Management of Spent Alkaline Cleaners

by George Cushnie, Paul Chalmer, Greg Marsh and David Ferguson*

How do you deal with spent alkaline cleaning solutions? When treated onsite, these nuisance wastes can cause significant upsets of treatment systems that may result in compliance problems. Various methods are used for disposal, including bleeding them into the wastewater treatment system, batch treatment and contract hauling. Also, some shops nearly avoid generating spent cleaners altogether by installing bath maintenance equipment. This article presents the results of tests performed at C.R. Hudgins Plating, a metal finishing shop located in Lynchburg, VA. Testing was performed to quantify the impact that bleeding spent alkaline cleaning solutions into the general wastewater has on the precipitation of zinc during wastewater treatment. Also, cost impacts were examined, taking into account factors such as chemical cost and sludge disposal. Although results can be expected to vary from shop to shop, the methodology employed here and the site-specific results obtained may help some shops rethink their own practices.

Facility background

C.R. Hudgins Plating, founded in 1948, is a metal finishing job shop with over 11,600 m^2 (125,000 ft^2) of production area that specializes in zinc electroplating, powder coating and silk screening. The State of Virginia and the Metal Finishing Strategic Goals Program (SGP) recognized C.R. Hudgins for their success in recovering chemicals, reducing wastewater discharges and sludge generation and reducing energy use. This facility has several zinc electroplating lines, each with alkaline cleaning stations. Prior to 1996, spent cleaners were mixed with the general wastewater and treated with a conventional precipitation system. In 1996, a batch treatment system was installed to pretreat the spent cleaners prior to mixing. Shop personnel attribute a significant drop of zinc in the plant's effluent to this change (from an average of about 1.6 mg/L in 1997 to 0.6 mg/L in 2003).

Testing

Spent alkaline cleaners have long been suspected of causing wastewater treatment problems when they are mixed with the general wastewater (*i.e.*, rinse water) prior to treatment. The spent cleaners contain emulsified oil and chelators, such as ethylenediaminetetraacetic acid (EDTA) that hinder metals precipitation and solids settling. This can lead to higher than expected metal concentrations in the effluent.

At the test facility, the only pollutant found at significant concentrations is zinc. Federal zinc discharge standards are shown in Table 1. Many local governments enforce standards that are even more stringent than these federal limits.**

Nuts & Bolts: What This Paper Means to You

Dealing with spent alkaline cleaning solutions can pose serious challenges to environmental compliance if the wrong approach to waste treatment is taken. This paper presents the results of quantitative tests performed at an operating metal finishing shop. Approaches taken included bleeding the spent solutions into the wastewater treatment system, batch treatment, contract hauling and life extension through more stringent bath maintenance. The outcome may cause some platers to rethink this entire issue.

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** *As an aside, the Metal Products and Machinery (MP&M) proposed limits for zinc were 0.35 mg/L daily maximum and 0.17 mg/L monthly average for job shops and 0.38 mg/L daily maximum and 0.22 mg/L monthly average for captive facilities. However, EPA withdrew these controversial limits after concluding that further regulation was not warranted.*

Table 1
Federal electroplating and metal finishing effluent standards

Regulation	Maximum Daily Limit, mg/L Zn	Average Limit, mg/L Zn*	Design Target Concentration, mg/L Zn
Electroplating Job Shops (40 CFR 413)	4.20	2.60	1.00
Captive Facilities (40 CFR 433)	2.61	1.48	0.55

**A moving 4-day average limit for electroplating job shops and a 30-day average limit for captive facilities.*

To assure continuous compliance, metal finishers must design and operate their treatment systems with much lower values in mind than the maximum daily or average limits due to expected variability (*e.g.*, abrupt changes in wastewater characteristics). To meet the 40 CFR 413 and 40 CFR 433 standards for zinc, EPA data[***] suggest that a company should aim for 1.0 mg/L and 0.55 mg/L zinc concentration, respectively.

Testing was conducted at C.R. Hudgins Plating to quantify the impact of bleeding spent alkaline cleaner into the general wastewater flow prior to treatment, which is the most common method of treatment employed. Bench top tests mimicked the standard treatment methods used by the company. Samples (500 mL) containing zero to 3% of spent cleaner were used. The procedures consisted of (1) ferric chloride addition with rapid mix; (2) adjusting the pH to 9.2 - 9.5 using caustic with rapid mix; (3) reducing mixer speed and adding polymer to flocculant solids; (4) turning off the mixer and allowing the floc to settle and (5) sampling and analyzing the clear supernate. Each sample condition was repeated three times and the results were averaged. These averaged results are shown in Table 2.

The test results show that spent alkaline cleaner inhibits zinc removal. At this particular facility, a wastewater containing 1% spent cleaner exhibits only a small effect. However, at 3%, there is a very pronounced effect. For this particular situation, it appears that the cleaner could be bled into the general wastewater flow at a rate of 1% without compliance concerns. It should be noted that the average concentration of zinc in the treated 1% sample contained 0.56 mg/L Zn. This is approximately equal to the design target value needed to account for the variability (as discussed above, a design target of 0.55 mg/L Zn should be used to assure continuous compliance with the 40 CFR 433 standards). However, at a 3% bleed rate, the average residual zinc concentration was 2.58 mg/L. At this level, looking at the effluent standards in Table 1, one finds that compliance excursions would definitely occur at captive facilities and most likely would occur frequently at job shops (due to the variability issue previously discussed).

Although C.R. Hudgins Plating generates only 11,400 L (3,000 gal) of spent cleaner each year, a single tank dump can be as large as 5,680 L (1,500 gal). The wastewater flow at C.R. Hudgins averages 49,200 L/day (13,000 gal/day). To dilute a single 5,680 L (1,500 gal) batch of spent cleaner to 1% requires a wastewater volume of 492,000 L (130,000 gal). However, due to the variable nature of wastewater flow at this facility (flow fluctuates hourly by a factor of about 50%) a wastewater flow of about 984,000 L (260,000 gal) would actually be needed to consistently maintain a minimum 1% dilution rate. Therefore, with an average daily wastewater flow of only 49,200 L/day (13,000 gal/day), it would take 20 days to bleed a single batch of spent cleaner into their waste treatment system. To accomplish treatment, the operator would have to restart and stop the bleed each day, since the facility operates on a 16-hr day and there is no flow on the off shift.

[***] USEPA, "Development Document for Effluent Limitations Guidelines and Standards for the Metal Finishing Industry Point Source Category," USEPA 440/1-83/091, June 1983.

Table 2
Test results

Sample (500 mL)	Average Zinc Concentration Before Treatment	Ferric Chloride Dosage*	Final pH	Average Zinc Concentration After Treatment	%Zn Removal
100% wastewater	5.17 mg/L	0.4 mL	9.3	0.43 mg/L	91.6%
1% spent cleaner, 99% wastewater	5.16 mg/L	0.8 mL	9.4	0.56 mg/L	89.1%
3% spent cleaner, 97% wastewater	5.13 mg/L	1.6 ml	9.3	2.58 mg/L	49.7%

**Note: The required ferric chloride dosage was determined by preliminary testing, which showed that 0.8 mL of ferric chloride were needed for good settling and zinc removal for the 100% wastewater sample and that an additional 0.08 mL were needed for each mL of spent cleaner added.*

Other facilities may determine that a higher or lower maximum bleed rate is needed. In any case, testing should be performed to determine an acceptable rate, at which continuous compliance is maintained with an adequate safety margin. One should aim for the design target concentration, not the average or daily limit.

Evaluation of options

The test results show that spent alkaline cleaners can have a detrimental impact on wastewater treatment. Many shops won't have sufficient general wastewater flow to use the bleed method of treatment. Others, such as the test facility, have decided not to use the bleed method because it increases the risks of non-compliance. There are other options available. The four primary options include:

1. Bleed into general flow,
2. Pretreatment of spent cleaner before combining with general flow,
3. Hauling spent cleaner to a treatment/disposal site and
4. Cleaner bath maintenance.

These four options will now be described and then compared, considering factors such as compliance assurance, capital and operating cost and practicality.

Bleed into general flow

To implement this option a shop would typically install a holding tank sized to hold one or more cleaner tank dumps in the waste treatment area. Drain valves on the cleaner tanks would be piped to this holding tank. It would be necessary to schedule tank dumps to adequately space out the expected volume of spent cleaner. Once a cleaner dump is transferred to the holding tank, it would be bled at a predetermined rate (*e.g.*, 1%) to the treatment process using a chemical metering pump.

Pretreatment of spent cleaner before combining with general flow

To implement this option, a shop would typically install a batch treatment system in place of the holding tank discussed in the previous option. Frequently, a conical bottom tank equipped with a mixer and chemical feed systems is used for this purpose. The spent cleaner is chemically treated, solids are removed through a valve in the bottom of the tank and the treated liquid is metered into the general wastewater flow.

Hauling spent cleaner to a treatment/disposal site

To implement this option, a facility would transfer spent cleaner from the cleaning tanks to drums suitable for holding/transporting hazardous waste [*e.g.*, 208-L (55-gal) DOT-approved drums]. Spent aqueous cleaning solutions may or may not be hazardous, depending their pH and toxic metal content.**** The drums would be stored on-site and transported by a licensed transporter to an appropriate treatment/disposal site. The EPA hazardous waste manifest system would be utilized if the spent cleaner were determined to be a hazardous waste.

Cleaner bath maintenance

Even after extensive use, a high percentage of a cleaning bath is usable chemistry. However, it may contain soils and oil that redeposit on work pieces and cause production quality problems. Various technologies exist for separating and removing contaminants from used cleaning solutions. Some technologies can almost indefinitely extend bath life. Typically, bath maintenance technologies are utilized on a continuous basis to maintain a consistent cleaning solution. Examples include simple methods such as filters and oil skimmers and more advanced technologies such as oil coalescence and microfiltration. When using these technologies, chemical additions to the cleaning bath must still be made to replace dragout and consumed chemicals. However, not discarding what are still useful chemicals and not having to deal with treatment/disposal can achieve significant savings.

Comparison of options

Table 3 shows a cost comparison of the four options for five sizes of cleaning operations, ranging from 5,680 to 114,000 L/yr (1,500 to 30,000 gal/yr) of spent cleaner generated. In each case, for labor calculations, it is assumed for options 1, 2 and 3 that cleaning baths

**** *Federal rules for determining if a waste is hazardous can be found at 40 CFR 261. State rules may supersede federal rules (state hazardous waste rules can be downloaded at: http://www.envcap.org/hwrl).*

Table 3
Cost comparison of alkaline cleaner management options for various total cleaner capacities

Option	Sum of Annualized Capital and Operating Costs for Volume of Spent Cleaner Indicated				
	1,500 gal/yr	3,000 gal/yr	6,000 gal/yr	12,000 gal/yr	30,000 gal/yr
1. Bleed into general flow at 1% rate	$1,351	$2,503	$4,905	$9,610	$23,525
2. Batch Treatment	$1,991	$3,233	$5,965	$11,130	$26,325
3. Hauling	$2,720	$5,240	$10,580	$21,160	$51,400
4. Bath Maintenance*	$4,300	$4,550	$6,300	$10,050	$19,225

* *Assumed that only 25% of volume indicated is dumped.*

are replaced every two months and that the cleaner is not replaced with option 4.***** The costs shown in Table 3 are the sum of annualized capital costs and operating costs.

Table 4 shows an example of a breakdown of these costs for one of the five cleaning operation sizes (45,400 L/yr; 12,000 gal/yr). The cost analysis in Table 4 shows that for all but the largest cleaning capacity evaluated, bleeding spent cleaner into the wastewater is the most economical option. For the largest capacity, bath maintenance is the more economical option. Although the bleed method is usually less expensive to implement, in many cases, this option is not practical or feasible because wastewater flow is insufficient (and/or too variable) to dilute the spent cleaner to a point where it no longer interferes with the treatment processes. It is also important to keep in mind that intentional dilution is unlawful; so adding clean water to the wastewater flow to achieve a treatable spent cleaner dilution rate is not an option.

Getting back to the cost analysis in Table 3, if bleeding spent cleaner at a sufficiently low rate is unfeasible, impractical or just too risky, then either batch treatment or bath maintenance are the most cost effective options. Batch treatment is more economical with small volumes of spent cleaner. With larger cleaning tank volumes, bath maintenance becomes more economical. This occurs because, between a spent cleaner generation rate of 22,700 and 45,400 L (6,000 and 12,000 gal) cleaner, the replacement costs for cleaner begin to out weigh the annualized cost of bath maintenance equipment. With a 114,000-L (30,000-gal) cleaner capacity, bath maintenance is clearly more economical than batch treatment. In every case analyzed, hauling the spent cleaner was not economical, primarily due to the high labor cost associated with drumming and managing the waste.

For this analysis, microfiltration was used to establish the costs and benefits of bath maintenance. The underlying assumptions used for cost calculations were based on an EPA test of this technology published in September 2000.

Conclusions

Bleeding spent cleaner into the general wastewater flow is risky business considering the low dilution rate that is required and the normal variability of wastewater flows. As shown previously, at C.R. Hudgins Plating, a single cleaner dump has a volume of 5,680 L (1,500 gal) and would require 984,000 L (260,000 gal) of wastewater in order to dilute the spent cleaner to 1%. With an average daily wastewater flow of only 49,200 L/day (13,000 gal/day), it would take 20 days to bleed the spent cleaner into the waste treatment system. C.R. Hudgins considers such a slow bleed rate to be an impractical solution and further, because of the risk of noncompliance associated with the bleed method, they have chosen to employ batch treatment. Their decision is corroborated by the results of the cost analysis shown in Table 3.

Batch treatment of spent cleaners is an economical alternative for small operations. However, where a sufficient volume of cleaner is used, bath maintenance is a more attractive alternative. The breakeven point appears to occur approximately at 45,400 L (12,000 gal) of spent cleaner generated per year. At this point, the

***** *Therefore, the cleaning tank capacities (could be one or more tanks) for the five sizes of operations are 946 (5,680/6 = 946), 1,890, 3,780, 7,570 and 18,900 L [250 (1,500/6 = 250), 500, 1,000, 2,000 and 5,000 gal].*

Table 4
Breakdown of annualized capital and operating costs for 45,400 L/yr (12,000 gal/yr)*

Option	Annualized Capital Cost	Operating Costs				Sum of Annualized Capital and Operating Costs
		Cleaner Replacement	Treatment Chemicals	Disposal Fees	Labor	
1. Bleed into general flow at 1% rate	$400	$4,800	$1,800	$1,410	$1,200	$9,610
2. Batch Treatment	$1,200	$4,800	$1,800	$1,410	$1,920	$11,130
3. Hauling	$1,000	$4,800	$0	$12,000	$3,360	$21,160
4. Bath Maintenance	$4,300	$1,200	$450	$350	$3,750	$10,050

*Assumptions:

1. *10 year straight line depreciation for capital.*
2. *Labor cost: $20.00/hr. Includes labor for solution disposal, solution treatment, formulating new bath, waste treatment, waste management and technology operation, where applicable.*
3. *On-site treatment cost for cleaner: $0.15/gal.*
4. *Replacement cleaner: $0.40/gal (after dilution to a 5% solution).*
5. *Sludge generation form on-site treatment of spent cleaners: 0.17 lb. dry solids/gal of cleaner treated.*
6. *Sludge dewatered to 35% solids before disposal.*
7. *Sludge disposal cost: $0.25/lb.*
8. *Haul/treat spent cleaner: $1.00/gal.*

sum of cleaner replacement cost savings and other savings begin to out weigh the annualized capital cost of bath maintenance equipment and other associated costs.

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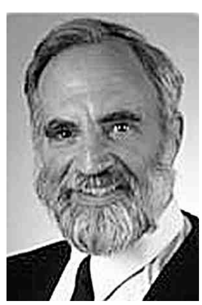

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