Encouraging Water and Energy Conservation: Driving Forces

John F. Russo, President, Separation Technologists, Inc.

Introduction

In the "Rime of the Ancient Mariner" (Samuel Coleridge, 1798), the Mariner says, **"**Water, water every where … Nor a drop to drink anywhere." There was no drinkable water for the ship, only a sea of salty water.

We, too, can look at the Southwest region of the United States and clearly see that water availability is an increasingly serious problem. But unlike the Ancient Mariner, we can treat seawater to make it drinking water. It's only a matter of cost.

While in the Northeast and Northwest 30+ inches of rain per year is typical. In Florida there is even greater availability, but with the additional problem of a high water table allowing widespread water pollution. This is unlike the ledge and clay soils in other parts of the country.

We have a different problem than that of the Ancient Mariner—how to effectively reuse the increasingly limited water and energy in different parts of the United States within this finite world.

Water and energy conservation is a simple concept that we all understand from our own personal experience. But implementation is usually fraught with difficulty, especially after the obvious solutions are implemented.

1.0 Driving Forces

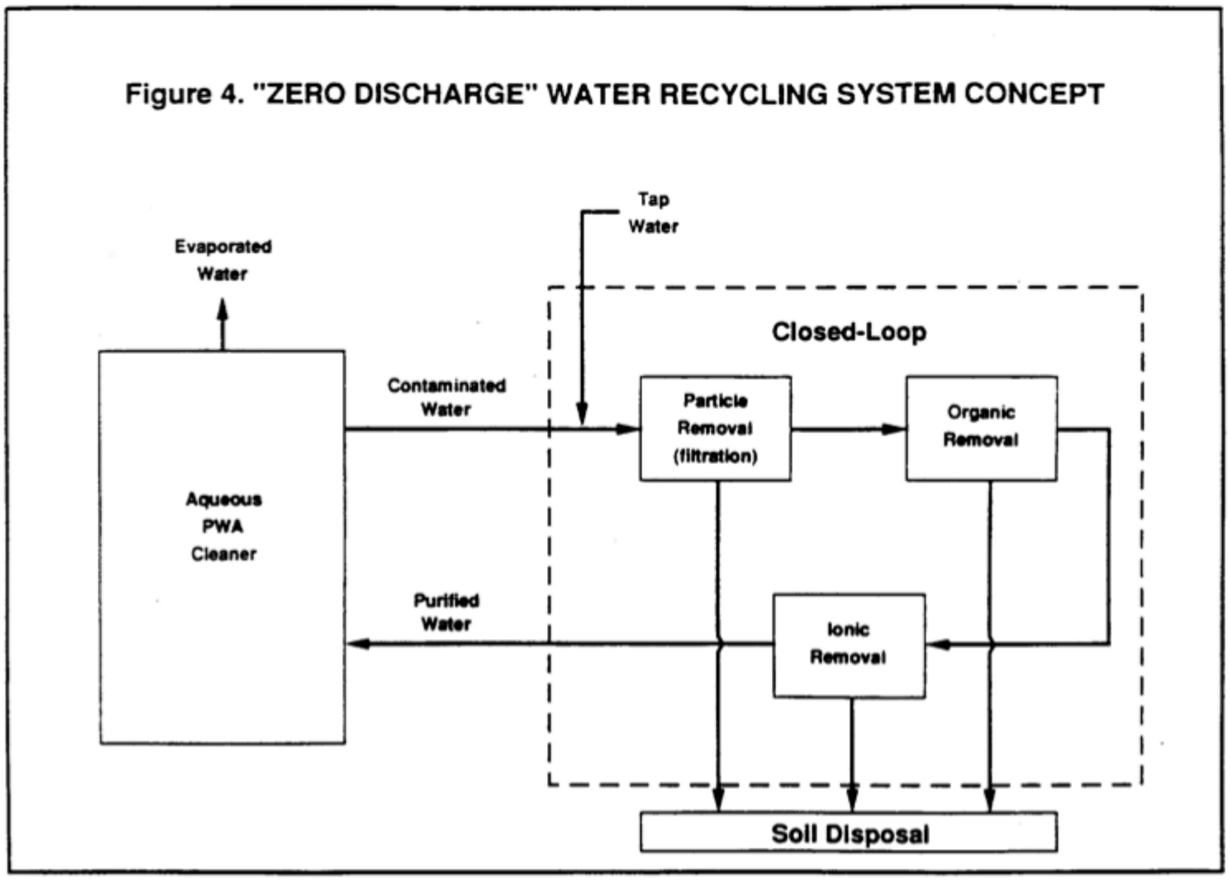
For industrial manufacturers, the key driving force is achieving cost savings from an investment in conserving water and energy. Without this, a manufacturer has little incentive to buy water and energy conserving equipment except for its green-initiative, peer pressure, novelty, and many other reasons.

The following are the most significant factors that affect the operational costs of recycling. Water savings come mainly from source (tap) water, treatment of water, compliance with regulations for disposal of wastewater, and ability to reuse wastewater, or a combination of these factors. Energy savings can occur by locating a facility near a low cost source and recovering energy from water before reuse or disposal.

There are many kinds of soldering such as lead tinning and cleaning parts such as stencils and many other items. But one of the largest applications is the soldering devices on printed circuit boards. Regardless, the same principles can apply to many other processes.

Let's look at an electronics industry case history illustrating one of the best examples of water and energy conservation and elimination of wastewater pollution when cleaning soldered parts having toxic heavy metals, specifically arsenic, cadmium, lead, and silver.

Schematic 1 illustrates a printed circuit board washer (in-line, batch, or handspray) and a recycling system that treats all of the washer wastewater in a closed-loop design. When using water soluble fluxes, no wastewater is discharged to the drain or hauled except for water added to make up for evaporation losses because of drying parts and incidental amounts from changing the solid granular media.[1] [2] [3] [4] [5] [6] In 1990 was the first EPA (Environmental Protection Agency) publication of a closed-loop design after stratospheric ozone depletion issue became a worldwide issue. Separation Technologists then received the U.S. EPA Stratospheric Ozone Protection Award for "Leadership in Closed-Loop Water Recycling."



Schematic 1. *Manual of Practices to Reduce and Eliminate CFC-113 Use in the Electronics Industry*, U.S.EPA, 1990.[7]

For electronics assembly applications, a closed-loop is the best investment for optimum profitability, that is, continuous return on the capital and maintenance costs that exceeds other designs. This is the reason this design, using specific soldering chemistries, has become the standard for the electronics industry worldwide. However, other soldering chemistries can make the operating costs prohibitive to operate a closed-loop. The limitations of this design will be discussed.

1.1 Water and Wastewater[8 9]

1.1.1 Incoming water

One driving factor for water and energy conservation is the availability of source (tap) water. The cost of water can vary widely, but even to a greater degree, is the variation in availability, which is a far greater concern.

The extent of water conservation actions by users is dependent upon water availability from a surface well, aquifer, or municipal water supply (lake, river). The higher the demand for water is, the greater the concern about the location of a manufacturing facility. For example, regional drought conditions for years occur periodically, especially in the Southwest United States. If a user is limited by the local municipality or is in a drought prone area like California, serious consideration should be given to a closed-loop.

Another driving force is the rinse water purity requirement such as deionized (DI) water. It now becomes profitable for a manufacturer to invest in a closed-loop DI water recycling system. Two factors make a closed-loop so cost effective. First, deionizing water increases the cost of water by about ten times over the cost of the source (tap) water alone. Second, the water purity of typical wastewater from a washer going to drain has a far higher purity than using tap water in a non-recycle system.[10] In the latter case, it is substantially more cost effective to deionize wastewater for a closed-loop than it is to deionize the source (tap) water to the washer, which then goes down the drain in non-closed-loop. (A non-closed-loop does not recycle water but discharges it to a drain.)

Another driving factor is the cost of energy. Electronic assemblers use hot water to rinse electronic assemblies. The higher the temperature of the washer water, the faster the payback for an investment. The great majority of the heat from the wash and rinse is recovered at a low cost in a closed-loop or non-closed-loop. Since a closed-loop already recovers all of the wastewater, it can also recover the heat from the heated water at a minimal additional cost.

For a non-closed-loop, the recovery of energy is possible with a simple heat exchanger. The source (tap) or DI water washes and rinses the electronic assemblies and, if necessary, the wastewater is treated to meet the discharge regulations.

The cost of water can vary greatly throughout the United States. The average price of water in the United States is about $1.50 for 1,000 gallons.[11]

1.1.2 Outgoing wastewater

Another driving force is wastewater discharge regulations.[12] Regulations can vary greatly depending on facility location. They can be so severe that no wastewater, regardless of its purity level, can be discharged to ground water (like a septic system).

This was the impetus to pioneer a closed-loop in 1983 when Apollo Computer was located in a community that did not allow any discharge of wastewater regardless of its purity. We provided the first known—no one else has claimed any earlier date—electronics assembly closed-loop.

If a facility is located near a lake, pond, river, or stream, wastewater discharge becomes a choice between hauling wastewater and a closed-loop. A closed-loop might be more cost effective than hauling, especially if hundreds of gallons of water are required.

When choosing a location for your new facility, it is best that contact be made with the local, state, and federal regulatory agencies about discharge to a municipality or ground water.

1.1.2.1 Water Soluble Fluxes

The use of water soluble fluxes is an operating requirement to utilize the full benefits of a closed-loop. One chemist determined that, "… the selection of fluxes and solder pastes can impact system operating costs by as much as 50%."[13] There are also other requirements. Other soldering chemistries, such as dissopads, temporary water soluble mask, finger tape, defoaming agents and others all increase the operating costs of a closed-loop. It is a matter of the kind and amount of these other soldering materials used. The greater the amount, the higher the operating costs. In some cases, for example, the use of water soluble mask and others in sufficient quantities can cause the operating costs to be prohibitive.

1.1.2.2 Rosin Based Fluxes

For rosin based fluxes, source (tap) water or DI water cannot effectively remove inorganic or organic contaminants. These fluxes provide an additional margin of safety against corrosion that water soluble fluxes cannot. Therefore, in addition to water, other cleaning are usually used to meet military specifications. This ensures the highest margin of safety for board cleanliness.[14] [15] [16] [17] [18]

These cleaning agents usually make the operating cost of a closed-loop prohibitive.[19] [20] [21] [22] [23] [24] When using saponifiers, newer surfactant-free, or other cleaning agents there is a much higher ionic content in the wastewater compared with a water soluble flux application. However, this does not occur with terpenes, hydrogen-based, and ester-based cleaning agents. So additional treatment equipment, an RO (reverse osmosis), is used before the DI to reduce the ionic loading. An evaporator would also be required to evaporate the concentrated wastewater from the RO. These two pieces of equipment would be added to the typical closed-loop to make the final system complete. This new design does not allow any wastewater to be discharged to the drain. However, the increase in capital and operating costs negates the profitability features of a closed-loop used for a water soluble flux. Sometimes with a non-closed-loop, compliance for arsenic, cadmium, lead, and silver in the wash wastewater requires a specific resin media to meet regulations for heavy metals.[25] [26] [27]

1.1.2.3 Solid waste

Another aspect of saving water that has to be considered is the solid waste generated by either a closed-loop or a non-closed-loop if deionized water is used.

In a closed-loop, the DI tanks are exposed to the arsenic, cadmium, lead, and silver, which are listed by the EPA as four of the eight toxic metals stringently regulated throughout the United States. In certain circumstances the contents of the tanks are hazardous waste. Regardless, each user must characterize the solid waste by having it analyzed by a certified laboratory.[28] [29] The EPA requires that a TCLP test (toxic characteristic leaching procedure) be performed on solid waste that contains the toxic heavy metals, arsenic, cadmium, lead, and silver, in electronics assembly.[30] If the fluxes used are changed, it is strongly advised to retest the solid waste. It is a matter of demonstrating due diligence in handling toxic metal waste. The more aggressive the flux, the higher the concentration of the toxic metals typically found in the DI tank system.

In a non-closed-loop application, the deionizer tanks make deionized (DI) water from source (tap) water, which is then used by a board washer, and the wastewater goes to a POTW (publicly owned treatment works). The used DI tanks can be transported without any consideration about the toxicity of the wastewater because the DI tanks only treat tap water, not wastewater.

1.2 Case histories: regulatory factors and myths

There are two factors to consider:

First, almost without exception, whenever water and wastewater are reused, very often there are other operational concerns and factors that have to be considered.

Second, over the years we have learned that what we think customers know far too often is much different than what they actually know.

The following case histories revolve primarily around these two considerations:

- Electronics assembly processes use arsenic, cadmium, lead, and silver in the soldering process
- Corporations must meet federal, state, and local regulatory discharge requirements at a minimum

1.2.1 "I'm only using a dishwasher"

But you're not washing dishes! You are washing electronic assemblies that have toxic metals that can result in dissolved arsenic, cadmium, lead, and silver in the wash and/or rinse water. This is an industrial wastewater discharge application that requires a permit to discharge and the wastewater must comply with the federal, state, and local discharge regulations.

Solution: Use a closed-loop, haul all wastewater, or determine the ability to discharge to a POTW or ground water by contacting local, state, and federal agencies.

1.2.2 "I've tested my wastewater and it meets federal, state, and discharge regulations."

Users can do their own regulatory compliance testing. But discharging any wastewater or solid waste requires a permit to discharge, regardless whether or not it complies with federal, state and local regulations. Regulatory agencies want to know who discharges and what is being discharged to POTWs, septic systems, or ground water.

Solution: Contact local regulatory agencies. Otherwise a user will get into far greater difficulty when officials find out. Increasingly, employee awareness and whistleblowers are encouraging management to act responsibly.

1.2.3 "Someone transports my deionizer tanks and recharges them at their facility. They are a large water treatment company and I trust them."

The EPA uses a concept called "cradle to grave." This means any solid or liquid waste transported by a vendor must comply with federal, state, and local regulatory agencies and that the responsibility **always resides with the generator of the solid and liquid waste** regardless of the actions (legal or illegal) by the vendor. The responsibility is ultimately with the generator.

Case history: An electronics assembly user's spent tanks are transported to his vendor's facility to replace the spent granular media. However, the vendor's facility also has spent tanks used in sensitive areas, such as kidney dialysis centers, biotech, pharmaceutical, and medical research and related applications.

There are two ways a sensitive user's tanks can become contaminated. After the spent granular media from a toxic metal user is regenerated by a chemical process or just replaced with new media, the toxic metal generator's newly regenerated media or the empty tanks alone could be used by a sensitive user in error. Even using the most rigorous cleaning process, there is a high probability of residual toxic metals in the corners or pipe connections of the used tanks.

How serious is this situation? It has happened enough times decades ago that the largest United States water treatment corporation has taken very stringent precautions. They use three methods: one separate facility in the United States for only toxic metal applications; using interconnecting tank fitting with reverse threads so that the tanks cannot be easily used in wrong applications; and lastly, the tanks have different colors. These incidents are increasing substantially because the number of non-heavy-metal customers in the United States has shrunk dramatically and new markets are being explored.

Solution: There are two ways to reduce and even eliminate cross contamination of your toxic metal waste with a sensitive user's tanks.

First, use a vendor that only handles toxic metal bearing waste. An easy way to determine the acceptability of a vendor is to go to their website. Even if a vendor services sensitive users such as hospitals, medical facilities and similar, this is not the company to send toxic metal bearing waste to, regardless of what the vendor says to you. If your current vendor does not state specifically that he does not service sensitive users and guarantees it in writing on their website, then a toxic metal generator could very likely be exposed to very serious liability.

Second, to ensure a toxic metal generator will not contaminate a sensitive user's tanks, the user should actually replace the spent media in his own facility with his own personnel or a contract service. By the user disposing the toxic metal bearing solid waste through a licensed hauler, it allows complete control of the process and prevents any of a user's empty tanks being mistakenly replaced by a vendor and then used by a sensitive user.

In summary:

1. Closed-loop water recycling is the best method to reduce the amount of water and energy used. Also, it reduces the amount of toxic metal pollution dispersed in the environment by concentrating the arsenic, cadmium, lead, and silver on the DI ion exchange resins for safer disposal.

2. Electronic assemblers use solder that contains the toxic heavy metals, arsenic, cadmium, lead, and silver, which are stringently regulated by local, state, and federal regulatory agencies throughout the United States.

3. Regulatory requirements vary throughout the United States because a state might have more stringent regulations than the EPA and the local community might have more stringent regulations than the state.

4. Before planning a new facility, it is strongly advised that a preliminary review of the regulatory and operational requirements be made before final decisions are made.

Presented at the High Performance Cleaning and Coating Conference
November 16-18, 2010 at the Renaissance Hotel & Convention Center
Schaumburg, IL

Organized by the SMTA and IPC

Endnotes:

[1] Russo, J. F. and Fischer, M. "Closed-Loop Water Recycling for PWB Aqueous Cleaners," *Nepcon West Proceedings*, March 1989.
[2] Dunne, Keith and Russo, J. F. "Cleaning It: Closed-Loop Wastewater Recycling," *U.S. Tech* 1993 October.
[3] Riser, Jr., William M. (United Technologies Corporation). "Closed-Loop Recycling of Wastewater from Relay Cleaning Process," *Nepcon West Proceedings*, 1994.
[4] Russo, J. F. and Fischer, M. "Recycling Boosts Aqueous Cleaners," *Circuits Manufacturing*, 1989 July: 34-37.
[5] Russo, J. F. "The Total Solution Approach for Water, Wastewater and Waste Disposal for Aqueous and Semi-Aqueous PCB Cleaning," *Nepcon West Proceedings*, 1992.
[6] Russo, J. F. and Fischer, M. "Closed-Loop Water Recycling for PC Board Aqueous Cleaning," *The First CFC Alternatives Conference*, June 1990.
[7] *Manual of Practices to Reduce and Eliminate CFC-113 Use in the Electronics Industry,* Arthur D. FitzGerald, Murray D. Brox, Stephen 0. Andersen, Ph.D. US. Environmental Protection Agency, 1990, http://www.p2pays.org/ref/12/11433.pdf.
[8] Russo, J. F., author of electronics' assembly water and wastewater current standards in IPC-AC-62A in section 9.0 *Water Resources and Quality Wastewater*, p.11 and 15.1.2 *Wastewater*, p.26
[9] Russo, John F., "Making Decisions about Water and Wastewater for Aqueous Operations," pp. 349-375 of a chapter in *Handbook of Critical Cleaning*, Barbara and Ed Kanegsberg, CRC Press, 2001
[10] Russo, J. F. and Fischer, M., "Operating Cost Analysis of PWB Aqueous Cleaner Systems: Zero Discharge Water Recycling System vs. Once-Through," *Third International SAMPE Electronics Conference*, 20-22 June 1989.
[11] American Water Works Association, 2002, http://www.drinktap.org/kidsdnn/Portals/5/story_of_water/html/costs.htm.
[12] Chen, Donna T. and Sachse, Marvin H. (City of Los Angeles). "Compliance and Waste Minimization Makes 'Cents'," Hazardous and Toxic Materials Office, *Nepcon West Proceedings*, 1994.
[13] Borek, Kevin (Northern Telecom). "A Clean Break from CFC's." *Circuits Assembly,* 1992 February: 43.

[14] Green, Howard (Safetran Systems Corporation). "Closed-Loop Recycling Costs Affected by the Process Chemistry," *Nepcon West Proceedings*, 1993.
[15] Gaxiola, Steve and Chou, Felix (AlliedSignal Aerospace). "Turnkey Installation of a Two-Stage Wastewater Treatment System used on Saponifier Cleaning PWA Operations," *Nepcon West Proceedings*, 1994.
[16] Russo, J. F., "Eliminating Wastewater Discharge from RMA Flux/Saponifier Cleaning Operations," *Nepcon East Proceedings*, June 1995.
[17] Russo, J. F. "What To Do About Wastewater Discharge from Cleaners Using Saponifier-Type Cleaning Agents," *Nepcon East Proceedings*, 1994.
[18] Borek, Kevin (Northern Telecom). "First Large Scale Aqueous Cleaning Operation in the USA with a Closed- Loop Water Recycling System on a Surface Mount Production Line," *Nepcon West Proceedings*, 1993.
[19] Limia, Gene and Smith, Matt (Motorola). "Closed-Loop Water Recycling with Terpene Semi-Aqueous Cleaning in High Volume SMT Manufacturing," *Surface Mount International*, 1991.
[20] Suppelsa, A. B. and Liebman, H. F. (Motorola). "Successful Implementation of Closed-Loop Semi-Aqueous Cleaning." *Nepcon West Proceedings*, 1991.
[21] Russo, J. F. and Fischer, M. "Closed-Loop Recycling of Semi-Aqueous Terpene Rinse Water," *Nepcon West, Proceedings*, 1990.
[22] Russo, J. F. "Aqueous and Semi-Aqueous Cleaner Discharge: Compliance with Environmental Regulations for Wastewater and Solid Waste," *Nepcon Southeast Proceedings*, 1993.
[23] Marino, Frank A. (Raytheon). "Cost and Environmental Ramifications of Alternative Nonhalogenated Solvents," *Nepcon East Proceedings*, 1992.
[24] Russo, J. F. "Adaptability of Wastewater Treatment Systems to Different Aqueous/Semi-Aqueous Cleaning Chemistries," *Nepcon East Proceedings*, 1993.
[25] Tevels, John R. (Harris Corporation). "Membrane Closed-Loop Recycling of a Wastewater containing Hydrocarbon Ester Solvent," RF Communications Group, *Nepcon West Proceedings*, 1994.
[26] Jones, Robin (Teltronics Corporation). "Wastewater Discharge from an Aqueous Cleaner Complying with Local Discharge Regulations for Lead," *Nepcon West Proceedings*, 1993.
[27] Benton, David H. (Hughes Aircraft Company). "Lead Removal from a New Aqueous Cleaning Agent Before Discharge," *Nepcon West Proceedings*, 1994.
[28] Russo, J. F. "Users' Compliance With Environmental Regulations for Wastewater and Hazardous Solid Waste From Cleaning Processes," *Nepcon West Proceedings*, 1994.
[29] Russo, J. F. "Aqueous and Semi-Aqueous Cleaner Discharge: Compliance with Environmental Regulations for Wastewater and Solid Waste," *Nepcon Southeast Proceedings*, 1993.
[30] EPA Code of Federal Regulations, *40 CFR: Protection of the Environment*, chapter 1 (7-1-02 edition), 261.4, p. 58.