U.S. Environmental Protection Agency

Concurrent Technologies Corporation

ETV VERIFICATION STATEMENT

TECHNOLOGY TYPE:	**REVERSE OSMOSIS**
APPLICATION:	**INDUSTRIAL WASTEWATER TREATMENT**
TECHNOLOGY NAME:	**High Efficiency Reverse Osmosis (HEROÔ)**
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The United States Environmental Protection Agency (EPA) has created the Environmental Technology Verification (ETV) Program to facilitate the deployment of innovative or improved environmental technologies through performance verification and dissemination of information. The goal of the ETV Program is to further environmental protection by substantially accelerating the acceptance and use of improved, cost-effective technologies. ETV seeks to achieve this goal by providing high-quality, peer-reviewed data on technology performance to those involved in the design, distribution, financing, permitting, purchase, and use of environmental technologies.

ETV works in partnership with recognized standards and testing organizations, and stakeholder groups consisting of buyers, vendor organizations, and states, with the full participation of individual technology developers. The program evaluates the performance of innovative technologies by developing test plans that are responsive to the needs of stakeholders, conducting field or laboratory tests (as appropriate), collecting and analyzing data, and preparing peer-reviewed reports. All evaluations are conducted in accordance with rigorous quality assurance protocols to ensure that data of known and adequate quality are generated and that the results are defensible.

The ETV Metal Finishing P2 Technologies (ETV-MF) Program, one of 12 technology focus areas under the ETV Program, is operated by Concurrent Technologies Corporation, in cooperation with EPA's National Risk Management Research Laboratory. The ETV-MF Program has evaluated the performance of a reverse osmosis (RO) technology for the treatment of industrial wastewater. This verification statement provides a summary of the test results for the Hydrometrics, Inc., High Efficiency Reverse Osmosis (HERO™) Industrial Wastewater Treatment System.

VERIFICATION TEST DESCRIPTION

The Hydrometrics, Inc., HERO™ system was tested, under actual production conditions, on combined industrial wastewater at Honeywell Federal Manufacturing & Technology's (FM&T's) Kansas City Plant (KCP) in Kansas City, Missouri. A mobile pilot-scale HERO™ system was installed at the KCP, after their conventional wastewater treatment system, in order to evaluate the system's ability to treat and recycle the KCP's combined, post-treated wastewater for reuse within the facility. While beyond the scope of this verification test, the equipment vendor claims the HERO™ system may also be used to treat dilute rinse waters directly (pre-treatment), and more concentrated wastes after appropriate conditioning (post-treatment).

Testing was conducted on two separate processes over a four-day period:

- A large portion (46 percent) of the combined KCP wastewater is dilute, non-production wastewater. The remaining 54 percent of the KCP's spent process water consists of non-metal-finishing industrial process wastewaters, and rinse waters from metal finishing. The HERO™ system was evaluated on its ability to separate chemical contaminants from the post-conventionally-treated wastewater and condition it for reuse within the facility.

- A very small amount of the KCP's wastewater, about 330 gallons per day (gpd), is cyanide-bearing rinse water from the KCP metal finishing shop's copper plating operations. Copper is a potential recyclable/salable metal. This verification test included a separate weak acid cation (WAC) ion exchange unit installed between the pre-conventional treatment cyanide rinse water storage tank and the first step of the cyanide oxidation process. This smaller-scale WAC unit used resin identical to the WAC unit within the HERO™ system where metals recovery normally takes place. Due to the KCP's conventional wastewater treatment system, this separate WAC unit was installed upstream in order to recover the copper. The verification on this WAC unit demonstrated the HERO™ system's ability to remove valuable metals for recovery, recycle and/or sale.

Historical operating and maintenance labor requirements, chemical usage, and waste generation data were collected to perform the cost analysis.

TECHNOLOGY DESCRIPTION

The patented three-step HERO™ process combines "off-the-shelf" equipment to convert wastewater into reusable water. In the first step of the HERO™ process, ion exchange removes ions that form scale (water softening). Removing the hardness from the wastewater results in a concentrated brine waste. The second step is membrane degasification, which removes the buffering effect from carbon dioxide to lower caustic demands in the final step of the process. Carbon dioxide is the only byproduct of the second step, where the wastewater alkalinity is removed. The final step in the HERO™ process is RO. Addition of NaOH to the wastewater raises the pH to the proper operating level before entering the final stage of treatment. The high pH of the wastewater entering this stage eliminates fouling of the RO membrane. A concentrated brine waste is generated from this step as well.

VERIFICATION OF PERFORMANCE

Daily grab samples were collected over a four-day period from the HERO™ influent, HERO™ effluent, HERO™ RO waste solution, copper recovery WAC unit influent, and copper recovery WAC unit effluent. Samples were analyzed to determine the contaminant levels before and after each process in order to calculate contaminant removal efficiency. Results from the HERO™ RO waste solution analysis were used for mass balance purposes, and to determine waste disposal restrictions and costs.

Average analytical results for key parameters are shown in **Table i.** Wastewater parameters of concern include heavy metals from metal finishing and other rinsing operations, hardness, alkalinity, specific conductivity, residual chlorine and cyanide from the conventional wastewater treatment system, sulfate, sulfides, nitrate, and total dissolved solids (TDS).

Various other parameters were monitored in order to determine external water quality standards compliance, such as local regulatory discharge as well as KCP recycled water quality standards.

Parameter	HEROÔ Influent (mg/L)	HEROÔ Effluent (mg/L)	KCP Recycle Standard (mg/L)	HEROÔ RO Waste (mg/L)	Disposal Limits (mg/L)
Aluminum	<0.075	<0.075	<0.075	0.537	-
Arsenic	<0.085	<0.085	<0.085	<0.085	1.82
Barium	0.024	<0.004	<0.0185	0.045	-
Cadmium	<0.005	<0.005	<0.005	<0.005	0.05
Calcium	112.2	0.2	<31.8	166.1	-
Chromium	<0.007	<0.007	<0.007	0.537	1.268
Copper	0.011	<0.01	<0.01	0.029	1.547
Iron	0.011	<0.04	<0.0429	0.027	-
Lead	<0.050	<0.050	<0.050	<0.050	0.316
Magnesium	0.09	<0.05	<6.88	1.10	-
Manganese	<0.007	<0.007	<0.007	0.0018	-
Mercury	<0.0002	<0.0002	<0.002	<0.0002	0.052
Molybdenum	0.252	<0.02	<0.02	4.502	-
Nickel	0.008	<0.03	<0.03	0.119	1.822
Silver	<0.007	<0.007	<0.007	0.016	0.197
Sodium	56.2	11.5	<31.6	440	-
Tin	<0.250	<0.250	<0.250	<0.250	-
Zinc	<0.100	<0.100	<0.100	<0.100	1.195
TDS	527	36	<246	5,192	-
TSS	<5.0	<5.0	<5.0	1.25	-
TOC	<10.0	<10.0	<10.0	37.3	-
O&G	<5.0	<5.0	<5.0	<5.0	150
Chloride	18.8	<1.0	<17.8	277	-
Fluoride [1]	0.8	0.3	<1.5	12.6	-
Nitrate as N	4.6	1.3	<2.13	70.4	-
Sulfate [1]	145.7	<1.0	<93.9	2,302.5	-
Sulfide	<0.500	<0.500	<0.500	<0.500	102
Total Alkalinity	148.8	29.9	<46	288.6	-
Total Cyanide	0.003	<0.005	<0.0212	0.074	0.86
Dissolved Silica	3.3	<1.0	<5.73	40.1	-
Total Residual Cl_2	<0.02	0.01	<2.14	<0.02	-
Specific Conductivity	1,116	142 (µS/cm)	<441	6,616	-

[1] This data is an estimate only, due to a wide range of accuracy used by the lab.
[2] Total Discharge Limits

Table i. Summary of Key Analytical Data

Wastewater & Copper Recovery. The recovery percentages for wastewater were consistently high. Using flowmeters installed on the HERO™ system influent and effluent, along with the system's operational schedule, accurate wastewater recoveries were calculated for each verification test day. The overall membrane flux was 17.7 gfd (gallons per foot per day), which is much higher than the industry standard of 11 gfd. These results indicate the HERO™ system is very efficient in recovering water for reuse within the facility. Copper recovery percentages from the separate WAC ion exchange unit were less pronounced, showing that the HERO™ system did a fair job of recovering copper for resale or reuse.

The relatively low concentration of copper in the influent could have had an effect on the copper recovery efficiency. Passing the water through the WAC unit multiple times may increase the copper recovery percentage significantly. Wastewater and copper recovery are summarized in **Table ii.**

	Average	Min	Max	Standard Deviation
Wastewater Recovery %	94.3	92.20	96.7	1.8
Copper Recovery %	40.6	25.6	51.3	11.2

Table ii. Summary of Wastewater & Copper Recovery

Contaminant Removal. Since this pilot test treated wastewater that had already gone through the KCP's traditional wastewater treatment process, the HERO™ influent already met local regulatory discharge limits for the sanitary sewer. The HERO™ influent did not meet the quality standards for in-facility reuse. The wastewater had excess levels of calcium, sodium, TDS, total alkalinity, and nitrate (as N). Throughout the four days of sampling, analysis showed that the daily average contaminant levels of the HERO™ effluent were low enough to meet KCP's recycled water standard. The HERO™ RO waste solution met the current local sanitary sewer discharge limits. Contaminant removal is summarized in **Table iii.**

	Average	Min	Max	Standard Deviation
Calcium % Removal	99.8	99.8	99.9	0.05
Sodium % Removal	79.7	69.7	89.8	9.13
Nitrate (as N) % Removal	68.0	63.5	77.9	6.65
Total Alkalinity % Removal	81.6	70.2	90.5	8.66
TDS % Removal	93.8	90.6	96.5	2.45

Table iii. Summary of Contaminant Removal

Energy Use. Energy requirements for operating the HERO™ pilot unit at the KCP included electricity for the five liquid feed pumps. Electricity is also used for system instrumentation, compressed air and reagent feed pumps; however, the energy requirements for these are less significant and were not evaluated during this project. Electricity for the pilot trailer lighting and air conditioning was also not included in the HERO™ system energy use calculations. Electricity use was determined to be 36.7 kWh/10,000 gallons (gal) of treated wastewater.

Waste Generation. A waste generation analysis was performed using operational data collected during the verification test period, and historical records from the KCP and Hydrometrics. Waste generation data normalized to the amount of wastewater processed over the verification test period showed an RO waste generation rate of about one gal for every 12.6 gal of wastewater treated. Implementation of the HERO™ system reconditioned the wastewater for potential reuse within the KCP, thus eliminating the discharge of this wastewater to the sanitary sewer. However, some of this waste reduction is offset by the RO waste solution and WAC ion exchange regeneration waste generated by the HERO™ system.

Since the WAC ion exchange system was not regenerated during the verification test period, a theoretical extrapolation had to be considered.

Chemical mass balance calculations determined a WAC regeneration waste solution creation rate of approximately one gal for every 128.5 gal of KCP wastewater processed. Analytical characterization of this waste stream was not possible, but historical records of the HERO's™ WAC regeneration waste solution for similar wastewaters indicate that a standard dischargeable water-softener-like regeneration solution would be generated. Hydrometrics provided an estimate of approximately one gal of combined pretreatment waste for every 41.3 gal of wastewater processed. The combined waste stream is a brine solution with a high hardness count, and is generally suitable for direct discharge to the sanitary sewer. The cumulative waste generation rate from the HERO™ system is approximately one gal for every 8.93 gal of wastewater processed, an overall waste reduction of 89 percent.

Operating and Maintenance Labor. Hydrometrics personnel operated the HERO™ pilot system during verification testing. The HERO™ system requires an operator during startup and shutdown. During operation, the system is self-regulating; however, for testing purposes, a Hydrometrics operator was on-site at all times during the HERO™ system operation. The operational tasks performed by the Hydrometrics operator during the verification test period included: daily inspections of the unit, recording of system parameters, filter change-outs, minor adjustments, and chemical additions. Considerable labor was expended when the membrane degassifier and SAC unit failed to operate initially, however, these were start-up equipment issues, and not counted as general operating and maintenance labor activities. The down-time of these components had no significant effects on water quality, chemical or electrical demand. Estimates by Hydrometrics and validation of operational tasks indicate that for a full-scale 86,400 gpd HERO™ system, approximately seven hours of operating and maintenance (O&M) labor each week would be required.

Cost Analysis. A cost analysis of the HERO™ system was performed using current operating costs and historical records from the KCP normalized to a cost/savings per gal of treated water. An estimated capital cost (2001) of a HERO™ system able to process the KCP average of 86,000 gpd of industrial wastewater is $270,000 (includes $216,000 for the system and $54,000 for installation costs). Based on the reduction of sewer discharge and cost avoidance realized from recycling the wastewater for reuse, the annual cost savings associated with the unit is approximately $60,065. The projected payback period would be approximately 4.5 years.

SUMMARY

The test results show that the HERO™ system provides an environmental benefit by conditioning the KCP's industrial wastewater for reuse within the facility, thereby reducing the amount of fresh make-up water required each day. The HERO™ system achieved a very high recovery of the treated water (94%), and a high membrane flux rate (1.6 times higher than the conventional norm). There was no indication of membrane fouling during the verification test period. Copper recovery operations performed marginally, but further adjustments and processing could yield significantly better results. The relatively low concentration of copper in the KCP wastewater may have been a poor matrix to test the effectiveness of the HERO™ system's metals recovery ability. The major economic benefit associated with this technology is in reduced waste disposal costs and raw water purchase costs associated with the recycling of the wastewater within the facility. When the labor and electrical costs associated with operating the HERO™ system are factored in, the payback period is approximately 4.5 years. The equipment vendor also claims that other benefits at some installations may include: reduced wastewater in support of zero liquid discharge, reduced clarifier or other pre-treatment needs, and improved operations associated with reuse of low-hardness, high-quality water. As with any technology selection, the end user must select appropriate wastewater treatment equipment and chemistry for a process that can meet their associated environmental restrictions, productivity, and water quality requirements.

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