removed by activated carbon filters, RO, ultrafiltration, UV light (to some extent), and distillation (to a large extent).

Table 1
Specifications for different types of reagent-grade water
(ASTM 2000, "D1193. Standard Specification for Reagent Water")

	ASTM Type I	ASTM Type II	ASTM Type III	ASTM Type IV
Specific conductance ($\mu\text{mhos/cm}$ or $\mu\text{S/cm}$)	0.056	1	0.25	5
Specific resistance ($\text{M}\Omega\text{-cm}$)	18	1	4	0.2
Total organic carbon (TOC) (mg/L, maximum)	0.1	0.05	0.2	No limit
Silica (mg/L, maximum)	0.003	0.003	0.5	No limit
Potassium permanganate reduction (Barnstead 1989) and oxidation of Fe(II) and Mn (min, minimum)	>60.0	>60.0	>10.0	—
Culture/colony count b (colony-forming units)	Type A 10/1000 mL	Type B 10/100 mL	Type C 100/10 mL	—
pH	N.A.*	N.A.	N.A.	5.0–8.0
Methods of purification	Distillation or RO (water must have conductivity of 20 $\mu\text{S/cm}$ or less); mixed- bed ion-exchange; 0.2- μm membrane filter	Ion-exchange, distillation, or RO; 'double distillation'	Distillation, ion- exchange, or RO (or any combination); 0.45- μm membrane final filter	Distillation, ion-exchange, RO, or electrodialysis (or any combination)
Applications	Whenever minimum levels of ionized contami- nants are essential: trace metal analysis; atomic absorption; enzymology; pH and specific ion determinations; blood gas analysis; preparation of solutions for analysis; Type I water may contain organics	Whenever water must be free of organic or biological contaminants and silica: HPLC; trace organic analysis	Whenever low levels of ionized contaminants are required: initial rinsing; washing glassware	Whenever low levels of ionized contaminants are necessary: initial rinsing; washing glassware

* N.A. indicates there are insufficient dissolved constituents to alter pH. "D1293. Standard Test Methods for pH of Water" (ASTM 2000) cannot be used adequately for water with conductivity less than 5 $\mu\text{S/cm}$ or $\mu\text{mhos/cm}$.

Total hardness

Total hardness is the concentration of calcium and magnesium ions combined, measured in milligrams of calcium carbonate per litre of water (mg/L). Knowing the total hardness of water is important when installing a water softening unit, estimating the ability of water to cause scaling in pipes or boilers, and assessing the need for pretreatment of feedwater in water purification systems. Hardness ions are usually removed by ion-exchange; water softeners operate by exchanging calcium and magnesium ions with sodium ions.

Carbon dioxide

The concentration of carbon dioxide (CO₂) in water is an indication of the amount of decomposition of organic matter. In surface water the level is usually 10 mg/L (ppm) or less; in underground water or deep waters the concentration can be as high as several hundred parts per million (ASTM 2000, "D513. Standard Test Methods for Total and Dissolved Carbon Dioxide in Water"). In 1990, CCI's tap water (Barnstead 1990) had a CO₂ level of 6.5 mg of carbonate/L. The CO₂ content of the water directly affects its pH. Dissolved CO₂ can be removed by deionization.

pH

The pH of the water indicates the quantity of dissolved acids (e.g. organic acids from decomposition, CO₂, SO₂) and alkalis (e.g. carbonates) in the water. Feedwater that is too acidic (pH<3) or too alkaline (pH>8) can damage some RO membranes. In 1990, the pH of CCI's tap water (Barnstead 1990) was approximately 7–8. After several stages of purification, ASTM Type I water should (without boiling) have a pH of between 5.8 and 6.5 (using an ionic strength adjustor during pH determination). A pH of less than 5.5 or greater than 7.5 is an indication that the water has been contaminated.

Methods of Water Purification

There are many purification techniques, but no single method can produce perfectly pure water. When selecting a method for water purification, ensure that any claims for the removal of contaminants are supported by valid test data. Table 2 shows the strengths and weaknesses of the most common water purification systems.

Adsorption

Activated carbon filters remove chlorine and some organics by adsorption, and most home-use water filters, installed to improve the colour, odour, and taste of water, are based on this method. These filters can also be used as a pretreatment to distillation or RO, as certain types of these membranes are degraded by prolonged exposure to chlorine in the feedwater.

Filtration, microfiltration, and ultrafiltration

The function of any filter is to remove insoluble particles such as fine particulates, bacteria, colloids, and some high-molecular-weight dissolved materials from water. Different types of filters have different pore sizes and will exclude different types of materials. Table 3 shows various types of filters and the sizes of particles that each can remove effectively.

Distillation

Distillation is one of the oldest methods of water purification: water is boiled and the vapour is condensed and collected. It is an excellent way to remove most impurities, with the exception of certain volatile organics

Table 2
Strengths and weaknesses of water purification techniques (Barnstead 1989)

	Distillation	Deionization	Filtration	Reverse osmosis (RO)	Adsorption (carbon)	Ultra-filtration	UV disinfection
Dissolved ionized solids							
Dissolved organics							
Dissolved ionized gases (including CO ₂)							
Particulates							
Bacteria							
Pyrogens							

Excellent	Good	Poor

Table 3
Filtration methods and particle types

Types of filters	Particle size	Types of particles
Prefiltration	1–10 μm	Removes particulates (1–5 μm), Fe(III) particles
Microfiltration (Weissman 1981)	0.1–5 μm	Removes fine particles, bacteria (0.3 μm)
Ultrafiltration (Jordain 1981)	0.001–0.02 μm	Removes viruses and colloids
Nanofiltration (Wang et al. 1995)	0.0008–0.0016 μm	Used as a pretreatment to RO
Reverse osmosis	0.0001–0.001 μm	Used as a pretreatment in high-purity applications; removes salts (multivalent better than univalent), particulates, bacteria, and high-molecular-weight (>200) organics (smaller organics are not filtered out)

with boiling points below that of water. Proper pretreatment to remove organics and ionized gases prior to distillation can minimize this problem. Distilled water produced from such pretreatment can meet the criteria for ASTM Type II water, and may even have lower levels of organics than Type I (ASTM 2000, “D1193. Standard Specification for Reagent Water”).

Deionization by ion-exchange

A common way to remove dissolved ionized solids and gases in water is ion-exchange. Ion-exchange resins are synthetic polymers with exchange sites on the surface; cation resins commonly have hydrogen ions (H^+) and anion resins have hydroxide anions (OH^-) in the exchange sites. In two-bed techniques the cation and anion resins are separate; the water passes through the cation resins first and then it passes through the anion resins. Salt leakage in cation resins makes two-bed cartridges less suitable for complete ion-exchange than mixed-bed cartridges, where cation and anion exchangers are mixed intimately in a single column. Two-bed cartridges are mostly used for high-capacity ion-exchange, and are usually followed by a mixed-bed cartridge for final ion removal.

Ion-exchange alone can produce water with resistivity of 18 $\text{M}\Omega\text{-cm}$, i.e. complete removal of ionized solids and gases; however, it does not remove organics, particulates, or microorganisms. Ion-exchangers lose their effectiveness when they are exhausted (the resins have become saturated with contaminant ions) or when the resins deteriorate with time. Exhausted resins can be replaced with newly manufactured (commonly referred to as ‘virgin’) resins or with regenerated resins. Disposable cartridges use virgin resins; these cartridges are easy to maintain and the performance of the resins is reliable, but they are expensive. Regenerated resins are more economical and are adequate for most applications; however, there could be deterioration

of the resins over time or incomplete regeneration, either of which could result in contaminants in product water.

Reverse osmosis

RO separates pure water from dissolved materials using a semipermeable membrane. In normal osmosis, water diffuses from a lower concentration solution to a higher concentration one through the membrane. In RO, external pressure in excess of the osmotic pressure is applied on the side of the solution (e.g. feedwater: pure water + contaminants), resulting in the movement of the solvent (e.g. permeate: pure water) through the membrane. In such a way, a high percentage (up to 99%) of contaminants such as dissolved electrolytes, organics, bacteria, viruses, and pyrogens are rejected (Pohland 1981).

The quality of the RO water is dependent on the feedwater. In order to maintain high-quality feedwater and to lengthen the lifetime of the membranes (which tend to be expensive), pretreatment is usually required. Pretreatment can include removal of chlorine or chloramines by adsorption (carbon filters) to prevent damage to the membrane, and removal of particulates and hardness ions (Ca and Mg) by filtration and ion-exchange respectively to reduce fouling of the membrane.

RO is often used as a pretreatment when producing ultrapure water (ASTM Type I water) where organics, dissolved ions, and microbial contaminants are removed or when the water must be polished. ‘Polishing’ refers to further deionization, removal of organics, and submicron filtration of previously purified water at the point-of-use.

UV light disinfection

Disinfection is especially important for stored purified water in which chlorine or chloramines have been removed,

e.g. in RO or distilled water reservoirs, water storage containers, infrequently used water lines, or activated carbon cartridges.

A number of methods can help control microbial growth in water systems: keeping the system in the dark can slow down (but not prevent) algae growth; flushing the system (for >5 min) can remove most of the bacteria; if the water has been further polished, submicron (0.2- μ m) filters at the point-of-use can remove algae, bacteria, and other microbial contaminants. However, disinfection is necessary to eliminate microbial growth.

Chemical disinfection is not an appropriate treatment for purified water but the use of UV irradiation at 254 nm (Health and Welfare Canada 1979) is suitable and very effective. This treatment requires little maintenance and no addition of chemicals; it not only eliminates algae, bacteria, and viruses, but also destroys certain organics that may be present. UV light disinfection devices can be installed at the point-of-use or in RO or distilled water reservoirs.

Storage of Purified Water

Purified water is a very good solvent and can be easily contaminated by contact with containers, pipes, and airborne pollutants. Airborne contaminants include particulates as well as biological contaminants such as bacteria, mould, etc. To prevent contamination of purified water, it is essential to choose appropriate storage containers and delivery systems, and to ensure that they are properly maintained (see Ross 1987).

The choice of materials for storage is dependent on the application. Stainless steel is suitable for applications where ionic contamination is less important than biological contamination, e.g. in the medical or pharmaceutical field. The most common water storage containers are plastic or glass. Among the plastics, solid polytetrafluoroethylene (PTFE) is the most inert but also the most expensive; polypropylene or high-density polyethylene containers are also excellent choices.

Biological growth is a concern with all plastic containers. Eliminating light can reduce the rate of biological growth, but not eliminate it. The best way to avoid contamination is to use freshly polished, filtered and collected water; point-of-use UV light disinfection is also an option (Health Canada 1979). Avoid using water that has been stored for an extended period of time.

Preparation of containers for storage of purified water

To reduce potential contaminants, new plastic containers should be cleaned and then conditioned by soaking in

several changes of purified water for an extended period (1–2 days).

Sodalime glass containers should not be used because of the ions that could be leached. Borosilicate glass containers can be used, and 'aged' containers (used for 6 months or more) are better than new ones. Glassware that has been used previously or has an unknown history should be cleaned with warm soap and water, rinsed thoroughly with tap water, then rinsed three to six times with purified water. For certain applications (most analytical procedures), it may be necessary to soak glassware in 10% nitric acid to remove alkaline or metallic contaminants, or chromic acid cleaning solutions to remove organic residue, followed by thorough rinsing and soaking with purified water.

Containers for purified water should not be used to store any other types of solutions or chemicals.

Water Quality Requirements

For conservation applications, any water purification system is better than none. Certain applications have more stringent requirements than others.

Preparation of solutions

In general, any analytical work or solution preparation (such as preparation of buffers and poultices used in enzyme treatment, alkaline water, and bleaches) should be done using the highest quality of water available, preferably ASTM Type I water, obtainable by RO or distillation followed by some type of polishing.

pH measurements

The highest quality water should be used for pH measurement, as pH is particularly sensitive to water quality. Even low concentrations of acidic or alkaline contaminants can contribute to large errors in pH measurement. This is especially true when determining the pH of purified water. Although the theoretical pH of pure water is 7, in practice it is impossible to determine the pH of ASTM Type I water because there are insufficient conducting ions to give a meaningful value. However, it is possible to get a good estimate by using ionic strength adjustors (e.g. pHisa).²

When measuring the pH of low-ionic-strength solutions or purified water, it is essential to eliminate all contaminants. Common sources of contaminants include:

- deteriorated, exhausted, or contaminated resins or filters
- ineffective or insufficient purification
- microbial growth in 'purified' water that has been stored too long
- inappropriate storage containers (e.g. sodalime glass bottles or jars)

- contaminated storage containers or vessels used for measurement (e.g. beakers that are not properly cleaned and rinsed)
- carbon dioxide (boiling water to remove CO₂ can increase the pH of ASTM Type I water by 0.2–0.4 pH units)

More about pH measurements of diverse media can be found in Tse (1996).

Washing with deionized water

The practice of using deionized water for washing was based on the understanding that dissolved metal ions such

as iron, copper, and manganese that are sometimes present in tap water can accelerate the aging of paper and cellulosic textiles (Bicchieri and Pepa 1996; Shahani and Hengemihle 1986; Tang and Jones 1979; Williams et al. 1977). Deionization seemed to be the obvious solution, but washing with deionized water has been found to destabilize some papers possibly because of the removal of calcium and magnesium (Tang and Jones 1979) and to cause running of certain dyes during washing by immersion possibly because of weak dye–fibre bonding (AIC Textile Specialty Group 1995; Tímár-Balázs and Eastop 1998).

The effects of washing paper and cotton and linen textiles with deionized water have been studied at CCI for the past

Table 4
Comparison of various analyses of lab water

	Conductivity (μ mhos/cm or μ S/cm)	Ca (ppm)	Fe (ppm)	Cu (ppm)	pH	Total ionized solids (ppm as NaCl)	Alkalinity (ppm; carbonates, bicarbonates, and hydroxides)	Total organic carbon (ppm)	CO ₂ (ppm CaCO ₃)
CCI tap water (cold), boiler room 1993 by A.A.*	—	Ca: 12.6 Mg: 1.98	0	—	8	Na: 2.69 K: 0.81	—	—	—
CCI tap water (hot), CPMR lab 1993 by A.A.	—	Ca: 9.5 Mg: 2.8	0	—	8.5	Na: 11.4 K: 1.00	—	—	—
CCI tap water, CPMR lab 1990 †	130.94	42.5	—	—	7.1 good 51 avg. 171 poor 342	73.97	35.17	3.15	6.47
Washington tap water (40°C) ††	240	20.8	0.07	0.04	8	—	—	—	—
Lab DI water	2.3	0	0	0	6.3	—	—	—	—
Distilled water	1.6	0	0	0	5.8	—	—	—	—
Weak base DI water	24	0	0	0.01	5.8	—	—	—	—
Weak base DI water + CaCO ₃	122.5	10.6	2	0.02	7.4	—	—	—	—
Weak base DI water + CaCO ₃ at 40°C	88	14	0.02	0.04	7.6	—	—	—	—

* A.A.: atomic absorption.

† Barnstead (1990) water analysis report of CPMR lab water in July 1990:

Distilled water: 2 μ mhos/cm

DI (2-bed): 5.7 μ mhos/cm

DI (mixed-bed): 1 μ mho/cm

RO: 20–40 μ mhos/cm

Milli-RO (CCI-CPMR; Nov. 1997): feedwater, 110 μ mhos/cm; permeate, 1–2 μ mhos/cm

Milli-Q + Milli-RO water: pH 6.1 (addition of pHisa)

†† Tang and Jones (1979). DI-Ca water is delivered in copper pipes, which may explain the Cu concentration in this water.

15 years (Burgess et al. 1991; Tse unpublished). The results confirm that washing with deionized water (ASTM Type I water) removes calcium and magnesium ions from paper and textiles to varying extents, and other soluble salts such as those of sodium and potassium. The degree of removal depends on the physical characteristics of the substrate (e.g. absorbancy) and, presumably, the chemical nature (e.g. solubility) of the mineral salt. However, the relationship between the calcium and magnesium content and the stability of the cellulose is not straightforward, i.e. reduced calcium and magnesium content does not always destabilize cellulose. Among the paper and textiles samples studied, some were stabilized by deionized water washing, some showed no effect, and some were less stable with washing. It would appear that the final effect is a balance between removal of the detrimental compounds (e.g. acids, sodium and potassium ions) versus removal of the beneficial compounds (e.g. calcium and magnesium salts).

Table 4 compares the quality of CCI's tap water with the quality of different types of water used by Tang and Jones (1979). CCI used ASTM Type I water in all their washing studies, which is more aggressive than the water used by Tang and Jones.

To eliminate the possibility of destabilization and dye-running, some conservation labs have installed calcium carbonate (marble chips) cartridges at the point-of-use. Another alternative is to add small quantities (equivalent to 200 ppm of Ca^{2+} or Mg^{2+}) of calcium or magnesium bicarbonate or sulphate to the wash water. Bicarbonates have the dual benefits of mild deacidification as well as maintenance of the ionic content of the water. Sulphates have been recommended in place of bicarbonates if there are alkaline-sensitive colorants present in the artifact. CCI studies have found that high concentrations of sulphates (equivalent to 2000 ppm of Mg^{2+}) may destabilize some papers (CCI unpublished data).

Table 5
Water quality in some conservation applications

Activity	Concerns	Suggested water quality
Washing paper and textiles; mister; suction table	Chlorine/chloramines; heavy metals can cause degradation vs. possible destabilization of cellulose from removal of Ca or Mg ions; running of some colorants Salts and particulates can accelerate fibre deterioration Algae, mould, or bacteria can promote biological deterioration of the artifact	Deionized, fresh/sterilized RO, distilled, or polished RO; if there are no alkaline-sensitive colorants, an alkaline wash (200 ppm Ca or Mg bicarbonate) is acceptable
pH measurements	Acidic or alkaline contaminants in water, glassware, storage container, ionic strength adjustor	Freshly polished RO
Solution preparation, e.g. alkaline water, buffers	Contaminants can influence analytical results, or reduce the useful lifetime of the prepared solutions	Freshly polished RO
Bleaching	Heavy metal ions can decompose peroxide (Deasy 1967) and borohydride bleaches (Burgess 1988)	Polished RO
Enzymes	Metal ions can deactivate or inhibit enzymes	Freshly polished RO
Pastes and poultices	Microbial growth can greatly reduce the useful lifetime; if used with enzymes, may affect enzyme activity	Polished RO or distilled
Leaf-casting or papermaking	Heavy metals, organics, and particulates (ASTM 2000; Lorch 1987, p. 90; Barnstead 1989) can accelerate deterioration of paper	DI, RO, or distilled
Specific ion analysis, e.g. pH, Mg, Ca, chlorides	Contamination will introduce errors into analytical results	Polished RO
Washing glassware	Improperly rinsed glassware may lead to contamination of solutions (this is especially crucial for glassware used for enzyme solutions, poultices, pH measurement, or storing analytical samples)	Tap water followed by distilled, RO, or polished RO
Washing metals	Chlorides can cause corrosion; sulphides and organics can cause tarnishing	RO or polished RO
Dyeing	Heavy metal ions in water can alter the colour of the dye bath and lead to variation from batch to batch	RO or polished RO

Ultrasonic misters and suction tables

Freshly filtered and deionized, distilled, or RO water should be used for treatments that require the use of a mister or suction table. Use of freshly purified water eliminates the possibility of particulates or algae accumulating on the artifacts during treatment. This is particularly important when suction tables are used, as the artifact can act as a filter for any insoluble matter.

Table 5 presents a variety of conservation treatments, along with the concerns and suggested water quality for each.

Maintenance and Monitoring

The greatest danger with neglect of water purification equipment is a false sense of security (purity). Regular maintenance is essential, especially for central purification systems where there are additional lengths of pipes, joints, and tubing where contaminants can accumulate. Most manufacturers of purification systems have recommended maintenance programs, and these should always be followed.

General maintenance guidelines

Clean RO membranes on a regular basis (maybe monthly) to reduce biological fouling.

Replace exhausted deionizing resins, and carbon and other membrane filters. Membranes and cartridges may need to be replaced even if they have not been used very frequently.

Clean UV light disinfection devices regularly; replace lamps annually.

Use freshly processed water for washing or preparing solutions rather than water that has been stored in a container for a period of time.

General monitoring guidelines

To detect exhaustion and degeneration of resins:

- monitor the conductivity/resistivity of the water (changes up or down or erratic readings indicate a problem)
- monitor the pH of the water; it should not go up or down (i.e. it should not deviate from normal 5.8–6.5) (see section “pH Measurements”)

To detect degeneration of RO membranes:

- monitor the percentage rejection (when the RO membrane is functioning properly the percentage rejection should be 89–90%; the percentage rejection will go down or become erratic when the membrane is deteriorating)

To control microbial growth:

- disinfect water (UV light disinfection devices can be installed in reservoirs or at point-of-use)
- flush the system thoroughly (5–10 min) before collecting water, especially if the system is used infrequently
- monitor microbial levels using Millipore HPC samplers³

To test water hardness:

- use test strips⁴ to determine water hardness (these are useful for testing source water or feedwater but may not be sensitive enough for purified water)

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Endnotes

1. There are more than 260 standards related to testing of water in *Water. Vols 11.01 and 11.02. Annual Books of ASTM Standards* (ASTM 2000). The following is a list of standards that are useful for conservation applications:

D511.	Standard Test Methods for Calcium and Magnesium in Water
D512.	Standard Test Methods for Chloride Ion in Water
D513.	Standard Test Methods for Total and Dissolved Carbon Dioxide in Water
D596.	Standard Practice for Reporting Results of Analysis of Water
D1068.	Standard Test Methods for Iron in Water
D1125.	Standard Test Methods for Electrical Conductivity and Resistivity of Water
D1129.	Standard Terminology Relating to Water
D1193.	Standard Specification for Reagent Water
D1293.	Standard Test Methods for pH of Water
D2579.	Standard Test Method for Total Organic Carbon in Water
D4195.	Standard Guide for Water Analysis for Reverse Osmosis Application
D4453.	Standard Practice for Handling of Ultra-Pure Water Samples

2. Orion Pure Water Ionic Strength Adjustor (pHisa), cat. # 700003. Available from:

Fisher Scientific
112 Colonnade Road
Ottawa ON K2E 7L6
Tel.: 1-800-267-6633

or

Canadawide Scientific
2300 Walkley Road
Ottawa ON K1G 6B1
Tel.: 1-800-267-2363
E-mail: cws@canadawide.ca

3. Millipore HPC samplers are available from Millipore Corp. (1-800-645-5476), Canadawide Scientific, or Fisher Scientific.

Coli-count sampler	cat.# MC0010025
Yeast and mould sampler	cat.# MY0010025
Total count sampler	cat.# MT0010025
Heterotrophic plate count sampler	cat.# MHPC10025

4. EM Quant test strips for total hardness can be purchased from chemical supply companies such as Canadawide Scientific or Fisher Scientific.

50 mg/L CaCO ₃ equivalent	0.5 mmol/L (alk. earth metal)	(very soft)
70	0.7	(soft)
125	1.3	(medium)
250	2.5	(hard)
370	3.7	(very hard)
EM Quant chlorine test strips:	4, 12, 40 120 mg/L	
EM Quant iron (II) test strips:	3–500 mg/L	
EM Quant aluminum (III) test strips:	10, 25, 50, 100, 250 mg/L (testing aluminum sulphate in water)	
EM Quant peroxide test strips:	0.5, 2, 5, 10, 25 mg/L	

Further Reading

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Web Sites

WaterTech Online (<http://www.watertechonline.com>) contains a wealth of information about water treatment technologies, maintenance, and specifications, as well as a number of links to government agencies, etc.

Environment Canada (http://www.ec.gc.ca/water/en/manage/qual/e_qual.htm) contains facts and guidelines for Canadian water quality, a graph showing the composition of dissolved solids in Canadian rivers, and useful links to provincial and municipal sites and well water quality sites in the United States and Europe.

HACH (<http://www.hach.com>) contains information on water testing equipment and kits.

Health Canada (http://www.hc-sc.gc.ca/ehp/ehd/bch/water_quality.htm) has many excellent articles on water quality, especially for drinking.

Millipore (<http://www.millipore.com/H2O>) has a good section on water purification technologies (with illustrations).

Orion (<http://www.orionres.com/pHapplications.html>).

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