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Project Summary

Field Manual—Performance Evaluation and Troubleshooting at Metal-Finishing Wastewater Treatment Facilities

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The main purpose of this technical field manual is to provide a troubleshooting reference document for identifying, analyzing, and solving problems encountered during the operation of waste treatment equipment in metal-finishing facilities. It is also meant to assist owners and operators in improving the performance and efficiency of treating metal-finishing process wastes from these facilities. The manual describes general procedures for evaluating treatment processes and equipment commonly used in this industry, as well as other items related to the effective operation of treatment facilities.

The methodology used to evaluate compliance problems and to develop operation and maintenance (O&M) specifics is described in a review of the literature, followed by an assessment of the causes of permit violations and the recommended measures for improving compliance.

The unit processes described in this manual are those generally used in treating metal-finishing wastes. These procedures are: equalization, oil removal, cyanide oxidation, chromium reduction, pH control, metal precipitation, flocculation, sedimentation, filtration, gravity thickening, belt filter presses, vacuum filtration, pressure filtration for dewatering, and centrifugation. For each of these unit processes, the manual contains information on theory of operation, description of equipment, operational procedures, typical performance values, and a troubleshooting guide.

This Project Summary was developed by EPA's Industrial Environmental Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

Plant personnel responsible for waste treatment processes and for achieving permit compliance must be knowledgeable, not only about the problem area, but also about the electroplating and related metal-finishing concepts, and in-plant process modifications and changes as they relate to the waste treatment processes. Troubleshooting guides, operating strategies, and process monitoring material are discussed in detail for each unit process commonly used in metal-finishing waste treatment.

It is assumed that the manual user has a general understanding of treatment facilities and their operation. The style, language, and format are directed to the level and technical knowledge of a technician having some experience with in-plant operation, design, inspection, and performance evaluation.

Procedure

A literature review was conducted utilizing technical publications, government reports and documents, and a

computerized literature search. The literature search also included equipment manufacturers' information, data provided by professional organizations, and communications with personnel who were familiar with the treatment and disposal of metal-finishing wastes. The objectives of the literature review were to collect data that would aid in identifying the major causes of permit violations, and to collect information that could be used to develop O&M specifics on the treatment and disposal of metal-finishing wastes. Furthermore, by qualifying these data and information, methods and techniques for improving compliance of facilities could be developed.

Analysis of Permit Violations

Permit violations were analyzed to understand the problems associated with treatment of metal finishing wastes. The troubleshooting manual was then prepared to address the problems. An analysis of permit violations was performed utilizing the Quarterly Noncompliance Report published by the Office of Water of the U. S. Environmental Protection Agency (EPA). The report listed the major industries and parameters that were out of compliance. The violations in the Noncompliance Report were listed by SIC code. The SIC numbers used for identifying industries with metal wastes were 3471 (electroplating), 3631, 3632, 3633, 3639, 3714, 3721, and 3731.

The report cited 34 industries that were out of compliance from the third quarter of 1979 to the second quarter 1982. The 10 parameters that were most frequently out of compliance between 1979 and 1982 are listed below:

Parameter	Number of Permit Violation Occurrences
Nickel	17
Cyanide	16
Chromium	15
pH	12
Copper	11
Phenol	8
TSS	7
Cadmium	6
Zinc	6
Lead	4

This field manual addresses all the parameters listed except phenol. Treatment for removal of phenol was not included because it is not specifically regulated in the effluent guidelines for the electroplating industry. Treatment practices for control of the other nine parameters, as well as oil and grease, are included in the manual.

Operation and Maintenance Specifics

O&M specifics for the treatment of metal-finishing wastes were obtained from a search of technical publications, a computerized literature search, and contacts with equipment manufacturers and operators. The information collected from these sources was then interpreted, compiled, and developed into this field manual.

Computerized Literature Search

A computerized literature search was performed using DIALOG information Service* of Lockheed Corporation. The computerized literature review was conducted in three steps. The first step was to locate the abstracts from the various data base files. The second step was to search the abstracts for the appropriate publications and documents. The final step was to review the publications.

The first step was selecting the keywords or series of keywords used to describe O&M specifics for metal-finishing waste treatment. A series of keywords *coupled* by the words "and" or "or" is often used to select the desired abstract. A question mark in a keyword indicates that the identity of a letter is unknown and the computer is to identify all references including the letters that precede the question mark. For example, the keyword "chrom?" will cause the computer to search records labeled chrome, chromium, chromate, etc. The series of keywords selected are listed below.

1. NPDES or Permit and (Violation or Exceed) and Metal.
2. Wastewater and Operation? and Maintenance.
3. Operation and Maintenance and Metal?
4. Metal? and Precipitate? and Wastewater?
5. Cyanide? and (Oxidation or Removal or Treatment) and Wastewater.
6. Chrom? and (Reduction or Removal or Treatment) and Wastewater.

*Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

The keywords were then used t search the 37 data files in Lockheed' DIALINDEX. The search of the data files revealed the number of abstracts that contained the keywords. The information was used to ensure that the keyword series was restrictive enough without being overly restrictive. The two files that contained the most abstracts applicable to this project were the Metals Index (File 32) and the Pollution Abstracts Index (File 41). The Metals Index contained 99 abstracts that could be identified by the six series of keywords described above. The Pollution Abstracts contained 445 abstracts.

The second step was reviewing the abstracts identified by the keywords for both the metals data file and the pollution data file. These abstracts were reviewed to see which publications were most applicable to the project.

The final step was reviewing and evaluating the article chosen from the abstract search and incorporating this information into the O&M manual. Much of the information was used to review current treatment practices and to develop O&M specifics for the troubleshooting manual. These articles were only referenced when they contained specific information such as surface loading rates or mixing horsepower.

Technical Publications

The review of literature included technical publications that were not included in the computerized data base or those publications that were more easily obtained by a manual literature search. The former category contained articles that were published generally before 1970 and contained many reference books. The search of articles before 1970 was performed by reviewing annual indexes from publications such as *Proceedings of the Purdue University Industrial Waste Conference, Journal Water Pollution Control Federation,* and *Water and Waste Engineering.*

Sources from which information and data on metal-finishing waste treatment could be easily obtained were the EPA, the Water Pollution Control Federation (WPCF), the American Electroplating Society (AES), and reference books. More than 40 EPA publications relating to metal-finishing wastes were reviewed. A series of seven EPA Technology Transfer documents provided much general information about metal-finishing waste treatment. Twelve AES project reports were also reviewed.

Numerous reference books on treatment of metal wastes were also identified and reviewed. This review included books written for treatment of metal-finishing wastes, and materials that described pH control, sedimentation, and sludge dewatering.

Equipment Manufacturers

Several manufacturers of equipment for metal-finishing wastes were contacted. Information obtained from manufacturers' representatives was used to characterize and describe the different types of equipment, to develop O&M specifics, and to obtain performance data. This information on field O&M was referenced when used.

Results and Discussion

Conventional Wastewater Treatment

Conventional wastewater treatment in the electroplating industry consists of the following unit processes (see Figure 1):

- Chromium reduction (if needed) of segregated chromium waste streams to reduce the chromium from its hexavalent form to the trivalent state, which then can be precipitated as chromium hydroxide by alkali neutralization,
- cyanide oxidation (if needed) of segregated cyanide-bearing waste streams to oxidize the toxic cyanides to harmless carbon and nitrogen compounds,
- neutralization of the combined metal-bearing wastewaters, acid/alkali wastewaters, strong chemical dumps, and the effluent from the cyanide and chromium treatment systems to adjust the pH within acceptable discharge limits and to precipitate the dissolved heavy metals as metal hydroxides,
- clarification, in which flocculating/coagulating chemicals are added to promote the initial settling of the precipitated metal hydroxides, and
- gravity thickening over extended time to increase solids content of sludge before disposal.

These unit processes provide effective, reliable treatment for many electroplating waste streams. This is not to say, however, that such treatment is suitable for all applications or that the "normal" design parameters (retention time, reagent dosage, and so forth) will provide effective pollutant removal from every individual plater's wastewater discharge.

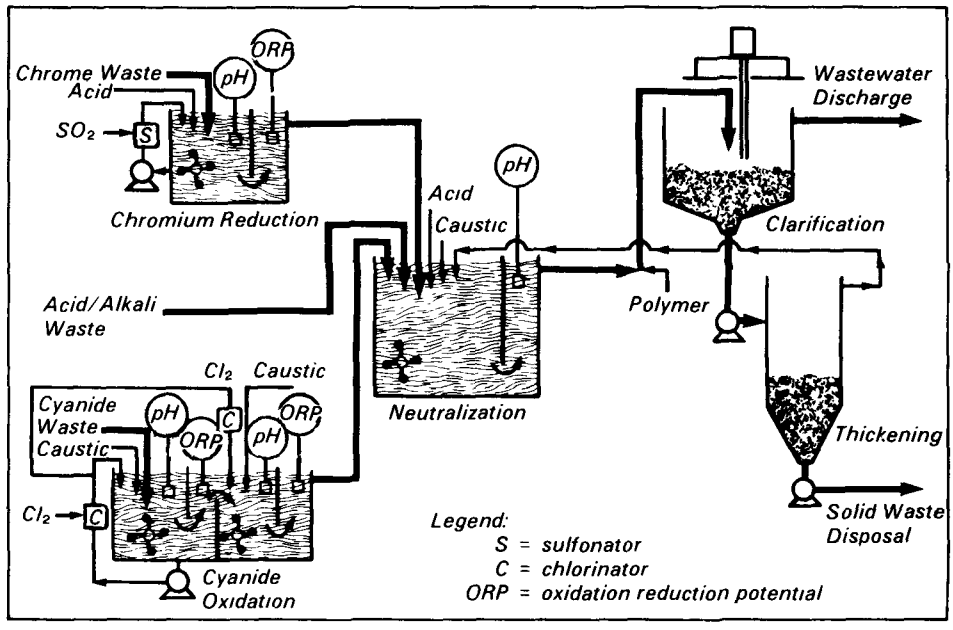

Figure 1. Electroplating industry conventional wastewater treatment.

Many of the items covered in this manual have their basis in a conventional wastewater treatment system such as the one described above.

Problem Assessment

A plant assessment is the initial step in a pollution control program and it involves a thorough analysis of the operations of a metal-finishing plant that relate to pollutant sources and water use. The information is used in evaluating the application of in-plant changes for reducing chemical loss and water use. A plant assessment includes the following steps: (1) inspect plating room layout, (2) review plant operation practices, (3) examine process water use, (4) perform sampling and laboratory analysis to characterize waste streams and to determine dragout rates, and (5) identify the frequency, volume, and characteristics of batch dumps.

Laboratory analyses of wastewater samples are performed using standard EPA-approved techniques. Throughout the manual, various analytical parameters and their concentrations are discussed. For all tests the analytical methodology presented in the EPA document, "Methods for Chemical Analysis of Water and Wastes" or "Standard Methods for the Examination of Water and Wastewater" should be followed.

The successful O&M of a waste treatment plant requires consistent performance that exceeds regulatory compliance levels. Failure to meet these compliance levels can result in costly disposal alternatives, fines, damage to the environment, and adverse public reaction. If a treatment facility fails to meet compliance standards, the problem usually can be attributed to one of the following causes:

1. shock loadings (hydraulic or contaminants) to the waste treatment plant,
2. poor understanding of O&M procedures,
3. poor process control,
4. equipment failure, and
5. treatment plant design inadequacies.

The potential effect of good O&M on each of the five categories of noncompliance reasons is discussed below. If a plant is out of compliance, it should be determined which categories of causes are applicable and appropriate action should be taken to see if improved O&M procedures could affect performance.

Shock Loadings

Frequently, noncompliance can result when shock loadings of flow or contaminants cause treatment process upsets. Sources of these shock loadings can be either spills or releases from production batch operations or cleaning opera-

tions. Their impact on the treatment process can be mitigated by installing sufficient equalization. Often their effect can also be controlled by changes in operating procedures in the production facility or in the treatment plant. Of foremost importance is communication between production and waste-treatment personnel. If waste treatment personnel are notified of potential shock loads in sufficient time, mitigating action often can be taken, such as diverting the shock load to sidestream equalization to temporarily bypass sensitive processes or to manually modify process operating parameters to adjust for the shock loading.

Modifying spill control and operating procedures for batch processes and cleaning operations can reduce the magnitude of shock loadings in several ways: wastes from batch or cleaning operations can be released slowly during times of low flow; spills can be cleaned up using dry chemicals, rather than down the drain; and chemical handling procedures can be modified to reduce the likelihood of spills and chemicals can be stored in diked areas to contain spills that do occur.

In all cases, implementation of the above procedures requires training of all personnel in proper operating procedures to control or mitigate shock loadings. Part of this training must include making production personnel aware that their procedures affect waste treatment. This factor is becoming increasingly important as some facilities have had to curtail production in order to achieve discharge compliance levels. This action may be diverting flow to sidestream equalization, bypassing an oil water separator while a non-oily hydraulic shock load is occurring, notifying production to stop or slow an excessive discharge, or other appropriate procedures.

Poor Understanding of O&M Procedures

Understanding O&M procedures is essential to successfully operate a metal-finishing wastes treatment facility. An operator who is well versed in the proper O&M procedures can usually operate the treatment facility to meet permit compliance, even though one or more of the above causes of permit violation exists at the treatment facility. This manual was developed to assist operators in implementing the proper O&M procedures at the treatment facility. While no manual can be general enough for all plants and yet specific enough for one plant, the intention of this manual is to aid in understanding the cause/effect relationship for several treatment processes. Once an operator has developed a cause/effect relationship for the control variables at the treatment facility, specific adjustments and/or set-points can be established. A successful O&M program enables understanding the cause of the problem and what effect it will have on compliance, and then adjusting the control variables so as to mitigate the problem.

Poor Process Control

One of the most common causes of continuous poor performance and frequent noncompliance is poor process control, which results in the treatment plant not achieving its full capacity and efficiency. When the full or design efficiency is not achieved, the blame is put frequently on poor design, but it must be remembered that the design is based upon the assumption of good process control, which may or may not be occurring. Process control can only be achieved by well-trained operators who understand their equipment and the purpose of all operating variables under their control. This includes understanding the interaction between operating variables and the trade-offs often involved. As an example, increasing the belt tension in a belt filter press can result in a drier cake, more solids in the filtrate, and a shorter belt life. However, the solids in the filtrate might adversely affect the performance of other treatment processes, such as an oil coalescer.

Process control through good operations is particularly important in the metal-finishing industry where several waste treatment processes require critical control of operating variables to achieve good treatment peformance. Examples include pH control for metal precipitation and pH and oxidation-reduction potential (ORP) control for chromium reduction and cyanide oxidation. A relatively slight change in these operating variables can result in significant degradation in performance, noncompliance, and in the case of cyanide reduction, the potential for release of toxic gases.

Equipment Failure

Equipment failure can readily cause a treatment plant to fail to meet regulatory compliance levels. The effect of the equipment failure can be minimal when repairs are implemented quickly or the effect may be major, since parts and repairs may take days to obtain and install. Therefore, it is essential to minimize equipment failure and downtime. Minimizing downtime can be achieved partially by a sufficient parts inventory and overdesign; it also requires proper O&M of existing treatment plant equipment. Mechanical equipment has a set of design operating conditions, and anytime these conditions are exceeded, premature equipment failure can occur. Treatment plant personnel should be aware of these design conditions and integrate them with plant operating procedures to ensure that mechanical equipment is not unduly stressed. It should be noted that this stress does not always come from mechanical forces. Improper pH levels can corrode equipment and excessively high temperatures can cause construction materials to fail. Once equipment failure has occurred, prompt repair of equipment by well-trained maintenance personnel is essential to minimize the effect and prevent recurrence. A regular and orderly inspection of equipment for wear or other early signs of trouble, such as vibration, can also prevent premature equipment failure.

Treatment Plant Design Inadequacies

No amount of proper O&M can make an incorrect or improperly designed treatment plant achieve consistent compliance with regulatory standards; conversely, inadequate O&M practices can render even the best designed treatment plant incompliant. Before any major design modifications are implemented, the potential for treatment plant performance improvement through improved O&M should be investigated thoroughly.

Conclusions

This manual details performance evaluation of wastewater treatment facilities for metal-finishing wastes. Troubleshooting guides on unit process operations are included to help pinpoint causes of treatment malfunctions.

It is concluded that operators and owners of metal-finishing plants can use this manual to help bring their wastewater treatment facilities into compliance. This can be accomplished best by a joint effort on the part of management and the operators.

Monitoring of treatment parameters is the key factor in determining performance of facilities and an early warning for non-compliance trends.

Recommendations

Improving Permit Compliance

The level of pollutants discharged to publicly owned treatment works by plants following pretreatment must meet new regulations. The electroplating and metal-finishing point source categories is regulated by the EPA (*Federal Register,* 48(137), 32462-32488J July 15, 1983).

Improving the level of permit compliance for treatment of metal-finishing wastes is a two-step process. The first step is to identify the problem and the second step is to take the necessary corrective actions. Permit compliance problems are generally in the following four categories: 1) design, 2) operation, 3) administration, and 4) maintenance.

The importance of proper design cannot be overstated. Each unit process along with the integrated waste treatment system must be designed with numerous factors accounted for. An improperly designed plan seldom operates well. Design improvement to enhance permit compliance is a long-term process; near-term improvements are seldom attainable through design changes.

Performance of a well-designed system may be affected by improper operating procedures. Thus, an operator's familiarity with correct O&M procedure can directly improve operation of a system. It is the goal of this publication to provide adequate O&M procedures and troubleshooting guides to produce improved levels of permit compliance in metal-finishing waste treatment plants.

Administration affects permit compliance, although often in an indirect manner. Such items as staff supervision, motivation, funding, and planning affect the operation of a facility, which, in turn, affects all aspects of the treatment plant.

Finally, maintenance affects permit compliance directly. In numerous instances throughout the descriptions that follow, routine inspection and maintenance are cited as the chief deterrents to operating problems, and hence to permit violations. A competent, well-trained maintenance group is indispensable in the smooth and successful operation of a treatment plant.

Although the tendency is to categorize permit compliance problems as belonging strictly to one of the four areas discussed above, the fact is that most problems have aspects of two or more areas. Plants owners and operators that hope to improve permit compliance must strive to achieve improvement in all four categories.

Resource Recovery Recommendations

Pollution control legislation has affected industry by increasing the economic penalty associated with inefficient use of resources. In the plating industry, for example, loss of a raw material in the wastewater can result in three distinct cost items: replacement of the material, removal of the material from the wastewater before discharge, and disposal of the residue. Similar cost items exist for process water: replacement of water (no longer inexpensive to purchase) used in processing, processing the water in the wastewater treatment system, and processing the water by the treatment plant after discharge into a public sewer system.

In response to the increased cost of raw material losses, plating shop processes are being modified to reduce these losses as well as water consumption. Recent years also have seen the cost-effective application of various separation processes that reclaim plating chemicals from rinse waters, enabling both the raw material and the water to be reused.

The impact of resource recovery and pollutant load reduction modifications on waste treatment and solid waste disposal costs must be measured, if these modifications are to be evaluated. Cost of sophisticated treatment necessary for electroplating wastewater and of residue disposal often provides a significant economic incentive for resource recovery.

Reduced Loading Recommendations

Modifications that will reduce the pollutants or wastewater loadings on a treatment facility range from using flow restrictors to eliminate excess dilution in rinse tanks to installing recovery units, such as reverse osmosis and evaporation, to separating plating chemicals from rinse water for recycle to the plating bath. Actions that can minimize wastewater volume include the following:

- implementing rigorous housekeeping practices to locate and repair water leaks quickly,
- employing multiple counterflow rinse tanks to reduce rinse water use substantially,
- employing spray rinses to minimize rinse water use,
- using conductivity cells to avoid excess dilution in the rinse tanks,
- installing flow regulators to minimize water use, and
- reusing contaminated rinse water and treated wastewater where feasible.

Steps to minimize pollutant loadings include:

- implementing a rigorous housekeeping program to locate and repair leaks around process baths, replacing faulty insulation or plating racks to prevent excessive solution drag-out, installing drip trays where needed, etc.
- using spray rinses or air knives to minimize solution drag-out from plating baths,
- recycling rinse waters to plating bath to compensate for surface evaporation losses,
- using spent process solutions as wastewater treatment reagents (acid and alkaline cleaning baths are obvious examples),
- using minimum process bath chemical concentrations,
- installing recovery processes to reclaim plating chemicals from rinse waters for recycle to the plating bath, and
- using process bath purification to control the level of impurities and prolong the bath's service life.

Closed-loop chemical recovery from a rinse stream can often provide the solution to treat. Applying a closed-loop recovery system to a plating operation eliminates the need to treat the rinse water normally associated with that step.

In the case of rinse streams requiring pretreatment (for example, cyanide or chromium) or rinses containing pollutants not effectively removed by conventional end-of-pipe technology (for example, some types of complexed metals), installing a closed-loop system to recycle the rinse may reduce the investment needed to comply with the effluent quality limitations.

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The complete report, entitled "Field Manual—Performance Evaluation and Troubleshooting at Metal-Finishing Wastewater Treatment Facilities," (Order No. PB 85-107 274; Cost: $23.50, subject to change) will be available only from:
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