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EDITION

How to Buy Water Purification Technology

A guide to all the key considerations to help you choose the best water purification system for your applications

eBook

SelectScience® 20 YEARS

Buying Water Purification Technology

The operation of all laboratories requires water for use in applications from general cleaning procedures to sensitive analytical techniques.

Water quality can significantly impact experimental results, so it is vital to have a reliable water purification system which provides the required quantity and purity of water for your applications.

This guide provides all the information you should consider when selecting a new water purification system for your laboratory.

arium® mini
by Sartorius Group.

Contents

1. Impurities in Water

Water can, to some extent, dissolve virtually every chemical compound, resulting in impurities.

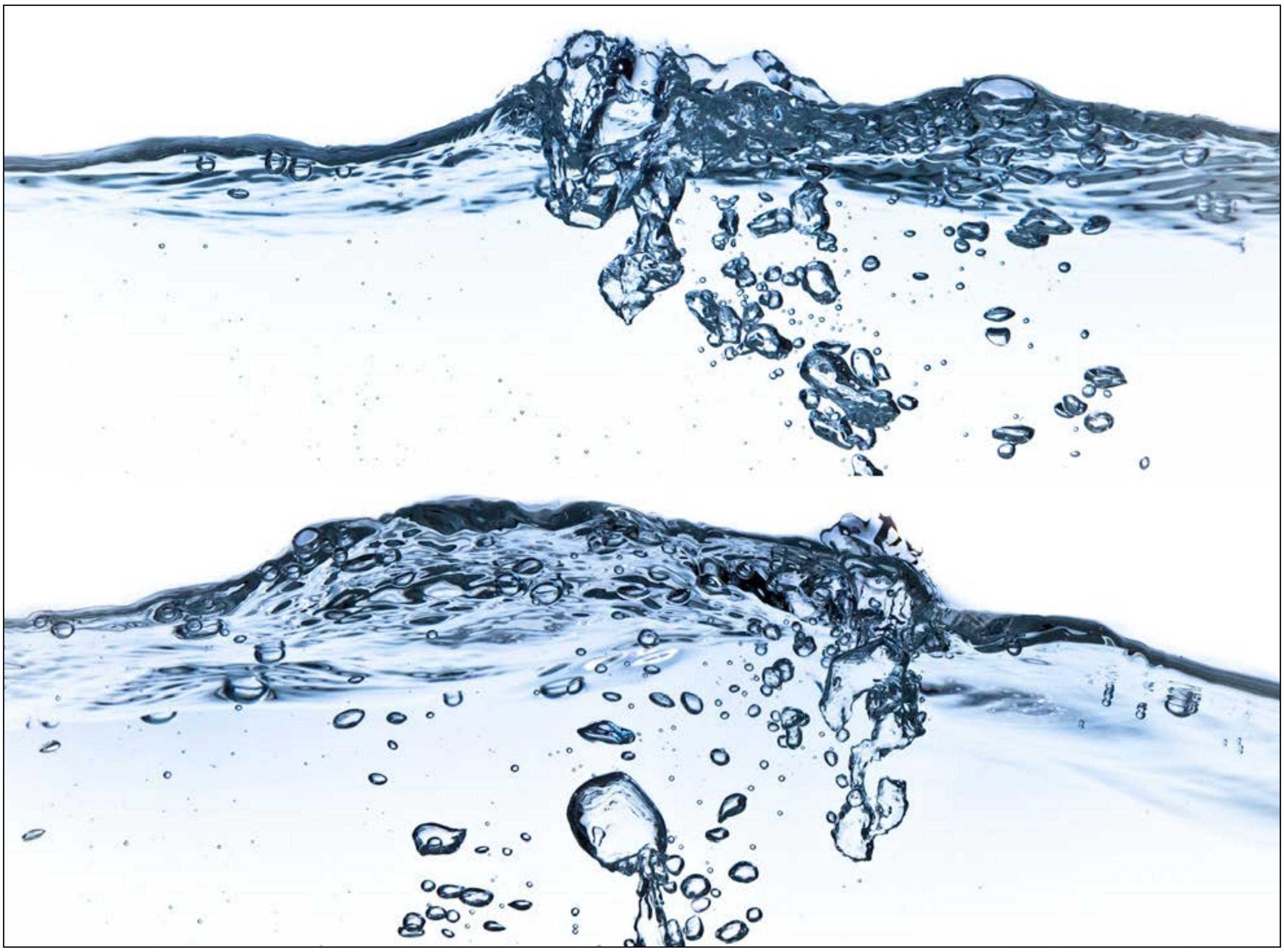
Thus, tap water is not suitable for most laboratory applications because it contains contaminants and varies significantly, depending on source, region and season. Table 1 shows the main water contaminants and how they affect experiments.

Several companies run courses where you

Impurity	Examples	Experimental Effects
Inorganic Ions	Calcium and magnesium salts (hardness salts), iron compounds, sodium salts, phosphates, nitrates...	• Interfere with protein-protein interactions • Lead to inaccurate results in elemental analysis and ion measurements (e.g. AA, ICP, IC) • Inhibit DNA polymerase activity, leading to poor PCR results
Organic Compounds	Decaying vegetable matter (tannins), pesticide residue, domestic waste, fats, oils, detergents...	• Increase in baseline noise in HPLC • Reduce sensitivity during HPLC experiments • Decrease HPLC column life • Bind non-specifically in place of DNA and RNA during hybridization, affecting cell cultures and blotting experiments
Particulates	Sand, silt, rock, pipe work debris, colloids, plant materials....	• Degrade the performance of reverse osmosis membranes • Clog small orifices in analytical instruments • Hinder the operation of valves, fittings and meters • Increase turbidity of the water and obstructs equipment operation
Microorganisms	Bacteria, such as staphylococcus, Pseudomonas aeruginosa...	• Release endotoxins and nucleases • Endotoxins inhibit sensitive processes such as in vivo fertilization and affect cell cultures • Nucleases disrupt many molecular biology applications, e.g. PCR • Form biofilms which excrete endotoxins, nucleases and bacteria randomly into the water supply
Dissolved gases	Nitrogen, oxygen, carbon dioxide...	• Lead to bubble formation that affects spectrophotometer experiments • High oxygen concentration can affect electrochemical and biochemical processes

Table 1. Water contaminants and how they affect laboratory experiments.

can find out more about where impurities are coming from, how to test for them and how to purify water to the standard required for your specific application. At the Sartorius Lab Water Academy, you can learn all this as well as how to work most efficiently with your lab water system and reduce your running costs without compromising on your water quality.



2. Laboratory Water Standards

Water is categorized into grades, specified by standards, for use in a vast range of laboratory applications. It is classified as Type I, II or III – Table 2 shows the parameters used to classify water type.

Type I is often referred to as "ultrapure water", Type II as "general lab water" or "DI" water and Type III as "primary grade water" or "RO" water.

Several professional organizations have detailed, published or proposed standards for water quality, such as:

- The American Society for Testing and Materials (ASTM)
- The International Organisation for Standardisation (ISO)
- The Clinical and Laboratory Standards Institute (CLSI)
- The International Pharmacopeia (including USP, EP and JP)

If any of the applications in your lab must adhere to the standards required by these organizations, it is important that the water purification system you are purchasing meets the specifications of the standard.

Parameter	Type III: Primary	Type II: Purified	Type I: Ultrapure
Resistivity / MΩ-cm	> 0.05	>1	>18
Conductivity/μS/cm	<20	>0.2	0.055
TOC / ppb	< 200	<50	<10
Bacteria / CFU mL^{-1}	<1000	<100	<1
Endotoxins / EU mL^{-1}	NA	NA	<0.03
Colloids / ppb	<1000	<10	<10

Table 2. General parameters used to classify water.

3. Water Requirements for Specific Applications in Your Laboratory

Some applications are very sensitive to certain contaminants, so when choosing your water purification system, you must consider the intended use of your purified water.

In certain situations, using Type II water instead of Type I could lead to errors. On the other hand, using Type I water when only Type II water is required may be uneconomical, wasting both money and resources. Table 3 shows several applications and the type of water required. This application note highlights the importance of water quality for LC-MS by evaluating its role in achieving sensitive and reliable LC-MS analyses.

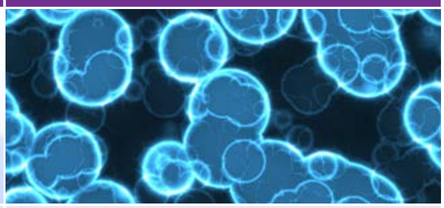
Type III: Primary	Type II: Pure	Type I: Ultrapure
		
• Glassware washing and rinsing • Autoclave feeds • Water baths and circulators • Environmental cabinets • Plant growth chambers • Feeds to stills • Feeding Type I water systems	• General laboratory use • Preparation of media, buffers and pH solutions • Preparation of reagents • Flame AAS • Cell culture incubators • Histology • Particle analyzers • Clinical analyzers • Colorimetry • Hydrogen generators • Kjeldahl • Spectrophotometry • Titrators • Feeding Type I water systems	• Highly sensitive analytical techniques • HPLC, LCMS, ICP-MS, • ICP-OES, AAS, GC, IC, MALDI • Molecular biology applications, e.g. PCR, DNA sequencing • Clinical analyzers • Mammalian cell culture media • Microbiology • Blotting • Electrochemistry • Immunohistochemistry • Electrophoresis

Table 3. Water types and associated application.

4. Methods of Water Purification

In this section, we briefly describe several technologies which can be used to purify water. The benefits and limitations of each technology are highlighted in Table 4.

Depth Filters
Microporous depth filters are constructed from materials in a matrix or matted fibres. They are an economical way to remove >98% of suspended solids and protect downstream technologies. They function by creating a physical barrier which entraps particulates and prevents their onwards passage.

Activated Carbon
Activated carbon can be used to remove organic contaminants from water. It is often used in pre-treatment cartridges, to help protect reverse osmosis membranes or ion exchange resins, especially where feedwater contains a high level of organic contaminants. It has a highly porous structure with a large surface area onto which organic molecules can adsorb through a diffusion-controlled process.

Distillation
Distillation is the oldest method of water purification, and removes a broad range of contaminants, providing the contaminants do not have vapor pressures close to water. Stills can be used in the distillation process to produce Type III water but are inefficient compared to other water purification methods, with high water and power usage. Therefore, despite low purchase costs, running costs are extensive.

> "Despite low purchase costs, running costs are extensive."

Reverse Osmosis (RO)
RO offers a cost-effective method to remove the majority of water contamination. RO membranes are stable over a wide pH range and can remove particulates of <1 nm diameter, approximately 90% of inorganic ions, and most organics. Type III water for daily laboratory applications can be produced using RO-membranes, using equipment such as the arium® advance RO or the Barnstead™ Smart2Pure™ Water Purification System.

Ion Exchange
Ion exchange resins are beads made of insoluble polymers with surface ionic exchange sites. The beads are packed into beds and are available as cartridges or cylinders, which are replaced or regenerated over time. The resins remove ions from water and replace them with H+ ions (from

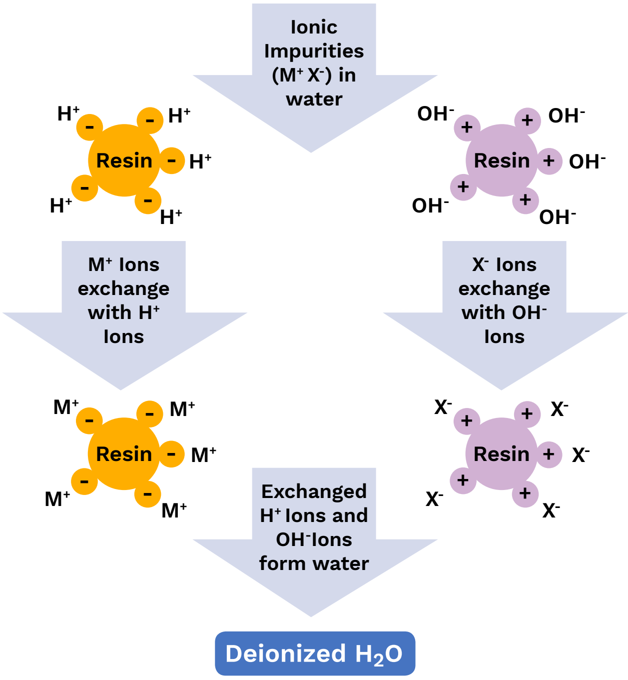


Figure 1: Deionization of water using ion exchange

cation exchangers) and OH- ions (from anion exchangers). Water is formed when the exchanged H+ and OH- ions combine (Figure 1). When the H+ and OH- sites on the resins are occupied, the resins are exhausted, and the cartridge/cylinder is replaced or recharged at a regeneration center.

Electrodeionization (EDI)
Electrodeionization (EDI) combines ion exchange resins and ion-selective membranes in the presence of an electric field to remove dissolved inorganic ions from water. EDI modules consist of two electrodes (anode and cathode) that are separated by columns of ion exchange resins and ion-selective membranes. Water passes through the column and ionic impurities attach to the ion exchange resins. Ions are pulled from the resin through the ion-selective membranes towards the electrode by an electric field applied across the EDI module. Cations travel through the cationic-membrane towards the cathode, and anions move through the anionic-membrane to the anode. Some ions are trapped within a concentration chamber and are flushed to waste. Regeneration of the ion-exchange resins occurs continuously throughout the process as the electric current splits water into H+ and OH- ions, overcoming the limitations of water purification using ion-exchange resins. EDI is commonly used to produce Type II water, for example in Sartorius's arium® advance EDI.

> "EDI is commonly used to produce Type II water."

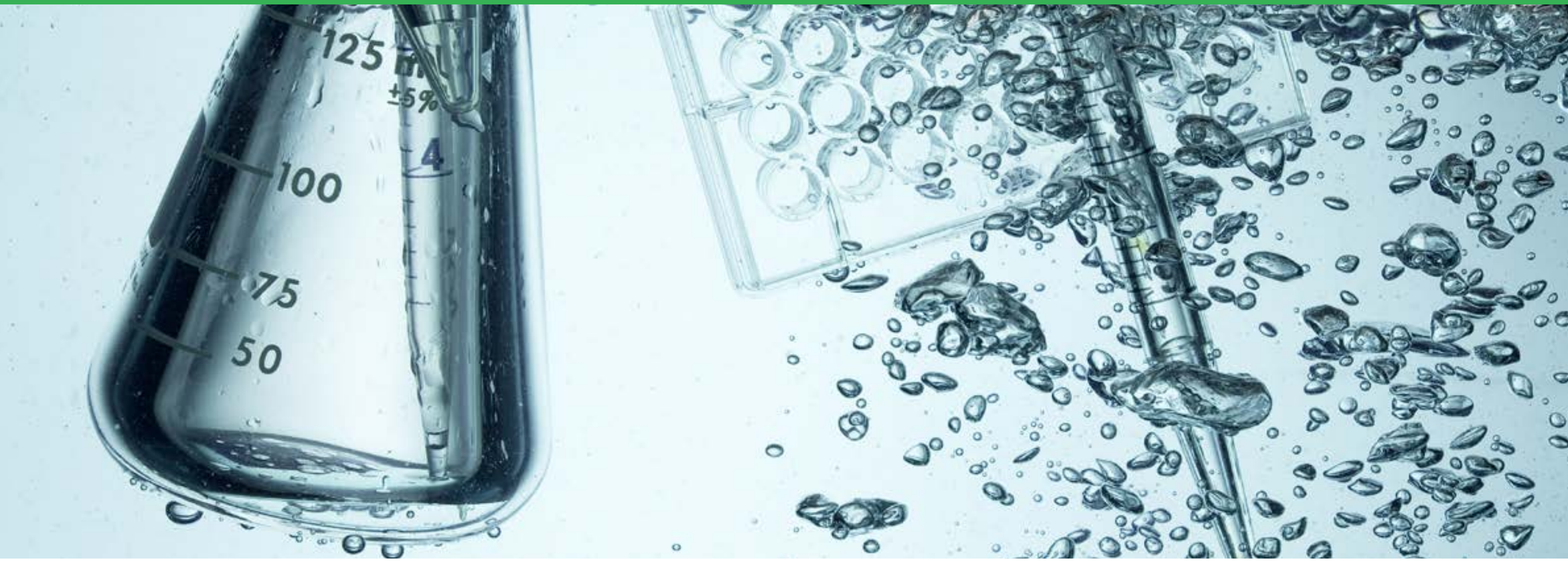
Ultrafiltration
Ultrafiltration uses a porous membrane filter (pore size 1-10 nm) to filter out colloids, microorganisms, particulates, enzymes and endotoxins, depending on the contaminant's size. Membranes are often in the form of hollow fibers to permit higher flow rates. Many Type I water systems contain an ultrafiltration filter to ensure consistent point-of-use quality with respect to bacteria, particles and endotoxins. MilliporeSigma's BioPak® Polisher shows how ultrafilters can be attached directly to a dispensing unit to provide a final filter for specific applications.

Ultraviolet (UV) Radiation
Ultraviolet radiation is an effective bactericide; it can also be used to ionize some organic contaminants to produce ionic species that can then be removed using ion-exchange resins. The UV lamps used in water purification systems can produce radiation at wavelengths of 254 nm and 185 nm. Radiation with a wavelength of 254 nm damages DNA and RNA polymerase in microorganisms to prevent replication, whereas at wavelengths of 185 nm, most organic contaminants are photo-oxidized to produce ionic species. UV radiation is a necessary step for certain applications which require very low TOC levels.

Membrane Filtration
Membrane filters are commonly used at the outlet of water purification systems for particle removal and sterile filtration. They are designed to remove all particles above the filter's rated pore size. In laboratory water systems, membrane filters usually have a rated pore size below 0.45 µm, with the most common size being 0.2 µm.

	Benefits	Limitations
Depth Filters	• Efficient operation throughout their lifetime, unless they are damaged • Maintenance is limited to replacement	• Do not remove dissolved inorganics, organics or pyrogens. • Not regenerable • They will clog when the surface is covered by contaminants
Activated Carbon	• Chlorine removed effectively • Significantly reduces TOC • Long life span	• Not all dissolved organic contaminants are removed • Carbon fines can be released • Cartridges need to be changed regularly
Distillation	• Removes broad range of contaminants • Low capital cost • No filters or cartridges required	• Slow process • High energy and water consumption • Requires periodic heater changes • Requires cleaning with strong acids • May necessitate the use of pre-treatment
Reverse Osmosis	• Removes a broad range of contaminants to various levels • Minimum maintenance • Economical • Easy to use and monitor	• RO membrane prone to fouling • Limited flow rate, therefore requires water storage solution • Requires pre-treatment to avoid membrane damage • Produces only Type III water
Ion Exchange	• Provides water resistivity of 18.2 MΩ-cm • Cost effective option for producing small volumes of purified water on demand • Easy to use • Resins regenerated by deionization	• Microorganisms, particulates and organics are not removed • Resin beds prone to fouling if feed water contains high levels of organic contamination • Resin beds require regeneration; beds that are chemically regenerated can form organics and particulates
EDI	• Provides water resistivity of 5-17 MΩ-cm and TOC below 20 ppb • Resins are continuously regenerated and do not require disposal	• Not capable of producing 18.2 MΩcm water • Feed water must be good quality for economical operation
UV Radiation	• Provides water with <5 ppb TOC • Effective at removing microorganisms	• Ions, particulates and colloids are not removed • To achieve <5 ppb TOC, photooxidation is required • CO_2 produced during photo-oxidation decreases the water's resistivity
Ultrafiltration	• Removes most particulates, colloids, microorganisms, enzymes and endotoxins • Efficient and easy to use • Long lifetime if regularly flushed with high speed water	• Dissolved inorganic and organic substances are not removed • Membrane pores can block if the water contains a high level of high molecular weight contaminants
Membrane Filtration	• Absolute filters that remove all particles and microorganisms greater than their pore size	• Clog when surface is covered by contaminants • Not regenerable • Dissolved inorganic and organic substances are not removed

Table 4. Benefits and limitations of water purification technologies.



5. Water System Configurations

Depending on your specific needs, there are several configurations to provide purified water for a facility or application.

One of the first decisions is whether a centralized or a point-of-use system is best for you. Table 5 presents some of the advantages and disadvantages of these systems.

Centralized systems may be used to feed polishers at the point of use, to provide water for a specific application. Some centralized systems, such as the Elga LabWater CENTRA, can use a single unit to perform both water purification and distribution. Separate feed systems are also available for applications such as to feed clinical analyzers which require a constant supply of purified water.

> "Is a centralized or a point-of-use system is best for you?"

Table 4, in the previous section, highlights the benefits and limitations of each water purification method, demonstrating that a single technology is not capable of removing all water impurities. It is therefore important to combine technologies to design a system

Centralized System	**Point-of-Use Systems**
Water for an entire facility. **Advantages:** • One system maintained by the facility, not individual lab budgets • Lower initial investment **Disadvantages:** • Difficult to determine water quality • No control of how the system is maintained – if system fails, the entire facility is without water	Water for an entire lab or application. **Advantages:** • Water quality is easily determined • Complete control of maintenance • Water immediately from the system **Disadvantages:** • Requires laboratory space • High initial investment • Maintenance costs from lab budget

Table 5. Advantages and disadvantages of centralized and point-of-use systems.

that meets your specific water purification needs. Different combinations of technologies are best suited to each application and water type. Figure 2 illustrates the usual order of purification technologies in a water system and the type of water they produce.

A single system or multiple different systems can be used to produce Type I water from tap water. This often depends on your needs and the systems already in place in your facility. Several steps are required to convert tap water to Type I water. Primary treatment produces Type II or III water. The polishing step then converts this water into Type I water. Systems such as the [arium mini plus] can produce both Type I and II water from different dispensing points. Whereas, if your lab already has a DI water outlet from a centralized system, you may be more suited to a polishing system such as the arium mini essential, which can use this as a supply to produce Type I water.

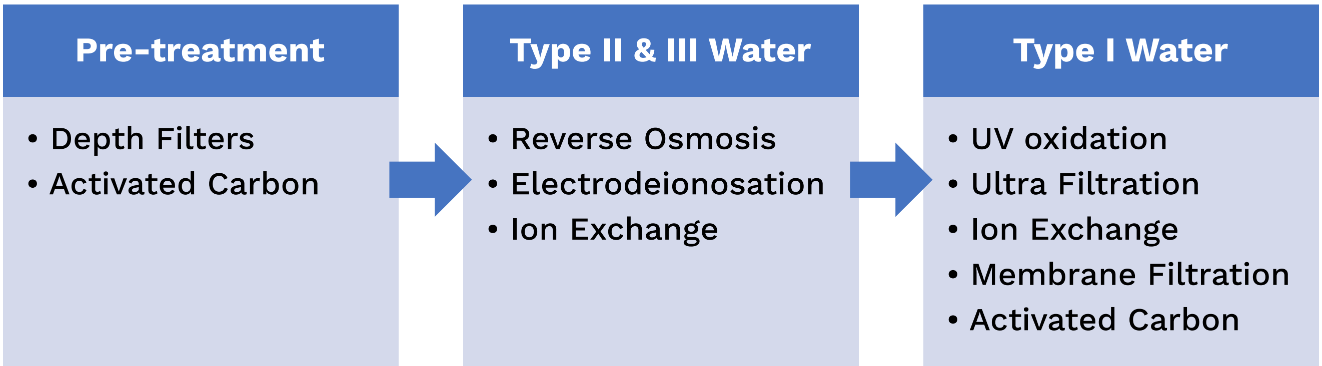


Figure 2. Technologies used to generate Type I, II and III water

6. Key Considerations when Choosing a Water Purification System

When purchasing a new water system for your laboratory or facility, ask yourself the following questions before discussing options with a manufacturer.

Application
To choose the correct purification system for your needs, evaluate the water quality requirements for the different applications in your laboratory.

- What analytical instruments will your water be used for?
- Will you use the water solely for specific experiments?
- What are these experiments?
- Will your water be used for more general purposes in the lab, such as feeding a dishwasher, autoclave or water bath?

It is common to have multiple intended uses for water in a laboratory. Many systems are available that can offer both Type I and Type II or III water. It is important to consider what experiments you will be using your purified water for, as some experiments have specific water requirements, as shown in Table 3. Some manufacturers have dedicated water purification systems for 'sensitive' applications, or application-specific, point-of-use polishers that can be connected to their polishing system to produce such application-specific Type I water. For example, the arium® pro uses your choice of modular components to deliver Type I water tailored to your specific application.

TOP TIP

If your lab needs more than one type of water, some manufacturers have systems that produce two water types from a single system, e.g. Type III and Type I, or Type II and Type I water from a single unit (at different dispensing points).

Volume of Water Required
- How much water do you use in your lab?
- What volume of water do you require at peak times?

- The quantity of water required should be based on when your water demand might peak, instead of total consumption levels over a period (daily, weekly, etc). Although a system may be able to deliver the total volume of purified water required for a day, it may not be able to generate the volumes of water required during peak times, such as the filling cycle of a lab glassware washer.
- What might your future water needs be?
- It may be wise to future-proof your lab by buying a system that slightly exceeds your current requirements, allowing you to cope should there be an increase in demand for pure water in the near future.

TOP TIP

Make sure your water system is not oversized. In the same way that you need a water system that is large enough to deliver the volume you need, it also should not be any larger than necessary. Oversized systems will take up more space and will allow the purified water to be stored for longer periods, which increases the chance of bacterial contamination.

Operation

- How user-friendly is the system?
- Do you want to dispense water unattended?
- Will you need to repeatedly dispense the same volume of water?

Many systems now have easy-to-use touch screen displays. Volumetric and remote dispensing options are also popular; the Barnstead GenPure xCAD Plus and Elga PURELAB Chorus with Halo advance dispenser both offer these functions. They allow specific volumes of purified water to be delivered some distance away from where it is generated, with monitors on the remote dispenser allowing you to check the quality of water that is being dispensed right at the point of use. Repeat dispensing of identical volumes is also possible with Sartorius's favourites function, another useful feature of the arium® mini.

Maintenance and Downtime

The system's performance depends on proper maintenance. Parts and cartridges must be replaced; most systems require regular sanitization. Maintenance of the system should be as easy as possible, allowing for minimal downtime.

Sanitization often uses harsh chemicals and adds to the downtime of the system. This can be prevented with bagtank technology, as featured in the arium® range of water systems. Not only does it prevent secondary contamination and the formation of a permanent biofilm by using materials tested in the pharmaceutical industry, but unlike traditional tank systems, it's disposable and easy to exchange. This process takes less than five minutes, resulting in significantly reduced downtimes.

You may choose a system with built-in alarms and calibrators that warn if certain components are coming to the end of their

TOP TIP

Make sure the water is circulated regularly, as moving water stays purer for longer, especially when considering biological impurities. Therefore, circulating water can prevent the need for such frequent sanitization.

lives. Make sure parts and accessories are easily obtainable. Ask the following questions to ensure your system will be well maintained:

- Does your laboratory have someone who oversees the maintenance of the water system?
- Are the parts and cartridges easy to replace?
- What is the parts warranty for the system?
- Does the manufacturer provide technical support?
- What are the manufacturer's service options?

Feedwater

It is critical to a water purification system's performance that the feedwater requirements of the system are met. If the system feeds on tap water, and the tap water does not meet the specifications set by the purification system manufacturer, pre-treatment might be necessary. For example, very high organic load in the tap water will require activated carbon to bring it down to acceptable levels. Using the correct feedwater is essential to obtain the correct purity of water and achieve the optimum lifetime for your cartridges and purification system.

The arium® mini series has a number of options depending on your feedwater source. The arium® mini plus can produce Type I water directly from tap water. The standard arium® mini uses pre-treated water from a supply container. Whilst the arium® mini essential directly connects to a pre-treated (RO, DI or EDI) water supply line.

TOP TIP

When buying a Type I water system, determine the source of the feedwater. There are Type I systems that feed directly on tap water. If you have an existing source of Type II or III water, you may decide to purchase just a polishing system. However, it is important to consider how reliable this existing source of Type II or III water is. Has the system broken down before? Does it have a history of contamination? Remember, the quality of Type I water depends a lot on the feedwater.

TOP TIP

Type II or III water is used as feedwater for Type I water systems. The performance of a Type I water system, and the quality of the water it produces, rely heavily on feedwater. It is therefore critical that you make a good decision about your Type II or III system if it is to be used to produce Type I water.

Laboratory Space

Laboratory space is at a premium, so it is important to choose a system that is flexible enough to be accommodated in your laboratory.

- Where will you locate your lab water system?
- Is the water system modular to fit your lab?
- Can the water system be mounted on the wall or under the bench?
- Does the water system have a remote dispenser that will free bench space?

The arium® mini series offers an attractive option for a compact system. The arium®

mini plus is only 28cm wide and can produce both Type I and II water directly from tap water. Edstrom Industries also produces the compact Pico system, which can produce either Type II or III water.

Online Monitoring

Is it important to your application that the water quality is monitored? Many systems now offer 24-hour online monitoring with email notifications when deviations from the required standards occur.

If your application is sensitive to ionic contamination, it would be useful to monitor the resistivity of the water. Whereas if organic contamination is critical for your applications, it is best to purchase a system with online TOC monitoring, and not just rely on the resistivity of the water. There is no correlation between ionic contamination and organic contamination. Water that has resistivity of 18.2 MΩ-cm does not necessarily mean it has low TOC.

Regulatory Guidelines

Some manufacturers offer programs to facilitate validation procedures, deliver certificates of calibration, or offer features ensuring full regulatory compliance. If you are concerned about traceability, you can select a system that stores a history of key information, or that allows remote access to the system status and water quality parameters through an internet browser.

Environmental Impact

What is the electricity and water consumption of your chosen technology? Innovations such as Sartorius's arium® iJust technology help ensure economical water usage. Variable motor speeds, as seen in Triple Red's Duo system, help save energy when a system is not in use.

What is the frequency of cartridge replacement? Some manufacturers have cartridge return programs and recycle the exhausted DI modules.

Consider a system that uses electrodeionization (EDI); it uses small quantities of ion exchange resin that are rapidly and continuously regenerated, avoiding the environmental impact of chemical regeneration associated with service deionization.

Another innovation making water purification more environmentally friendly is MilliporeSigma's mercury-free UV lamp which is part of the Milli Q IQ 7000 system. The video below introduces this, and other features of the system.

In this video, Veronique Fontalbat explains the vast range of innovations developed for the Milli-Q IQ 7000.

Cost/Budget

In order to get the best water purification system for your lab for the best price, be sure to ask these questions:

- What is the initial investment for the system?
- Are you buying the system as a bundle or as many individual parts?
- What are the annual costs?
- What are the costs for consumables?
- What will the power consumption be?
- What are the costs for a manufacturer's service contract?
- How much water goes to waste?

7. Future Trends in Water Purification – Ask the Experts

High purity water is being produced by many systems such as those featured in this eBook.

However, the demand for flexible, high-performance and user-friendly water systems to provide purified water to meet the needs of ever-improving analytical instruments is driving new innovations in this area. We asked a number of experts in the field: "What trends do you expect to see in lab water purification in the future?"

> "Reverse osmosis technologies will send less water to drain."

- Connectivity

« Connected » water systems that will send relevant data and information to e-Notebooks, chromatography data systems, LIMS, and building management systems, facilitating seamless — if not automatic — data management, technical service, product support, and procurement means, providing continuous service and performance.

- Fully-customizable lab water

Contaminant-specific purification steps.
Specific purification steps to meet the needs of future analytical instruments.

- Ease of use

Improved ergonomics to meet the varied needs of labs.
Easier set-up.
Improved menu navigation.
Reduced maintenance leading to no system downtime.

- Green technology

Reverse osmosis technologies will send less and less water to drain.
New purification media will result in smaller consumables, creating less waste.
Completely recyclable cartridges as a result of new media.

Reduction in the use of mercury-vapor lamps, leading to the elimination of special disposal steps for UV technologies.

8. Summary and Acknowledgements

It is important to select the best water purification system to ensure the water produced in your lab is the most suitable for your applications and research.

Visit the SelectScience® water purification product directory for an overview of the latest water purification technologies from leading manufacturers and to read product reviews.

Keep up-to-date with the latest advances in water purification technologies by visiting the SelectScience® General Lab pages for application notes, news and videos.

Acknowledgements
Nadia Brandes - Sartorius
Diane Donati and colleagues - EMD Millipore

arium® mini
by Sartorius Group.

7. Editor’s Picks

arium® mini

by Sartorius Group.

★★★★★

“Easy to set up and use. Refills while using. Very satisfied with system for our application.”

Thayer Coleman,
Evonik

Barnstead™ MicroPure™

by Thermo Fisher Scientific.

★★★★☆

“Must-have for trace metals lab!”

Petr Kuznetsov,
University of Alberta

Analytical Grade Type I DI System

by Aqua Solutions, Inc.

★★★★★

“Customer service is great - they have real people that know their stuff for you to talk to if you have problems or questions.”

Karin Krieger,
CRI

Milli-Q® IQ 7000 Ultrapure Lab Water System

by MilliporeSigma.

★★★★★

“Love small footprint of dispenser and cleanup unit tucked in the back of the bench.”

Joseph Bonadies,
Ag Division of Dow Chemical

PURELAB Chorus 2

by ELGA LabWater.

★★★★★

“Good product, easy to use and reliable.”

Chaoying Wan,
University of Warwick

Autwomatic Plus 1+2

by Wasserlab.

★★★★★

“The principal standard for our Labs.”

Guillermo Moraga,
Tecno-Center, C. A.