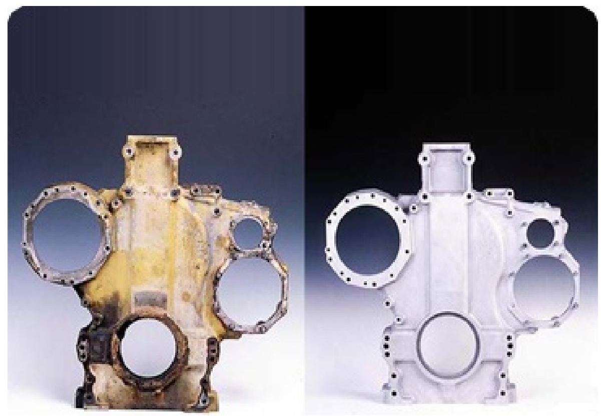
# Advanced Technologies in Electroplating and Effluent Treatment Plant



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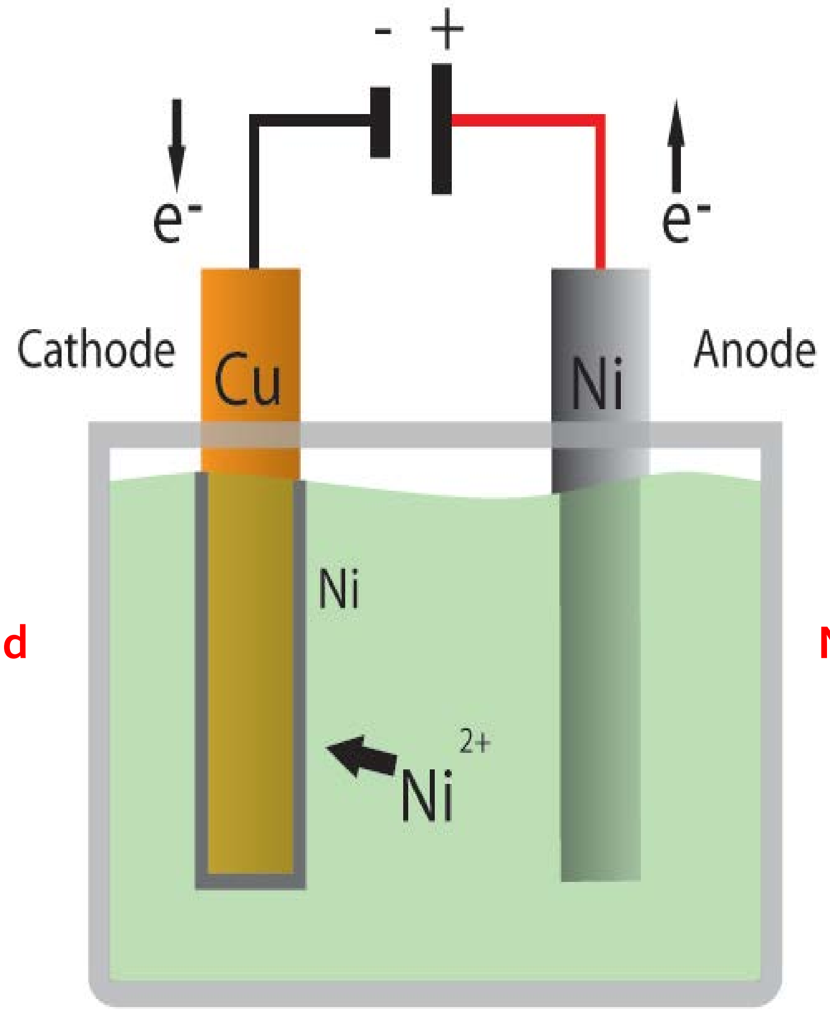
# What is Electroplating?

- An electrochemical process where metal ions are transferred from a solution and are deposited as a thin layer onto surface of a cathode.

- The setup is composed DC circuit with an anode and a cathode sitting in a bath of solution that has the metal ions necessary for coating or plating

- Electroplating can enhance;
  - Chemical properties---increase corrosion resistance
  - Physical properties---increase thickness of part
  - Mechanical properties---increase tensile strength & hardness

# How it works

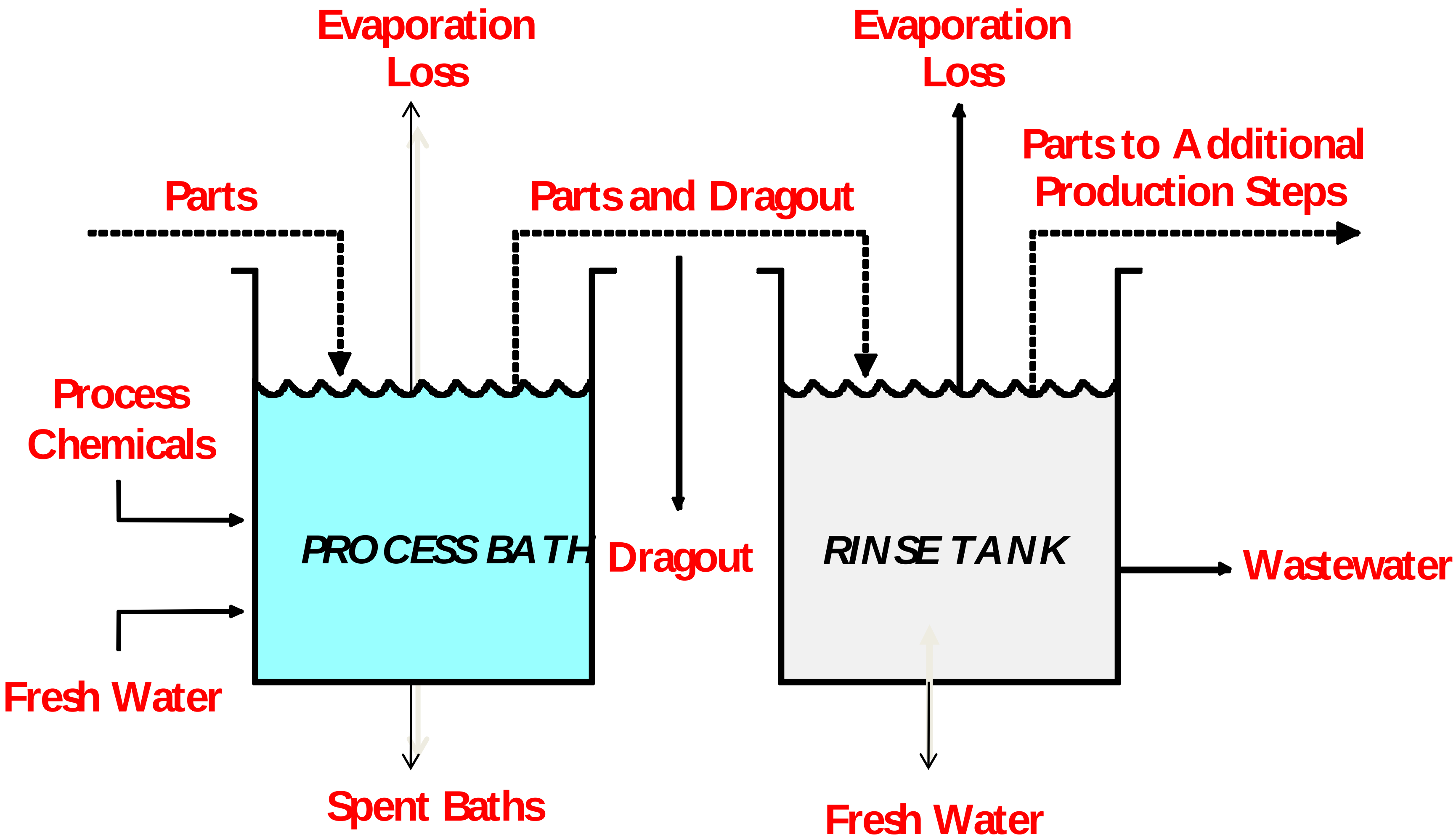



**Copper Cathode is reduced (accepts electrons)**

**Nickel Anode is oxidized (gives us electrons)**

**$Ni^{2+}$ ions within solution become attracted to Copper cathode**

# Metal Finishing "Process Unit"



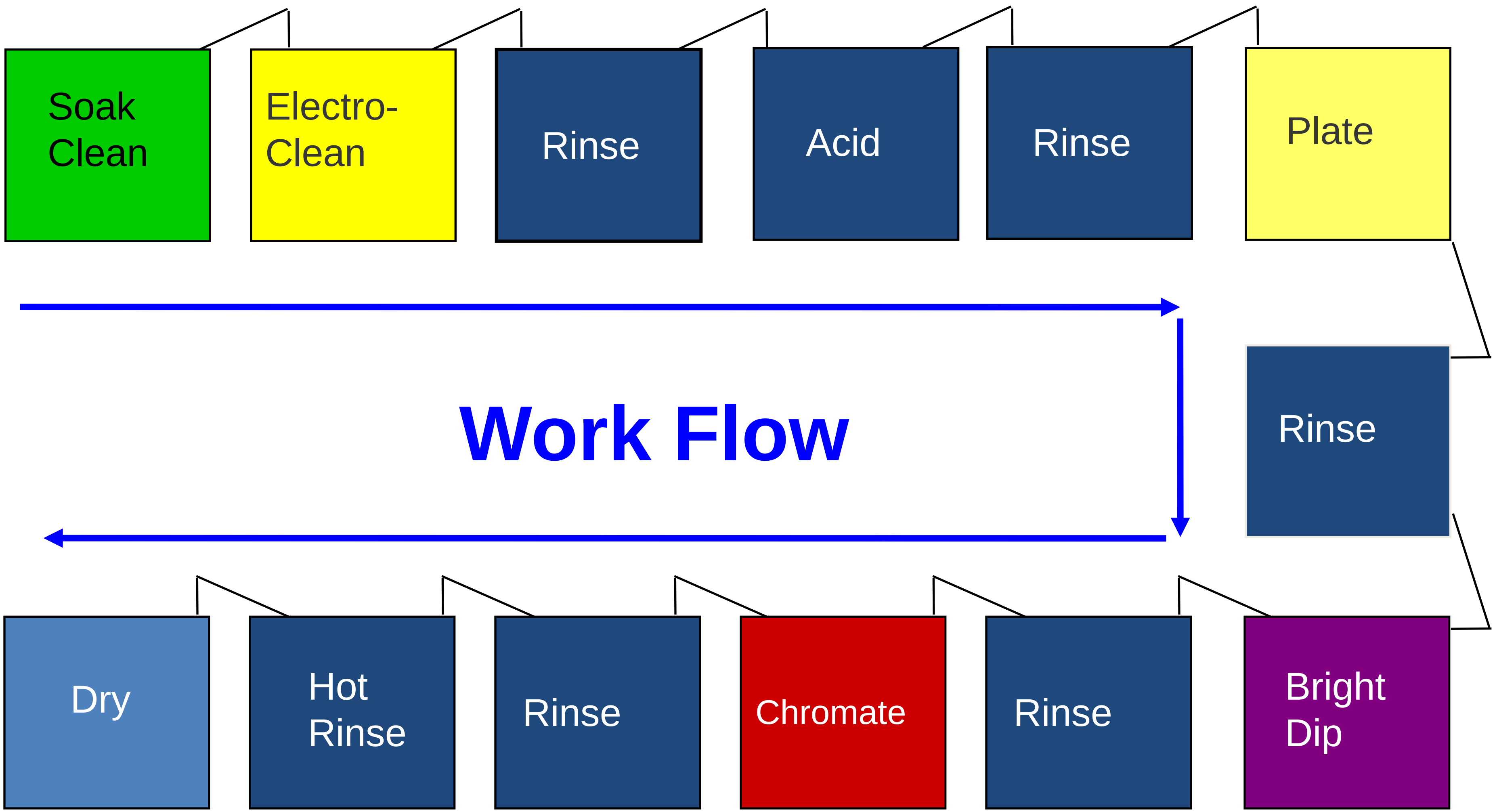
# Metal Finishing Processes

1. Surface Preparation and Cleaning:
   - alkaline cleaning
   - electropolishing
   - oxide removal

2. Metal Plating:
   - electroplating
   - electroless plating

3. Protection and Finishing Treatments:
   - anodizing
   - chromate conversion
   - phosphating

# Typical Plating Line



Barrel Plating, Vibratory Plating, Rack Plating, Heavy Build Plating, Selective Plating, Powder Coating, Selective Powder Coating, Passivation, Vapor Degreasing, Ultrasonic Cleaning, Hard Gold, Soft Gold, Matte Silver, Semibright Silver, Techni-crom, Bright Nickel, Ducta-bright Nickel, Watts Nickel, Sulfamate Nickel, Black Nickel, Electroless Nickel, Black Electroless Nickel (Tacti-black), Copper, Bright Tin, Matte Tin, Tin-cobalt, Tin-lead and Lead

# Rack Plating

- Workpieces hung or mounted to frames (racks)
- Most common and versatile processing method
- Dragout rates and rinse water use easier to control

# Barrel Plating

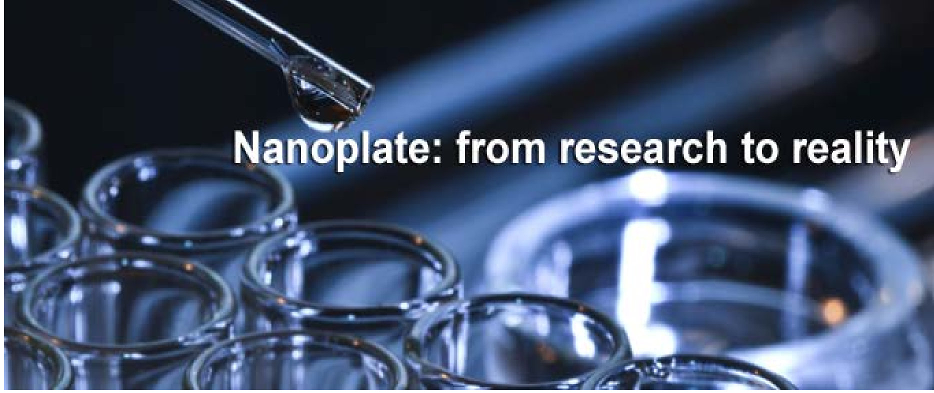
- Parts processed in containment "barrel"
- Typically small parts with low level of plating or processing tolerance requirements
- Dragout rates and water use relatively high

# Manual Plating

- Process steps performed by hand
- Smaller size parts, lower production

# Automated Plating

- **Fully Automated**
  - only requires manual racking and unracking
  - high production quantities and rates
- **Semi automated**
  - requires manual control of hoists and rails
  - larger parts, lower production rates, and varied parts


Nanotechnology - increasing the precision
- aerospace coatings to food preparation surfaces.
- nano-coating has more down-to-earth applications.

Plating silicon nanowires with electrodes

- time-consuming process,
- impractical for large-scale production of nanoelectronic materials.

Other methods, such as stripping, masking and metal deposition provide mixed results and often damage delicate nanowires.

In 2008, Nanotech Briefs for advances in nanotechnology. The new method allows for the parallel processing of millions of nanowires on a single wafer through selective electrodeposition. The nickel is “grown” over pre-patterned electrodes on the nanowires. The process allows for large-scale production at a much cheaper cost and with less material damage than previous methods.

## NANO-COATINGS AND AEROSPACE

Aerospace uses chrome in many forms to coat both the outer hulls and exposed devices on airplanes, spacecraft and satellites.

In the case of chromium plating, nanotechnology offers safer coating processes while increasing the efficiency of aerospace coatings. The nano-coatings offer more efficient thermal barriers, ice-repellant and protective properties while performing better under mechanical stress tests. Additionally, nanotech coatings lower friction and provide improved corrosion resistance.

## LOWERING FOOD CONTAMINATION WITH NANOPARTICLES

A fluorinated nickel nano-coating reduces cross-food germ contamination by an astounding 97 percent.

The new process uses an electroless nickel plating to deposit coatings. Previous plating required clean rooms and photolithographic techniques which greatly increased production costs.

# Advanced Thin Film Coating for Electroplating Metals

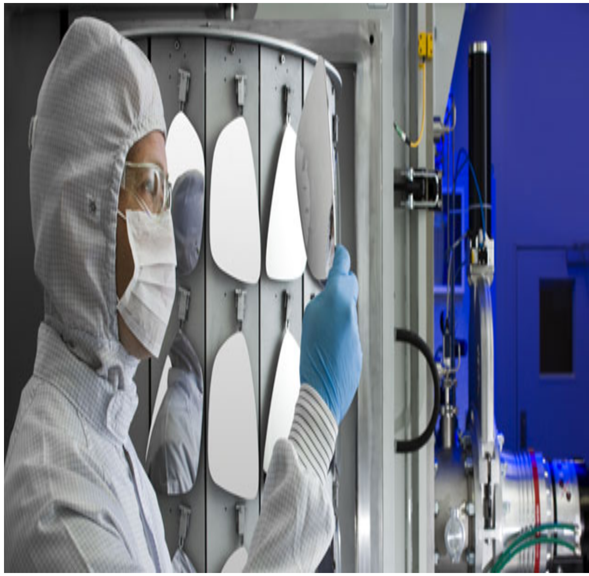
Thin film coatings - electric and microelectronic devices

Electroplating, uses toxic chemicals and generates significant process waste and water pollution.

Chemical vapor deposition (CVD) employs toxic gaseous organic precursors. The most common coating processes—sputtering, evaporation, CVD, and plating are not always compatible with heat sensitive substrates and semiconductor processes, and they provide only moderate output at a high cost.

Jet Vapor Deposition -  process vaporizes wire of appropriate composition completely into atoms, which are carried by sonic inert gas carrier jets and deposited on the substrate.

The JVD capability for using various material sources, leads to layered structures or alloys of multiple metal components, including  Au, Cr, Ni, Cu, Zn, Fe, Sn, and Ag.



Latest Nano Plating technology pioneered by Flexport

Nano Spray Chrome Plating system -Chrome Plating

Mens 18k Gold Nano Injection Plated Scorpion Pendant Chain

Electroless Nickel Plating

Electroless Nickel with Teflon® Plating

Boron Nitride Electroless Nickel

Black Electroless Nickel Plating

Gold Plating

Electrolytic Nickel Plating

Silver Plating

Tin Plating

Magnesium Plating

Passivation

Chromate Conversion Coating

# ADVANCED TECHNOLOGIES FOR WASTEWATER TREATMENT

# India population

| Year | Population | Growth Rate |
|---|---|---|
| 1961 | 458 626 687 | 2.01 % |
| 1971 | 567 805 061 | 2.27 % |
| 1981 | 715 105 168 | 2.31 % |
| 1991 | 886 348 712 | 2.01 % |
| 2001 | 1 059 500 888 | 1.65 % |
| 2011 | 1 221 156 319 | 1.29 % |
| 2015 | 1 286 956 392 | 1.34 % |

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India's population is equivalent to **17.5%** of the total world population.

India ranks number **2** in the list of world population.

The **population density** in India is **386 people per Km$^2$**.

**32%** of the population is **urban** (410,404,773 people in 2014).

# Water Requirements for Different Industries for 2010, 2025 and 2050 in India

| Category of Industry | Water Requirement Per Unit of Production ($m^3$) (1997-2010) | Water Requirement $km^3$ | | |
|---|---|---|---|---|
| | | 2010 | 2025 | 2050 |
| Integrated iron & steel | 22 | 5.838 | 5.739 | 10.941 |
| Smelters | 82.5 | 0.024 | 0.031 | 0.043 |
| Petro & Refinery | 17 | 0.030 | 0.035 | 0.049 |
| Chemical Caustic soda | 5.5 | 0.010 | 0.010 | 0.012 |
| Textile & Jute | 200 | 19.018 | 36.518 | 35.192 |
| Cement | 5.5 | 1.204 | 1.382 | 1.872 |
| Fertilizer | 16.7 | 0.630 | 1.026 | 1.192 |
| Leather Products | 40 | 0.087 | 0.089 | 0.143 |
| Rubber | 6.6 | 0.004 | 0.005 | 0.006 |
| Food Processing | 11 | 5.567 | 8.043 | 8.319 |
| Inorganic chemicals | 200 | 1.6 | 3.346 | 3.007 |
| Sugar | 2.2 | 0.071 | 0.334 | 0.318 |
| Pharmaceuticals | 22 | 0.184 | 0.243 | 0.343 |
| Distillery | 22 | 0.067 | 0.098 | 0.117 |
| Pesticides | 6.5 | 0.002 | 0.004 | 0.006 |
| Paper & Pulp | 280 | 2.898 | 10.189 | 18.905 |
| General Engineering | 2.2 | 0.024 | 0.028 | 0.055 |
| | Total | 37.263 | 61.124 | 80.525 |

Estimated water pollution load per year (in tons) by industry in India.

| Industry | Estimates using Output Intensities | Ranking |
|---|---|---|
| Iron and Steel | 1639368 | 1 |
| Pulp and Paper | 86245 | 2 |
| Aluminium | 47469 | 3 |
| Fertilisers | 31480 | 4 |
| Sugar | 16747 | 5 |
| Copper | 16035 | 6 |
| Distillery | 7740 | 7 |
| Zinc | 7737 | 8 |
| Pesticides | 7366 | 9 |
| Drugs | 5889 | 10 |
| Cement | 5168 | 11 |
| Oil Refinery | 4340 | 12 |
| Petrochemicals | 1818 | 13 |
| Leather | 894 | 14 |
| Caustic Soda | 836 | 15 |
| Dyes | 521 | 16 |

## Substances Present in Industrial Effluents

| Substances | Present in Wastewaters from: |
| --- | --- |
| Acetic acid | Acetate rayon, beet root manufact. |
| Acids | Chem. manufact.,mines, textiles manufact. |
| Alkalies | Cotton and straw kiering, wool scouring |
| Ammonia | Gas and coke and chem. manufacture |
| Arsenic | Sheep dipping |
| Cadmium | Plating |
| Chromium | Plating, chrome tanning, alum anodizing |
| Citric acid | Soft drinks and citrus fruit processing |
| Copper | Copper plating, copper pickling |
| Cyanides | Gas manufacture, plating, metal cleaning |
| Fats, oils, grease | Wool scouring, laundries, textile industry |
| Fluorides | Scrubbing of flue gases, glass etching |
| Formaldehyde | Synthetic resins and penicillin manufact. |
| Free chlorine | Laundries, paper mills, textile bleaching |
| Hydrocarbons | Petrochemical and rubber factories |
| Mercaptans | Oil refining, pulp mills |
| Nickel | Plating |
| Nitrocompounds | Explosives and chemical works |
| Organic acids | Distilleries and fermentation plants |
| Phenols | Gas and coke manufact., chem. plants |
| Starch | Food processing, textile industries |
| Sugars | Dairies, breweries, sweet industry |
| Sulfides | Textile industry, tanneries, gas manufact. |
| Sulfites | Pulp processing, viscose film manufact. |
| Tannic acid | Tanning, sawmills |
| Tartaric acid | Dyeing, wine, leather, chem. manufacture |
| Zinc | Galvanizing, zinc plating, rubber process[illegible] |

# Treatment Processes and Purpose of each Process in a Treatment System

| Principal purposes of Unit Processes | Unit Processes |
|---|---|
| Grit Removal | Grit Chambers |
| Removal or grinding of coarse solids | Bar Screens |
| Odour control | Perchlorination, Ozonation |
| Gross solids-liquid suspension, BOD reduction | Plain primary settling |
| Gross removal of soluble BOD and COD from raw wastewater | Biological treatment |
| Removal of oxidized particulates and biological solids | Plain secondary settling |
| Decomposition or stabilization of organic solids, conditioning of sludge for dewatering | Anaerobic sludge digestion |
| Ultimate sludge disposal | Sludge drying beds, land disposal, land reclamation |
| Removal of colloidal solids and turbidity from wastewater | Chemical treatment, sedimentation, mixed-media filtration |
| Phosphates removal | Chemical coagulation, flocculation and settling |
| Nitrate removal | Ammonia stripping |
| Removal of suspended and colloidal materials | Mixed-media filtration |
| Disinfections | Chlorination, UV treatment |

# TYPES OF WASTEWATER TREATMENT

- Primary treatment

Screening, Sedimentation, Floatation, Oil separation, Equalisation, Neutralisation

- Secondary treatment

Activated sludge process, Extendend aeration (or total oxidation) process, Contact stabilization, Other modifications of the conventional activated sludge process: tapered aeration, step aeration and completed mix activated sludge processes

Aerated lagoons, Wastewater stabilization ponds, Trickling filters, Anaerobic treatment

- Tertiary treatment (or advanced treatment)

Microscreening , Precipitation and coagulation, Adsorption (activated carbon), Ion exchange, Reverse Osmasis, Electrodialysis, Neutrient removal processes, Chlorination and ozonation, Sonozone process.

## Classification

1. Biodegradable substances:

   Biofilter treatment/ activated sludge treatment

2. Non-biodegradable substances

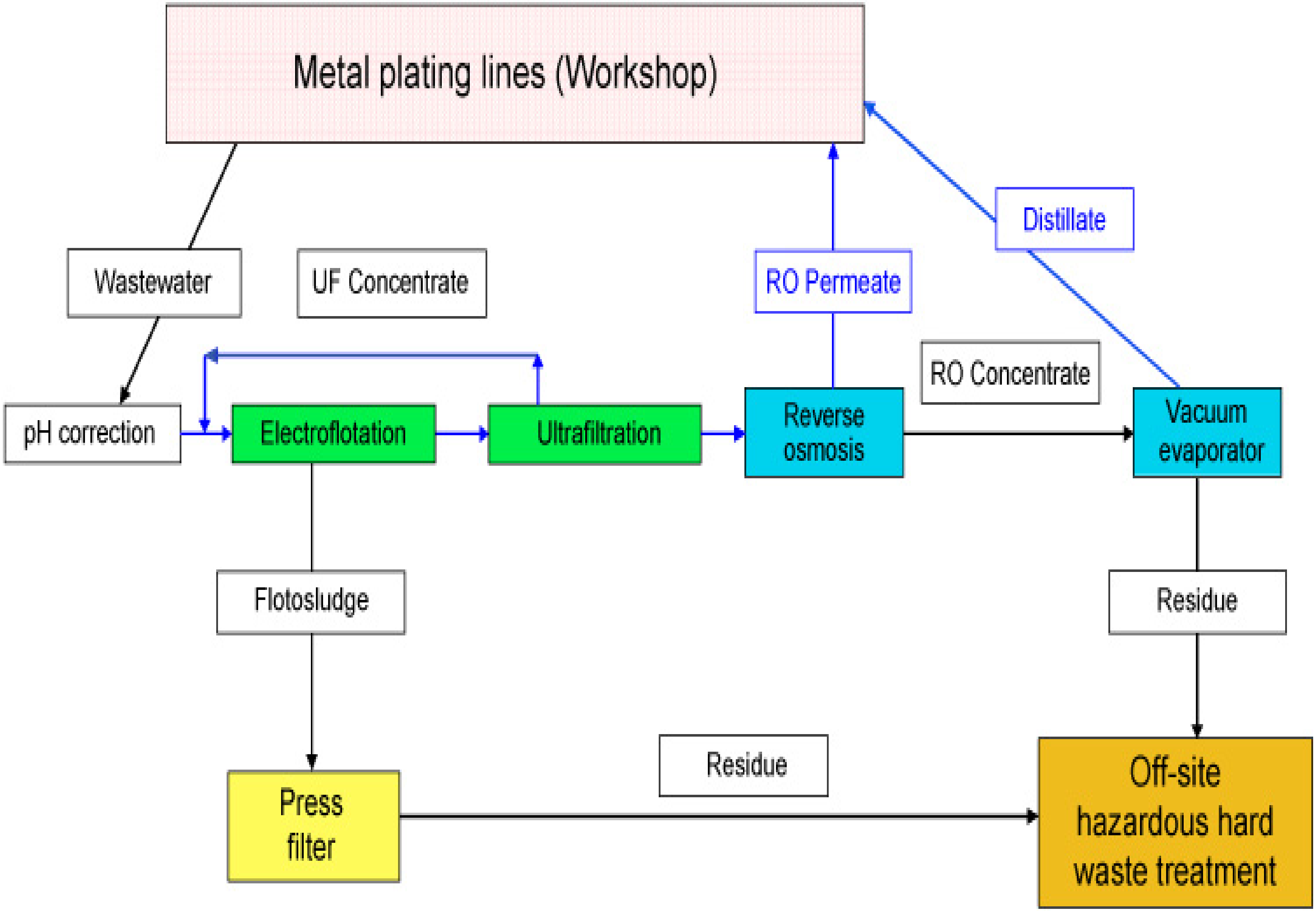
   Non-toxic / inert behaviour

   Acute toxicity

   Chronic toxicity

   Alternative treatment

- Phenols, nitrophenols and halophenols.
- Pharmaceutical -Pharmaceutical compounds (antibiotics, disinfectants...). –
- Water disinfection. – Agrochemical Agrochemical wastes (pesticides).
- Gasoline additives
- Chlorinated hydrocarbons (solvents, VOCs, etc). , etc).
- Residues from textile industry (dyes).
- Agrochemical wastes (pesticides)


Metal plating lines (Workshop)
Wastewater
UF Concentrate
RO Permeate
Distillate
RO Concentrate
pH correction
Electroflotation
Ultrafiltration
Reverse osmosis
Vacuum evaporator
Flotosludge
Residue
Residue
Press filter
Off-site hazardous hard waste treatment

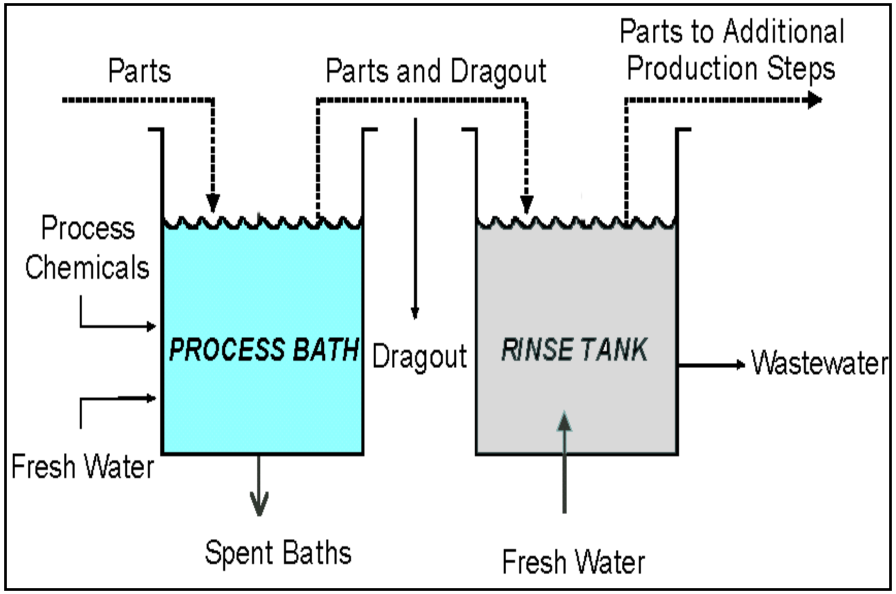
# Common Metal Finishing Wastes

- Rinse water effluent
- Spent plating baths
- Spent alkaline and acidic etchants and cleaners
- Spent strippers
- Solvent degreasers
- Waste and process bath treatment sludges
- Miscellaneous wastes (filters, empty containers, floor grates, off-spec chemicals)

* Some of these may be Persistent Bio-accumulative Toxic substances such as Cadmium, Chromium, Copper, Lead, Nickel, Zinc & Cyanide

# Dragout Impacts

- Increased **plating chemical use**
- Increased **rinse water use** or **decreased rinse quality**
- Increased **dragin into next bath**
- Increased **wastewater generation**
- Increased **WW treatment chemicals**
- Increased **WW filter cake**
- Increased **WW effluent metal concentration**



# Dragout Measurement

- Direct volume measurement (dragout volume drained from parts)
- Metal concentration/conductivity in rinse tanks
- Wastewater contaminant concentration

# Calculating Dragout

$$V_d = (\Delta C)(V_r)/C_p$$

where:

$V_d$ = dragout volume (L/rack)

$\Delta C$ = increase in rinse water metal concentration per rack or barrel (mg/L/rack)

$V_r$ = rinse tank volume (L)

$C_p$ = process bath metal concentration (mg/L)

# Dragout Reduction:

- Tank spacing and drain boards
- Tank sequence
- Dragout tanks (with or without sprays)
- Spray rinses

# Benefits of Reducing Rinse Water

- Lower water bills and sewer fees
- Wastewater treatment impacts
  - Lower treatment chemical costs
  - Higher retention time
  - Less O&M requirements
- Decreased sludge generation

# Techniques that Improve Rinse Efficiency

- Agitation
  - Rack motion
  - Forced air and/or forced water
  - Sprays
  - Double dipping

- Flow Controls and Water Quality
  - Flow restrictors
  - Conductivity control systems
  - Tap water vs. deionized water

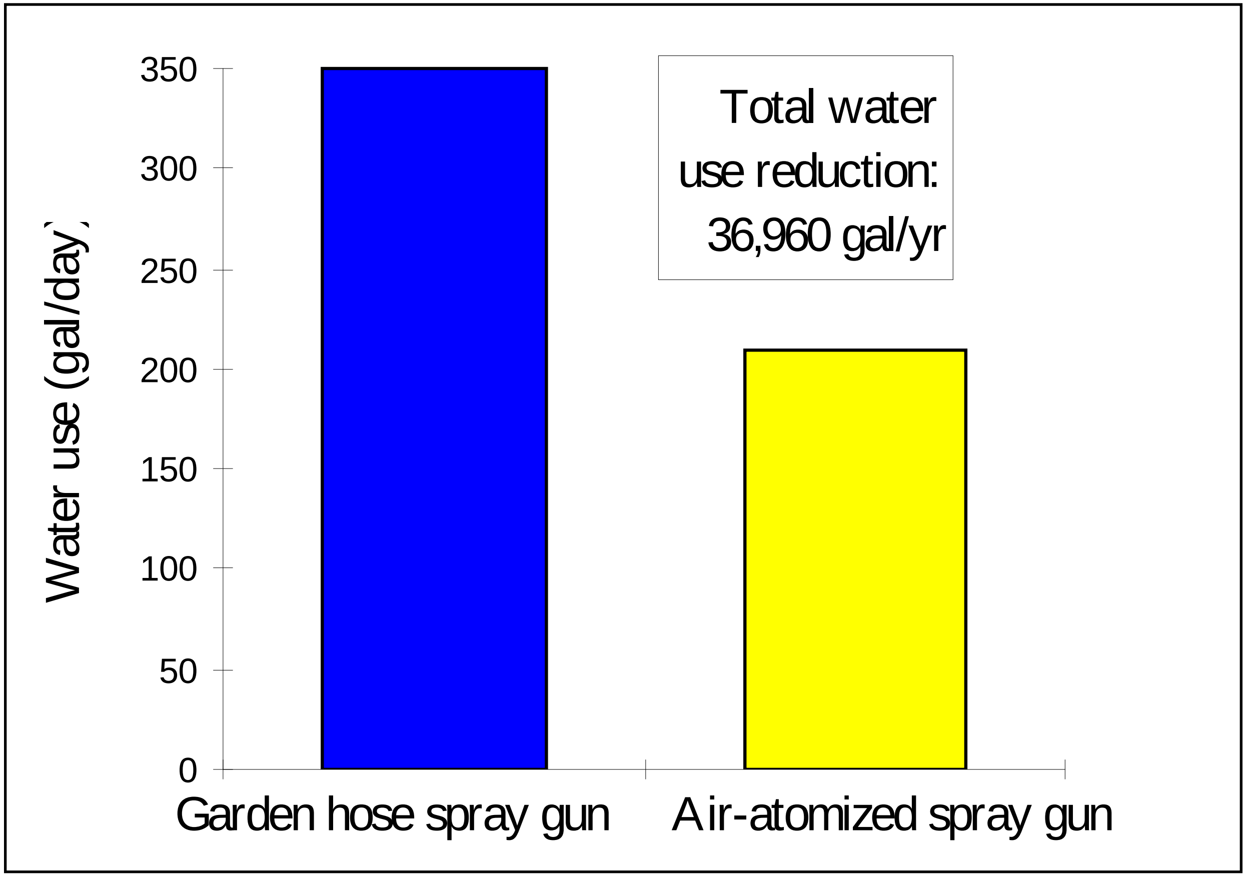
# Techniques that Improve Rinse Efficiency

- Tank Design
  - Size (not bigger than necessary)
  - Eliminate short-circuiting
- Tank Layout
  - Multiple tanks
  - Countercurrent rinses are extremely efficient
    - 90% reduction compared to a single rinse
    - Most old shops can not accommodate the larger "footprint"

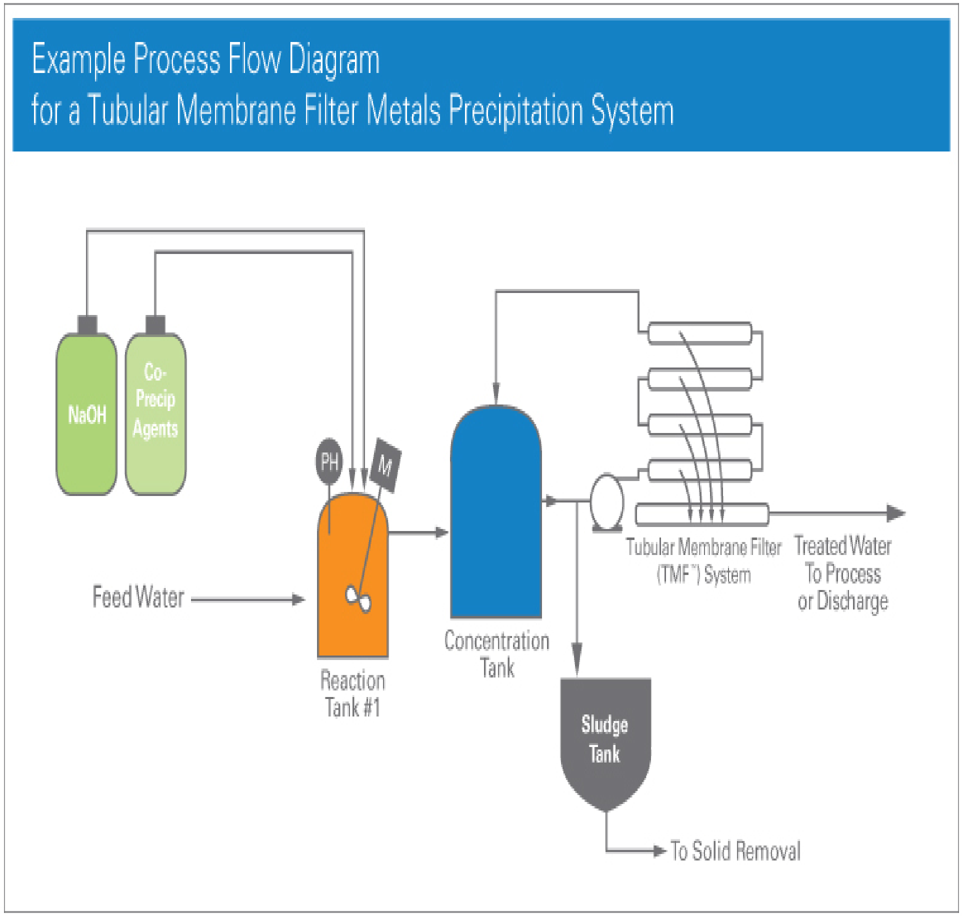
# Opportunities at Metal Finishing Facilities

- **Rinse Tank Optimization & Spray Rinsing**
  - are any measures in place to extend the life of the rinse baths, skimmers, agitation, sludge removal, water treatment?
  - are spray rinses utilized, if so, where are they located, how are they operated and why?
  - are rinse tanks utilizing counter current flow, are there flow restrictors or controls?
  - is the quality of the rinse water monitored or measured?
  - has the facility experimented with different rinse configurations, flows, or sprays?

# Air-Atomized Spray Guns



# Porex Tubular Membrane Filters




## Typical Metal Finishing and PCB Applications and Results

| Contaminant | Influent (mg/L) | Membrane Filtrate (mg/L) |
|---|---|---|
| Cadmium - Cd | 10 - 30 | < 0.05 |
| Chrome - Cr | 10 - 50 | < 0.1 |
| Copper - Cu | 20 - 130 | < 0.1 |
| Iron - Fe | 5 - 100 | < 0.1 |
| Lead - Pb | 1 - 15 | < 0.1 |
| Nickel - Ni | 5 - 75 | < 0.1 |
| Zinc - Zn | 5 - 130 | < 0.1 |
| Fluoride – Fl | 10-500 | <5.0 |
| Solids - TSS | 10 - 500 | < 1.0 |

Advanced Oxidation Processes are a source of hydroxyl radicals (•OH).

Near ambient temperature and pressure water treatment processes which involve the generation of hydroxyl radicals in sufficient quantity to effective water purification

decontamination of water containing organic pollutants, classified as bio-recalcitrant, and/or for Disinfection current and emerging pathogens.

Futuristic direct re-use systems involve only two steps:

1. Single-stage MBR with an immersed nanofiltration membrane,
2. Photocatalytic reactor to provide an absolute barrier to pathogens and to destroy organic contaminants that may pass the nanofiltration barrier.

Nevertheless, technical applications are still scarce. Process costs may be considered the main obstacle to their commercial application

# PROMISING COST-CUTTING APPROACHES

Integration of AOPs as part of a treatment train

To minimize reaction time (i.e. energy) and reagent consumption in the more expensive AOP stage by applying an optimized treatment strategy

The use of renewable energy sources, i.e., sunlight as the irradiation source for running the AOP.

## CECRI’s Activity on pollution control

- Electrochemical treatment of textile dye effluents (removal of colour and COD of waste dye bath and wash water)
- Design and fabrication of an electrochemical reactor for effluent treatment
- Electrochemical treatment of phenolic effluents
- Electrochemical treatment of tannery effluents (foul smell colour , COD, BOD from finishing unit)
- Electrochemical treatment of solid sludge
- Electrochemical scrubbing of SO2 in the flue gases
- Electrochemical treatment of effluent from paper and pulp industry (agro based) for removal of COD and colour
- Recycle of hexavalent chromium by electrochemical ion exchange
- Removal TDS by electrodialysis / electrochemical deionization
- Removal of arsenic by electro-coagulation and by EIX

## Conclusion

To lead to industry application it will be critical that the AOPs can be developed up to a stage, where the process:

- is cost efficient compared to other processes.
- is robust, i.e. small to moderate changes to the wastewater stream
- is predictable, i.e. process design and up scaling can be done reliably.
- is easy to implement, i.e. suppliers and engineering companies can start marketing the process without huge initial investment costs, which could only be recovered by high turnovers. is easy to operate and maintain, operation error must not lead to “catastrophic events”
- is safe regarding the environment (minimize risks of leakage, discharge of not sufficiently treated effluent).
- gives additional benefit to the industry applying the process (e.g. giving the company the image of being “green”.

***For more information….***

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