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Redrawing facility boundaries to promote industrial water reuse

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US industrial sector water management traditionally overlooks high-value treated water reuse opportunities. To reshape the narrative around industrial water reuse, water-related process boundaries should be expanded to include all water sources and sinks and focus on opportunities for on-site circularity.

Water is a critical input in industry, but there is growing stress on water supplies in the USA[1], such as from water quantity and quality concerns and the growth of data centres[2]. Encouragingly, corporate-level water-saving goals are being set[3] and there are many opportunities to reuse water within industrial sites, but there are barriers to achieving these goals. In this Comment, we identify the barriers to water savings that we commonly see in our work with industrial water in the USA and recommend ways to increase facility-level water reuse.

Conflict between goals and incentives

Lack of incentives and data can be major barriers to water savings. Corporate-level water-saving goals are undermined by the low direct price of water that industry pays in the USA and a perception that water is a cheap utility. For example, average industrial water in the USA ranges from less than US$1 (for self-supplied surface or groundwater) to just under US$4 (for municipal supplied) per thousand gallons[4] (or ~3,785 l). Such low water costs can lead to plants relying solely on external utility meters and not monitoring water use within a site. Compounding this, industrial sites might adopt a compliance-first posture, prioritizing regulatory discharge requirements as compliance issues are seen as acute risks to continued operation.

Our industry interactions also suggest that water-efficiency-specific projects often yield minimal cost savings when evaluated solely on supplied water price. Such projects typically fall short of conventional 1–3-year payback periods and are often left unfunded. Site personnel are therefore expected to deliver measurable reductions while operating under tight resource constraints, limited data visibility and minimal financial motivation. Moreover, manufacturers often do not have dedicated water specialists, and responsibility for water is often spread across environmental, social, governance and safety teams, limiting focus and implementation of water reuse initiatives. While some corporations have developed niche funding practices to reward high-visibility, low-return water-efficiency projects, these constraints are still prevalent in industry.

Improving reuse by redrawing boundaries

Industrial sites must consider water reuse opportunities across all operations within a site. Industrial water use can be characterized as process water used for specific operational needs (such as cooling, heating, rinsing, washing, dilution or input to chemical reactions), product water that is incorporated into finished goods, and facility support water used for across multiple units in the facility such as boilers, cooling towers, domestic water and landscaping. Each use has unique quality requirements, such as conductivity limits or pH.

Conventional industrial water use tends to manage each system that uses water separately, resulting in multiple isolated water streams, with some limited reuse within streams. This isolation leads to poor water efficiency (Fig. 1, left). Additionally, typical industrial water-efficiency programmes and best-practice guides prioritize boilers and cooling towers (facility support water) because these utility systems are widespread and use large amounts of facility water[5].

However, process water is a valuable reuse entity as it is often highly pure and expensive to produce. Hence, even at modest volumes, its marginal value of reuse is greatest. However, process water reuse within the same process is also the most complex owing to variability in contaminants[6], strict quality targets that vary by sector and limited in-house expertise.

To increase reuse of water, such as high-quality process water, industrial facilities therefore need to adopt a source-to-sink perspective. In this approach, water discharged after initial use that cannot be recycled within the same process can act as a source for other industrial water uses within the site (sinks).

Initial targets for water reuse could include sources such as rinse waters, reverse osmosis reject water, and boiler and air-handling condensate. The water post initial use can be mapped to reuse in cooling towers and pre-rinse wash steps that would not require additional treatment. Reuse could potentially also blend and/or condition streams for some uses. Blending relatively pure streams with outputs from reuse treatment technologies could create fit-for-purpose water that serves process needs while avoiding unnecessary disposal. This approach prioritizes pairings where quality tolerance aligns with minimal treatment, creating unconventional reuse opportunities (Fig. 1, right).

Cost savings and contribution to water-saving goals are the primary incentives to this approach. The rising cost of sewer discharge[4] could make on-site reuse options more financially attractive. By itemizing costs of treated water for each finished use (including the cost of disposal, chemicals, energy and operational costs), the incentives to avoid disposal become stronger. This shifts the balance towards enhanced reuse and goal achievements.

Implementing reuse

Expanding beyond conventional internal water reuse to include higher-value streams (such as process water) will require both technical and organizational readiness. Site managers should develop a facility water balance that maps all sources and sinks and should establish sufficient metering and data-quality requirements to make reuse decisions. Facilities should define fit-for-purpose water-quality

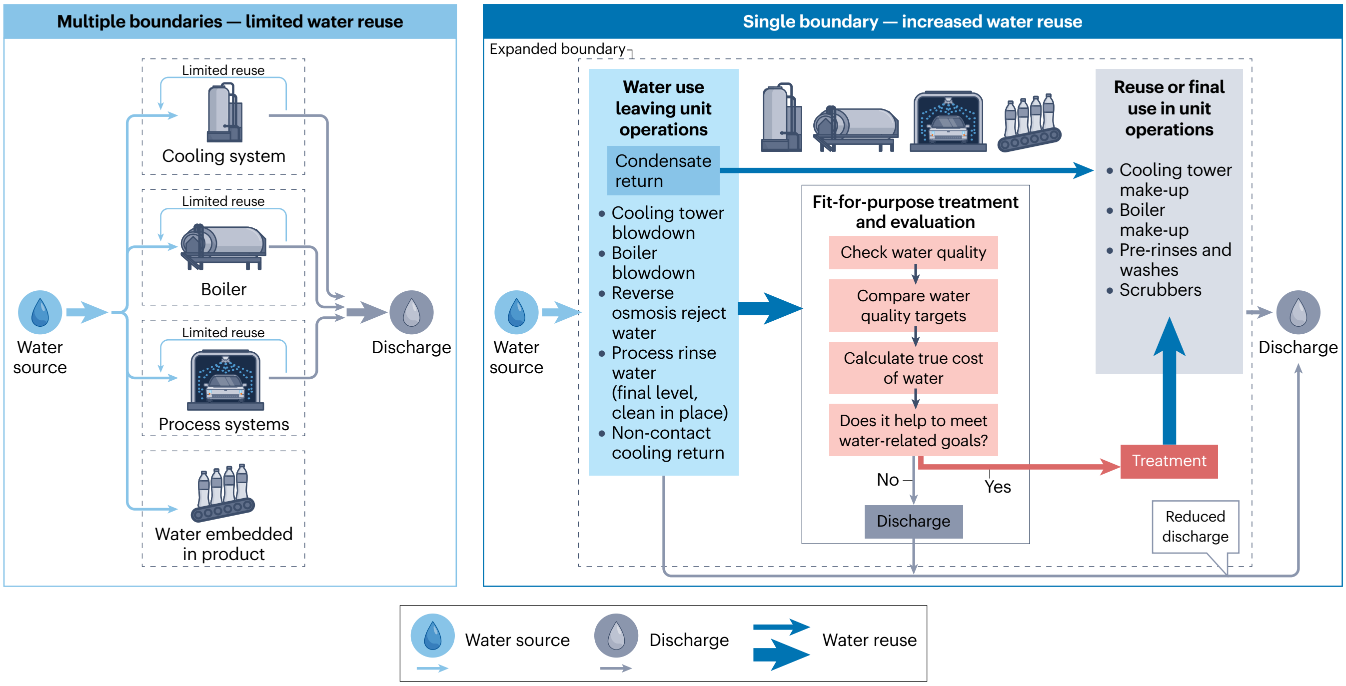

Fig. 1 | Mapping facility water sources to sinks to facilitate industrial water reuse. Water use within facilities is often considered within operational boundaries, with some limited reuse within a process (left). Considering water resources across a facility incentivizes process water reuse by pairing used water with other uses across a facility (right). This pairing should consider water quality needs and cost. The thickness of the arrows qualitatively indicates the volumetric water flow.

targets for priority end uses and screen candidate reuse pathways that explicitly account for water-quality compatibility (Fig. 1). Treatment trains aligned to those targets should then be evaluated, ranging from incremental upgrades to niche treatment technologies, such as closed-circuit reverse osmosis, ion exchange, electrolysis-based treatment, biological treatment, advanced membrane filtration and coagulation. Finally, facilities should implement a transparent cost-allocation that captures full supply, treatment and disposal costs into corporate investment models to prioritize water-saving projects.

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Competing interests

The authors declare no competing interests.