Pollution Control and Resource Recovery for PC Plating Shops

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ABSTRACT

A review of present day regulations of EPA covering plating waste water and sludge disposal.

Detailed discussion of various waste streams and methods recommended for recovery or reduction of waste losses and sludge generation.

A review of latest technology and equipment available for heavy metals removal from ammoniated and other chelated process chemicals. Reverse Osmosis, Evaporation, Ion Exchange and electrodialysis are discussed as recovery methods.

Economic considerations are reviewed in designing a waste treatment and pollution control facility for pc plating shops. Particular emphasis is placed on water saving methods for rinsing needs and savings of up to 90% in water usage shown.

OVERVIEW

Printed circuit shops having plating operations are faced with the problem of meeting local, state and federal pollution control regulations. Pollution control equipment is quite costly and the operation of these systems can add substantial costs to operating budgets. Proper planning of the pollution control system can aid the user in reducing operating costs. To achieve optimum operating costs, resource recovery must be included in the program. Resource recovery will include recovery of valuable metals, reduction of sludge generation and water reuse.

Because most printed circuit shops have small process tanks and employ a wide variety of highly chelated chemicals, particular care must be exercised in adopting resource recovery methods.

EPA REGULATIONS

Surface water discharges are covered under the program identified as the National Pollutant Discharge Elimination System (NPDES). Each plater must have a NPDES permit to be a legal operation. Platers discharging to sewers are covered by the Publicly Owned Treatment Works (POTW) pretreatment regulations. All platers must comply with the Resource Conservation and Recovery Act (RCRA) regulations. RCRA regulations govern the disposal...
All of these regulations require understanding on the part of the plating shop operators. In general, the government rules prohibit discharge of heavy metals and other related materials above certain specified limits. These limits are shown in charts in the appendix (Table I through Table V).

Present regulations adopted are scheduled to be in effect nationally by October, 1982.

Platers should be planning and budgeting their pollution control programs for adoption within the next few months to meet this schedule.

**REVIEW OF PLATING FACILITY**

The volume of water used in plating is the major factor used in design of a pollution control system. The main objective of the facility review shall be to obtain accurate information on all water needs for plating and identify the contamination levels.

The recommended first step for facility review is the preparation of a tank layout of the plating facility. The tank layout should show the volume and size of each tank to scale, with identification of the chemical content, or product, in each tank.

Next, a flow diagram should overlay the tank layout to reveal if the work flow is progressive and efficient through the existing plating facility. If criss-crossing and back-tracking occur, strong consideration must be given to smoothing the work flow.

Having identified the total water volume used in plating, it is necessary to define exactly how and where this water volume is being used. The water usage for each tank should be noted on a tank layout overlay.

The two overlays shall provide a good basis for making revisions in your plating facility that will result in more efficient work movement and better water usage. However, in those areas where water usage may still be excessive, it may be desirable to consider one or more of the following means for reduction of water:

A. **Countercflow rinsing** (addition of rinse tanks)
B. **Flow restrictors**
C. **Spray Rinses** (Intermittent)

Use of items listed above can reduce water needs by 50% or more, in many cases.

Having listed all the chemicals or products in each tank we now must classify them. The first classification quickly adopted by platers is the recovery of valuable chemicals - such as gold from gold plating solutions. Silver from photographic processes is also worthy of recovery.
For waste treatment considerations we need to know which chemicals are dumped as concentrated or strong chemicals. We need to know the volume, concentration and frequency of each dump. We also need to know the chemical composition of such wastes. If the material is proprietary, then the chemical supplier is required to reveal its composition or recommend a proper method for safe and efficient disposal as a waste.

Strong chemicals are treated separately or slowly added to the rinse water waste streams for disposal. Many strong chemicals offer recovery opportunities that should be considered. For example: Chemical companies will often reclaim copper etch solutions. Many such processes are designed so that no waste goes to sewer. These are considered to be "closed loop" systems and are highly recommended to pc platers.

Acid dips also can be recovered by removing the copper by ion-exchange or crystallization. Approximately 80% of the acid is reused thus lowering acid purchases and saving cost of neutralizing chemicals while putting copper in a form where recovery of the metal is feasible.

Some electroless plating baths also lend themselves to metals recovery and to recovery of chelating chemicals.

Copper carried over into rinse waters can also be recovered using evaporative methods for closed loop rinsing.

All of the above recovery methods, plus others not specified, should be considered during the design phase of a pollution control program.

The cost - payback evaluation on each recovery system must not ignore the ever-rising cost of sludge disposal. It is expected that as EPA defines proper disposal methods, sludge disposal costs will be the largest single cost in your pollution control program. Therefore, any payback evaluation of six years or less is a very worthy candidate for acceptance in your pollution control program today.

Special care must also be given when evaluating payback on recovery system to the ease or difficulty of postponed adoption. For example, if counterflow rinses are needed as a part of a recovery system, but you decide to postpone adoption of the system to lower capital expenditures, you are then faced with a potential larger cost in the future so that the extra tanks can be included. In cases like this, the extra tanks should be put in, or space left for them in the plating room design.

Having gathered the facts and evaluated the possibilities, you may now adopt your plating room tank layout. A proper layout should include all auxiliary equipment such as filters, rectifiers, etching machines, deburring machines, pollution control equipment, recovery equipment, chemical storage, etc. all in true scale.
DESIGN OF POLLUTION CONTROL SYSTEM

Now you have your plating room layout completed. The first step in your pollution control program is to isolate the plumbing and drainage for each "closed loop" system.

Gold - All rinse waters should circulate through a gold recovery chamber. No water to sewer. Gold filter is also a closed loop. Recovery: filter cartridges and ion-exchange cartridges are processed for gold recovery. Recovery can be done "in house" or with a trusted supplier who will faithfully account for all gold processed and charge a reasonable fee for such service.

Silver - Photographic: The silver contained in scrap film and in some photo chemicals can be reclaimed by companies who specialize in this work for hospital X-rays and other large users of photo silver. PC platers may purchase equipment for "in house" recovery of photographic silver. Plating: In small systems the most cost effective recovery is the use of counterflow rinsing. Ion-exchange can also be used for silver recovery. The filter cartridges and ion-exchange cartridges can be processed for silver recovery either "in house" or by outside contractors.

Nickel - Electroless: Electroless nickel is a highly chelated material. Rinse waters containing this solution must receive a treatment suited to releasing the complexed nickel. This will require a drainage line to an area suited to this type chemical treatment. The spent electroless nickel solution shall be placed in a separate holding tank for special handling. Watts Nickel: Rinses from this tank may go directly to neutralization and precipitation. Filter cartridges used on the Watts nickel are disposed of as scrap nickel. Most PC nickel plating operations are too small to consider nickel recovery. The sulfamate nickel bath (Wood's) should be treated as a complexed metal in the waste treatment system.

Copper - Mechanical: There are several sources of valuable copper to be recovered after mechanical treatment in the PC shop. All scrap from laminations shall be saved for copper recovery. All routing and drill wastes shall be saved for copper recovery. The water used in deburring or brushing operations shall be filtered and reused as a
Copper (Continued)

water to waste treatment or sewer. Filter cartridges containing copper are disposed of with scrap copper as a solid waste.

Chemical - Electroless: All rinses from electroless copper must go to the special treatment required to break metal complexes. The spent electroless copper must be collected in a separate holding tank for special handling.

Chemical - Acid: Rinses from the acid copper plating tank may go directly to neutralization and precipitation for treatment. Filter cartridges used on Acid Copper tank can be disposed of as scrap copper.

Recovery: Because pc plating shops have such a high percentage of copper in the waste materials, recovery becomes a feasible consideration due to: a) the value of copper and; b) reduction of sludge waste. This will be discussed later in this paper.

Tin-Lead Tin-Lead plating is carried out normally in a fluoboric acid solution to promote soldering operations. The rinse waters and strip solutions for tin-lead are disposed of in the neutralization-precipitation system.

Activators, Catalysts and Others: Some of the remaining solutions may have complexing agents, most will not. Where possible, complexing agents should be avoided. One popular bath in pc shops is Ammonium Persulfate plus Sulfuric Acid. This can be substituted with Hydrogen Peroxide and Sulfuric Acid which offers a copper recovery opportunity and avoids one complexing agent.

Disposal of the concentrate baths shall be directed to the holding tank. The rinse waters from these tanks shall go to waste treatment for complexed chemicals as a safety measure.

Photo Resist & Strip Screening: ALL PHOTO RESIST SOLUTIONS AND STRIPPERS MUST BE DISPOSED OF IN SEPARATE TREATMENT SYSTEM. Photo resist and stripping chemicals will foul pumps and piping in a conventional waste treatment system.

Solvent System: These systems frequently use 1,1,1 trichlor developer and methylene chloride with alcohol as the stripper. Use of distillation stills and fume scrubbers will provide a closed loop, leaving still "bottoms" for disposal.
Semi-Aqueous System: These systems use carbonate developer with a solvent for stripping. The solvent can be recovered in a solvent recovery still.

Aqueous System: This is a caustic-potash stripper of high pH. Once loaded with resist, neutralization of the caustic-potash will result in a gelatinous mass that may be disposed of to incinerator. The water will have high BOD and should go directly to sewer, by-passing normal waste treatment.

**EXAMPLE LAYOUT - PC PLATING SHOP**

Average rinse tank size - 50 gallons.

A. **CLEANING AND PREP LINE** (5000 sq. ft./8 hrs.)

**PROCESS**

1. Alkaline Cleaner  
2. Rinse  
3. APS & H₂SO₄  
4. Rinse  
5. 10% H₂SO₄  
6. Rinse  
7. 13% HCl  
8. Post Activation  
9. Electroless Copper  
10. Rinse  
11. Electroless Copper  
12. Rinse  
13. 10% H₂SO₄  
14. Rinse

**DISPOSAL**

Holding Tank  
Treatment System  
Holding Tank  
Treatment System  
Acid Recovery  
Copper/Water Recovery  
Holding Tank  
Holding Tank  
Special  
Treatment System  
Special  
Treatment System  
Acid Recovery  
Copper/Water Recovery

Estimated Rinse to Waste Treatment - 6 GPM

B. **COPPER PLATING LINE** (After cleaning)

**PROCESS**

1. Rinse  
2. Copper Plate (CuSO₄)  
3. Rinse  
4. 10% H₂SO₄  
5. Rinse

**DISPOSAL**

Copper/Water Recovery  
NONE (filtration)  
Copper/Water Recovery  
Acid Recovery  
Copper/Water Recovery

Estimated Rinse to Waste Treatment - NONE

C. **THROUGH HOLE PLATING & TIN-LEAD** (Two Lines)

**PROCESS**

1. Acid Clean  
2. Rinse  
3. APS/H₂SO₄*

**DISPOSAL**

Holding Tank  
Treatment System  
Holding Tank
C. **THROUGH HOLE PLATING & TIN-LEAD** (Continued)

<table>
<thead>
<tr>
<th>Step</th>
<th>Process</th>
<th>Treatment System</th>
<th>Acid Recovery</th>
<th>Copper/Water Recovery</th>
<th>None (Filtration)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>Rinse*</td>
<td>Treatment System</td>
<td>Acid Recovery</td>
<td>Copper/Water Recovery</td>
<td>None (Filtration)</td>
</tr>
<tr>
<td>5</td>
<td>10% H₂SO₄</td>
<td>Treatment System</td>
<td>Acid Recovery</td>
<td>Copper/Water Recovery</td>
<td>None (Filtration)</td>
</tr>
<tr>
<td>6</td>
<td>Rinse</td>
<td>Copper/Water</td>
<td>NONE (Filtration)</td>
<td>Copper/Water Recovery</td>
<td>Filteration</td>
</tr>
<tr>
<td>7</td>
<td>Copper Plate (CuSO₄)</td>
<td>NONE (Filtration)</td>
<td>Copper/Water</td>
<td>Filteration</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Rinse</td>
<td>Treatment System</td>
<td>Acid Recovery</td>
<td>Copper/Water Recovery</td>
<td>None (Filtration)</td>
</tr>
<tr>
<td>9</td>
<td>Copper Plate (CuSO₄)</td>
<td>NONE (Filtration)</td>
<td>Copper/Water</td>
<td>Filteration</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Pre-Dip (HBF₄)</td>
<td>Treatment System</td>
<td>Acid Recovery</td>
<td>None (Filtration)</td>
<td>Filteration</td>
</tr>
<tr>
<td>11</td>
<td>Rinse</td>
<td>Treatment System</td>
<td>Acid Recovery</td>
<td>None (Filtration)</td>
<td>Filteration</td>
</tr>
<tr>
<td>12</td>
<td>Tin-Lead Plating</td>
<td>NONE (Filtration)</td>
<td>Copper/Water</td>
<td>Filteration</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Rinse</td>
<td>Treatment System</td>
<td>Acid Recovery</td>
<td>None (Filtration)</td>
<td>Filteration</td>
</tr>
</tbody>
</table>

Estimated Rinse to Waste Treatment - 8 GPM (Two lines)

D. **TAB PLATING - PC PLATING SHOP**

<table>
<thead>
<tr>
<th>Process</th>
<th>Disposal</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Tin-Lead Strip</td>
<td>Holding Tank</td>
</tr>
<tr>
<td>2. Rinse</td>
<td>Treatment System</td>
</tr>
<tr>
<td>3. 10% H₂SO₄</td>
<td>Acid Recovery</td>
</tr>
<tr>
<td>4. Rinse</td>
<td>Copper/Water Recovery</td>
</tr>
<tr>
<td>5. Nickel Plate</td>
<td>NONE (Filtration)</td>
</tr>
<tr>
<td>6. Rinse</td>
<td>Treatment System</td>
</tr>
<tr>
<td>7. Gold Plate</td>
<td>NONE (Filtration)</td>
</tr>
<tr>
<td>8. Rinse</td>
<td>Separate Recovery</td>
</tr>
</tbody>
</table>

Estimated Rinse to Waste Treatment - 10 GPM

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*Figure 1* WORK FLOW  
PLATING ROOM LAYOUT

*Figure 2*  
ACID RECOVERY 
PLATING ROOM LAYOUT

*Figure 3*  
ION-EXCHANGE RECOVERY UNIT

*Figure 4*  
COPPER/WATER RECOVERY UNIT 
PLATING ROOM LAYOUT

*Figure 5*  
VC RECOVERY UNIT

*Figure 6*  
HOLDING TANK & WASTE TREATMENT

*Figure 7*  
HY-BOY TREATMENT UNIT

*Figure 8*  
SET-L-FLOC CLARIFIER

*Figure 9*  
LEAF FILTER/SLUDGE Dewater

*Figure 10*  
"AQUA-LOOP" DESALINATION PLANT
# TABLE I. DIRECT DISCHARGE EFFlUENT CONCENTRATION LIMITS

For rinse water flow of 80 L/m² operation*

<table>
<thead>
<tr>
<th>EFFLUENT PARAMETERS</th>
<th>(mg/L)</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphorus (P)</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Cyanide(^A) (amenable to Cl&lt;sub&gt;2&lt;/sub&gt;)</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Cyanide, Total</td>
<td>1</td>
<td>Refers to ferrocyanide mainly</td>
</tr>
<tr>
<td>Fluoride</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Aluminum</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Cadmium</td>
<td>0.6</td>
<td></td>
</tr>
<tr>
<td>Chromium, Cr(^6)</td>
<td>0.1</td>
<td>Soluble and Suspended Solids</td>
</tr>
<tr>
<td>Chromium, Cr(^T)</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Iron</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Lead</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Silver</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>Tin</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>TSS</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>pH (average daily discharge)</td>
<td>6.0-9.5</td>
<td></td>
</tr>
</tbody>
</table>

Metal concentrations are based on analysis of acidified solutions, expressed in total metal content.

* Units are liters per square meter of work processed per operation.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>1-day max.</th>
<th>4-day avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanide, amenable to chlorination</td>
<td>5.0</td>
<td>2.4</td>
</tr>
<tr>
<td>Lead</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Cadmium</td>
<td>1.2</td>
<td>0.7</td>
</tr>
</tbody>
</table>

September 7, 1979

**TABLE II. SMALL PLANT PRETREATMENT STANDARDS (mg/L)**

LESS THAN 38,000 L (10,000 gal.)/CALENDAR DAY

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1-day max.</th>
<th>4-day avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanide, Total</td>
<td>1.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Copper</td>
<td>4.5</td>
<td>2.7</td>
</tr>
<tr>
<td>Nickel</td>
<td>4.1</td>
<td>2.7</td>
</tr>
<tr>
<td>Chromium, Total</td>
<td>7.0</td>
<td>4.0</td>
</tr>
<tr>
<td>Zinc</td>
<td>4.2</td>
<td>2.6</td>
</tr>
<tr>
<td>Lead</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Cadmium</td>
<td>1.2</td>
<td>0.7</td>
</tr>
<tr>
<td>Silver</td>
<td>1.2</td>
<td>0.7</td>
</tr>
<tr>
<td>Total Metals (Cu, Ni, Zn &amp; Cr)</td>
<td>10.5</td>
<td>6.8</td>
</tr>
</tbody>
</table>

**TABLE III. LARGE PLANT PRETREATMENT STANDARDS (mg/L)**

MORE THAN 38,000 L/day (10,000 gal./day)
## TABLE IV. OPTIONAL PRETREATMENT STANDARDS (mg/L)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>1-day max.</th>
<th>4-day avg.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanide, Total</td>
<td>1.9</td>
<td>1.0</td>
</tr>
<tr>
<td>Lead</td>
<td>0.6</td>
<td>0.4</td>
</tr>
<tr>
<td>Cadmium</td>
<td>1.2</td>
<td>0.7</td>
</tr>
<tr>
<td>Total suspended solids</td>
<td>20.0</td>
<td>13.4</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>7.5-10.0</td>
</tr>
</tbody>
</table>

Stipulations: No Cr$^{+6}$, no strong chelating agents, lime neutralization.

## TABLE V. MASS DISCHARGE PRETREATMENT STANDARDS

(mg/m$^2$/operation)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>4-day avg.</th>
<th>Max. 1 day</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cyanide, Total</td>
<td>39</td>
<td>74</td>
</tr>
<tr>
<td>Copper</td>
<td>105</td>
<td>176</td>
</tr>
<tr>
<td>Nickel</td>
<td>100</td>
<td>160</td>
</tr>
<tr>
<td>Chromium, Total</td>
<td>156</td>
<td>273</td>
</tr>
<tr>
<td>Zinc</td>
<td>102</td>
<td>164</td>
</tr>
<tr>
<td>Lead</td>
<td>16</td>
<td>23</td>
</tr>
<tr>
<td>Cadmium</td>
<td>29</td>
<td>47</td>
</tr>
<tr>
<td>Silver</td>
<td>267</td>
<td>410</td>
</tr>
<tr>
<td>Total Metals</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Cu, Ni, Zn &amp; Cr)</td>
<td>29</td>
<td>47</td>
</tr>
</tbody>
</table>
ECONOMIC CONSIDERATIONS

The first capital consideration will be the changes required in your existing plating facility to optimize the pollution control and recovery program. These costs will vary with each plater and depend on the status of his plating operations at the time the pollution control evaluation becomes necessary. Some platers may need few or no changes in his shop. Others may require major changes in the shop.

The adoption of water-saving devices as listed earlier is generally a low cost project and usually will not exceed $5,000 or $10,000. For platers using city water and sewers, this cost can be recovered within a few months of operation. Lower flow rates will also reduce capital costs on pollution control or recovery equipment. You, therefore, benefit two ways by saving water.

In the Example Layout you will note that there are three (3) piping systems used to isolate various waters and chemicals. In a shop of this type the piping system will cost approximately $20,000. Some platers will do their own drain piping and reduce this cost by as much as one half. You will also note that a collection sump is needed in some systems. Each sump represents a cost of approximately $1,000.

CHEMICAL DESTRUCT SYSTEM

A large percentage of platers, in order to conserve capital, will use only a chemical destruct system initially, and later add methods of acid and water recovery as economics justify these expenditures. Using the Example Layout and an estimated total water flow of 60 GPM, the chemical destruct system is made up of:

- Sump Pumps and Transfer Pumps
- Chemical Treatment Tanks & Mixers
- Chemical Feed Tanks and Controls
- Clarifier, filter press & polishing filter

This equipment will cost approximately $130,000. Operating costs will include labor for two shifts of operation and chemicals totalling approximately $25,000 per year. Sludge generation will amount to as much as 100 to 200 lbs per day of 40% solids using the hydrated lime treatment, and cost $50 to $100 per drum for landfill or other disposal.

Smaller pc shops, presently operating at 10 GPM (5000 GPD) for a single shift operation can, by careful planning of water use, reduce to 2000 gallons per day. This amount of water allows the plater to adopt a batch treatment system. A batch treatment of 2000 gallons will consist of:

- Sump Pumps
- Treatment Tank with Mixer
pH Indicator with Chem-Feed Pumps
Work Platform, Centrifuge or Gravity Filter

This equipment can be purchased for approximately $20,000. Operating costs will include labor and chemicals totaling approximately $12,000 per year. Sludge generation will approximate 25 gallons per day of 8-12% solids with disposal cost of $50 to $100 per drum.

For small pc shops using batch treatment, recovery methods are not cost effective and therefore are not normally recommended.

RECOVERY METHODS

GOLD
As earlier described, gold is an obvious candidate for recovery. The two most popular methods are ion-exchange and electrowinning. Gold rinse tanks are usually small and flow rates of water low. Cost of gold recovery equipment is approximately $5,000 and recovery of costs occurs in the first 3 to 6 months of operation as a rule. Cost for gold recovery is higher if an outside contractor is used to carry out recovery work.

SILVER
Photographic. Photographic silver can be recovered by purchase of equipment suited to this purpose. The approximate cost of such equipment is $10,000 and will generally pay for itself within one year of operation.

NICKEL
Nickel is used in small quantities by most pc platers. The amounts lost to waste are also small. Although there are several methods of recovery available, there is no cost-effectiveness to nickel recovery.

COPPER
It is not unusual for a large pc plating shop to generate as much as 20 lbs. of copper per day in waste waters. Over a year of operation, this can amount to about 5000 lbs. of copper per year. This amount of copper however, translates into 40,000 lbs. of sludge per year. This converts to approximately $15,000 per year in present day sludge disposal costs. Thus, it copper can be recovered the savings can become

\[
\begin{align*}
\$15,000 & \text{ in sludge disposal} \\
5,000 & \text{ in copper value} \\
\$20,000 & \text{ net savings}
\end{align*}
\]

Associated with copper recovery will be the recovery of acid and rinse water. Assuming an annual value of $5,000 savings for each of these items we now have annual savings of approximately $30,000.
When a water savings occurs, total water usage is reduced, thus lowering the flow of waste water passing through the chemical destruct treatment plant. If copper, acid and water recovery are programmed into initial design the total flow can be reduced from 60 GPM to approximately 30 GPM as shown on the Example Layout.

A chemical destruction plant sized for 30 GPM will cost approximately $100,000, resulting in a net capital savings of $30,000 to be applied toward recovery equipment.

The cost of recovery equipment for copper acid and some water will be as follows:

<table>
<thead>
<tr>
<th>Equipment</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acid Recovery Unit (ion-exchange)</td>
<td>$ 30,000</td>
</tr>
<tr>
<td>Copper/Water Recovery (evaporator)</td>
<td>100,000</td>
</tr>
<tr>
<td>(and electrowinning)</td>
<td>5,000</td>
</tr>
<tr>
<td></td>
<td>$ 135,000</td>
</tr>
</tbody>
</table>

The evaporator selected is a "low energy" unit working on the vapor recompression principle. These units utilize 1/10th the energy normally associated with conventional vacuum evaporators.

The estimated annual operating costs of the units listed will be $10,000/yr. based on the fact that they are fully automatic and run on continuous cycle.

The total cost-effectiveness of copper recovery from a 5000 square feet per 8 hours plating operation will be:

<table>
<thead>
<tr>
<th>Cost</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>Equipment Cost</td>
<td>$ 135,000</td>
</tr>
<tr>
<td>less capital savings</td>
<td>-30,000</td>
</tr>
<tr>
<td>Net cost difference</td>
<td>$ 105,000</td>
</tr>
<tr>
<td>OPERATING COST SAVINGS (Chem-Destruct)</td>
<td></td>
</tr>
<tr>
<td>less Recovery Costs</td>
<td>-10,000/yr.</td>
</tr>
<tr>
<td>Net Savings</td>
<td>$ 20,000/yr.</td>
</tr>
</tbody>
</table>

The payback therefore, will be $105,000 divided by $20,000 or 5.25 years.

Taking into consideration that sludge disposal costs will probably increase in the next five years and copper will increase in value as well as capital equipment costs, this looks like a very attractive investment at this time.
TIN-LEAD & ACTIVATORS/CATALYSTS will not offer any cost-effective recovery opportunities at this time. These wastes to be combined with Nickel and other wastes not recovered.

ETCHING SOLUTIONS
Most chemical suppliers and most suppliers of etch machines have recovery processes available through counterflow rinsing and other methods. Since these units represent a "closed loop" they are strongly recommended to pc shop operators. Cooperation with the chemical supplier will provide you with a recovery credit and eliminate a disposal problem.

DEBURRING & BRUSHING
Equipment suppliers of deburring and brushing machines frequently offer a "closed loop" water reuse system. These systems include a good quality micro-filter that traps copper particles and reuses the water. This water is never dumped. This is a highly recommended step to take for each of your deburring/brushing machines.

PHOTO RESIST & STRIP SCREENING
As much as possible this waste shall be treated as a batch if an aqueous solution is used. The aqueous solution can be treated to cause the photo resist to coagulate and be removed as a solid waste for incineration. The remaining water is then neutralized and discharged directly to sewer, by-passing the chemical destruct treatment unit.

For solvent type systems, the solvents shall be recovered in a distillation unit or sent to a solvent reprocessor.

The cost of either type treatment equipment will be approximately $10,000.

WATER REUSE
The ultimate savings will be the reuse of water after heavy metals removal in chemical destruction systems.

Water discharged from the chemical destruct system can be reused in your plating line without further treatment. However, continued reuse of such water will build salt content to an unacceptable level. Therefore, by using desalinizing equipment on a "side stream" basis, salt can be continuously removed and discharged.
There are several acceptable methods of desalinizing such as:

Reverse Osmosis
Ion-Exchange
Evaporation

Of these R-O appears most acceptable because it can run on a continuous basis, does not require frequent backwashing and is a low energy system.

For a 30 GPM system such as shown in the Example Layout, the following equipment:

5000 gallon storage
Water Pump system
R-O Desal Unit...

would cost approximately $50,000 and recovery approximately 85% of the water.

For critical rinsing operation the R-O unit can provide high purity water.

The cost-effectiveness of water reuse is determined by the cost of water at your location. If you pay $30,000 per year for use of 6.5 million gallons per year, your water reuse investment can have a payback of 1.67 years.

If you also pay a surcharge in addition to your water bill, your payback can be more rapid.

There are other recovery methods available that have not been discussed in detail. This review is offered to show pc platers some of the opportunities available for resource recovery as related to pollution control.