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## **Water Recycling and Reuse**

Water, water, everywhere,  
Nor any drop to drink  
—Samuel Taylor Coleridge, *The Rime of the Ancient Mariner*

From outer space, the Earth seems to be literally awash in water, girdled as it is with vast oceans that cover more than 70 percent of the planet.

The genesis of all life began in the ocean. Water is the inheritance of every living thing on the planet. Water is the largest constituent of animal and vegetable tissue. It is the largest part of anything we drink.

Water is also the source of enormous energy. It can provide the fury of a thunderstorm or power a man-made device.

Water is vital to the continued survival of the human race. Without it, there would be no life. Not only would agriculture be impossible, a large part of our industries would be rendered impotent as well.

In all, the world contains approximately 1.4 million cubic kilometers of water. Despite this abundance, however, all life on Earth depends on less than one percent of the total volume of water on the planet.

The problem lies in quality, not just quantity. Most of earth's water is salty, leaving only about 2.5 percent as fresh water. Most of this is frozen in polar ice caps or glaciers. Much of the rest lies essentially beyond human reach deep underground in aquifers.

Even this small fraction of available potable water is believed to be adequate to support all life on earth. Unfortunately, water is not distributed evenly throughout the planet. Large semi-arid and arid regions exist where water is not available in sufficient quantities to meet human needs.

And the amount of water that humans need varies in large part with the circumstances in which they live and work.

### **WATER USE**

Water use increased ten-fold between 1900 and 2000. On a global scale, about 70 percent of water from available sources is used for agricultural purposes, primarily irrigation, with the remainder used for domestic and industrial purposes.

The U.S. Department of Commerce estimates that major industrial water users discharge approximately 285 billion gallons of wastewater daily.

This increasing demand on water resources is taking its toll. The world is already facing water shortages in Africa, the Middle East and parts of North America, Asia and Europe. Eighty-eight developing countries, containing close to one-half of the world's population, already experience

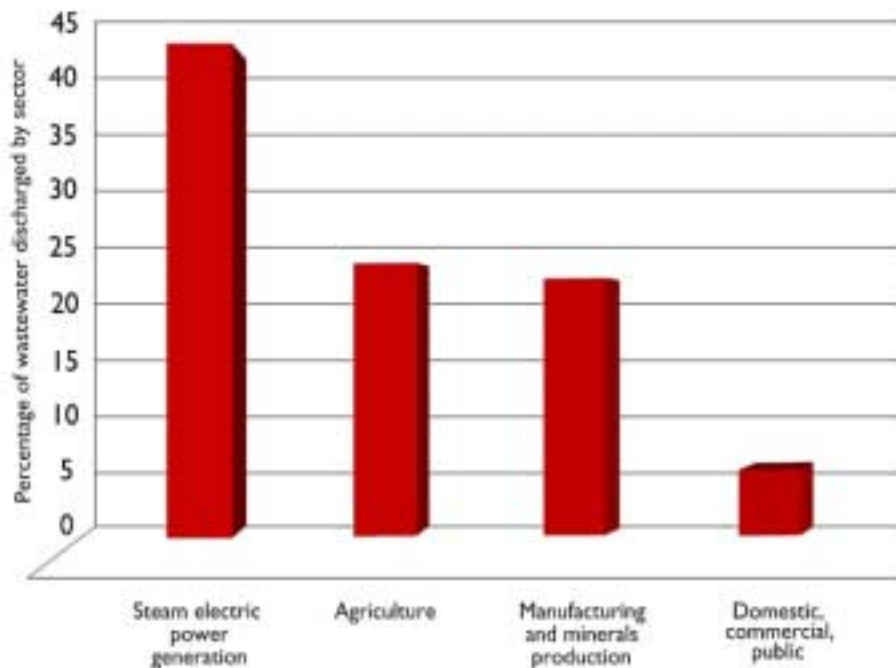
water deficits, with resulting constraints on human and ecosystem health, as well as economic development.

In addition to these shortages, the poor quality of many water supplies has its own human and environmental costs. Up to 90 percent of all diseases and more than one-third of all deaths in developing countries are caused by contaminated water.

Figure 1 is a graphic illustration of the relative discharges from various segments of society.

More than 90 percent of all the water used by industry and about two-thirds of the total wastewater generated by U.S. manufacturing plants is the result of cooling operations.

The use of water for cooling operations varies by industry. Cooling needs account for nearly 100 percent of the water use for electric power generation. In manufacturing industries, this can range from 10 percent in textile mills to 95 percent in beet-sugar refineries.



**Fig. 1**

To combat these shortages, water reuse is becoming increasingly common in developed countries. The concept of zero discharge, total reuse with no wastewater being released into the environment, is being promoted in Germany, the U.S. and elsewhere. However, no nation has progressed farther than Japan in the field of water reuse.

In 1992, reuse efforts led to a staggering 76.3 percent recovery rate in industrial water usage in Japan.

To put it simply, Japan only used 15 billion cubic meters of fresh water out of a total consumption of 63.3 billion cubic meters of water for industrial purposes. The majority came from reuse.

In all, the industrial delivery value for water in the same year was ¥ 329.5 trillion (\$2.03 trillion). That means the industrial delivery value per cubic meter for water is ¥ 5,200 (\$5.20/m<sup>3</sup>, \$19.68/1000 gallons).

According to the 1992 Industrial Census by the government agency of Japan, Ministry of Industrial Trade (MITI), about 70 percent of water consumption in the country is for cooling water, 18 percent for process and washing water, 7 percent for air-conditioning water, and comparatively less for boiler feed water.

Using water more than once is an effective strategy in overcoming the water needs of the United States and other developed nations, especially in arid and drought stricken areas and should be given high priority and taken seriously because, in reality, there is **no new water** on our horizon.

## **WATER FOR COOLING**

Most industrial production processes need cooling water to operate efficiently and safely. Refineries, steel mills, petrochemical manufacturing plants, electric utilities and paper mills all rely heavily on equipment or processes that require efficient temperature control. Cooling water systems control these temperatures by transferring heat from hot process fluids into cooling water. As this happens, the cooling water itself gets hot. Before it can be used again, it must be cooled or replaced by a fresh supply of cool water.

Cooling water systems are either nonevaporative or evaporative. Nonevaporative systems include once through cooling and closed loop systems. Evaporative cooling systems include open recirculating systems in which heat rejection is accomplished in cooling towers, evaporative condensers, spray ponds or cooling lakes.

As recently as 20 years ago, cooling towers were more the exception than the rule in general industry because of their severely high operating cost and the large amount of capital required for construction. But with today's need for water conservation, industry is turning more and more to cooling towers for recycling coolant water to process operations.

## **SYSTEM PROBLEMS**

By their very design, open recirculating cooling systems are prime candidates for contamination problems. As the water continues to circulate throughout the system, evaporated water exits the system as pure vapor leaving solids behind, which begin to concentrate over time.

This concentration of dissolved solids can lead to what is called scale formation. An everyday example of this phenomenon is the common kitchen teakettle, which can become encrusted with scale build-up as water evaporates.

In a cooling system, the concentration of solids in the re-circulated water increases as replacement (make-up) water evaporates leaving behind even more solids. Left unchecked, the system would reach a point where the water could not hold all of the solids in a dissolved state. Once this occurs, the solids would begin to precipitate out of solution as scale, which affects the ability of the system to transfer heat. A total plant shutdown or operational inefficiencies can result.

When enough water is evaporated to increase the concentration of solids to twice their initial value, 60 parts per million becomes 120 ppm, the newly constituted water is said to have two cycles of concentration.

Typically, three to 10 cycles of concentration can be tolerated without adverse impacts depending on how much water is evaporated.

Clearly, water that has a low concentration of initial dissolved solids can attain a very high number of cycles before the solids precipitate from solution. Conversely, water with high initial solids can be cycled only a limited amount before precipitation occurs.

In either case a saturation point will be reached where concentration cannot be increased. To control solids build-up a portion of the cooling water is bled from the cooling tower basin. Called blowdown, this is controlled by a technician using a conductivity monitor. It is accomplished on a continuous or on a controlled bleed cycle basis.

The desire to save water costs by increasing the cycles of concentration can jeopardize system performance and longevity.

Makeup water contains dissolved minerals and insoluble matter that pose a serious threat to efficient cooling. Microbiological organisms, dirt, silt, dissolved minerals and gases, if left untreated, can concentrate and cause serious reductions in heat transfer efficiency, increased maintenance problems or even total system failure. All systems require a chemical treatment program that addresses four areas:

- Scale
- Corrosion
- Fouling
- Microbiological growth

Scale and corrosion inhibitors are typically injected into the system by positive displacement pumps that meter precise dosages. Although these chemicals add dissolved solids they do allow the water to retain increased solids content.

## **RECYCLING COOLING WATER**

EET offers a sensible solution for recycling up to 90 percent of water normally lost as cooling tower blowdown with the combined use of multimedia filtration and the patented and patents-pending High Efficiency Electrodialysis (HEED™) process. The process controls cooling water quality by continuously removing suspended solids and dissolved minerals from the system.

## **PARTICLE FILTRATION**

Side stream filtration is required and used in conjunction with the HEED™ process. Multimedia filtration (to 15 microns or less) is especially effective in removing particulate matter, even lightweight biological material killed by biocides. The entire system volume should be filtered at least once each hour for good water clarity.

It is recommended that the returned filtrate be routed through nozzle jets that agitate the water at the basin floor, which places the debris in suspension to increase the chances of it being withdrawn by the filter suction piping.

## **CONTINUOUS DEMINERALIZATION**

HEED allows salt to be removed at specified levels and can adapt to changing mineral content of either feed-water supply or desired product water to maintain the desired water quality limits in the cooling tower. HEED™ moves dissolved minerals away from the water stream rather than the reverse as with evaporative or alternative pressure-based membrane processes. Because the quantity of minerals in the feed stream is far less than the quantity of the fluid, this unique feature offers many practical advantages over classical desalting technology.

Both systems use dedicated pumps to draw dirty water from the cooling tower and return filtered and demineralized water to the basin in a batch recycle mode. A flow schematic for blowdown

reuse is shown in Figure 2 and further illustrated in Figure 3. Typical results of treating cooling tower blowdown are given in Table 1. Benefits include:

- Conserve water
- Reduce chemical usage
- Less maintenance
- Increased system efficiency & life

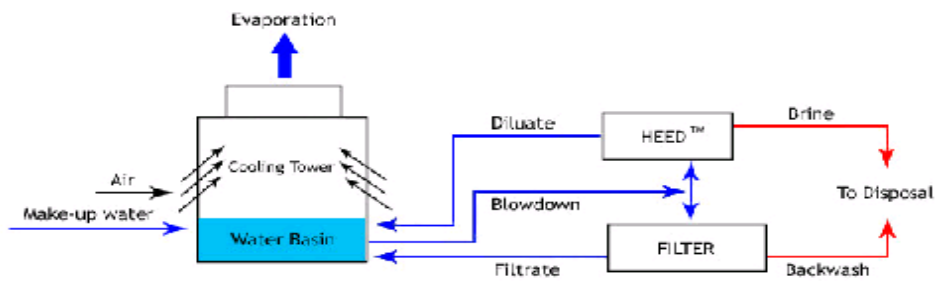


Fig.2



**Fig. 3**

**Table 1**

**COOLING TOWER TREATMENT  
USING HIGH EFFICEIENCY ELECTRODIALYSIS**

| <b>Parameter</b>                      | <b>Blowdown</b> | <b>Treated<br/>Blowdown<br/>Recycled to<br/>Cooling<br/>Water</b> |
|---------------------------------------|-----------------|---|
| Conductivity, $\mu\text{S}/\text{cm}$ | 2600            | 1000  |
| TDS, ppm                              | 1350            | 498   |
| pH                                    | 7.24            | 6.8   |
| Chloride, ppm                         | 271             | 67.7  |
| Sulfate, ppm                          | 819             | 266   |
| Nitrate, ppm                          | 17.2            | 3.50  |
| Nitrite, ppm                          | <0.6            | <0.3  |
| Phosphorous, ppm                      | <1.8            | <0.9  |
| Fluoride, ppm                         | <1.0            | <0.9  |

## INDUSTRIAL LAUNDRY WATER RECYCLING

Water is the single most important resource to a laundering operation although it is most commonly only used once. Large industrial laundry operations begin with lots of clean water and finish with lots of dirty water. A typical commercial laundry discharges 100,000 gallons of dirty water daily.

About 25 percent of industrial laundries reuse the final rinse water from light soil loads. These rinses are generally so free of chemical carryover that they can be used in place of fresh water. Most final rinses are in the 90-100 F range and reuse can mean saving the reheating cost that would be needed to heat water from 50-60 F to the 90°F reclaimed rinse water temperature.

Wastewater from laundering operations is high in oil, grease, biochemical oxygen demand (BOD), chemical oxygen demand (COD), total suspended solids (TSS), total dissolved solids (TDS) detergents and surfactants.

These contaminants must be removed to achieve the highest percentage of recycling. Reducing TDS using desalting technologies is required to prevent long term graying of garments rendering them unusable. This threshold is believed to be 2000 ppm by industry sources. A need exists within the industry to establish a how-clean-is-clean consensus for water reclamation purposes.

Several different methods of pretreatment are used on the wash water before it is discharged to the sanitary sewer. The complexity of pretreatment varies from location to location depending on the size of the facility, the volume of water and chemicals consumed, the type and usage of products used by the customers being serviced, and the specifics of local, state, and federal requirements.

Generally, most plants use shaker screens to remove lint and acid cracking to break the oil water emulsion and addition of coagulants and flocculants to facilitate oil and soil removal. The oil/soil phase is normally separated by use of dissolved air flotation (DAF) and the resulting sludge is dewatered for off-site disposal.

Additional treatment is necessary to increase the amount of water that can be reclaimed. Many combinations including microfiltration (MF) and ultrafiltration (UF) are used. These methods further reduce oil and grease, TSS, and insoluble BOD/COD associated with suspended solids but are ineffective for removing TDS. Typical performance using DAF followed by MF is shown in Table 2.

**Table 2**  
Industrial Laundry Water Treatment  
Using DAF and MF

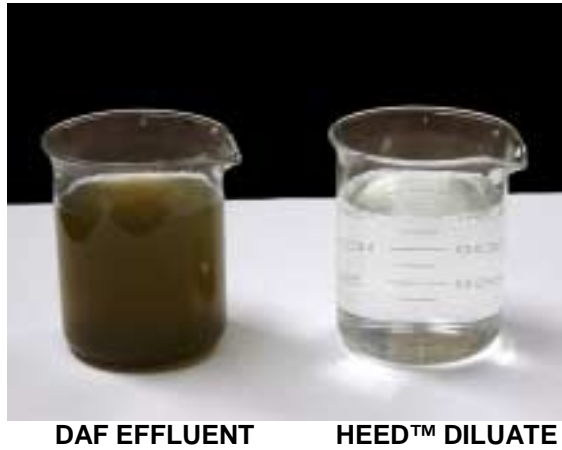
| Parameter         | Influent | DAF Effluent | % Removed | MF Permeate | % Removed |
|-------------------|----------|--------------|-----------|-------------|-----------|
| TSS, ppm          | 1330     | 222          | 83        | 10          | 95        |
| TDS, ppm          | 2370     | 2030         | 14        | 1960        | 3.4       |
| BOD, ppm          | 1300     | 950          | 27        | 775         | 18        |
| Oil & Grease, ppm | 954      | 120          | 87        | 18.2        | 99        |
| Chloride, ppm     | 150      | 300          | ---       | 300         | 0         |
| Sulfate, ppm      | 220      | 230          | ---       | 210         | 8.6       |
| pH                | 12.2     | 11.8         | ---       | 11.5        | ---       |

EET's laundry water treatment process addresses all these contaminants by combining the use of multimedia filtration and adsorption to further reduce suspended solids, oil & grease and soluble BOD/COD followed by HEED™ for removing TDS to a desired level. Performance of the

recycling process for industrial laundry water is shown in Table 3 and typical results for healthcare laundry water is given in Table 4.

**Table 3**  
Typical Performance Industrial Laundry Water  
Using Multimedia & HEED™

| Parameter              | DAF Effluent | HEED™ Diluate | % Removed |
|------------------------|--------------|---------------|-----------|
| pH                     | 11.0         | 10.0          | ---       |
| TSS, ppm               | 258          | 8.00          | 96.8      |
| TDS, ppm               | 1,837        | 547           | 70.2      |
| COD, ppm               | 2,194        | 269           | 87.7      |
| BOD <sub>5</sub> , ppm | 637          | 170           | 73.3      |
| O&G, Total, ppm        | 48.5         | <1.0          | >98       |
| Chloride, ppm          | 162          | 31.5          | 80.5      |
| Sulfate, ppm           | 150          | 113           | 24.6      |
| Phosphorous, ppm       | 5.8          | 1.6           | 72.4      |
| Nitrate, ppm           | <1.6         | <0.6          | 62.5      |
| Nitrite, ppm           | 2.4          | <0.3          | >87.5     |
| Fluoride, ppm          | 18.4         | 5.8           | 68.4      |



DAF EFFLUENT      HEED™ DILUATE

**Table 4**  
Healthcare Laundry Performance  
Using Multimedia & HEED™

| Parameter                | Tunnel Washer Wastewater | HEED™ Diluate | % Removed |
|--------------------------|--------------------------|---------------|-----------|
| pH                       | 11.0                     | 6.8           | ---       |
| Conductivity, $\mu$ S/cm | 1252                     | 400           | 68        |
| TDS, ppm                 | 678                      | 210           | 69        |
| TSS, ppm                 | 28                       | 1.2           | 95.7      |
| Oil & Grease, ppm        | 210                      | 3.5           | 98.3      |
| BOD <sub>5</sub> , ppm   | 96.3                     | 31.7          | 67        |
| COD, ppm                 | 473                      | 101           | 78.6      |

|                               |      |      |      |
|-------------------------------|------|------|------|
| Chlorine, Total Residual, ppm | 5.83 | 0.02 | 99.6 |
| Chloride, ppm                 | 182  | 74.5 | 59   |
| Fluoride, ppm                 | 2.1  | 1.3  | 38   |
| Sulfate, ppm                  | 9.4  | 6.9  | 26.5 |
| Nitrate, ppm                  | <0.2 | <0.2 | ---  |
| Nitrite, ppm                  | <0.1 | <0.1 | ---  |
| Phosphorous, Total, ppm       | 16.8 | 8.4  | 50   |
| Calcium, ppm                  | 8.21 | 3.30 | 59.8 |
| Magnesium, ppm                | 1.30 | 0.51 | 60.7 |