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An AES Heritage Paper

A Look Back at Important Journal Articles from Past Issues

Pollution Control and the Plating Industry

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ABSTRACT

A metal finishing consultant looks at the present state of affairs in a dynamic, constantly changing and increasingly controversial area - pollution control in the plating industry. The social, political, economic and technological aspects of the problem are all considered.

Enforcement of pollution control laws has developed out of urgent necessity rather than by planned evolution, with the result that it varies widely across the North American continent. Thus, a company on the Ohio River has come under fire much sooner than one in Brooklyn. A new plant was required to install waste treatment before it could open its doors, but an established company was allowed to go on polluting. With increased rapidity this is now changing. Established control authorities are increasing their activities and new ones are coming into being. In the United States, the passing of the Federal Water Control Act in 1965 and the Clean Water Restoration Act of 1966 brought into being a unifying force. A similar act will come into force in Canada in 1970.

These acts establish minimum standards for interstate and provincial water courses and provide for cooperation among the lower levels of government, to bring standards to a uniform level. Now, slowly, a pattern of common approach is developing over the entire continent. Enforcement of laws concerning waterways is generally in the hands of the states and provinces, with enforcement of effluents discharged to sanitary sewers under control of the receiving municipality.

All of the enforcing agencies attempt to work by a combination of pressure, persuasion, and education. Court action is used as a last resort. This is partly a matter of economics, since court actions are expensive and time consuming. It does give industry a chance to exploit the situation and places an added burden on the industries acting responsibly. More individual companies take advantage of this opportunity to at least postpone waste treatment than the authorities realize.

Techniques of control

A clear pattern is discernible here. The longer the need has existed, the longer the existence of control bodies, the greater the sophistication of control. The Ohio River Valley Water Sanitation Commission, which originated in the early fifties, has constant metering at thirteen locations feeding information into a central recording and scanning system in Cincinnati. In Birmingham, England, where there is one of the greatest densities of plating industry in the world, detailed testing is performed on effluents every two weeks with surprise visits thrown in. The State of Michigan not only monitors streams for specific impurities but is now measuring the biological status of the streams so that any synergistic effects of a combination of pollutants may be identified. This may occur even though individual impurities are below required levels. They are also now licensing carriers for transporting waste products and establishing dumps that may be used for disposal.

The degree to which these and other techniques are being applied is still restricted by the availability of funds and of competent personnel. There is also, of course, a general tightening of funds to all government agencies and this has a substantial influence on the rate at which enforcement is proceeding.

An increasing influence is coming from various citizen pressure groups. These are more often led by legal-minded rather than practical people and seldom are in a position to recognize an order of priorities. They can make it very difficult for a particular industry that they single out. In Toronto recently one of these groups threatened to get an order of mandamus to force the Ontario Water Resources Commission to take action against a borough of the city for discharging to a stream without proper sewage treatment. They are getting response.

Politics still play an important part, especially at the municipal level. It is difficult to conceive that a local authority would shut down the town's major industry. In most instances, now, the higher authority may step in but many companies have taken advantage of this situation to delay installation of waste treatment.

Industry's point of view

Why has industry adopted delaying tactics in many instances? It is certainly because of cost with little or no return, lack of knowledge and a feeling that there must be a better way. The plating industry's usual sources simply weren't able to help. Just a short time ago the only people active in the field were engineers consulting in municipal sewage treatment and industrial consultant firms large enough to have a staff familiar with a variety of industrial applications. Generally, these firms could not handle anything costing less than $150,000.

A very few specialists began to enter the field. They had plating knowledge and some ideas, but their activities were limited. Specialists in instrumentation use also appeared, but they lacked process and chemical knowledge, causing rather serious errors. They preferred to sell the hardware and leave the engineering to someone else. Even more dangerous is the man with a little knowledge, a calling card and an answering service. He may be cheap but he leaves a poorer but wiser plater in his wake.

Belatedly, and perhaps understandably late, the plating equipment manufacturers are entering the market. There is no after-market sales for them in waste treatment, yet they will be expected to give the same service platers are used to on major equipment from these sources. The industry has come to demand service from these sources that they do not demand from any other major equipment suppliers. In England the plating supply companies have largely stayed out of waste treatment and instead work in conjunction with specialists who appeared at a much earlier stage there. These specialists are catering almost exclusively to the metal finishing industry and are able to bring a higher degree of design sophistication to each project than is usually available here. Had there been a greater availability of this kind of organization here it is doubtful that the plating equipment suppliers would have become directly involved at all.

Some organizations are now evolving in this pattern in North America and I welcome their emergence. At least one of the English companies is entering the market in Canada on a limited scale.

Information

All industry that I have encountered have complained about lack of information to guide them. This complaint I reject out of hand. Many platers could improve their situation today if they would read information provided by the Ohio River Valley Authority[1] as far back as the early fifties. The various state and provincial water resources commissions have become much more knowledgeable partly by learning the hard way from past errors. But everything I could say in the way of sound advice has been said at the many seminars and annual meetings of the AES. Anyone seeking the best way to approach a problem should read the papers presented at Miami in 1966 and San Francisco in 1968.[2-4]

European development

I should like to comment briefly on progress in Europe. This, too, is a great source of information.[5-6] Since they have been down the road sooner, we can learn from them. There is no reason why we should make the same mistakes they made, although we seem to have a perverse desire to do so. There is no great difference in equipment available. It is essentially a matter of better understanding of the applications by the controlling authorities, industry and waste treatment suppliers. There is simply more total knowledge and I believe industry accepts a greater responsibility for their part of the problem.

On the other hand, I visited one plant in Leeds where the treatment plant was not working and the attitude was "The municipality is happy when it works at all." Another plant near Birmingham wasn't controlling pH because the operator hadn't got around to turning on the power.

Basic problems of systems

Having quoted two of the reasons why systems don't work, it would seem appropriate to detail other reasons and quote some case histories. If some seem ridiculous, let me assure you they have all happened.

1. *Wrong information*
   A meter reading in ft^3 was taken as gallons and pumps designed accordingly.
2. *Mechanical failures*
   A pump failure can mean a complete plant shutdown. Twinning of pumps and valves is becoming a necessity.
3. *Installation personnel*
   A new industry means new personnel. Competence varies widely, even in established organizations.
4. *Engineering*
   Wrong choice of materials and layouts.
5. *Cost*
   "Bargain Basement" installations - a poor investment.
6. *Liquid-solid separation + cake and sludge disposal*
   This most frequently misunderstood part of the problem requires more thought and engineering than is generally given it.
7. *Space*
   Insufficient space provision will lead to constant trouble.
8. *Personnel*
   Even when a requirement is recognized, it is difficult to get adequate people. It is not a glamour job.

Problem case histories

To illustrate some of these problems, here are case histories of companies that are household names in North America.

Company “A,” in the midwestern United States, was to install waste treatment in one location for an old plating facility and in another with a new plating plant. The manager of the new plant was quite pleased that he didn't have to be involved since head office engineering was handling everything for both plants. Subsequently, I received a call from this manager asking me how much I thought the waste treatment should cost. I suggested \$80,000 to \$90,000. The lowest bidder on the design presented to him was \$250,000. He is on incentive and is now very much involved, but a lot of time has been lost and money wasted.

Company “B” gave the chief engineer an inadequate budget, and no authority to change process methods, which included an incentive system on manual hard chromium plating. This is one of the dirtiest operations I've seen. There is a strong possibility that the budget would be sufficient if the wasteful practices in the plating shop were corrected. The problem remains unsolved.

Company “'C” has assigned the installation of a new plating facility to the process engineers and waste treatment to the plant engineer. The only intercourse between them concerned layout flows and constituent contaminants. The plant engineer will use head office consultants for his design. They are headed straight down the road of Company “A,” but will probably keep going and spend the extra money.

Plating equipment design

Having introduced the necessity for coordination of plating equipment design and waste treatment I would like to expand further. Plating equipment manufacturers have not been inclined to add many waste treatment features to plating equipment, fearing that their competition would not. Perhaps, too, they were influenced by the fact that they sold the chemicals that went down the drain. At any rate, with the exception of counterflowing rinses, I have found it necessary to specify the features that lead to good retention of plating chemicals. The desirability of this approach was covered by Dr. Lancy and Kramer and Nierstrasz at the AES Convention in Miami in 1966. It has been successful with both fully automatic and programmed equipment. Figure 1 shows a programmed automatic at Webster Mfg. (London) Ltd., London, Ontario, which processes up to 2000 ft^2/hr of copper-nickel-chromium on die castings for the automotive industry. This is not only designed for maximum production, but also for maximum waste control. It is not solving pollution by dilution since water flows are in the order of 4500 gph.

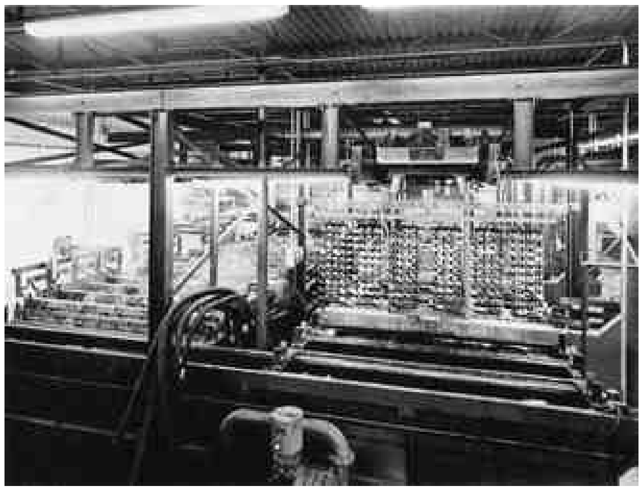

Figure 1 - A programmed automatic plating line at Webster Mfg. (London) Ltd., London, Ontario. This equipment, which processes up to 2000 ft^2/hr of copper-nickel-chromium on die castings for the automotive industry, is designed for maximum waste control.

The effluent contamination illustrated in Table 1 rarely reaches 2 ppm of any constituent and the pH remains at a respectable figure below 9. Although this level of contamination is acceptable to the sanitary sewer system of London, Ontario, provision was made for three-stream separation and underground tankage installed to treat any or all streams should it become necessary. Dump tanks are provided for concentrated discharge and independent treatment before bleeding into the main effluent stream.

Table 1 - Waste Disposal, Webster Manufacturing, London, Ontario.

Date	Cr(VI), ppm	Cyanide, ppm	pH	Copper, ppm
03/31/1970	3.2	3.2	7.9	1.01
04/01/1970	1.0	1.0	7.1	0.4
04/07/1970	1.2	3.0	8.6	0.4
04/09/1970	0.5	2.0	9.3	1.1
04/15/1970	0.85	3.0	8.4	0.6
04/17/1970	0.46	---	---	---
05/20/1970	0.7	1.2	---	0.76
05/25/1970	0.4	0.8	8.1	1.2
05/27/1970	0.34	0.71	8.1	9.52
06/01/1970	0.55	1.1	8.3	1.0
06/08/1970	0.3	1.4	9.0	0.95

The potential problems mentioned in Dr. Lancy's paper referred to above, concerning build-up of carbonates in the copper plating solution have not been a problem in this installation. Only one treatment was made to remove carbonates from the copper bath in 2200 hours of plating. This was performed more on a precautionary basis than out of necessity. Retention, as with some forms of recovery, will tend to increase impurities in baths, but efforts to minimize this build-up are simply good plating practices and the rewards are substantial.

The extra cost to the plating equipment, which now also includes waste control equipment, is small in comparison with the chemical savings and the capital savings on waste facility when it becomes necessary. I would estimate the additional cost of new equipment to be only 3-5 per cent.

Waste treatment systems

When everything has been done to minimize the volume of flow and contaminate concentration, the selection of control equipment can be made. The various systems will be discussed in order of size. There is no precise delineation of these approaches and many combinations of two or more systems are to be found.

Chemistry

Details of the chemistry of the reactions used in waste treatment are available from many sources, so I shall just touch on them here. Lime or caustic soda, is usually used to raise the pH, sulfuric acid to lower it. CN is destroyed by introducing chlorine, as a gas or in liquid form, with sodium hypochlorite at a pH of 11. The cyanide is converted to CO_2 and N_2 when enough chlorine is added.

Hexavalent chromium is reduced to trivalent chromium using SO_2 gas or SO_2 releasing chemicals such as sodium metabisulfite. Ferrous sulfate is sometimes used for the reduction when available at low cost. Trivalent chromium and other heavy metals are precipitated as hydroxides at a pH above 8.

Chromium is also precipitated as barium chromate with barium carbonate the reactant.

Batch treatment

This oldest of treatment plants consists of a minimum of two tanks for each stream, each of which is big enough to hold one shift effluent flow. The first tank is allowed to fill, and then flow is switched to the other tank and an operator adds treatment chemicals. The tank is allowed to settle, the "clean" water on top is sent to drains and the sludge pumped out by the time the second tank is filled. Sludge is held in tanks until removed to a suitable disposal area.

The method is very simple but requires substantial labor, is subject to overdosing and needs rather large tanks in pairs. In early installations all waste was mixed together, but this proved very unsatisfactory, particularly with Ni-CN combinations. It is rarely used where flow rates are above 3 gpm.

Continuous flow treatment

Most systems installed today are one or other of the continuous flow approaches. Figure 2 shows a schematic layout of a typical waste treatment system for removing heavy metals, destroying cyanide and adjusting pH to acceptable levels. Package units now offered are either scaled-down versions of larger tanks or mixing towers, as indicated in the diagram. All of these continuous flow systems use instrumentation for measuring and controlling treatment. Additional settling facilities and/or filtering equipment are still required.

Package units were designed to meet special needs but have sought and found a larger market. It is unfortunate that in the process both sellers and buyers did not appreciate the limitations inherent in them. One design, used extensively at first in Europe and then finding its way here, has the various treatment tanks all mounted on one frame or arranged in a compact configuration. Additions of reactants are in liquid form through air-operated valves or by pumps. Rate of addition is controlled by pH controller meters and ORP (oxidation reduction potential) controller meters. The reaction takes place in tanks with mixers providing agitation. An attempt is made to provide 20 minutes reaction time but it is seldom achieved.

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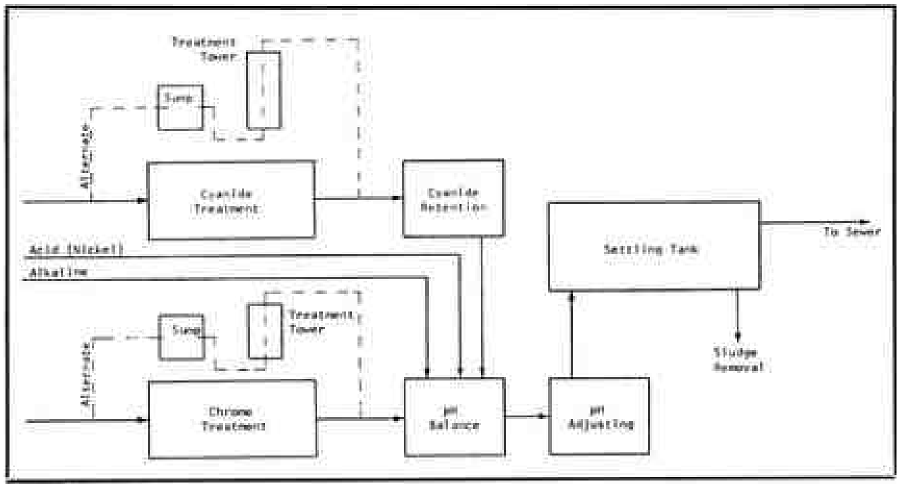

Figure 2 - Diagram of a typical continuous flow system for removing heavy metals, destroying cyanide and adjusting pH.

The tower units incorporate principles that permit faster reacting time between effluent and reactant, with claims as low as 2 - 3 minutes. They are quite small in themselves, but in many situations require additional time for the reactions to complete in supplemental tanks. The tower units usually use chlorine or SO_2 gas fed through mixing valves. The package units serve a useful purpose for flow rates below 20 gpm where space is severely limited. They have the advantage of being prefabricated to a large extent. In the past, some of the suppliers marketing them did not provide any engineering service and misapplication was frequent. Disadvantages include inability to cope with shock loads and a tendency for tower units in some installations to scale up. A typical package unit installation is shown in Fig. 3. This installation is at Grenville Tinnes Ltd., in England.

Figure 3 - A continuous flow system for pH treatment of acid dipping effluents at Grenville Tinnes Ltd., England.

A special case

Fitting somewhere between the package unit and standard continuous treatment units is one recently entering the market. Instead of following the usual procedure of chromium reduction and precipitation of the hydroxide, it precipitates chromium as barium chromate in one stage with carefully controlled pH. Since settling is fast it permits this operation to be completed in the same tank. In fact, settling is so fast and the precipitate so dense that a plow is required to prevent caking. Barium chromate is bled off periodically by gravity flow. This is a particularly useful approach if chromium is the only source of pollution. The supernatant water can usually be returned to the plating system with a 90 per cent recovery of the involved rinses (Fig. 3).

Continuous flow treatment

For the widest range of applications, the greatest control and the least labor and chemical costs, this is the approach now finding widest application. It differs from the mixing tank approach of package units only in size. Tanks are provided to allow 25 - 30 minutes reaction time for each stage. The tanks may be above or below grade and are provided with mixers for agitation. Below-grade tankage permits gravity flow and minimized pump problems. Design of baffling to prevent shortcutting of flow and instrument probe location is very important in these tanks.

A completely different continuous treatment system is known as an integrated system. This incorporates treatment into the plating line. Parts coming from a plating bath enter a rinse containing an excess of the treating chemicals. Two tanks and two stages are used for chromic acid removal, but in other treatments only one stage is used. The rinse bearing the reactant constantly overflows into a large reservoir where the chemical reaction in the wash has time to be completed and precipitated metals time to settle. Reactants are also added to the reservoir tank in an empirically determined quantity. As with all of the above systems, dump tanks must be provided. Any precipitated solids remaining in the running rinses are settled in a separate tank with the overflow going to the sewer.[7]

Recovery

If recovery is such an obvious way of getting something back from all of the above nonprofitable investments, why has it not found greater favor? Because it is not simple in most applications. It is either expensive or it recovers some undesirable ingredients.

Recovery approaches involve recirculating water, the simplest, and collecting and recovering plating chemicals. Once having removed pollutants to the satisfaction of the authorities, the effluent is often good enough to return to some portions of the plating process. One is mentioned above on chromium. Another, where the chromium is precipitated as the hydroxide, is an installation at Super Oil Seals and Gaskets Ltd., Redditch, England, where 80 per cent of the rinse is returned (Fig. 4).

Figure 4 - A recovery system at Super Oil Seals and Gaskets, Ltd., Kedditch, England.

Water and sewer cost increases are greatly accelerating this approach. Deionizers, used in conjunction with evaporators to remove unwanted impurities and by themselves to provide partial concentration of the effluent (about ten times) are increasing in application. Costs of equipment and resins and resin limitations provide restricting factors at the present.

Evaporators have been in use for a long time and may be installed to provide a closed loop, returning concentrated solution to the plating bath and high quality water to the rinses. They do not have an application at contamination levels below 500 ppm and more likely 1000 ppm. They do not eliminate waste treatment because of other sources of contamination such as DI unit backwash.[8]

Liquid-solid separation

Solving this problem has more often than not escaped a satisfactory solution. Early efforts using settling techniques common to municipal waste treatment just did not work here. Lagoons were first thought to be an answer when enough land was available, but they are subject to failure and flooding and eventually fill. They are now considered only acceptable in some places for receiving sludge.

Settling tanks will usually permit sufficient settling to meet requirements for sanitary sewers, but even with four hours retention time difficulty is encountered in meeting 10-15 ppm suspended solids called for, before discharging to storm sewers or streams. Flocculating agents help, but are expensive. Only a very few equipment suppliers have found the key to design here.]

Filters

To the plater a logical direction to turn is to the filter. That is, until he sees the cost. "On stream" filtering requires either two filters or a large amount of body feed to keep the filter in service until a weekend shutdown. The first approach duplicates the capital cost and the second is a very expensive operating cost. I am very hopeful, however, that demand will produce a filter design that will be automatic in operation and reasonable in cost.

Typical costs

Package units, where each effluent stream is in the range below 20 gpm and the total effluent at 80 gpm, will cost between $8000 and $10,000 [in 1970 Dollars] for each component. If there is a requirement for CN destruction, chromium reduction, precipitation of heavy metals and pH adjustment, three components would be needed. In addition, there would be dump tanks, settling tanks and/or filters, floor trenching and piping. All of this must be engineered and when finally put together the total cost will range from $70,000 to $90,000.

An integrated system where the installation involves a copper-nickel-chromium line, a barrel zinc system and a hand zinc line with dichromate dip, with a total effluent of 150 gpm, will cost about $100,000. Monthly operating cost will be about $3000, including chemicals, labor and overhead. This will represent about 12 per cent of the total operating cost of the plating plant.

A continuous flow treatment system of the same size and meeting the same conditions will cost from $70,000 to $90,000. Of this, about one third will represent the control instrumentation and the balance, tanks, mixers, pumps and the additional items mentioned under package units.

I am well aware that installations have been made which cost a great deal more than those quoted in this size range, but I believe it is possible to stay near these costs unless there are very unusual conditions. Older installations with extensive changes to plant or building will cost more.

A general guide is that capital costs will be 12 - 15 per cent of the cost of a completely new plating facility and operating costs will be increased by 12 - 15 per cent of total manufacturing cost.

Costs of recovery system

A recent installation already had a chromium treatment system, but a daily waste of 300 - 400 lb. of chromic acid and a cost of 80¢ to destroy each pound of chromic acid. It was decided they could pay for deionization and evaporation in two years. The total installation cost $80,000, and after a few months of running they have extended the expected payback period to over three years.

Summary

These systems will work. These costs can be held. There is some likelihood that better methods will evolve and that costs will come down a little. The AES project to investigate reverse osmosis as a means for treatment and recovery (AES Research Project 31) is in its second year. Nickel carbonate recovery systems are being tried here and in Europe, but today this is what we must live with.

Finally I suggest a few steps to help bring focus to the problem:

1. *Management must be involved*
   - To coordinate production and engineering
   - To be able to appreciate capital requirements
2. *Do not underestimate the problem*
   - With respect to operating personnel
   - With respect to size
3. *Have consultation*
   - Amongst your own staff.
   - With the authorities.
   - With competent outside advice.
4. *The project engineer must*
   - Anticipate future requirements. It is difficult to tack on.
   - Not short-cut. Use competitive bidding for best price, but don't buy "bargain basement."
5. *Throw out the "garbage man" philosophy and regard waste treatment as a process.*

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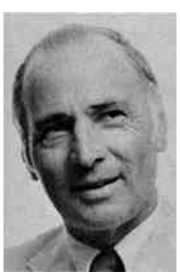
About the author



Kenneth R. Coulter, P.E., AESF Fellow has been a pillar of the AESF organization for many years, as a long-time member of the Toronto Branch. He was Chairman of the AESF Annual Conference held in Toronto in 1975. He served two terms on the Board of Directors in the 1980s as well as many years on the Environmental Committee. From 1973-77 he was a Consultant to the Canadian Department of the Environment during its establishment of effluent guidelines for metal finishers. He was also Chairman of the Board of Comco Metal & Plastic Industries, and auto parts manufacturer, from 1972-82, as well as a Director and Consultant to Superior Metal Industries of London, Ontario. He presented many papers on environmental topics, was a panelist at the first AESF/EPA Conference and was Director of the AESF

Research Project on "Electroplating Wastewater Sludge Characterization." He also helped initiate the public relations program that led to the production of the highly successful AESF film, *Surface Finishing - You Can't Live Without It.* Mr. Coulter was a Chemical Engineering graduate of the University of Toronto and served in the Royal Canadian Artillery.