Closed-Loop Treatment of Electrolytic Nickel Rinse Water by Point-Of-Use Ion Exchange: A Case Study.

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Many recent pilot tests have demonstrated the benefits and cost effectiveness of point-of-use treatment technologies as opposed to centralized wastewater treatment for all sizes of plating facilities. A 9-month case study at a small plating facility in Cincinnati Ohio utilizing point-of-use ion exchange is described in this report. The principal constituents were tracked through the rinsing process for the electrolytic nickel lines. These results were used to develop simple mathematical tools that allow one to estimate the effectiveness of an existing rinsing station / ion exchange configuration and explore new options. We describe how these tools can be used to identify relationships between workload, rinsing station design, ion exchange system design, and temporal fluctuations in the mass loads handled by the point-of-use ion exchange system. This facility has recently switched from using an ion exchange service to a totally on-site system. The effectiveness, operational experience and costs associated with the each ion exchange approach are also presented.

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Introduction

Many demonstrations have shown the benefits and cost effectiveness of point-of-use treatment technologies as opposed to centralized wastewater treatment for all sizes of plating facilities (e.g. Sengupta, 1995). A 9-month case study at a small plating facility in Cincinnati Ohio utilizing point-of-use ion exchange is described in this report. The principal bath constituents were tracked through the rinsing process for five electrolytic nickel lines. Recently the shop switched from using an ion exchange service to a totally on-site system. The effectiveness, operational experience and costs associated with the each ion exchange approach are presented along with simplified methods of analysis. The goal of this project was to evaluate different rinse station configurations and compare the costs of using an ion exchange service to in-house ion exchange. The shop operates under a batch discharge permit and recycles all nickel-plating rinse water by passing it through an ion exchange system.

Five nickel plating lines are in operation at the facility, which runs on average two ninehour shifts per day. A simplified schematic illustrating the flow of parts and the dragout recovery scheme is illustrated in Figure 1.



Figure 1. A simple representation of the plating facility used in this case study.

Lines 1, 2, and 5 have dedicated save rinse tanks labeled L1-S1, L2-S1, and L5-S1 respectively. Parts from lines 1 and 2 move through their respective dedicated save rinse tanks and converge at the combined save rinse tank, labeled L12-S2, before moving into a two-stage flowing rinse. Parts from lines 3, 4, and from the dedicated save rinse tank L5-S1 converge on the combined save rinse tanks labeled L345-S2 before moving into a two stage flowing rinse. Water from both two-stage flowing rinses passes through the ion exchange system.

Most commercial plating baths are composed of nickel sulfate (major constituent). nickel chloride, boric acid and proprietary low molecular weight organic compounds e.g. sucrose. Recovery of nickel salts or metal and water from rinses are the usual key pollution prevention objectives. All electrolytic nickel baths are operated at elevated temperatures and lose significant amounts of water through evaporation. Consequently, almost all facilities use at least one static rinse for nickel dragout recovery immediately after the plating tank where some of the static rinse water is periodically returned to the plating tank to make up for evaporative water losses. At this facility, shop personnel have estimated evaporation from each plating tank to be 55-60 gallons per day and dragout from the plating and rinse tanks to be approximately one gallon per day per line. An average nickel concentration in the plating tanks is 80g/L. These values are approximate annual averages. In practice these parameters are dependent on many factors and fluctuate through large ranges.

Monitoring

125 mL grab samples were taken from each rinse tank every Tuesday morning between 9:00 a.m. and 10:00 a.m. beginning March 28, 2000 and ending on October 24, 2000. These samples were immediately transported back to the laboratory and diluted 1:10 with 2% nitric acid. The nickel present in these rinse water samples was quantified by inductively coupled plasma spectroscopy. The nickel concentrations in the dedicated save rinses L1-S1, L2-S1, and L5-S1 are plotted in Figure 2. The average nickel concentrations and standard deviations in the dedicated save rinses L1-S1, L2-S1, and L5-S1 are given in Table 1. The nickel concentrations in the combined save rinses L12-S2 and L345-S2 are plotted in Figure 3. The average nickel concentrations and standard deviations in the combined save rinses L12-S2 and L345-S2 are given in Table 2.



Figure 2. Nickel concentrations in the dedicated save rinses L1-S1, L2-S1, and L5-S1



Figure 2. Nickel concentrations in the combined save rinses L12-S2 and L345-S2.

Table 1.	Dedicated	save rinse	tanks	(all	data)

L1-S1	L2-S1	L5-S1
(ppm)	(ppm)	(ppm)
1279	452	1201
1200	272	878
366	36	81
5560	1070	3960
	L1-S1 (ppm) 1279 1200 366 5560	L1-S1 L2-S1 (ppm) (ppm) 1279 452 1200 272 366 36 5560 1070

Table 1a. Dedicated save rinse tanks (3/28/00 to 5/30/00)

Concentration (ppm)	L1-S1 (ppm)	L2-S1 (ppm)	L5-S1 (ppm)
Average	1518	523	1141
Std. Deviation	1083	334	1195
Minimum	397	36	81
Maximum	1550	1070	3280

Table	1b.	Dedicated	save	rinse	tanks	(6/6/00	to
10/24/	00).						

Concentration	L1-S1	L2-S1	L5-S1
(ppm)	(ppm)	(ppm)	(ppm)
Average	1152	415	1229
Std. Deviation	1271	236	721
Minimum	366	75	644
Maximum	5560	998	3960

Table 2. Combined save rinse tanks (all data).

Concentration	L12-S2	L345-S2
(ppm)	(ppm)	(ppm)
Average	23	926
Std. Deviation	21	299
Minimum	1	321
Maximum	75	1570

Table 2a. Combined save rinse tanks (3/28/00-5/30/00).

Concentration (ppm)	L12-S2 (ppm)	L345-S2 (ppm)
Average	31	900
Std. Deviation	26	405
Minimum	1	321
Maximum	33	1440

Table 2b. Combined save rinse tanks (6/6/00 to 10/24/00).

Concentration	L12-S2	L345-S2
(ppm)	(ppm)	(ppiii)
Average	20	938
Std. Deviation	16	247
Minimum	1	473
Maximum	67	1570

Mass Balance Calculations Around the static rinse tanks

The nickel load into the flowing rinse, which is the load treated by the ion exchange system, is calculated by multiplying the average concentration in the combined save rinse tanks by the average dragout. As mentioned previously, the dragout for each line was estimated to be 3.9 L/day (1 gallon/day). Using the average nickel concentration values in tables 2, 2a, and 2b and multiplying by the dragout from each line we find that the average nickel loads (g/day) are:

Average nickel load all data (Table 2):

Load =
$$2 \cdot \left(3.9 \cdot \frac{L}{day} \cdot 23 \cdot \frac{mg}{L} \right) + 3 \left(3.9 \cdot \frac{L}{day} \cdot 926 \cdot \frac{mg}{L} \right)$$

Load = $11.014 \cdot \frac{gm}{day}$

Average nickel load for 3/28-5/30/00 (Table 2a)

Load =
$$2 \cdot \left(3.9 \cdot \frac{L}{day} \cdot 31 \cdot \frac{mg}{L} \right) + 3 \left(3.9 \cdot \frac{L}{day} \cdot 900 \cdot \frac{mg}{L} \right)$$

Load = $10.772 \cdot \frac{gm}{day}$

Average nickel load for 6/6-10/24/00 (Table 2b)

Load =
$$2 \cdot \left(3.9 \cdot \frac{L}{day} \cdot 20 \cdot \frac{mg}{L} \right) + 3 \left(3.9 \cdot \frac{L}{day} \cdot 938 \cdot \frac{mg}{L} \right)$$

Load = $11.131 \cdot \frac{gm}{day}$

Comparison of Point-of-Use Ion Exchange

Initially, management at this facility opted for the convenience and reliability of using an ion exchange service with off-site recovery. This system consisted of two 2.5 ft^3 cylinders loaded with a mixture of strong acid and strong base ion exchange resins in a lead-lag configuration. When the conductivity exceeded a set point on the lead cylinder, it was removed, the lag cylinder was moved into the lead position, and a fresh cylinder was put in the lag position. The service charged \$494 to pick-up and regenerate a spent cylinder. We monitored the concentration of nickel for a period of 65 days while this system operated.

Table 3	Ion	avahanga	Sarvica	raganaration	datas
radic 5.	1011	CACHAIIge	SUMUC	regeneration	uaics.

Date	Day	Regeneration No.	Cost \$
3/28/00	0		
4/4/00	7	1	494
4/13/00	16	2	494
4/20/00	23	3	494
4/25/00	28	4	494
5/2/00	35	5	494
5/8/00	41	6	494
5/11/00	44	7	494
5/18/00	51	8	494
5/25/00	58	9	494
6/1/00	65	offline	na
		Total	\$4446

The cost of renting cylinders was \$35 per month. Generally four cylinders were kept on-site with two in service at any given time. The cost of labor associated with monitoring and changing out the cylinders was negligible. We estimated the total cost of operating this service to be \$4656 for the 65-day period over which we observed it or \$71.63/day. Since there were slightly different average mass loads over the different time periods of consideration and we wanted to compare strategies for reducing the nickel load, we can normalize the results dividing by the nickel mass load to obtain a cost of \$6.65/gm nickel removed. This service became unavailable and was curtailed on 6/01/00.

The in-house ion exchange system was installed in June 2000. It consisted of two pairs of 2.5 ft³ strong acid and strong base ion exchange resin cylinders. One pair is online while the remaining pair is on standby. When the preset conductivity probe indicates that a cylinder is exhausted, the online pair is removed to the regeneration station and the standby pair is brought online. Cation exchange tanks are regenerated with hydrochloric acid and anion exchange tanks are regenerated with sodium hydroxide. The regeneration station uses 4.5 gallons of HCL at \$1.02/gallon and 1.0 gallon of sodium hydroxide at \$2.10/gallon per regeneration cycle. The total cycle, including rinses, generates 235 gallons of regeneration brine. The regeneration station is

partially automated and requires 0.5 hr of labor per regeneration cycle to connect the tanks, move the tanks, etc. A rate of \$18/hr for labor and \$0.075/kW-hr for electricity is used in all subsequent calculations. We monitored this system for a period of 180 days.

Table 4. In-house regeneration dates.

Date	Day	Regeneration No
6/1/00	0	start
6/19/00	18	1
6/26/00	25	2
7/11/00	40	3
7/18/00	47	4
7/31/00	60	5
8/8/00	68	6
8/30/00	90	7
9/18/00	109	8
9/26/00	117	9
10/3/00	124	10
11/1/00	153	11
11/28/00	180	12

The operating cost and payback for this system depends on the manner in which the regeneration brine is handled. One option for handling the brine is to contract for it to be hauled away. The cost for hauling non-hazardous liquid waste in this case is \$0.41/gallon. The operating cost for each regeneration under this scenario is \$112 and the total operating cost over the monitoring period was \$1344. Multiplying by the total number of regeneration cycles, 12, and dividing by the number of days this system was online results in an operating cost of \$7.47/day or \$0.67/gm nickel removed. This results in a cost savings of \$64.16/day when compared to the ion exchange service. Factoring in the capital cost of the regeneration station \$11,176,and two pair of ion exchange tanks at \$1948 per set (total capital cost= \$15,072) results in a payback of 0.64 years. If amortization is combined with the operating cost, the actual cost (operating + amortization cost) is \$13.37/day or \$1.20/gm nickel removed.

Another option for handling the brine is to concentrate it through evaporation. As a rule of thumb, it takes about 9000 BTU to evaporate one gallon of water. This facility already had an evaporator on-site that was not being used to its full capacity. For this evaporator unit the manufacturer estimates that it takes approximately 2.64 kW-hr to evaporate 1 gallon of water. If the volume of regeneration brine is reduced by 90% through evaporation and the concentrated liquid is pumped out and disposed of at a cost of \$1.25.gallon, the operating costs for on-site ion exchange drops to \$5.75/day or \$0.52/gm nickel removed. The cost savings are \$65.87/day with a payback of 0.63 years. If amortization is combined with the operating cost the actual cost (operating + amortization cost) is \$11.64/day or \$1.04/gm nickel removed.

If an evaporator is not available and must be purchased (approximately \$5700) then the total capital cost of the ion exchange system and evaporator increases to \$20,772 and the payback period increases to 0.86 years. For this case the operating cost (operating + amortization cost) increases to \$13.88/day or \$1.25/gm nickel removed.

Other Pollution Prevention Opportunities

Inspection of the monitoring data show that most of the nickels load on the ion exchange unit comes from the dragout from L345-S2. A potentially low cost approach that would reduce the load into the flowing rinse is to install dedicated save rinse tanks on lines 3 and 4. This simple change has the potential to reduce the average concentration in L345-S2 from an average of 938 to something on the order of 30 ppm nickel. Consequently the nickel load on the existing ion exchange service can be reduced from an average of 11 gm/day to 0.5 gm/day. The operating cost savings could range from \$5.46 to \$7.03 per day or on an annual basis \$1993 to \$2567. The capital cost of such a change (installation of two 750L tanks) is about \$1,000. The additional labor incurred by increasing the number of rinses is difficult to predict and depends on the type of parts and work throughput on lines 1 and 2. For many applications it may not incur any additional labor Consequently, the payback for the charges. dedicated save rinse tanks is on the order of 0.5 year. In addition to the cost savings, inclusion of these additional save rinses will decrease energy consumption and green house gases, and reduce the volume of liquid waste by 95%.

Conclusions

This short term monitoring study showed the effectiveness of point of use ion exchange for the recovery of nickel rinse water. Experience with a contracted ion exchange service and a completely in-house ion exchange process showed that the in-house process is at least as efficient in removing nickel and much more cost effective. Additional pollution prevention opportunities can often be found by performing simple mass balance and load calculations around the rinsing process in plating operations.

References

A. K. Sengupta, ed., Ion Exchange Technology, Technomic Publishing Co., Lancaster, PA, 1995; p. 377.

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