pure water

mark bosley, technical director, looks at the challenge of producing purified water in cleanroom applications.

suez

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Water is perhaps one of the most important raw materials used in cleanroom processes for research and development and in laboratory and production applications, ranging from the manufacture of specialised electronics, sensors and optical instruments, to drug development, reagent mixing and glass washing.

The quality of raw water, however, drawn from mains or local borehole supplies, can be extremely variable in terms of chemical composition, dissolved minerals and contamination from organic and other particulate matter, while the hardness of source water can change dramatically from region to region.

As a result, most cleanroom facilities will have measures in place to ensure a consistent supply of high purity or ultrapure water, using a variety of solutions from bottled distilled water to advanced and automated reverse osmosis and deionisation plant.

Many of these systems will, however, have been in use for extended periods and may no longer be compliant with the latest standards or, as importantly at a time when raw water and energy costs are rising fast, have become expensive to operate and maintain; it therefore makes sense periodically to review existing arrangements.

Smaller and more efficient

Many of the recent developments in water purification technology have been designed to reduce the overall size of units, while increasing their efficiency through improvements in filtration and separation processes and by introducing sophisticated data capture and real time monitoring and control devices.

In addition, the capital and operational cost of many smaller laboratory size units, for bench or wall mounting, has fallen to the point where they offer a viable alternative to the purchase of bottled distilled water, or the use of an on-site still; as a result, they can provide a remarkably fast return on investment together with the ability to have a supply of high purity water available on tap, whenever required and at the point of use.

Self contained benchtop systems, requiring just water and electrical connections, are ideal for many laboratory and small scale cleanroom operations, where between 5 and 45l/hr of purified water is required. These systems generally use high quality reverse osmosis (RO) and pre-treatment modules, with options for deionisation, UV disinfection and additional point of use filtration. In terms of water quality, they are capable of producing

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water from 5µs/cm right up to 18MΩ.cm; or water that is suitable for feeding units such as humidifiers through to ultra pure water for use in tissue culture, IVF, life science and molecular biology applications.

The latest benchtop systems, such as the Select Fusion from SUEZ, also offer a range of features that make them easier to use in smaller cleanrooms and laboratories, where space is at a premium. For example, in addition to a small footprint, typically measuring less that 0.5m², they have internal storage tanks and can be supplied with dual outputs providing lower grade water for general duties and ultra pure water for specialised use. These units also incorporate automatic water recirculation systems to maintain quality and minimise energy consumption when the system is not being used.

This is achieved by pre-filtering and de-chlorinating the raw water feed, then passing the pressurised water stream through high performance semi-permeable polymer RO membranes. The permeate of purified water passes through the membrane, which rejects up to 98% of minerals and salts; this concentrate is normally run to drain or reclaimed if there is an appropriate use for it.

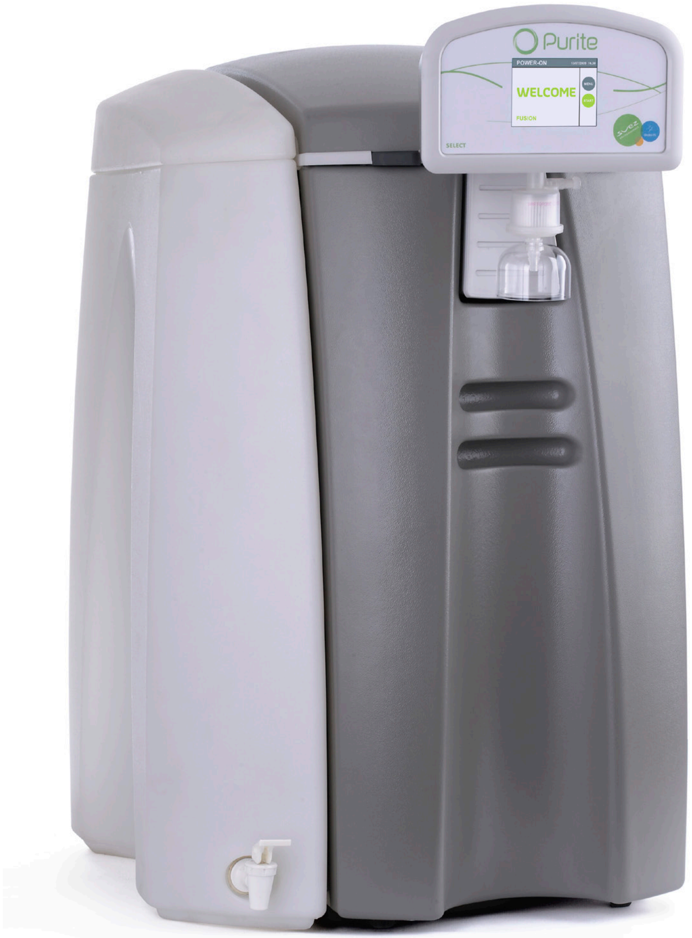
RO membranes typically operate at an efficiency of up to 75% recovery, dependant on feed water quality, and in addition to demineralising the water, can remove over 99% of micro-organisms.

The purified water is stored in an internal tank from where it can be used directly; alternatively, for the ultra pure stream, the RO treated water is then fed through a polishing cartridge filter containing nuclear grade resins. These specialised high purity materials remove residual ionic contaminants by chemically bonding the charged ions to the ion exchange resins; the system can produce water rapidly to a purity of 18.2MΩ.cm with low total organic carbon (TOC) content.

Finally, the water stream can be fed to an ultraviolet (UV) disinfection unit, using the photo-oxidising properties of UV at either 185nm to break chemical bonds, producing water with extremely high resistivity and low TOC, or at 254nm to enhance the disinfection effect and reduce levels of bacteria to the lowest possible level.

Production volumes

For applications where higher volumes of purified water are required, typically up to 600l/hour, then the technology described above can effectively be scaled up. Again, purification units can be self contained and although physically larger remain relatively easy to move



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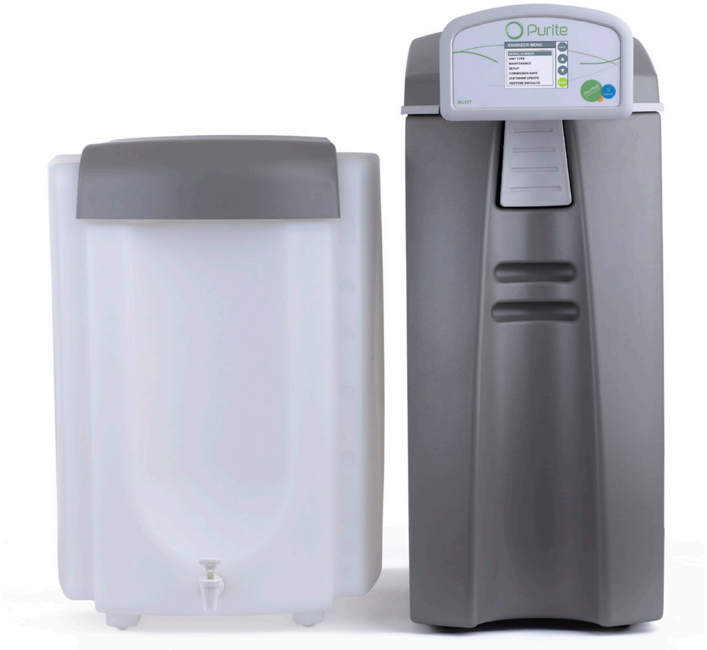
and locate, with integrated raw water break and pure water tanks, semi-automatic chemical sanitisation, re-circulation and rinse systems.

Where even higher volumes of water are required then custom built plant will generally be needed, using a combination of pre-treatment, reverse osmosis and ion exchange technology, such as electro-deionisation (EDI or CEDI).



The degree of pre-treatment will depend on the scale of the plant and the nature of the raw water feed-stream, especially if it contains high levels of particulates, organic matter or contamination that would otherwise interfere with the RO process. Pre-treatment is generally achieved by means of sand or multimedia filters, cartridge filters, used in series or, where raw water quality is particularly poor and has a high fouling potential, ultrafiltration using membrane technology.

The feed water for a large RO system is normally softened to prevent the build up of calcium deposits on the RO membranes and this is achieved using softening resins that remove the hardness by exchanging calcium ions, which are the main contributor to hardness, with sodium ions.

The pre-treatment stage may also require carbon filtration, which has the dual function of removing free chlorine, frequently present as a disinfectant in drinking water, and reducing the level of dissolved organics. Both of these are important for RO treatment as free chlorine irreversibly degrades the RO membranes, and organic matter can lead to fouling.

The function of the RO membranes in larger plant is identical to that for smaller benchtop units; similarly,

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larger plant uses deionisation processes to remove the ions that remain following reverse osmosis.

Although ion removal can be achieved in larger plant using cation or anion specific ion exchange resins a more efficient electrodeionisation (EDI) process is generally preferred. EDI combines ion exchange resins sandwiched between charged membranes. Under an applied voltage the potential difference set up across the membranes attracts the charged ionic contaminants from the water and towards their respective electrodes where they are rejected in a waste stream.

The process is also self-regenerating due to the production, in-situ, of small amounts of hydrogen and hydroxyl ions, which help to maintain the ion exchange resins in a regenerated state. Following EDI, the water typically has a resistivity in the range 10-18 MΩ.cm. The removal of dissolved carbon dioxide, prior to the EDI cell, will further enhance the system performance at this stage and can be achieved by the use of specialised membrane degassers.

Data is key

Regardless of the scale of the water purification system, the ability to capture, analyse and monitor data is rapidly becoming a critical element in maintaining overall function, performance and reliability. As a result, the latest generation of equipment features sophisticated control technology that can, for example, monitor temperatures, flow rates, pressures, element condition and TOC; in addition, this data can be stored internally for long periods, to comply with Good Manufacturing Practice, and can also be uploaded to remote systems for subsequent analysis.

The ability to gather and analyse data in real time also makes it possible to minimise maintenance and operating costs. The can be achieved both through better energy usage and by regularly monitoring the actual condition of filters and other consumable components, so that they are only replaced or regenerated when their performance has fallen below a pre-determined limit, rather than at arbitrary maintenance internals.

The latest water purification systems for laboratory, and for low and high volume production applications in the cleanroom sector offer managers and technicians important advantages, both technically and commercially.

These include the ability to improve water quality and delivery, from reliable systems that operate to consistent and approved standards, and the opportunity to reduce long term operating costs which, at a time of rising energy and water prices, may prove to be a valuable weapon in the war to protect profit margins.

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