

A

Guide

To

Laboratory

Water

Purification



*Protecting your
laboratory environment*

LABCONCO[®]

An Industry Service Publication

Foreword

This booklet has been prepared by Labconco Corporation to serve as a basic guide in the selection of water purification equipment. The information presented is “generic” in nature. That is, while experienced Labconco personnel have compiled this booklet, it is our intention to provide a non-biased review of water quality standards, common water contaminants and purification methods. The purpose of this booklet is to help you make an informed choice for your laboratory situation.

Our Method

We begin our discussion of water purification by looking at current water quality standards which have been established by several scientific groups. Secondly we examine the many types of contaminants commonly found in water supplies and why their removal is important to various laboratory procedures. Next, purification methods are compared for effectiveness and ease of use. Throughout these discussions are **Qualifying Questions** which will help you determine what level of water purity is needed for your laboratory procedures and what purification methods are most practical to achieve these levels of purity. Finally, towards the end of this guide is a list of problems associated with traditional approaches to water purification and a brief discussion of how Labconco’s water purification systems address these problems.

Introduction

Water is a reagent that has often been taken for granted. It falls from the sky, it flows in the rivers, it is available at the tap at the turn of the faucet, we drink it, bathe in it — if it looks clear and tastes okay we are accustomed to thinking of it as being pure. However, in the laboratory, potable water is often not pure enough.

It is common for analytical and experimental scientists to be concerned with elements and compounds in the parts per billion (ppb) and parts per trillion (ppt) range. Life science research is often very sensitive to many contaminants, especially heavy metals and dissolved organics. High performance liquid chromatography (HPLC) requires ultrapure water in many of its applications, including calibration of detector base lines and elution of reverse phase columns. Trace element analysis requires water that is free of the elements in question.

What kind of work are you doing with pure water?

How are you purifying your water now?

Is the water in your laboratory pure enough for the sensitivity of your analytical procedures?

Water Standards

In response to developments in scientific technique and technology and the increasing sensitivity of research, several professional organizations have established water quality standards. These groups include the American Chemical Society (ACS), the American Society for Testing and Materials (ASTM), the National Committee for Clinical Laboratory Standards (NCCLS), and the U.S. Pharmacopeia (USP).

As an example, the NCCLS has specified three types of water — I, II, III — and Special Purpose, which are listed below with their intended uses.

NCCLS Water Types and Applications

<p>Type I - Test methods requiring minimal interference and maximum precision and accuracy: Atomic absorption Flame emission spectrometry Ligand assays Trace metals Enzymatic procedures sensitive to trace metals Electrophoretic procedures High sensitivity chromatographic procedures Fluorometric procedures Buffer solutions Standard solutions</p> <p>Type II - Test methods in which the presence of bacteria can be tolerated: General reagents without preservatives Microbiology systems (not to be sterilized) Test methods for which requirements leading to the choice of Type I or Special Purpose waters do not apply: Stains and dyes for histology General reagents with preservatives Microbiology systems (to be sterilized)</p> <p>Type III - General washing and feedwater for producing higher grade water, as well as bacteriological media preparation.</p> <p>Special Purpose - Procedures requiring removal of specific contaminants: Removal of pyrogens for tissue/cell cultures Removal of trace organics for HPLC</p>

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A summary of the various Type I water quality standards provides a starting point to determine the important quality parameters of reagent grade water:

Type I Water Quality Standards

	NCCLS	ASTM
Resistivity ¹ , megohms-cm, at 25° C, minimum	10.0	18.0
Conductivity, microsiemens/cm, maximum	0.1	0.056
Silicate, mg/l, maximum	0.05	.003
Particulate matter, µm filter	0.22	0.2
Microorganisms, colony forming units per milliliter	10	see note 2

¹ Resistivity and conductivity of Type I water must be measured in-line. Measuring in a container will give inaccurate readings.

² For ASTM: Type IA water - 10/1000 ml
Type IB water - 10/100 ml
Type IC water - 100/10 ml

Contaminants and Water Testing

For a better idea of what these standards mean, let us examine the kinds of contaminants that may be found in water.

First of all, water is an excellent solvent and the medium of most life processes on this planet. That is why water gets contaminated with just about everything it encounters and why microorganisms grow in it so well. The aforementioned is why purifying water is a much more difficult procedure than it initially might seem to be.

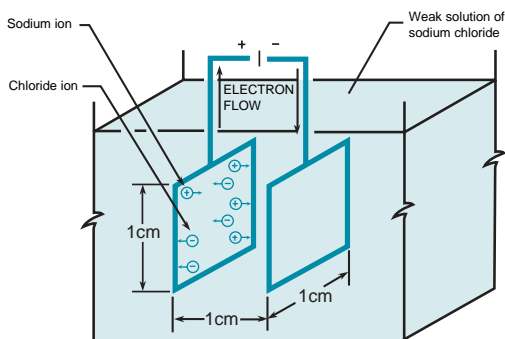
The five types of contaminants that may be found in water are:

1. Particulates
2. Dissolved inorganics (solids and gases)
3. Dissolved organics
4. Microorganisms
5. Pyrogens

PARTICULATES include silt, plumbing pipe debris, and colloids. These suspended particles can plug filters, valves, lab tubing, reverse osmosis membranes and conductivity meters. Particulates are visible as cloudiness or turbidity, and are detected using filtration and gravimetric means, or microscopic methods. A 10 to 20 micron prefilter is often placed as the first component in a water purification system to filter out the larger particles. Smaller particles are removed subsequently by reverse osmosis, submicron filters and ultrafiltration membranes.

DISSOLVED INORGANICS include calcium and magnesium ions dissolved from rock formations (these two ions make water hard), gases such as carbon dioxide that ionize in water (carbon dioxide dissolves readily in water to make mildly acidic carbonic acid), silicates leached from sandy river beds or glass containers, ferric and ferrous ions from rusty iron pipes, chloride and fluoride ions from water treatment plants, phosphates from detergents, nitrates from fertilizers, and many others.

There are several tests for identifying specific dissolved inorganics. The simplest test is a direct measurement of electrical conductivity or resistivity. Most dissolved inorganics are either negatively charged (anions) or positively charged (cations), and will transmit a current when a voltage is applied to electrodes inserted in the water. The more ions present, the greater the conductivity, or the lower the resistivity of the sample water.



This figure shows the standard configuration of a conductivity cell and the movement of the anions (-) and cations (+) toward the charged poles.

Reprinted from Handbook of Water Purification 1981 by courtesy of Walter Lorch, editor, and McGraw Hill, publisher.

Conductivity is expressed in microsiemens/cm and is used to measure water with a large number of ions present. Resistivity is expressed in megohms-cm and is used in the measurement of water with few ions. Conductivity and resistivity are reciprocals of each other. Thus, at 25° C, 18.2 megohm water, which is the highest purity water obtainable with today's technology, also has a conductivity of 0.055 microsiemen/cm.

Resistivity	0.1	1.0	10.0	18.24	megohm-cm
Conductivity	10.0	1.0	0.1	0.055	microsiemens/cm

Does your analytical work require that your water be free of dissolved inorganics? _____

DISSOLVED ORGANICS may include pesticides, herbicides, gasoline, and decayed plant and animal tissues. Dissolved organics may also include the plasticizers leached out of plumbing lines, fittings and storage tanks.

Note the sources of the last organic contaminant — all are from improperly designed water purification systems. Thus, a water purification system must both remove the contaminants present in the feedwater, and be designed to minimize the addition of contaminants to the water.

The absence of dissolved organics is very important when performing analyses of organic substances in HPLC, gas chromatography,

electrophoresis, and fluoroscopy, or in research involving tissue cultures.

There are several ways of measuring dissolved organic levels. The potassium permanganate (KMnO₄) color retention time test is a qualitative organic test that may be used. The premise of this test is that the bright purple-colored potassium permanganate, a powerful oxidizing agent, will change color to clear if there are sufficient organics present in the water to be oxidized. The drawbacks of this test are that it is slow, it is not sensitive to very low levels of organics (that might still be too high for HPLC purposes), and it is not quantitative — it doesn't tell how many parts per billion of organics are present.

Total Organic Carbon (TOC) analyzers, which oxidize the organics and measure the CO₂ liberated, are being used more and more to determine organic levels in Type I water due to their low-level detection sensitivities. A low TOC level is very important for HPLC users.

Are you doing HPLC? _____

Is it important to you to have very low levels of dissolved organics? _____

MICROORGANISMS constitute another group of contaminants found in water. Surface water may contain a wide variety of microorganisms, including bacteria, protozoa, algae, amoebae, rotifers, diatoms and others. Since most laboratory water comes from municipal water treatment plants, which is extensively treated to remove microorganisms, the chief microbes of concern for water purification systems are bacteria. A typical bacterial level for a potable laboratory water supply is one colony forming unit per milliliter (cfu/ml).

The challenges for an ultra-pure water purification system are to:

- remove the bacteria present in the feedwater
- prevent bacteria from entering the system and contaminating it
- ensure that no bacteria are in the product water
- inhibit bacterial growth through proper design and operation.

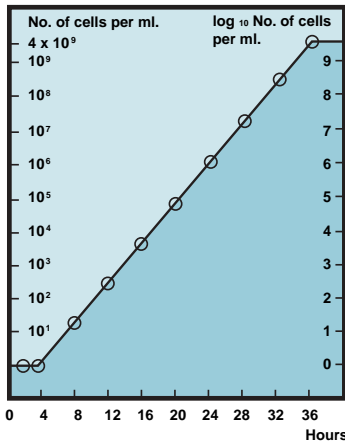
Bacteria are one celled organisms that multiply at exponential rates, thrive in standing water, and may be present on many surfaces and in the air. Bacteria subsist on a variety of substrates in purified water including dissolved organics such as plasticizers and dissolved inorganics such as iron and sulfur.

Bacteria will enter an unprotected water purification system from the feedwater, any breaks in the system, or through the dispenser. Once in the system, bacteria secrete a polymeric substance that adheres them to surfaces of storage tanks, deionization cartridges, plumbing, and hard-to-clean surfaces.

Bacteria are usually detected and enumerated by filtering the sample water through a 0.45 micron

filter and culturing the filter on a suitable medium for several days. Bacteria counts are usually reported in colony forming units per milliliter (cfu/ml).

Bacteria can be killed with disinfectants like hydrogen peroxide, hypochlorite, and formaldehyde. However, when bacteria die, their polymeric secretions and lipopolysaccharide cellular fragments remain and may be a source of contamination if not removed.



A culture of bacteria (one organism per milliliter) in glucose medium after a lag of about 4 hours grows exponentially with a doubling time of one hour.

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Pyrogens, are typically gram-negative bacterial cell wall fragments or lipopolysaccharides. When injected into a mammal, pyrogens cause a rise in body temperature. Thus pharmaceutical grade water must be pyrogen-free. Pyrogens also have a detrimental or lethal effect on tissue cultures.

Pyrogens are detected either by injecting the sample water into specially bred rabbits and monitoring them for a body temperature rise, or with the LAL (Limulus Amoebocyte Lysate) test, a sensitive test for very low concentrations of lipopolysaccharides.

Have you analyzed your feedwater and product water for bacterial and pyrogen levels? _____

Have you had problems with bacteria proliferating in your water purification system? _____

Do you require that your water be bacteria-free? _____

Do you require that your water be pyrogen-free? _____

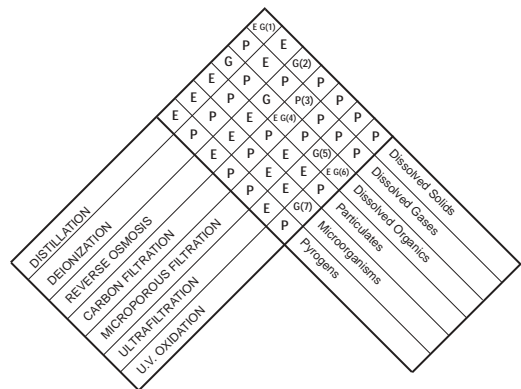
Discussing the types of contaminants found in water leads us to a review of the ways that these contaminants may be removed from feedwater to produce ultrapure reagent quality water. A discussion of these technologies follows.

Purification Methods

Eight different methods are commonly used to purify water. These are:

1. Distillation
2. Deionization
3. Reverse osmosis
4. Activated carbon filtration
5. Microporous filtration
6. Ultrafiltration
7. Ultraviolet oxidation
8. Electrodialysis

The following NCCLS chart compares the effectiveness of seven of these technologies for the removal of the various contaminants found in water. (Electrodialysis was not listed in this NCCLS chart.)



Water Purification Process Comparison

- E = Excellent (capable of complete or near total removal)**
- G = Good (capable of removing large percentages)**
- P = Poor (little or no removal)**

Permission to reprint portions of C3-A2, "Preparation and Testing of Reagent Water in the Clinical Laboratory — Second Edition; Proposed Guideline," has been granted by the National Committee for Clinical Laboratory Standards. NCCLS is not responsible for errors or inaccuracies. The complete current standard may be obtained from NCCLS, 771 E. Lancaster Avenue, Villanova, PA 19085.

- (1) The resistivity of water purified by distillation is an order of magnitude less than that produced by deionization, due mainly to the presence of CO₂.
- (2) The residual concentration of dissolved solids is dependent on the original concentration in the feedwater.
- (3) Activated carbon will remove chlorine by chemisorption.
- (4) Special grades of carbon are available which exhibit excellent trace organic removal capabilities.
- (5) Ultrafiltration will remove organics based on molecular weight cutoff of ultrafilter membrane.
- (6) Certain UV oxidation systems have been specifically designed to exhibit excellent trace organic removal capabilities. These are not to be confused with UV sterilizers.
- (7) UV systems, while not physically removing bacteria, may have bacteriocidal or bacteriostatic capabilities limited by intensity, contact time and flow rate.

DISTILLATION has several positive features. The equipment is relatively inexpensive, there are no expendables other than replacement glassware and heating elements, and it produces water of generally good quality. Distillation typically produces water of Type II or III quality, with a resistivity of about 1.0 megohm.

Distillation has several drawbacks, however, and because of these, is not as widely used as in the past. Distillation is not an on-demand process. Because of this aspect, a quantity of water must be distilled and stored for later use. If the storage container is not made of an inert material, ions or plasticizers will leach out of the water container and recontaminate the water. Bacteria are known to grow well in standing water. The bottles may be sterilized and the collected water autoclaved. However, once the bottle is opened, it is exposed to bacteria and contamination begins.

Distillation has other drawbacks, including being highly wasteful of energy and water — typically only 5% of the water used in the process ends up as product water. Stills require regular cleaning due to build-up of mineral deposits from the feedwater.

DEIONIZATION is commonly used in laboratories for producing purified water on demand. Deionization systems have typically consisted of one to four cylindrical cartridges hooked up to plumbing lines and hanging on a wall near a sink.

Deionization functions by exchanging hydrogen ions for cationic contaminants and hydroxyl ions for anionic contaminants in the feedwater. The deionization resins are tiny spherical plastic beads through which the feedwater passes. After a period of time, cations and anions from the water displace all the active hydrogen and hydroxyl groups in the beads and the resin must be replaced or regenerated.

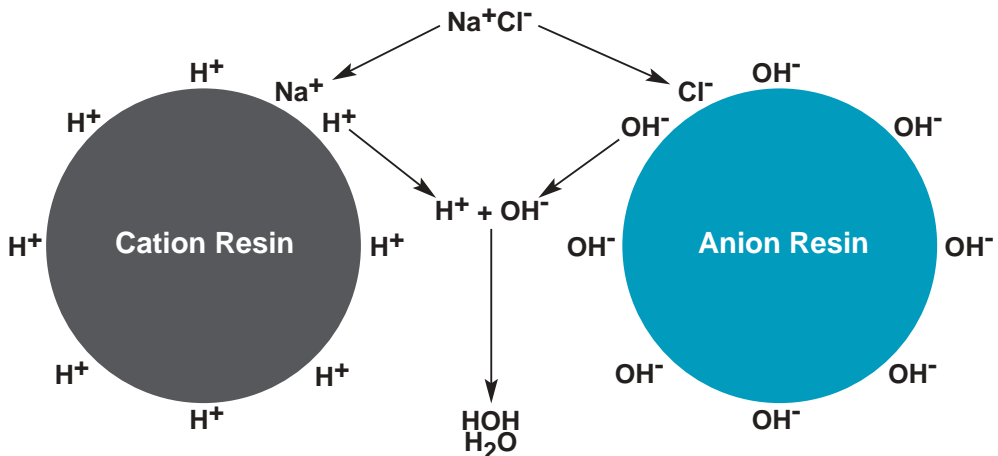
Deionization has several advantages (over distillation) for the production of purified water. It is an on-demand process supplying purified water when needed. Nuclear grade deionization resin or polishing mixed bed resin removes almost all the ionic material in the water to a maximum resistivity of 18.2 megohm-cm (at 25° C).

Deionization alone, however, does not produce absolutely pure water. Tiny fragments of the ion exchange resin are washed out of the system during operation and stagnant water in the cartridges may allow excessive bacterial growth. Deionization also does not remove all dissolved organics from the feedwater, and in fact, dissolved organics can foul the ion exchange resin. Finally, deionization cartridges can be an expensive option for labs that choose to replace their cartridges rather than regenerate them.

There have been many attempts to overcome the shortcomings of deionization and distillation. In some setups, distillation has preceded deionization — the cartridges last much longer, but the problems of bacterial contamination remain.

REVERSE OSMOSIS is a process which overcomes many of the shortcomings of distillation and deionization.

Reverse osmosis can be explained better after understanding the natural process of osmosis. Osmosis is the movement of water across a semipermeable membrane from the less concentrated (purer) side to the more concentrated (saltier) side. This movement continues until the concentrations reach equilibrium or the pressure on the more concentrated side becomes high enough to stop the flow. Osmosis is the natural process by which water is drawn into a plant's root, or moved from one cell to another in our bodies.



Anions and cations in the feedwater pass through the ion exchanger resins and replace the hydrogen and hydroxyl ions attached. The hydrogen and hydroxyl ions then combine to form pure water molecules.

If a pressure greater than the osmotic pressure is applied to the more concentrated solution, using a high pressure pump, water molecules are pushed back across the membrane to the less concentrated side, yielding purified water. This is the process of reverse osmosis.

Reverse osmosis typically removes 90-99% of most contaminants. A table of reverse osmosis performance characteristics follows:

Contaminant	Removal Efficiency
Suspended solids	100%
Bacteria	99.5%
Viruses	99.5%
Pyrogens	99.5%
Organics, molecular weight > 250 Daltons	97-99.5%
Monovalent inorganics	94-96%
Divalent inorganics	96-98%
Trivalent inorganics	98-99%

Because of its exceptional purifying efficiency, reverse osmosis is a very cost effective technology and is often used to pre-purify tap water for further purification by other technologies. Since reverse osmosis removes a high percentage of bacteria and pyrogens, it is often combined with ion exchange to significantly prolong the life of the deionization "polishing" cartridges. In addition, a system which allows dispensing of the reverse osmosis water gives a source of high quality pre-purified water, which is suitable for many routine laboratory purposes.

ACTIVATED CARBON FILTRATION removes chlorine by chemisorption and dissolved organics by adsorption and is often found at two places in a water purification system. Because thin film composite reverse osmosis membranes are sensitive to chlorine, and to a lesser degree, fouling from dissolved organics, activated carbon is often placed before the RO membrane to remove these contaminants.

A granular activated carbon filter is also often placed in the polishing loop of a water purification system to remove trace amounts of dissolved organics for water quality suitable for HPLC work.

MICROPOROUS FILTRATION or submicron filtration uses a membrane or hollow fiber with an absolute pore size of 0.2 micron that prevents any contaminant larger than 0.2 micron from passing through it. The submicron filters retain carbon fines from the carbon cartridge, resin fragments from the deionization cartridges and any bacteria that may have entered the system.

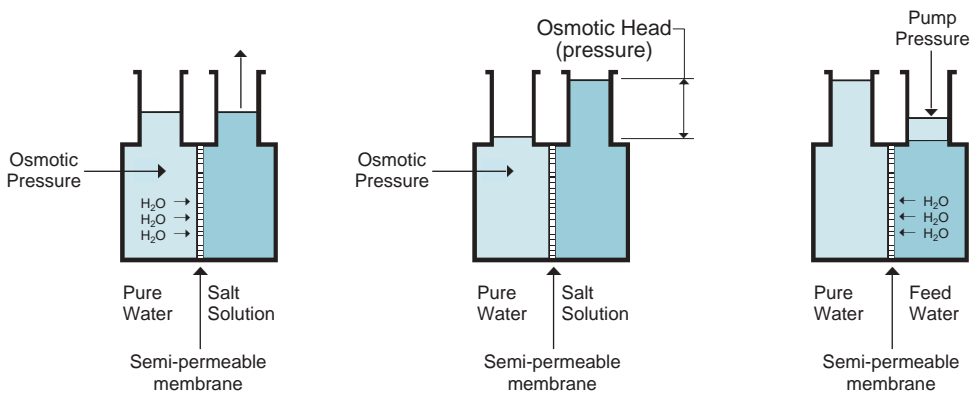
NCCLS considers water to be particulate free when it has been passed through a 0.2 micron filter. Microporous membranes are generally considered to be indispensable elements of a water purification system, unless they are replaced by an ultrafilter.

Do you need laboratory water to be particulate-free per Type I standards? _____

ULTRAFILTRATION uses a membrane very similar in design to reverse osmosis systems except that the ultrafilter's pores are slightly larger. The ultrafilter is used to remove pyrogens and other long chain organic molecules such as RNase from the purified water.

Since a high percentage of the water brought to the ultrafilter passes through it, it will eventually plug if not maintained. In a properly designed system, the ultrafilter is regularly and tangentially washed free of contaminants. With this type of design, ultrafiltration is an outstanding technology for ensuring very consistent ultrapure water quality.

Does your work require that you use pyrogen-free water? _____

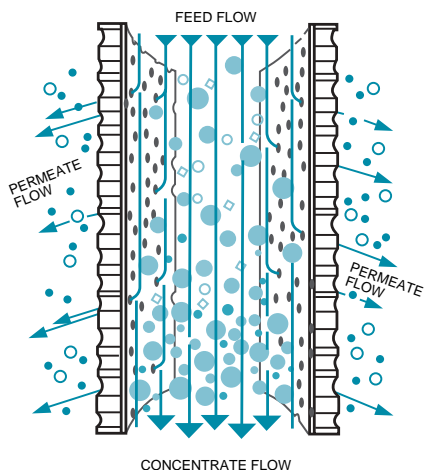


(a) OSMOTIC FLOW

(b) OSMOTIC EQUILIBRIUM

(c) REVERSE OSMOSIS

Reprinted from Handbook of Water Purification 1981 by courtesy of Walter Lorch, editor, and McGraw Hill, publisher.



Crossflow filtration in an ultrafilter showing pyrogens and particles larger than 0.002 micron being retained, while only pure water molecules pass through the pores.

Courtesy of OSMONICS, INC., Minnetonka, MN, USA.

ULTRAVIOLET OR PHOTO OXIDATION uses ultraviolet radiation at the biocidal wavelength of 254 nanometers to eliminate bacteria from the system. It also cleaves and ionizes certain organics at 185 nanometers for subsequent removal by the deionization and organic adsorption cartridges in the polishing loop.

ELECTRODIALYSIS (ED) removes impurities from water using an electrical current to draw ionic contaminants through ion selective membranes (ion exchange resin in sheet form) and away from the purified water. Used occasionally to produce potable water from clean brackish feedwater, ED is cost competitive with reverse osmosis.

To produce laboratory grade water, however, ED has several drawbacks and, as such, is rarely used in lab settings. First, the contaminants ED can remove are limited. ED cannot remove contaminants such as certain organics, pyrogens and elemental metals which have weak or nonexistent surface charges because they are not attracted to the membranes. Second, ED requires a skilled operator and routine maintenance. Large molecules which bear a significant charge such as certain colloids and detergents can plug the membranes' pores, reducing their ionic transport ability and requiring frequent cleaning. During operation, ED liberates caustic soda which may cause scaling, and hydrogen gas which is potentially dangerous. Finally, ED is relatively expensive. As ionic contaminants are removed from the water, its electrical resistance increases, so that higher electrical current is required to continue the purification process. Purification beyond the potable level is considered uneconomical due to the increased electrical consumption. Component materials such as platinum and stainless steel are also expensive.

Problems With The Traditional Approaches

While the water purification systems available today are often complex, they rely on traditional methods and are not problem-free.

The most common problems are:

1. Inconsistent quality.
 - a) water quality that is good on Friday, bad on Monday
 - b) bacteria-free water one day, bacteria-ridden water the next, often to levels that are non-potable
 - c) unpredictable pyrogen levels
 - d) difficult to monitor water quality — conductivity meters unrealistic or semi-functional
2. Lack of quality control with central systems.
 - a) reliance on others to maintain the system could result in several days' wasted work due to neglect or errors in regeneration of resins
 - b) difficulty in getting the system plumbed properly by trained personnel using inert materials
 - c) product water contaminated by plumbing and bacteria en route to the dispenser
3. System that makes product water of poorer quality than the feedwater.
 - a) organics leaching out of the system rather than being removed by the system, thus the water is unsuitable for HPLC purposes
 - b) carbon fines, resin fragments, and fiberglass fibers appearing as particulate matter in the product water
4. Traditional modular system designs.
 - a) heavy wall-mounted units that require professional maintenance crews to install
 - b) difficult to service
 - c) leaks likely when trying to service the unit
 - d) no sound insulation — very noisy
 - e) excessive costs for replacing cartridges and submicron filters
5. Improper specification of a water purification system.
 - a) inadequate investment in equipment resulting in system with low production rate or need for frequent cartridge changes
 - b) inconsistent water quality with components difficult to troubleshoot and correct

Which of these problems is your laboratory experiencing? _____

Labconco's Concepts in Water Purification

Labconco has developed three point-of-use water purification systems that directly address the shortcomings found in traditional approaches to water purification. The concepts that Labconco brings to the field of water purification, along with its high standards of quality construction of laboratory equipment and excellent service, are:

- a) *Recirculation throughout the polishing system*, to the dispenser(s), to minimize bacterial buildup found in standing water.
- b) *Unique dispensing gun* for sensitive one-hand control of flow rates and enhanced flexibility.
- c) *Informative diagnostic panels* to relay system status and performance.
- d) *Higher capacity filters* providing longer life, requiring fewer filter replacements, and reducing operating costs.
- e) *Highest quality materials*, including spiral wound thin film composite reverse osmosis membranes, nuclear grade resins, and all inert materials of construction, such as virgin polypropylene in the water pathway.
- f) *Timed dispense feature*, which automatically shuts off the dispenser once user set time has elapsed, to allow for unattended operation.

The first of the three water purification systems manufactured by Labconco is the **WaterPro Softener**. An ideal partner for any reverse osmosis water purification system, the Softener extends the life of the reverse osmosis membrane by protecting it from scaling due to hard water. The Softener may also be connected to a glassware washer to provide pretreated water to any cycle.

The **WaterPro RO Station** delivers laboratory grade water for routine use or for further purification by a polishing station. Its reservoir holds 17 liters of water and dispenses up to 8.7 liters per minute (gravity fed). When the reservoir is empty, the WaterPro RO typically dispenses water at a rate of one liter per minute (at 25° C). The RO Station may be mounted on a wall or on an accessory benchtop stand. It easily connects to

the WaterPro PS Polishing Station or to Labconco's glassware washers. An accessory 70 liter storage tank may be connected to the RO Station to provide additional water storage.

The **WaterPro PS Polishing Station** has a dispensing center equipped with either a dispensing valve or with a pistol to typically dispense up to 1.8 liters per minute of Type I water. Like traditional water purification systems, the WaterPro PS may hang on the wall or other vertical surface or be bench mounted using an accessory stand. Various cartridge configurations are available to suit the needs of analytical chemists, clinical and life scientists, and HPLC analysts. An optional dual wavelength ultraviolet reactor ensures both low TOC levels and bacteria-free water.



*Labconco #9000501 WaterPro PS Polishing Station
On Support Stand #9077400*

In addition, an accessory mobile stand adds portability to pure water delivery. It accommodates the WaterPro RO Station on one side and the WaterPro PS Polishing Station on the other side.

Testing the feedwater before selecting a water purification system is essential. Labconco offers the **WaterProfile Water Test Kit**, a free analysis. For a WaterProfile Kit or additional assistance in the selection of a water purification system, contact Labconco at 800-821-5525, 816-333-8811, or e-mail labconco@labconco.com.



Labconco #9075000 WaterPro RO Station

Glossary

ACS: American Chemical Society

Activated Carbon: A porous carbon material used for adsorption of organics and absorption of free chlorine.

Adsorption: The physical attraction and adherence of gas or liquid molecules to the surface of a solid.

Anion: A negatively charged particle or ion.

APHA: American Public Health Association.

BOD: Biological oxygen demand.

CAP: The College of American Pathologists.

Carbon fines: Very small particles of carbon that may wash out of an activated carbon filter.

Cartridge: A prepacked method for housing the filtering components of a water purification system. Because of the modular design of filter elements placed in a cartridge, the changing of exhausted filters is greatly facilitated.

Cation: A positively charged particle or ion.

Cfu/ml: Colony forming units per milliliter; a measure of viable microbial populations in water.

Chemisorption: The formation of bonds between the surface molecules of carbon and chlorine coming in contact with it.

COD: Chemical oxygen demand.

Colloid: A stable dispersion of molecular aggregates in water that have a size ranging between one and two hundred millimicrons. Colloidal iron, aluminum, and silica are commonly found in water.

Concentrate: The reject water from a reverse osmosis membrane; called the concentrate because it contains a higher level of contaminants than the feedwater.

Conversion rate: A quantification of the relationship between the volume of feed and product water of a reverse osmosis membrane.

Dalton: A unit of molecular weight, 1.66×10^{-24} grams; One Dalton is equivalent to the weight of one hydrogen atom. 1,000 Daltons are equivalent to a .0013 micron diameter for globular proteins.

Deionization: The process of removing the charged constituents or ionizable salts (both organic and inorganic) from solution. A purification process that uses synthetic resins to accomplish the selective exchange of hydrogen or hydroxyl ions for the ionized impurities in the water.

Distillation: A purification process involving the phase change of water from liquid to vapor and back to liquid, leaving behind certain impurities.

Electrodialysis: A purification process that removes impurities from water using an electrical current to draw ionic contaminants through ion selective membranes (ion exchange resin in sheet form) and away from the purified water.

Endotoxin: The lipopolysaccharide fragments of bacterial cell walls, ranging in size from 15,000 to one million Daltons in size; considered pyrogenic if they have a fever inducing effect.

Endotoxin Units: EU; a quantification of endotoxin levels using the LAL test.

Exhaustion: The state in which an ion exchange resin is no longer capable of useful absorption: the depletion of the exchanger's supply of available ions. The exhaustion point is typically determined in terms of the reduction in quality of the effluent water as determined by a conductivity bridge which measures the resistance of the water to the flow of an electric current.

Exotoxin: A toxic substance secreted by a bacterium, often causing disease, such as tetanus or botulism.

Feedwater: The water brought to a filtering method before it is filtered; the water entering a purification system.

GC: Gas chromatography.

Grain: A unit of weight; 0.0648 gram, 0.000143 pound.

Hardness: The scale-forming and lather-inhibiting qualities which water possesses when it has high concentrations of calcium and magnesium ions. Temporary hardness, caused by the presence of magnesium or calcium bicarbonate, is so-called because it may be removed by boiling the water to convert the bicarbonates to the insoluble carbonates. Calcium sulfate, magnesium sulfate, and the chlorides of these two elements cause permanent hardness.

Hardness as calcium carbonate: The expression ascribed to the value obtained when the hardness-forming salts are calculated in terms of equivalent quantities of calcium carbonate; a convenient method of reducing all salts to a common basis for comparison.

HPLC: High performance liquid chromatography; an analytical technique for separating one organic compound from another based on differential molecule weights and polarities.

Hydroxyl: The term used to describe the anion (OH^-) which is responsible for the alkalinity of a solution.

ICP: Inductively coupled plasma; a technique for analyzing a large number of different heavy metals simultaneously, usually preceded by a digestion using concentrated strong acids.

Ion: Any nonaggregated particle of less than colloidal size possessing either a positive or a negative electric charge.

Kilohms: One thousand ohms.

KMnO₄: Potassium permanganate.

LAL: Limulus Amoebocyte Lysate, a test for pyrogen/endotoxin levels. LAL is an extract from the horseshoe crab which forms a gel in the presence of sufficient pyrogens.

Mass Spectroscopy: A very sophisticated technique for molecular analysis that breaks a molecule into recognizable portions.

Megohm: A unit of electrical resistance; one million ohms.

Megohm-cm: The measure of electrical resistance across a one centimeter gap, used as an indicator of ionic contamination.

Micron: 1×10^{-3} millimeters; 1×10^{-6} meters; also known as a micrometer.

Microsiemen: A unit of measure of conductivity; also called micromho; the inverse of the megohm; 1×10^{-6} siemens. One microsiemen is equal to one megohm; ten microsiemens are equal to 0.1 megohm.

Monovalent: An ion in solution that has given up or gained only one electron, represented by one plus or minus sign in front of the ion's symbol. Sodium ion (Na^+), chloride ion (Cl^-), and ammonium ion (NH_4^+) are all monovalent ions.

Mixed Bed Ion Exchange: A combination of anionic and cationic exchange resins mixed together in one container.

Nanograms: 1×10^{-9} grams; 0.000000001 gram.

NCCLS: The National Committee for Clinical Laboratory Standards.

Nuclear Grade Resin: The quality of deionizing resin material required for the nuclear energy industry; the highest quality grade of resin.

pH: An expression of the acidity of a solution; the negative logarithm of the hydrogen ion concentration. pH 1 is very acidic; pH 7 is neutral, the theoretical pH of water; and pH 14 is very basic. The electromotive force between a glass electrode and a reference electrode when immersed in an aqueous solution as compared to that measured for a reference buffer solution.

Polish: The process of removing the remaining contaminants from a preprocessed feedwater.

Polishing Mixed Bed Resin: A mixed bed of cation and anion exchange resins designed for use in high purity water systems.

Pyrogen: A thermostable component of gram-negative bacteria cell walls that may cause a fever when injected or infused.

Reject water: The water from a reverse osmosis membrane which contains a higher level of contaminants than the feedwater that is carried out the drain; the concentrate.

Reverse Osmosis: A process in which water is forced under a pressure sufficient to overcome osmotic pressure through a semipermeable membrane leaving behind a percentage of dissolved organic, dissolved ionic, and suspended impurities, typically 90-100%. Product water quality depends on feedwater quality.

Silt Density Index: SDI; also called the Fouling Index; a test used to determine the concentration of colloids in water; derived from the rate of plugging of a 0.45 micron filter run at 30 psi pressure.

Specific Resistance or Resistivity: The electrical resistance in ohms measured between opposite faces of a one centimeter cube of an aqueous solution at a specified temperature. Resistivity is usually corrected to 25°C and expressed as megohms-cm.

Total Organic Carbon: TOC; measures the degree of contamination by microorganisms and organic compounds.

Total Dissolved Solids: TDS; a semi-quantitative measure of the sum total of organic and inorganic solutes in water.

Turbidity: Refers to the degree of cloudiness of the water caused by the presence of suspended particulate or colloidal material. In a photometric method, turbidity acts as an analyte by reducing the transmission of light; measured in turbidity units.

Ultrafiltration: A process in which water flows tangentially across a semipermeable membrane having a highly asymmetric pore structure. The membrane is tight enough to retain contaminants and macromolecules at its surface while allowing water to pass through. Typical pore diameter may range from 0.1 to 0.002 micron.

Ultraviolet (Photochemical) Oxidation: A process using extremely short wavelength light than can kill microorganisms (disinfection) or cleave organic molecules (photo oxidation) rendering them polarized or ionized and thus more easily filtered from the water.

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