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Environmental Protection
Agency

The 2014 Annual Effluent Guidelines Review Report

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TABLE OF CONTENTS

Page

TABLE OF CONTENTS (Continued)

Page

LIST OF TABLES

Page

LIST OF TABLES (Continued)

Page

LIST OF FIGURES

Page

PART I: INTRODUCTION

1. 2014 Annual Review Executive Summary

Effluent limitations guidelines and standards (ELGs) are an essential element of the nation's clean water program, which was established by the 1972 Clean Water Act (CWA). ELGs are technology-based regulations used to control industrial wastewater discharges. EPA issues ELGs for new and existing point source categories that discharge directly to surface waters, as well as those that discharge indirectly to publicly-owned treatment works (POTWs). These ELGs are applied in discharge permits as limits to the pollutants that facilities may discharge. To date, EPA has established ELGs to regulate wastewater discharges from 58 point source categories. This regulatory program substantially reduces industrial wastewater pollution and continues to be a critical aspect of the effort to clean the nation's waters.

In addition to developing new ELGs, the CWA requires EPA to revise existing ELGs when appropriate. Over the years, EPA has revised ELGs in response to developments such as advances in treatment technology and changes in industry processes. To continue its efforts to reduce industrial wastewater pollution and fulfill CWA requirements, EPA conducts an annual review and effluent guidelines planning process. The annual review and planning process has three main objectives: (1) to review existing ELGs to identify candidates for revision, (2) to identify new categories of direct dischargers for possible development of effluent guidelines, and (3) to identify new categories of indirect dischargers for possible development of pretreatment standards. To achieve these objectives, EPA conducts a two-phase review. First, EPA screens industrial discharges based on the relative hazard they pose to human health and the environment. Then, for those categories identified as a hazard priority, EPA conducts a more detailed evaluation to determine if the category is a candidate for new or revised ELGs.

Beginning with the 2012 Annual Review, EPA began augmenting the methods and data sources it uses to identify industrial categories for which new or revised ELGs may be developed. This new approach combines the traditional toxicity rankings analysis (TRA) and the analyses of new hazard data sources not included in the TRA, coupled with an expanded review of new or improved treatment technologies. EPA performs these review efforts in alternate years—completing the TRA in odd years and the analyses of additional industrial hazard data sources and new treatment technologies in even years. The aim of the even-year review is to expand EPA's ability to identify new pollutants of concern and to identify wastewater discharges in industrial categories not currently regulated by ELGs. This review also enables EPA to screen industrial wastewater discharges based on a broader set of hazard data and to account for advances in treatment technologies much earlier in the review process. Both of these factors are keys to improving the effectiveness of the Effluent Guidelines Program. EPA has already completed its odd-year review for 2013 using the TRA and published the results in the *Preliminary 2014 Effluent Guidelines Program Plan* (Preliminary 2014 Plan) (79 FR 55472).[1]

For the 2014 Annual Review, EPA followed up on several proposed actions identified in the Preliminary 2014 Plan (79 FR 55472). Specifically, EPA continued the following reviews: (1) preliminary review of the Metal Finishing Point Source Category; (2) targeted review of

[1] The Preliminary 2014 Plan is combined with the Final 2012 Plan in the document *Final 2012 and Preliminary 2014 Effluent Guidelines Program Plans*. The Plans discuss the findings of both the 2012 and 2013 Annual Reviews (79 FR 55472).

pesticide active ingredients (PAIs) for which the discharge from manufacturing is not currently regulated under the Pesticide Chemicals ELGs; and (3) review of the use of wet air pollution controls within the brick and structural clay products manufacturing industry. EPA also initiated an investigation of the manufacture and processing of engineered nanomaterials (ENMs) as a potential new source of industrial wastewater discharge; continued its review of industrial wastewater treatment technology data for the Industrial Wastewater Treatment Technology (IWTT) Database; and reviewed public comments submitted on the Preliminary 2014 Plan. For more information on the 2014 Annual Review analyses, see the bullets below.

- *Continued Review of the Metal Finishing Category (40 CFR Part 433).* As a follow up to the findings in its 2012 and 2013 Annual Reviews, and in response to some public comments on the *Preliminary 2012 Effluent Guidelines Program Plan*, EPA continued its preliminary review of the Metal Finishing Category in the 2014 Annual Review. Specifically, EPA reviewed the scope of the existing ELGs, examined the current industry profile, and gathered data on wastewater treatment technologies. EPA also contacted regional EPA pretreatment coordinators to further discuss metal finishing operations and potential applicability issues associated with the Metal Finishing ELGs.

- *Targeted Review of Pesticide Active Ingredients (PAIs) Without Pesticide Chemical Manufacturing Effluent Limits (40 CFR Part 455).* As part of the 2012 Annual Review, EPA reviewed analytical methods that it recently developed or revised to facilitate its identification of unregulated pollutants in industrial wastewater discharge. By examining these methods, EPA identified 30 PAIs that are now measured by existing analytical methods under 40 CFR Part 136, but that do not currently have pesticide chemicals manufacturing effluent limits under Subparts A and B in the Pesticide Chemicals ELGs (40 CFR Part 455) (U.S. EPA, 2014). For the 2014 Annual Review, EPA began evaluating data sources that would provide information on the production of the 30 PAIs of interest to identify and prioritize for further review any that are manufactured in the U.S. These sources included pesticide registration status under Section 3 of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) and production information reported under Section 7 of FIFRA.

- *Continued Review of Brick and Structural Clay Products Manufacturing.* As part of EPA's 2012 Annual Review, EPA identified brick and structural clay products manufacturing as an industry not currently regulated by ELGs that may have industrial wastewater discharges resulting from federal air pollution control requirements. For its 2014 Annual Review, EPA reviewed the current National Emission Standards for Hazardous Air Pollutants (NESHAP) for the industry, and contacted EPA's Office of Air and Radiation and the Brick Industry Association to learn more about the NESHAP and the potential impacts on the industry, specifically regarding the installation of wet air pollution controls.

- *Review of Engineered Nanomaterials (ENMs) in Industrial Wastewater.* EPA began evaluating ENMs as a potential emerging industrial wastewater pollutant category of concern as part of the 2014 Annual Review. EPA reviewed current literature and communicated with leading researchers and government stakeholders about the fate, transport, and effects of ENMs on the environment and human health, and about the presence and discharge of ENMs in industrial wastewater.

- *Review of Industrial Wastewater Treatment Technologies.* EPA continued reviewing technical papers and research articles regarding the performance of new and improved industrial wastewater treatment technologies and began populating the performance data and treatment information into a searchable IWTT Database. As part of the 2014 Annual Review, EPA described its industrial wastewater treatment technology data collection methodology, data quality assurance and control, and database design, development, and storage. EPA also summarized the industrial wastewater treatment technology information collected to date.

Based on the data and analyses conducted for the 2014 Annual Reviews, and public comment and stakeholder input, EPA identified several outstanding data gaps and topics that warrant further investigation. These include:

- New metal finishing processes, pollutants of concern, and advances in wastewater treatment technologies (see Section 5.1);
- The production of PAIs of interest that do not have pesticide chemicals manufacturing limits under Subparts A and B of the Pesticides Chemicals ELGs, particularly for those PAIs that are not currently registered under FIFRA, but that may be produced in the U.S. for export only (see Section 5.2); and
- ENMs, particularly silver, titanium dioxide, and carbon-based nanomaterials, as new potential pollutants of concern in industrial wastewater discharge (see Section 6.1).

From the 2014 Annual Review, EPA determined that one industry, brick and structural clay products manufacturing, is not generating a potential new source of industrial wastewater discharge that warrants regulation at this time (see Section 5.3).

As part of the 2014 Annual Review, EPA also compiled and presented the information collected to date in the IWTT Database from 163 articles, 98 of which provide both treatment system information and performance data. The treatment system performance data cover 142 pollutant parameters and 35 different industries (see Section 6.2).

This report details EPA's methodology for its 2014 Annual Review and supports EPA Office of Water's *Final 2014 Effluent Guidelines Program Plan* (U.S. EPA, 2015). The Plan, pursuant to Section 304(m) of the Clean Water Act (CWA),[2] discusses the findings of the 2014 Annual Review and details EPA's proposed actions and follow-up. The Plan also identifies any

[2] Available at: http://water.epa.gov/lawsregs/lawsguidance/cwa/304m/.

new or existing industrial categories selected for effluent guidelines rulemaking and provides a schedule for such rulemaking.

1.1 References for 2014 Annual Review Executive Summary

1. U.S. EPA. 2014. *The 2012 Annual Effluent Guidelines Review Report*. Washington, D.C. (September). EPA-821-R-14-004. EPA-HQ-OW-2010-0824-0320.

2. U.S. EPA, 2015. *Final 2014 Effluent Guidelines Program Plan*. Washington, D.C. (July). EPA-821-R-15-002. EPA-HQ-OW-2014-0170. DCN 08107.

2. BACKGROUND

This section explains how the Effluent Guidelines Program fits into EPA's National Water Program, describes the general and legal background of the Effluent Guidelines Program, and summarizes EPA's process for making effluent guidelines revision and development decisions (i.e., effluent guidelines planning), including details of its annual review process.

2.1 The Clean Water Act and the Effluent Guidelines Program

The Clean Water Act (CWA) is based on the principle of cooperative federalism, with distinct roles for both EPA and the states, in which the goal is to restore and maintain the chemical, physical, and biological integrity of the nation's waters. To that end, the Act is generally focused on two types of controls: (1) water-quality-based controls, based on water quality standards, and (2) technology-based controls, based on effluent limitations guidelines and standards (ELGs).

The CWA gives states the primary responsibility for establishing, reviewing, and revising water quality standards. Water quality standards consist of designated uses for each water body (e.g., fishing, swimming, supporting aquatic life), criteria that protect the designated uses (numeric pollutant concentration limits and narrative criteria, for example, "no objectionable sediment deposits"), and an antidegradation policy. EPA develops recommended national criteria for many pollutants, pursuant to CWA section 304(a), 33 U.S.C. § 1314(a), which states may adopt or modify, as appropriate, to reflect local conditions.

EPA is responsible for developing technology-based ELGs, based on currently available technologies, for controlling industrial wastewater discharges. ELGs apply to pollutant discharges from industrial facilities directly to surface water (direct discharges) and to publicly owned treatment works (POTWs) (indirect discharges). For sources discharging directly to surface waters, permitting authorities—states authorized to administer the National Pollutant Discharge Elimination System (NPDES) permit program, and EPA in the few states that are not authorized— must incorporate EPA-promulgated limitations and standards into discharge permits, where applicable (U.S. EPA, 2010). Categorical pretreatment standards are directly enforceable.

While technology-based effluent limitations and standards in discharge permits are sometimes as stringent as, or more stringent than necessary to meet water quality standards, the effluent guidelines program is not specifically designed to ensure that the discharges from each facility meet the water quality standards of the receiving water body. For this reason, the CWA also requires authorized states to establish water-quality-based effluent limitations where necessary to meet water quality standards. Water-quality-based limits may require industrial facilities to meet requirements that are more stringent than those of a national effluent guideline regulation. In the overall context of the CWA, ELGs must be viewed as one tool in the broader set of tools and authorities Congress provided to EPA and the states to restore and maintain the quality of the nation's waters.

The 1972 amendments to the CWA marked a distinct change in Congress's efforts "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters" (see

CWA section 101(a), 33 U.S.C. 1251(a)). Before 1972, the CWA focused principally on water quality standards. This approach was challenging, however, because of the difficulty in determining whether a specific discharger, or combination of dischargers, was responsible for decreasing the water quality in a receiving stream.

The 1972 CWA directed EPA to promulgate effluent limitations guidelines and standards that reflect pollutant reductions achievable by categories or subcategories of industrial point sources through the implementation of available treatment and prevention technologies. The ELGs are based on specific technologies (including process changes) that EPA identifies as meeting the statutorily prescribed level of control (see CWA sections 301(b)(2), 304(b), 306, 307(b), and 307(c)). See Appendix A of this report for more information on the CWA and an explanation of the different levels of control for ELGs.

Unlike other CWA tools, ELGs are national in scope and establish pollution control obligations for all facilities that discharge wastewater within an industrial category or subcategory. In establishing these controls under the direction of the statute, EPA assesses, for example: (1) the performance and availability of the best pollution-control technologies or pollution-prevention practices for an industrial category or subcategory as a whole; (2) the economic achievability of those technologies, which can include consideration of the affordability of achieving the reduction in pollutant discharge; (3) the cost of achieving effluent reductions; (4) non-water-quality environmental impacts (including energy requirements); and (5) such other factors as the EPA Administrator deems appropriate.

In passing the CWA, congress viewed the creation of a single national pollution control requirement for each industrial category, based on the best technology the industry can afford, as a way to reduce the potential creation of "pollution havens" and set the nation's sights on eliminating pollutant discharge to U.S. waters. Consequently, EPA's goal in establishing national ELGs is to ensure that industrial facilities with similar characteristics, regardless of their location or the nature of their receiving water, will, at a minimum, meet similar effluent limitations and standards representing the performance of the best pollution control technologies or pollution prevention practices.

ELGs provide the opportunity to promote pollution prevention and water conservation. This may be particularly important in controlling persistent, bioaccumulative, and toxic pollutants discharged in concentrations below analytic detection levels.

2.2 Effluent Guidelines Review and Planning Process

In addition to establishing new regulations, the CWA requires EPA to review existing effluent guidelines annually. EPA reviews all point source categories subject to existing effluent guidelines and pretreatment standards to identify potential candidates for revision, consistent with CWA sections 304(b), 301(d), 304(m)(1)(A) and 304(g). EPA also reviews industries consisting of direct-discharging facilities not currently subject to effluent guidelines to identify potential candidates for effluent guidelines rulemakings, pursuant to CWA section 304(m)(1)(B). Finally, EPA reviews industries consisting entirely or almost entirely of indirect-discharging facilities that are not currently subject to pretreatment standards, to identify potential candidates for pretreatment standards development under CWA section 307(b).

2.2.1 Effluent Guidelines Review and Prioritization Factors

In its annual reviews, EPA considers four major factors to prioritize existing effluent guidelines or pretreatment standards for possible revision, or to identify new industries of concern through alternate analyses. These factors were developed in EPA's draft National Strategy, described at http://water.epa.gov/scitech/wastetech/guide/strategy/fs.cfm.

The first factor EPA considers is the amount and type of pollutants in an industrial category's discharge and the relative hazard posed by that discharge. Using this factor enables EPA to prioritize rulemakings to achieve significant environmental and health benefits.

The second factor EPA considers is the performance and cost of applicable and demonstrated wastewater treatment technologies, process changes, or pollution prevention alternatives that could effectively reduce pollutant concentrations in the industrial category's wastewater and, consequently, reduce the hazard posed by these pollutant discharges to human health or the environment.

The third factor EPA considers is the affordability or economic achievability of the wastewater treatment technology, process change, or pollution prevention measures identified using the second factor. If the financial condition of the industry indicates that it would not be affordable to implement expensive and stringent new requirements, EPA might conclude a less stringent, less expensive approach to reduce pollutant loadings would better satisfy applicable statutory requirements.

The fourth factor EPA considers is the opportunity to eliminate inefficiencies or impediments to pollution prevention or technological innovation, or opportunities to promote innovative approaches such as water-quality trading, including within-plant trading. This factor might also prompt EPA, during annual reviews, to decide against revising an existing set of effluent guidelines or pretreatment standards where the pollutant source is already efficiently and effectively controlled by other regulatory or non-regulatory programs.

2.2.2 Annual Review Process

EPA's annual review process includes an odd- and even-year annual review cycle, to address cohesively and comprehensively the factors laid out in EPA's draft National Strategy. In the odd-year reviews, EPA screens industrial dischargers through a toxicity ranking analysis (TRA) that identifies and ranks those categories whose reported pollutant discharges pose a substantial hazard to human health and the environment (the first draft National Strategy factor). For the TRA, EPA relies on discharge monitoring report (DMR) and Toxics Release Inventory (TRI) data to rank industrial discharge categories based on toxic-weighted pound equivalents (TWPE) released. EPA relies on facility and state contacts, permits, and publicly available data sources to review top ranking industrial categories (see Section 2.2.2.1 for more detail on the TRA).

In the even years, EPA reviews additional hazard data sources and conducts alternate analyses to enhance the identification of industrial categories for which new or revised ELGs may be appropriate, beyond those that traditionally rank high in the TRA. This is consistent with the Government Accountability Office's (GAO) recommendation that EPA's annual review approach include additional industrial hazard data sources to augment its screening-level review of discharges from industrial categories.[3] Furthermore, EPA recognizes the need to consider, in the screening phase, the availability of treatment technologies, process changes, or pollution prevention practices that can reduce the identified hazards (the second and fourth draft National Strategy factors). Specifically, in the even-year reviews, EPA is targeting new data sources that will provide information on other considerations not previously captured as part of the TRA, including, but not limited to, the following:

- Industrial process changes;
- Emerging contaminants of concern;
- Advances in treatment technologies and pollution prevention practices;
- Availability of new, more sensitive analytical methods; and
- Other hazard data and information not captured in the TRA and/or suggested by stakeholders or by public comments.

Using the TRA in the odd-year review in conjunction with additional analyses and hazard data in the even-year review, EPA is considering more cohesively and comprehensively the factors laid out in EPA's draft National Strategy. This approach allows the Agency to prioritize existing effluent guidelines or pretreatment standards for possible revision, or identify new industries of concern through alternate analyses. See Section 2.2.2.2 for an overview of EPA's even-year analyses.

EPA also conducts a more detailed preliminary category review of those industrial discharge categories that rank highest in terms of TWPE (i.e., pose the greatest hazard to human health and the environment) in the TRA, or are identified as warranting further review during the even-year analyses. If EPA determines that further review is appropriate for an industrial category, EPA may complete a preliminary or detailed study of the point source category (see Section 2.2.2.3 and Section 2.2.2.4, respectively), which may eventually lead to a new or revised guideline.

2.2.2.1 Overview of the Toxicity Ranking Analysis and Odd-Year Annual Reviews

In the odd-year annual reviews, EPA conducts a TRA using data from the TRI and data from DMRs contained in the Permit Compliance System (PCS) and the Integrated Compliance Information System for the National Pollutant Discharge Elimination System (ICIS-NPDES). Figure 2-1 details how EPA uses the TRA to identify existing ELGs that may warrant revision. Figure 2-2 addresses how EPA identifies new categories that may warrant regulation.

TRI and DMR data do not identify the effluent guideline(s) applicable to a particular facility. However, TRI includes information on a facility's North American Industry Classification System (NAICS) code, while DMR data include information on a facility's Standard Industrial Classification (SIC) code. Thus, the first step in EPA's TRA is to relate each

[3] GAO's recommendations for the review of additional hazard data sources were published in GAO's September 2012 report, *Water Pollution: EPA Has Improved Its Review of Effluent Guidelines but Could Benefit from More Information on Treatment Technologies*, available online at http://www.gao.gov/assets/650/647992.pdf.

SIC and NAICS code to an industrial category.[4] The second step is to use the information reported in TRI and DMR for a specific year to calculate the pounds of pollutant discharge to U.S. waters. These calculations are performed for toxic, nonconventional, and conventional pollutants. For indirect dischargers, EPA adjusts the facility discharges to account for removals at the POTW. The third step is to apply toxic weighting factors (TWFs)[5] to the annual pollutant discharges to calculate the total discharge of toxic pollutants as TWPE for each facility. EPA then sums the TWPE for each facility in a category to calculate a total TWPE per category for that year. EPA calculates two TWPE estimates for each category: (1) an estimate based on data in TRI and (2) an estimate based on DMR data. EPA combines these two estimates to generate a single TWPE value for each industrial category. EPA takes this approach because it found that combining the TWPE estimates from TRI and DMR data into a single TWPE number offered a clearer perspective of the industries with the most toxic pollution.[6]

EPA then ranks point source categories according to their total TWPE discharges. To identify categories for further review, EPA prioritizes categories accounting for 95 percent of the cumulative TWPE from the combined DMR and TRI data. For more information on EPA's odd-year review process and methodology, see Section 3 of EPA's *Preliminary 2012 Effluent Guidelines Program Plan* (U.S. EPA, 2013).

As illustrated in Figure 2-1, EPA typically excludes from further review categories for which an effluent guidelines rulemaking is currently underway, or for which effluent guidelines have been promulgated or revised within the past seven years.[7] EPA also excludes categories in which only a few facilities account for a large majority of toxic-weighted pollutant discharges. EPA generally does not prioritize such a category for additional review, but suggests that individual permits may be more effective in addressing the toxic-weighted pollutant discharges than a national effluent guidelines rulemaking. For more information on the results of the 2013 Annual Review, see Section 6 of EPA's *2013 Annual Effluent Guidelines Review Report* (U.S. EPA, 2014).

As illustrated in Figure 2-2, EPA may also evaluate discharges in the odd-year TRA that are associated with SIC or NAICS codes that are not currently regulated or that may be a potential new subcategory of an existing ELG. EPA evaluates these discharges to determine if new ELGs are warranted for the new industrial category or subcategory. Similarly, EPA can supplement this information with findings from new analyses conducted in the even-year annual

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[4] For more information on how EPA related each SIC and NAICS code to an industrial category, see Section 5.0 of the *2009 Technical Support Document for the Annual Review of Existing Effluent Guidelines and Identification of Potential New Point Source Categories* (U.S. EPA, 2009).

[5] For more information on TWFs, see *Toxic Weighting Factor Development in Support of CWA 304(m) Planning Process* (U.S. EPA, 2006).

[6] Different pollutants may dominate the TRI and DMR TWPE estimates for an industrial category due to the differences in pollutant reporting requirements between the TRI and DMR databases. The single TWPE number for each category highlights those industries with the most toxic discharge data in both TRI and DMR. Although this approach could have theoretically led to double-counting, EPA's review of the data indicates that, because the two databases focus on different pollutants, double-counting is minimal and does not affect the order of the top-ranked industrial categories.

[7] EPA chose seven years because this is the typical length of time for the effects of effluent guidelines or pretreatment standards to be fully reflected in pollutant loading data and TRI reports.

review, as well as review of treatment technology performance data, to identify new industrial categories that may warrant ELGs (see Section 2.2.2.2).

2.2.2.2 Overview of Even-Year Annual Reviews

In the even-year annual reviews, EPA identifies additional hazard data and reviews treatment technologies to augment the TRA completed in each odd-year review. EPA prioritizes the review of these additional hazard data sources based on three factors: (1) the likelihood of identifying unregulated industrial discharges, (2) the utility of identifying new wastewater treatment technologies or pollution prevention alternatives, and (3) representativeness of the data for an industrial category. These new analyses take into account a broader set of hazard data and advancements in treatment technologies. In addition to the new hazard data sources, the even-year reviews will include information from the public comments received on the Preliminary Plan and any continuing preliminary category reviews identified during the odd-year review, as illustrated in Figure 2-3. The specific methodologies and analyses of EPA's 2014 Annual Review are described in more detail in Part II of this report.

2.2.2.3 Preliminary Category Reviews

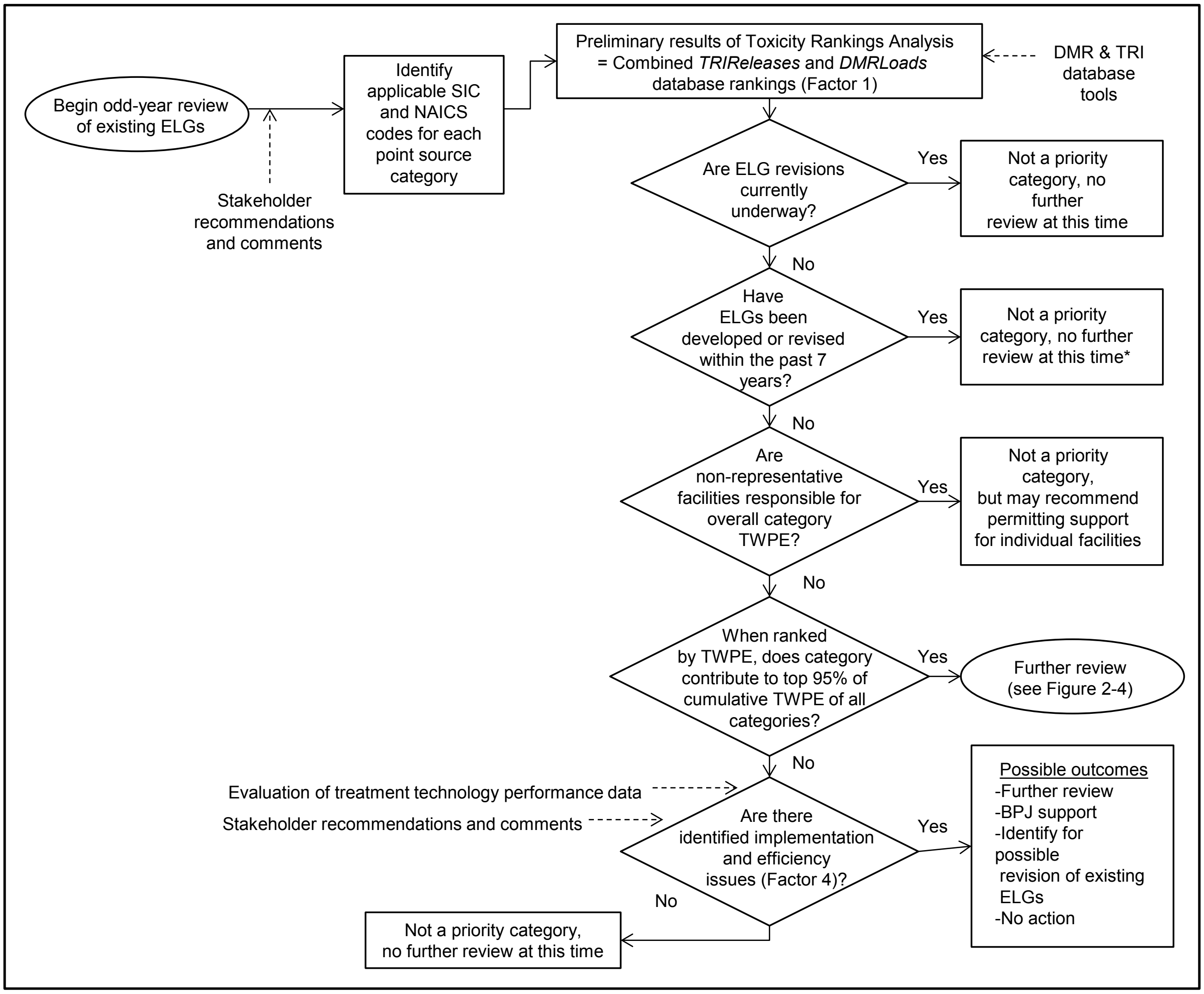
EPA may complete preliminary category reviews as part of the annual review cycle, depending on the industrial categories warranting review at that time. EPA may conduct a preliminary category review for the industrial categories with the highest hazard potential identified in the TRA, or identified as a priority from any of the even-year review analyses, particularly if it lacks sufficient data to determine whether regulatory action would be appropriate, as illustrated in Figure 2-4. In its preliminary category reviews, EPA typically examines the following: (1) wastewater characteristics and pollutant sources, (2) the pollutants driving the toxic-weighted pollutant discharges, (3) availability of pollution prevention and treatment, (4) the geographic distribution of facilities in the industry, (5) any pollutant discharge trends within the industry, and (6) any relevant economic factors.

In executing preliminary category reviews, EPA first attempts to verify the toxicity ranking results and fill in data gaps. These assessments provide an additional level of quality assurance for the reported pollutant discharges and number of facilities that represent the majority of toxic-weighted pollutant discharge. After the ranking results are verified, EPA next considers costs and performance of applicable and demonstrated technologies, process changes, or pollution prevention alternatives that can effectively reduce the pollutants in the point source category's wastewater. Finally, and if appropriate based on the other findings, EPA considers the affordability or economic achievability of the technology, process change, or pollution prevention measure identified using the second factor.

During a preliminary category review, EPA may consult data sources including, but not limited to the following: (1) the U.S. Economic Census, (2) TRI and DMR data, (3) trade associations and reporting facilities that can verify reported releases and facility categorization, (4) regulatory authorities (states and EPA regions) that can clarify how category facilities are permitted, (5) NPDES permits and their supporting fact sheets, (6) EPA effluent guidelines technical development documents, (7) relevant EPA preliminary data summaries or study reports, and (8) technical literature on pollutant sources and control technologies. If a preliminary category review reveals that the reports of toxic discharges are correct, not geographically isolated, and likely to be the result of the production practices in use broadly throughout the category, EPA may decide to conduct a preliminary or detailed study prior to initiating a rulemaking. In many cases, the information and data gathered for a study forms the basis of information used for the rulemaking. However, in some instances, EPA may decide not to move forward with a rulemaking following a study, if the data and information gathered indicates that a new or revised guideline is not warranted. Regardless of the outcome, EPA announces to the public and other stakeholders decisions to conduct studies, or to develop rulemakings, in the Effluent Guidelines Program Plan. When a rulemaking is determined appropriate, schedules are also announced in the Plan.

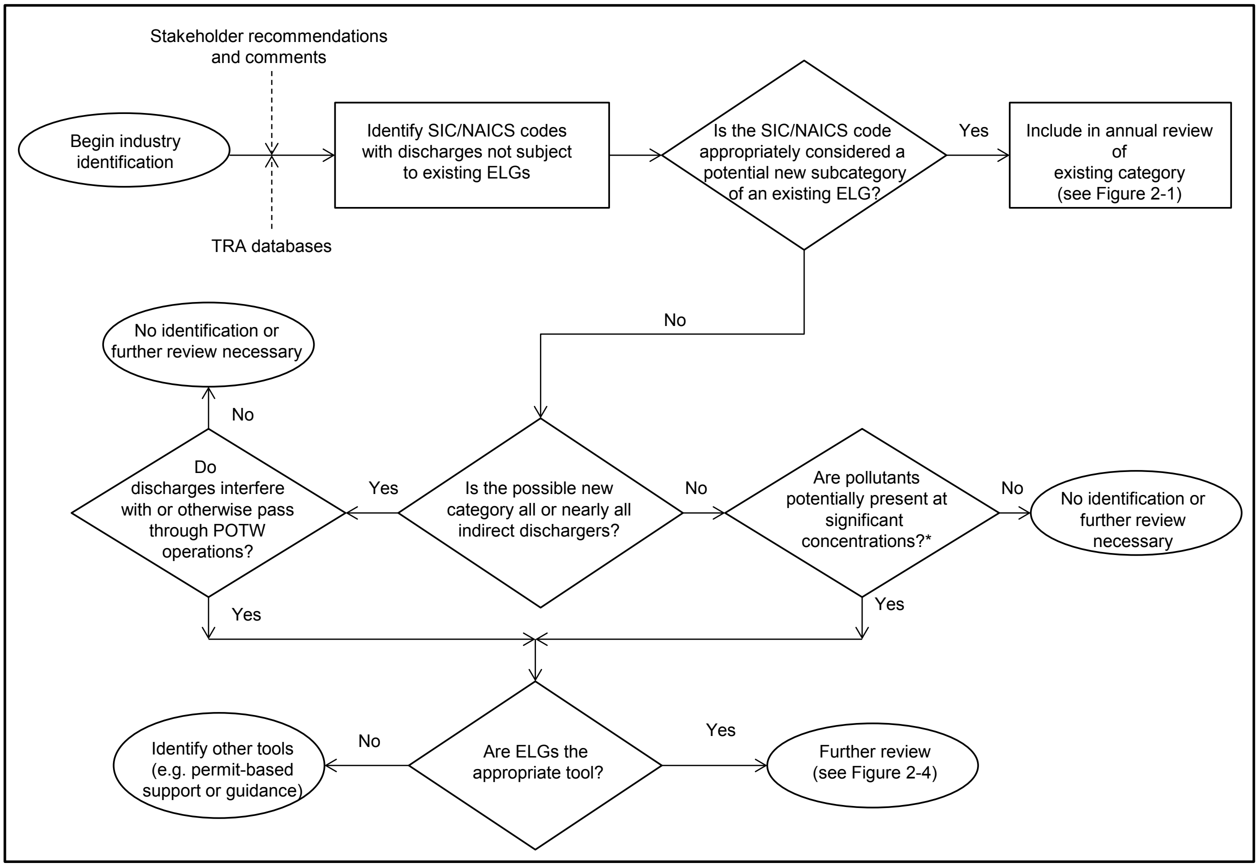
2.2.2.4 Preliminary and Detailed Studies

After conducting the preliminary category reviews, as shown in Figure 2-4, EPA may then conduct either a preliminary or detailed study of an industrial category. Typically, these studies profile an industry category, gather information about the hazards posed by its wastewater discharges, collect information about availability and cost of treatment and pollution prevention technologies, assess the financial status of the facilities in the category, and investigate other factors to determine if it would be appropriate to identify the category for possible effluent guidelines revision. During preliminary or detailed studies, EPA typically examines the factors and data sources listed above for preliminary category reviews. However, during a detailed study EPA's examination of a point source category and available pollution prevention and treatment options is generally more rigorous than the analysis conducted during a preliminary category review or study, and may include primary data collection activities (such as industry questionnaires and wastewater sampling and analysis) to fill data gaps.



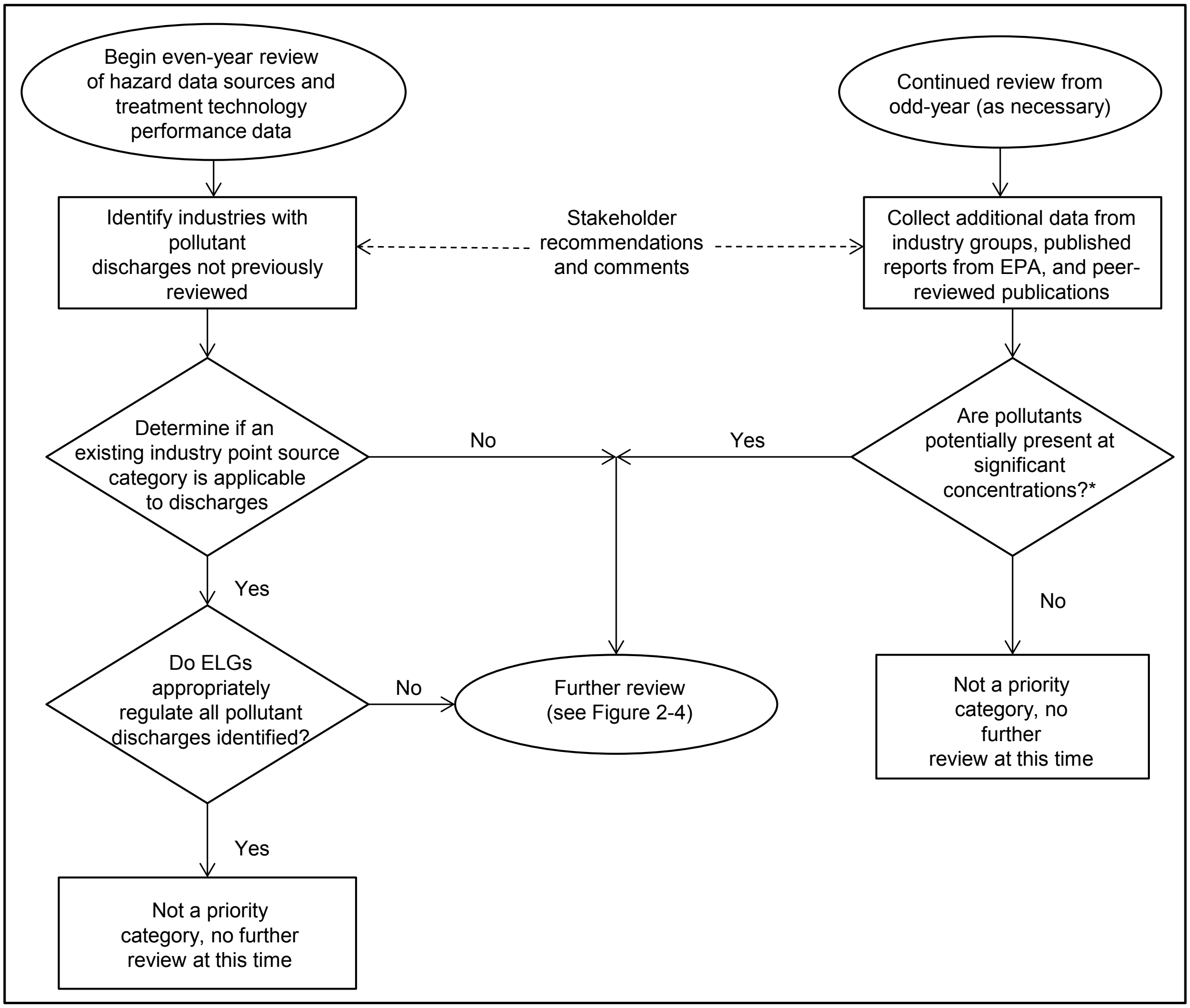
* If EPA is aware of new segment growth within such a category or new concerns are identified, EPA may do further review.

Figure 2-1. Odd-Year Annual Review of Existing ELGs



* Significant concentrations include levels above minimum levels from 40 CFR Part 136 or other EPA-approved methods, levels above treatability levels, or at levels of concern to human health and toxicity.

Figure 2-2. Odd-Year Identification of Possible New ELGs



* Significant concentrations include levels above minimum levels from 40 CFR Part 136 or other EPA-approved methods, levels above treatability levels, or at levels of concern to human health and toxicity.

Figure 2-3. Even-Year Annual Review of Existing ELGs and Identification of Possible New ELGs

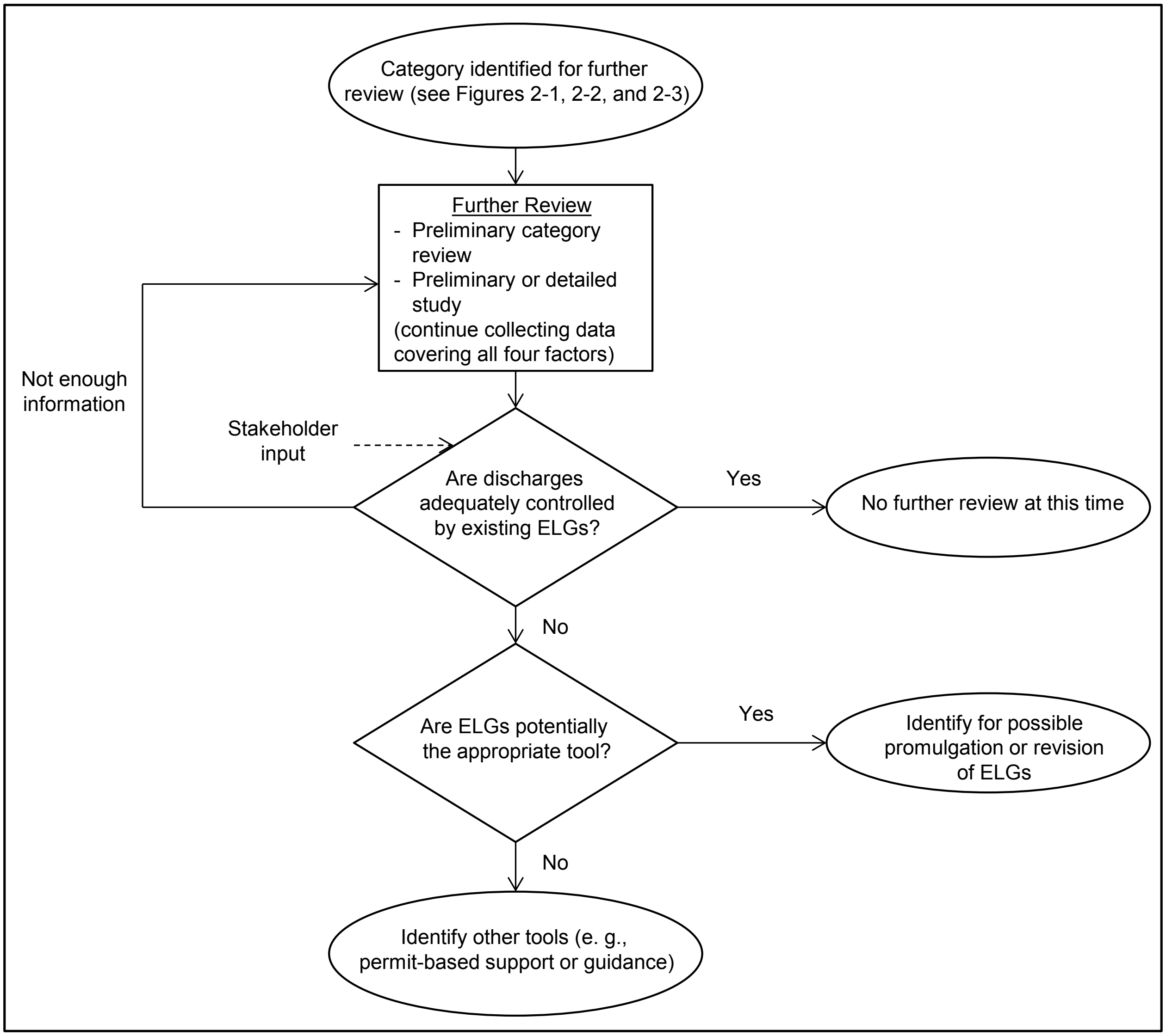


Figure 2-4. Further Review of Industrial Categories Identified During Annual Reviews

2.2.3 Effluent Guidelines Program Plans

CWA section 304(m)(1)(A) requires EPA to publish an Effluent Guidelines Program Plan (Plan) every two years that establishes a schedule for the annual review and revision, in accordance with section 304(b), of the effluent limitations guidelines that EPA has promulgated under that section. EPA publishes the results of the TRA and preliminary category review conducted during the odd-year review in a Preliminary Plan, and takes public comment. In the even year following publication of the Preliminary Plan, EPA identifies and evaluates additional data sources and hazard analyses to supplement the TRA. EPA then publishes a Final Plan in the even year. The Final Plan presents the compilation of the odd- and even-year reviews and any public comments received on the Preliminary Plan. EPA may initiate, continue, or complete preliminary category reviews or in-depth studies during the odd- or even-year reviews, depending upon when it identifies a category warranting further review. Additionally, EPA may publish the findings from these studies as part of the Preliminary Plan or Final Plan, based on when during the planning cycle the study or review is completed.

EPA has several reasons for coordinating its annual reviews under section 304(b) with publication of Plans under section 304(m). First, the annual reviews are inextricably linked to the planning effort because each review year's results may inform the content of the Preliminary and Final Plans (e.g., by identifying candidates for effluent guidelines revision, or by identifying point source categories for which EPA has never promulgated effluent limitations guidelines). Second, even though it is not required to do so under either section 304(b) or section 304(m), EPA believes it can serve the public interest by periodically describing the annual reviews (including the review process used) and review results to the public. Doing so while simultaneously publishing the Preliminary and Final Plans makes both processes more transparent. Third, by requiring EPA to review existing effluent limitations guidelines each year, Congress appears to have intended for each successive review to build on the results of earlier reviews.

2.3 References for Background

1. U.S. EPA. 2010. *U.S. EPA NPDES Permit Writers' Manual.* Washington, D.C. (September). Available online at: http://cfpub.epa.gov/npdes/writermanual.cfm?program_id=45. EPA-833-K-10-001. EPA-HQ-OW-2010-0824-0236.

2. U.S. EPA. 2013. *Preliminary 2012 Effluent Guidelines Program Plan*. Washington, D.C. (May). EPA-821-R-12-002. EPA-HQ-OW-2010-0824-0194.

3. U.S. EPA. 2014. *The 2013 Annual Effluent Guidelines Review Report*. Washington, D.C. (September). EPA-821-R-12-003. EPA-HQ-OW-2014-0170-0077.

PART II: EPA'S 2014 ANNUAL REVIEW METHOLOLOGY AND ANALYSES

3. INTRODUCTION TO EPA'S 2014 ANNUAL REVIEW

The even-year review provides EPA with an opportunity to identify additional available hazard data sources and conduct further analyses at the pollutant, industry, or wastewater treatment technology levels. As described above in Section 2.2.2.2, EPA identified and prioritized additional data sources and analyses for the 2014 Annual Review based on (1) the likelihood that they would assist in identifying unregulated industrial discharges, (2) their utility in identifying new wastewater treatment technologies or pollution prevention alternatives, and (3) how well the data represent the activity of an industrial category.

EPA is using the data sources and analyses identified in this 2014 Annual Review to screen additional industrial discharge categories and pollutants of concern and to identify for further review those that potentially pose a hazard to human health or the environment. The 2014 Annual Review consisted of three components:

- Consideration of public comments on the *Preliminary 2014 Effluent Guidelines Program Plan* and other stakeholder input (see Section 4).
- Continuation of the industrial category reviews (e.g., collecting additional data, contacting permit writers, evaluating available treatment technology information) of specific industrial categories that EPA identified as warranting additional review in the *Final 2012 and Preliminary 2014 Plan Effluent Guidelines Program Plans* (see Section 5).
- Identification and evaluation of new industrial hazard data sources and analyses of these data to identify new wastewater discharges or pollutants not previously regulated and to identify wastewater discharges that can be more effectively treated or eliminated (see Section 6).

The specific data sources, analyses, and findings for each of the 2014 Annual Review components listed above are described in detail in Sections 4, 5, and 6. A summary of the 2014 Annual Review findings is presented in Part III of this report.

4. Public Comments and Other Stakeholder Input on the Final 2012 and Preliminary 2014 Effluent Guidelines Program Plans

EPA's annual review process considers information provided by the public and other stakeholders regarding the need for new or revised effluent limitations guidelines and pretreatment standards. Public comments received on EPA's prior reviews and pans helped the Agency prioritize its analysis of existing effluent guidelines and pretreatment standards. This section presents a summary of the public comments and stakeholder input received on the *Preliminary 2014 Effluent Guidelines Program Plan* (Preliminary 2014 Plan).

4.1 Public Comments and Stakeholder Input

EPA published its Preliminary 2014 Plan together with the Final 2012 Plan and provided a 60-day public comment period on the Preliminary 2014 Plan starting on September 16, 2014 (see 79 FRN 55472). The Docket supporting the Final 2014 Effluent Guidelines Program Plan (Final 2014 Plan) includes a complete set of the comments submitted, as well as the Agency's responses (see DCN 08110). EPA received comments on the Preliminary 2014 Plan from 18 organizations; Table 4-1 presents a summary of these comments.

Commenting organizations representing industry included:

- American Petroleum Institute;
- Coalbed Methane Association of Alabama;
- American Forest & Paper Association;
- National Association for Surface Finishing;
- American Chemistry Council Nanotechnology Panel;
- American Fuel & Petrochemical Manufacturers;
- Valero Companies;
- Greenway Products, Inc.; and
- NORA: an Association of Responsible Recyclers.

Commenting organizations representing environmental groups included:[8]

- Clean Water Action;
- Earthjustice;
- Earthworks;
- Environmental Defense Fund;
- League of Conservation Voters;
- Natural Resources Defense Fund; and
- Sierra Club.

[8] Seven environmental organizations submitted one combined public comment on the Preliminary 2014 Plan. One of the environmental organizations also submitted a separate public comment on the Preliminary 2014 Plan.

Additionally, one consultant to pretreatment programs for local governments, CWA Consulting Services, LLC and one state representing organization, the Association of Clean Water Administrators (ACWA).

EPA received five comments on its proposed CWTs detailed study from one consultant to local government pretreatment programs, two industry representatives, and several environmental organizations. The consultant to local government pretreatment programs commented that EPA should review and clearly define the applicability of CWT effluent limitations guidelines and standards (40 CFR Part 437) as they relate to accepting oil and natural gas produced wastewater. One industry representative questioned the intent and basis for the CWTs detailed study, citing a lack of definition for what qualifies as a CWT, a lack of a reasonable basis for initiating the study, and potential overlap with the Oil and Gas Extraction ELGs for shale gas facilities that direct their wastewater to CWTs. The other industry representative commented that revising the CWT ELG may not be necessary to address discharges of oil and gas extraction wastewater (to CWTs, POTWs, or surface water) and that any new regulations and/or guidelines for CWT facilities could be aided by direct meetings between EPA, industry experts in the field, and the operators of CWT facilities.

The environmental organizations supported EPA's decision to undertake a detailed study of CWTs that accept oil and gas wastewaters and requested the study be expedited, citing that (1) the CWT ELGs are out of date in light of the developments in the oil and gas extraction industry; (2) CWTs may not have treatments in place for pollutants in oil and gas wastewaters; (3) oil and gas wastewaters may have potential impacts on drinking water sources; and (4) pretreatment standards under development for discharges to POTWs from onshore unconventional oil and gas extraction could result in more discharges to CWTs. One environmental organization also provided recommendations for resources and information in support of the CWT detailed study.

For the Petroleum Refining Category (40 CFR Part 419), EPA received three comments from industry representatives questioning the quality and appropriateness of data used as the basis for initiating the study. Industry representatives also questioned EPA's objective for examining feedstock metals. One industry representative questioned the basis for EPA's investigation of polynuclear aromatic hydrocarbons. EPA also received a comment from the consultant to local government pretreatment programs supporting the detailed study and suggesting that EPA specifically evaluate common problem pollutants, including benzene and sulfides. In addition the commenter indicated that EPA should evaluate groundwater pump-and-treat operations to clearly define regulated, unregulated, and dilute waste streams.

EPA received comments on its proposed continued preliminary review of the Metal Finishing Category (40 CFR Part 433) from the consultant to local government pretreatment programs, one industry representative, and an organization representing states. The consultant to the local government pretreatment programs did not support reopening the regulation because it could make the regulation vulnerable to weakening by special interest groups. The industry representative did not support further review of the Metal Finishing Category, stating that EPA recently reviewed the industry as part of the Metal Products and Machinery ELGs rulemaking and determined that revised guidelines were not necessary. Further, the industry representative commented that the industry is not using new processes or treatment technologies that would suggest the need to revise the applicable Metal Finishing ELGs, and POTWs have the ability to impose stricter limits to address specific concerns. The organization representing states supported further review of the Metal Finishing Category, stating that the industry has changed significantly since the existing regulations were developed. These changes include updated chemical formulas and processes, new pollutants of concern, new treatment technologies, and a broader scope for the metal finishing universe. The organization representing states also commented that clarification is needed regarding classification of a facility as an existing or new source, that there are inconsistencies in categorical determinations across the country for certain metal finishing applications (etching vs. cleaning, coating vs. adsorption, phosphate coating vs. cleaning), and that EPA should consider adopting a sunset provision for the Electroplating ELGs (40 CFR Part 413) to require eventual compliance with the Metal Finishing ELGs (40 CFR Part 433).

For nanomaterials, the consultant to local government pretreatment programs and one industry representative supported EPA's effort to characterize nanomaterials in industrial wastewater discharges. Specifically, the industry representative urged EPA to recognize the diversity of nanomaterials and their applications across multiple industries in its future reports; coordinate closely with EPA's New Chemicals Program to understand nanomaterial releases in water; consider work on the fate and transport of nanomaterials completed or currently underway; and recognize the potential for nanotechnology to provide new and improved tools for wastewater treatment. One wastewater treatment products manufacturer also commented that he is currently testing a coagulant/flocculent/filter aid that has shown success at settling nano-particles, E. coli, phosphorus and other particulates.

The group of seven environmental groups commented that ongoing revisions to pretreatment standards for discharges to POTWs need to reflect changes in onshore oil and gas exploration, stimulation, and extraction. One environmental organization commented that the oil and gas ELG rulemaking for the unconventional oil and gas facilities be finalized as soon as possible, and provided recommendations for resources and information in support of the rulemaking.

The organization representing states supported EPA's new even-year review methodology, used in the 2012 Annual Review, as well as inclusion of the current status of ELGs under development in the Final 2012 Plan. This commenter also suggested improvements to the ELG review and planning processes, including an increase in EPA staff allocated to work on ELGs and pretreatment standards, and publication of Annual Review Reports earlier in the planning process, as well as more timely publication of future ELG Plans.

The consultant to local government pretreatment programs commented that EPA should add biodiesel manufacturing to the list of industrial sectors to evaluate.

Lastly, EPA received three unsolicited comments on final decisions announced in the Final 2012 Plan. EPA did not solicit public comment on the content of the Final 2012 Plan since public comments were solicited on the actions and decisions when they were proposed in the Preliminary 2012 Plan on August 7, 2013. Regardless, one industry commenter indicated support for EPA's decision in the Final 2012 Plan to delist coalbed methane as a new subcategory under the Oil and Gas Extraction Category (40 CFR Part 435), and an environmental organization indicated they did not support EPA's decision to delist coalbed methane. The third unsolicited comment by an industry organization indicated support for EPA's final decision in the Final 2012 Plan not to further review Pulp and Paper industry discharges.

In general, the public comments submitted on the Preliminary 2014 Plan did not result in any new direction or determinations with respect to the proposed actions announced in the Preliminary 2014 Plan, or EPA's final decisions and actions indicated in this Final 2014 Plan. EPA did, however, receive useful information and input from the public review that will help inform ongoing studies, in particular Petroleum Refining, Metal Finishing and CWTs. EPA's responses to the specific comments can be found in EPA's comment response document (DCN 08110).

Table 4-1. Comments on the Preliminary 2014 Effluent Guidelines Program Plan EPA Docket Number: EPA-HQ-OW-2014-0170

No.	Commenter Name	Commenter Organization	EPA Docket No.	Comment Summary
1	Curt A. McCormick	CWA Consulting Services, LLC (CWACS)	0081	Supports EPA's evaluation of centralized waste treatment (CWTs) facilities to clarify whether facilities that accept oil and natural gas produced wastewaters by truck for treatment, which is subsequently discharged to publicly-owned treatment works (POTWs) meet the definition of a CWT (and whether they are subject to 40 CFR Part 437 (CWTs) or 40 CFR Part 403 (General Pretreatment Regulations). Supports EPA's study of the Petroleum Refining (40 CFR Part 419) industry and suggests that that EPA specifically evaluate common problem pollutants such as benzene and sulfides, as well as groundwater pump-and-treat operations to clearly define regulated, unregulated, and dilute wastestreams. Opposes reopening of the Metal Finishing ELGs (40 CFR Part 433) because it could make the regulation vulnerable to weakening by special interest groups. Supports EPA's efforts to characterize nanopollutants and requests that EPA add biodiesel manufacturing to the list of industrial sectors to evaluate.

Table 4-1. Comments on the Preliminary 2014 Effluent Guidelines Program Plan EPA Docket Number: EPA-HQ-OW-2014-0170

No.	Commenter Name	Commenter Organization	EPA Docket No.	Comment Summary
2	Roger E. Claff	American Petroleum Institute (API)	0082	Raises several issues related to the proposed Petroleum Refining (40 CFR Part 419) study, specifically the use of TRI data, EPA's objectives for examining petroleum refinery feedstock metals, the basis for evaluating polynuclear aromatic hydrocarbons (PNAs), and EPA's request for information on oil refining processes. Also raises several issues related to the proposed CWTs (40 CFR Part 437) study including the lack of criteria used to define CWTs, the basis for initiating the study, and the need for consistency with ELGs for oil and gas extraction for shale gas facilities that direct their wastewaters to CWTs. Supports continued engagement and communication with EPA during the studies.
3	Dennis Lathem	Coalbed Methane Association of Alabama (CMAA)	0083	Supports EPA's decision to delist coalbed methane as a new subcategory under the Oil & Gas Extraction Category (40 CFR Part 435) because EPA did not identify a new wastewater treatment technology that would be economically achievable.
4	Jerry Schwartz	American Forest & Paper Association (AF&PA)	0084	Supports EPA's decisions in the Final 2012 Plan that no further review of the Pulp, Paper, and Paperboard (40 CFR Part 430) industry is necessary and its decision not to include the category for further review in the Preliminary 2014 Plan.
5	Jeffrey S. Hannapel	National Association for Surface Finishing (NASF)	0085, 0093 (duplicate comment)	Opposes EPA's continued preliminary review of the Metal Finishing Category (40 CFR Part 433) because EPA's recent review of the industry under the Metal Products and Machinery (MP&M) rulemaking (40 CFR Part 438) determined further revisions to the guidelines are not necessary, the industry is not using new processes or treatment technologies that would suggest the need for ELG revisions, and POTWs may impose more stringent limits as necessary.
6	Jay West	American Chemistry Council (ACC) Nanotechnology Panel	0086	Supports EPA's review of nanomaterials; however, urges EPA to recognize the diversity of nanomaterial substances and their applications, work with the New Chemicals Program to understand nanomaterial releases in water, consider work on nanomaterials completed or currently underway, and recognize the potential for nanotechnology to provide new and improved tools for wastewater treatment.

Table 4-1. Comments on the Preliminary 2014 Effluent Guidelines Program Plan EPA Docket Number: EPA-HQ-OW-2014-0170

No.	Commenter Name	Commenter Organization	EPA Docket No.	Comment Summary
7	Jeff Gunnulfsen	American Fuel & Petrochemical Manufacturers (AFPM)	0087	Urges EPA to demonstrate the specific concerns with the current Petroleum Refining ELGs (40 CFR Part 419). Specifically, questions the data, data quality, and information evaluated as part of the annual reviews and used to form the basis for the proposed study. Urges EPA to work with industry representatives to develop a path forward.
8	Matthew H. Hodges	Valero Companies	0088	Opposes further study of the Petroleum Refining (40 CFR Part 419) industry, citing that EPA has not fully considered the data or data quality to support the decision to conduct a detailed study. Specifically raised issues related to the data demonstrating discharges of metals and dioxins, the correlation of crude feedstock to pollutant discharges, and EPA's demonstration that the current ELGs are not sufficient to protect human health and the environment.
9	Michael Fulton	Association of Clean Water Administrators (ACWA)	0089	Supports further study of the Metal Finishing (40 CFR Part 433) industry, stating that there have been drastic changes in the industry, including new chemical formulas and processes, new pollutants of concern, new treatment technologies, and changes in the scope of the metal finishing industry. Encourages EPA to more clearly define gray areas in the current regulations, such as the definition of etching vs. cleaning, coating vs. absorption, and phosphate coating vs. phosphate cleaning. Recommend that EPA clarify new and existing sources and sunset the Electroplating ELGs (40 CFR Part 413) to require eventual compliance with the Metal Finishing ELGs (40 CFR Part 433). Recommends EPA increase the staff allocated to working on ELGs and pretreatment standards and issue future ELG Plans and Annual Review Reports in a timelier manner. Supports EPA's new methodology used in the 2012 Annual Review Report.
10	Bryan Holt	Greenway Products Inc.	0090	Stated that their company is currently testing a coagulant/flocculent/filter aid to remove nanoparticles, E.coli, phosphorus, and other particulates.

Table 4-1. Comments on the Preliminary 2014 Effluent Guidelines Program Plan
EPA Docket Number: EPA-HQ-OW-2014-0170

No.	Commenter Name	Commenter Organization	EPA Docket No.	Comment Summary
11	Lynn Thorp Jessica Ennis Lauren Pagel Scott Anderson Madeleine Foote Amy Mall Deborah J. Nardone	Clean Water Action Earthjustice Earthworks Environmental Defense Fund League of Conservation Voters Natural Resources Defense Fund Sierra Club	0091	Oppose EPA's decision to delist coalbed methane extraction and discontinue the ELG rulemaking because the industry produces large volumes of wastewater with contaminants at potentially high concentrations. Stated that inadequate treatment and discharge of these wastewaters could jeopardize the integrity of the surface water, that EPA's decision to delist was premature, that ELGs are necessary, and that affordable treatments are available. Support EPA's decision to undertake a detailed study of the CWTs (40 CFR Part 437) that accept oil and gas wastewaters because the ELGs are out of date, CWTs may be lacking treatment for pollutants in oil and gas wastewaters, these wastewaters could have impacts on drinking water sources, and pretreatment standards under development for discharges to POTWs from onshore unconventional oil and gas extraction could results in more discharges to CWTs. Additionally, commented that ongoing revisions to pretreatment standards for discharges to POTWs need to be revised to reflect changes in oil and gas exploration, stimulation, and extraction.
12	Scott Anderson	Environmental Defense Fund (EDF)	0092	Supports comments from the group of environmental organizations. Encourages EPA to finalize the oil and gas ELG rulemaking as fast as possible due to the potential severity of the consequences if discharges too significantly outpace regulation. Supports a detailed study of the CWTs (40 CFR Part 437) that accept oil and gas wastewaters, but reminds EPA that conducting the CWT study is only a first steps toward materially improving oversight of CWTs. Provided additional resources and studies on oil and gas wastewaters and CWTs.
13	Christopher Harris	NORA: Association of Responsible Recyclers, Inc.	0094	States that revising the CWT ELG may not be necessary to address discharges of oil and gas extraction wastewater (to CWTs, POTWs, or surface water) and that the organization plans to be closely involved with any regulatory changes and/or guidelines for CWTs (40 CFR Part 437). Suggested that any new regulations and/or guidelines for CWT facilities could be aided by direct meetings between EPA, NORA's experts in this field, and the operators of CWT facilities.

5. CONTINUED REVIEW OF SELECT INDUSTRIAL CATEGORIES

For the 2014 Annual Review, EPA continued to evaluate several industrial categories that the Preliminary 2014 Plan identified as warranting further review: Metal Finishing (40 CFR Part 433), Pesticide Chemicals (40 CFR Part 455) and brick and structural clay products manufacturing (not currently regulated) (U.S. EPA, 2014).

EPA documented the usability and quality of the data supporting its continued review of these industrial categories, analyzed how the data could be used to improve the characterization of industrial wastewater discharges (universe of facilities with known or potential discharges, concentration and quantity of pollutants, availability and performance of advances in wastewater treatment), and prioritized the findings for further review. See Appendix B of this report for more information on data usability and quality of the data sources supporting these reviews.

Section 5.1 through Section 5.3 of this report details EPA's continued review of these three industrial categories.

5.1 Continued Review of the Metal Finishing Category (40 CFR Part 433)

EPA reviewed the Metal Finishing Category (40 CFR Part 433) as part of the 2012 and 2013 Annual Reviews and determined that the category warranted further review. EPA continued its review of this category in its 2014 Annual Review.

During the 2012 Annual Review, EPA's review of the Targeted National Sewage Sludge Survey (TNSSS), combined with available indirect discharge data from the Toxics Release Inventory (TRI), suggested further investigation of the Metal Finishing Category relating to the indirect discharge of metals, particularly chromium, nickel, and zinc, to publicly-owned treatment works (POTWs). These metals could transfer to sewage sludge, where their concentrations could diminish the sludge's beneficial use. EPA evaluated beneficial use by comparing the metal concentrations against the regulatory ceiling concentrations for sewage land application (40 CFR 503 Subcategory B) and sewage sludge concentration limits for surface disposal (40 CFR 503 Subcategory C) (U.S. EPA, 2014a). EPA also received comments from the Association of Clean Water Administrators (ACWA) urging EPA to revise regulations or issue new guidance for the industry due to applicability concerns and advancements in process and treatment technology for metal finishing and metal finishing wastewater (ACWA, 2013). In the 2013 Annual Review, the Metal Finishing Category also ranked high, in terms of toxic weighted pound equivalents (TWPE), in EPA's toxicity ranking analysis (U.S. EPA, 2014b).

As part of this 2014 Annual Review, EPA reviewed the scope of the existing Metal Finishing Effluent Limitations Guidelines and Standards (ELGs), examined the current profile of metal finishing operations in the U.S., and gathered data on existing and advanced metal finishing wastewater treatment technologies. EPA also held discussions with regional EPA pretreatment coordinators who are involved in the implementation of POTW pretreatment programs throughout the U.S. to further understand metal finishing operations and potential applicability issues with the Metal Finishing ELGs. The following sections present the findings of EPA's continued review of the Metal Finishing Category.

5.1.1 Overview of Existing ELGs Related to Metal Finishing

To provide background and context for EPA's continued review of the Metal Finishing Category (40 CFR Part 433), this section provides a brief history of the development and review of the existing ELGs related to metal finishing operations. Metal finishing is defined as the process of changing the surface of an object for the purpose of improving its appearance and/or durability. Wastewater discharges from metal finishing operations are primarily regulated by two ELGs:[9] pretreatment standards for existing sources (PSES) for the Electroplating Category (40 CFR Part 413) and the effluent limitations, pretreatment standards, and new source performance standards (NSPS) for the Metal Finishing Category (40 CFR Part 433).

5.1.1.1 Pretreatment Standards for Existing Sources in the Electroplating Category

EPA promulgated PSES for the Electroplating Category (40 CFR Part 413) on September 7, 1979. The rule established pretreatment standards for facilities that indirectly discharge to POTWs above and below a discharge threshold of 10,000 gallons per day (gpd). Standards for new sources and direct dischargers were not established under this rule. The pretreatment standards include concentration-based limits with alternate mass-based limits for metals, cyanide, and total toxic organics. Facilities had the option of complying with either concentration- or mass-based limits. At promulgation, these standards applied to existing facilities that perform one or more of six electroplating operations, which are defined below and in the *Development Document for Existing Source Pretreatment Standards for the Electroplating Point Source Category* (U.S. EPA, 1979):

- *Electroplating:* the production of a thin surface coating of one metal upon another by electrodeposition. This surface coating is applied to provide corrosion protection, wear or erosion resistance, or anti-frictional characteristics, or for decorative purposes.

- *Electroless plating:* a chemical reduction process that depends on the catalytic reduction of a metallic ion in an aqueous solution containing a reducing agent and the subsequent deposition of metal without the use of external electrical energy.

- *Anodizing:* an electrolytic oxidation process that converts the surface of the metal to an insoluble oxide.

- *Coating:* the process of chromating, phosphating, metal coloring, and immersion plating.[10] In chromating, a portion of the base metal is converted to a component of the film by reaction with aqueous solutions containing hexavalent chromium and active organic or inorganic compounds. Phosphate coatings are used to provide a good base for paints and other organic coatings, to condition the surfaces for cold forming operations by providing a base for drawing compounds and lubricants, and to impart corrosion resistance to the metal surface by the

[9] Discharges from facilities performing metal finishing operations may also be regulated under other ELGs (e.g., aluminum forming, iron and steel) that take precedence over the Metal Finishing ELGs, as discussed in Section 5.1.1.2.

[10] The Metal Finishing ELGs refer to immersion plating as passivation.

coating itself or by providing a suitable base for rust-preventative oils or waxes. Metal coloring by chemical conversion methods produces a large group of decorative finishes. Immersion plating is a chemical plating process in which a thin metal deposit is obtained by chemical displacement of the basis metal. A common example of immersion plating is the deposition of copper on steel from an acid copper solution.

- *Etching and chemical milling:* producing specific design configurations and tolerances on metal parts by controlled dissolution with chemical reagents or etchants. Included in this classification are the processes of chemical milling, chemical etching, bright dipping, electropolishing, and electrochemical machining.[11] Chemical etching is the same process as chemical milling, but with much lower rates and depths of metal removal. Bright dipping is a specialized form of etching, used to remove oxide and tarnish from ferrous and nonferrous materials. This unit operation also includes the stripping of metallic coatings.

- *Printed circuit board manufacturing:* the formation of a circuit pattern of conductive metal (usually copper) on nonconductive board materials such as plastic or glass. It usually involves cleaning and surface preparation, catalyst and electroless plating, pattern printing and masking, electroplating, and etching.

The National Association of Metal Finishers and the Institute of Interconnecting and Packaging Electronic Circuits challenged the PSES for the Electroplating Category. On March 7, 1980, EPA entered into a settlement agreement with these two organizations, agreeing to publish amendments to the final electroplating pretreatment standards if the petitioners dismissed their petition for review of the standards. These amendments were implemented on January 28, 1981 (U.S. EPA, 1981). As a result, EPA agreed to develop best available technology economically achievable (BAT) effluent limits, NSPS, and pretreatment standards for new and existing sources (PSNS and PSES) under a new regulation for the Metal Finishing Category.

Metal finishing facilities are categorized as either captive facilities or job shops, which EPA defined as follows (U.S. EPA, 1984):

- *Captive facility:* a facility that in a calendar year owns more than 50 percent (on an area basis) of the materials undergoing metal finishing. Captive facilities were further categorized as integrated or non-integrated to characterize the wastewater discharges generated. Integrated facilities combine electroplating waste streams with significant process waste streams not covered by the Electroplating Category, whereas non-integrated facilities have significant wastewater discharges only from electroplating operations covered under the Electroplating Category.

- *Job shop:* a facility that in a calendar year owns less than 50 percent (on an area basis) of the materials undergoing metal finishing. Although job shops can be also

[11] The Metal Finishing ELGs do not include electropolishing or electrochemical machining in the classification of etching and chemical milling.

categorized as integrated and non-integrated, approximately 97 percent were found to be non-integrated during the development of the new regulation.

By February 15, 1986, all existing captive facilities under the Electroplating Category shifted to the Metal Finishing Category and were required to comply with the Metal Finishing ELGs. Any new sources of wastewater discharges (both direct and indirect) as well as existing, direct discharging sources from metal finishing facilities that were not regulated under the Electroplating Category would also fall under the Metal Finishing Category. Only existing indirect discharging job shops, including independent printed circuit board (IPCB) manufacturers, remained in the existing Electroplating Category after the final compliance date for the Metal Finishing ELGs.

5.1.1.2 Effluent Guidelines for the Metal Finishing Category

The Metal Finishing ELGs were promulgated on July 15, 1983. They establish one set of concentration-based limitations, summarized in Table 5-1, that apply across a single subpart (subpart A: Metal Finishing). Direct dischargers comply with BAT and NSPS limits, whereas indirect dischargers comply with PSES and PSNS limits for existing and new sources, respectively. As the table shows, the limits are the same between new sources and existing sources of industry wastewater, except for cadmium, which has a lower limit for direct or indirect new sources of metal finishing wastewater. The Metal Finishing ELGs regulate wastewater discharges from the same six core operations addressed in the PSES for the Electroplating Category. If any of these six operations is present, the Metal Finishing ELGs apply to an additional 40 unit operations (summarized in Table 5-2) (U.S. EPA, 1983).

Table 5-1. Regulated Pollutants and ELG Limits for the Metal Finishing Category, Subpart A

Process Operations Covered	Pollutant	BAT/PSES Daily Max (Monthly Average) (mg/L)	NSPS/PSNS Daily Max (Monthly Average) (mg/L)
See Table 5-2 for the list of 46 unit operations[a]	Silver	0.43 (0.24)	0.43 (0.24)
	Copper	3.38 (2.07)	3.38 (2.07)
	Lead	0.69 (0.43)	0.69 (0.43)
	Cyanide[b]	1.20 (0.65)	1.20 (0.65)
	Cadmium	0.69 (0.26)	0.11 (0.07)
	Chromium	2.77 (1.71)	2.77 (1.71)
	Nickel	3.98 (2.38)	3.98 (2.38)
	Zinc	2.61 (1.48)	2.61 (1.48)
For industrial facilities with cyanide treatment, and upon agreement between a source subject to those limits and the pollution control authority, the following amenable cyanide limit may apply in place of the total cyanide limit.	Cyanide amenable to alkaline chlorination	0.86 (0.32)	0.86 (0.32)

Source: 40 CFR Part 433.

[a] The provisions of this subpart apply to discharges from six electroplating operations on any basis material: electroplating, electroless plating, anodizing, coating (chromating, phosphating, and coloring), chemical etching and milling, and printed circuit board manufacturing. If any of these six operations are present, the provisions of this subpart also apply to discharges from 40 additional metal finishing operations, listed in Table 5-2. These limits do not apply to (1) metallic platemaking and gravure cylinder preparation conducted within or for printing and publishing facilities or (2) existing indirect discharging job shops and independent printed circuit board manufacturers, which are covered by 40 CFR part 413.

[b] Anti-dilution provisions are stipulated in 40 CFR Part 433, which require self-monitoring for cyanide after cyanide treatment and before dilution with other waste streams.

Table 5-2. Unit Operations Regulated by ELGs for the Metal Finishing Category

Six Electroplating Operations (Introduced in 40 CFR Part 413)	40 Additional Metal Processing Unit Operations (Introduced in 40 CFR Part 433)	
• Electroplating	• Cleaning	• Laser beam machining
• Electroless plating	• Machining	• Plasma arch machining
• Anodizing	• Grinding	• Ultrasonic machining
• Coating	• Polishing	• Sintering
• Etching and chemical milling	• Barrel finishing	• Laminating
• Printed circuit board manufacturing	• Burnishing	• Hot dip coating
	• Impact deformation	• Sputtering
	• Pressure deformation	• Vapor plating
	• Shearing	• Thermal infusion
	• Heat treating	• Salt bath descaling
	• Thermal cutting	• Solvent degreasing
	• Welding	• Paint stripping
	• Brazing	• Painting
	• Soldering	• Electrostatic painting
	• Flame spraying	• Electropainting
	• Sand blasting	• Vacuum metalizing
	• Abrasive jet machining	• Assembly
	• Electrical discharge machining	• Calibration
	• Electrochemical machining	• Testing
	• Electron beam machining	• Mechanical plating

Source: 40 CFR Part 433.

In some cases, ELGs for other industrial categories may be effective and applicable to wastewater discharges from metal finishing operations. The rule specified the following regulations that take precedence over 40 CFR Parts 413 and 433 when such an overlap occurs:

- Nonferrous Smelting and Refining (40 CFR Part 421);
- Coil Coating (40 CFR Part 465);
- Porcelain Enameling (40 CFR Part 466);
- Battery Manufacturing (40 CFR Part 461);
- Iron and Steel Manufacturing (40 CFR Part 420);
- Metal Casting Foundries (40 CFR Part 464);
- Aluminum Forming (40 CFR Part 467);
- Copper Forming (40 CFR Part 468);
- Plastic Molding and Forming (40 CFR Part 463);
- Electrical and Electronic Components (40 CFR Part 469);[4] and
- Nonferrous Forming (40 CFR Part 471).[12]

During the development of the Metal Products and Machinery (MP&M) rule (40 CFR Part 438, promulgated in 2003), EPA evaluated all industries involved in the "manufacture, rebuild or maintenance of metal parts, products, or machines," including facilities in the

[12] 40 CFR Parts 469 and 471 were added in the corrections to the final rule dated September 26, 1983.

Electroplating and Metal Finishing Categories. EPA proposed limits for these facilities under four MP&M subcategories: general metals, metal finishing job shops, non-chromium anodizing, and printed wiring board (U.S. EPA, 2000). However, following consideration of comments submitted on the proposed MP&M regulation, EPA decided not to promulgate limits for these subcategories (68 FR 25690). Table 5-3 summarizes and compares these limits from the proposed MP&M regulation to the existing limits from the Metal Finishing and Electroplating ELGs.

Table 5-3. Comparison of Maximum Monthly Average Effluent Limits Between Parts 413 and 433 and the Proposed Limits for Part 438

Regulation		Electroplating 40 CFR Part 413[a]		Metal Finishing 40 CFR Part 433		Metal Products and Machinery 40 CFR Part 438 Proposed Limits							
Subcategories		>10,000 gpd[b]	<10,000 gpd[b]	Metal Finishing		General Metals		Metal Finishing Job Shops		Non-Cr Anodizing		Printed Wiring Board	
Standards		PSES Only		NSPS/ PSNS	BAT/ PSES	NSPS/ PSNS	BAT/ PSES[c]	NSPS/ PSNS	BAT/ PSES	NSPS Only	BAT Only	NSPS/ PSNS	BAT/ PSES
Pollutant	Unit												
TSS[d]	mg/L					18	18	18	31	22	31	18	31
Oil and grease[d]	mg/L					12	12	12	26	12	26	12	26
TOC	mg/L					50	50	59	59			67	67
Total organics parameter	mg/L					4.3	4.3	4.3	4.3			4.3	4.3
Total metals	mg/L	5.0											
Aluminum	mg/L									4.0	4.0		
Cadmium	mg/L	0.5	0.5	0.07	0.26	0.01	0.09	0.01	0.09				
Chromium	mg/L	2.5		1.71	1.71	0.07	0.14	0.07	0.55			0.07	0.14
Copper	mg/L	1.8		2.07	2.07	0.16	0.28	0.16	0.57			0.01	0.28
Total cyanide	mg/L	0.23		0.65	0.65	0.13	0.13	0.13	0.13			0.13	0.13
Amenable cyanide	mg/L		1.5	0.32	0.32	0.07	0.07	0.07	0.07			0.07	0.07
Lead	mg/L	0.3	0.3	0.43	0.43	0.03	0.03	0.03	0.09			0.03	0.03
Manganese	mg/L					0.18	0.09	0.18	0.10	0.09	0.09	0.18	0.64
Molybdenum	mg/L					0.49	0.49	0.49	0.49				
Nickel	mg/L	1.8		2.38	2.38	0.75	0.31	0.75	0.64	0.31	0.31	0.75	0.14
Silver	mg/L	0.5[e]		0.24	0.24	0.03	0.09	0.03	0.06				
Sulfide, total	mg/L					13	13	13	13			13	13
Tin	mg/L					0.03	0.67	0.03	1.4			0.07	0.14
Zinc	mg/L	1.8		1.48	1.48	0.06	0.22	0.06	0.17	0.22	0.22	0.06	0.22

Sources: (U.S. EPA, 1979; U.S. EPA, 1983; U.S. EPA, 2000).

Gray highlighting indicates that no limits were set for the pollutant.

[a] See 40 CFR Part 413 for alternative mass-based limits. Facilities could comply with either concentration-based or mass-based limits.

[b] EPA established discharge limits based on a wastewater production threshold of 10,000 gallons per day. Similar limits were set for all six subparts of Part 413, except where noted in footnote e.

[c] Part 438 proposed a minimal flow rate of 1 million gallons per year to trigger compliance with PSES.

[d] Part 438 did not propose TSS and oil and grease limits for PSES or PSNS.

[e] The silver pretreatment standard applies only to Subpart B, precious metals plating.

5.1.2 Profile of Metal Finishing Operations in the U.S.

As part of the 2014 Annual Review, EPA updated and evaluated the current industry profile for the Metal Finishing Category. This section identifies the number of facilities currently regulated under the category (40 CFR Part 433), the types of metal finishing operations and discharge practices that are in use, and the types of wastewater treatment technologies that are available or are being evaluated for treating metal finishing wastewater.

5.1.2.1 Number of Facilities

At promulgation of the 1983 Metal Finishing ELGs, the Metal Finishing and Electroplating Categories included a total of 13,470 facilities, consisting of 10,000 captive facilities and 3,470 job shops and IPCB manufacturers (U.S. EPA, 1984). The existing captive facilities ultimately fell into the Metal Finishing Category (after the final compliance date) and the 3,470 job shops and IPCB manufacturers remained in the Electroplating Category.

EPA evaluated the metal finishing industry, as part of the MP&M Rulemaking efforts. EPA estimated that about 12,700 facilities were performing metal finishing operations, classified into four general subcategories (U.S. EPA, 2000): general metals, metal finishing job shops, non-chromium anodizing, and printed wiring boards (see Table 5-4). These estimates were primarily based on responses to industry surveys sent to facilities in 1989 and 1996.

Table 5-4. Estimated Number of Metal Finishing Facilities Identified During the MP&M Rulemaking Efforts

Applicable Subpart in Proposed Part 438	Subpart Description	Number of Facilities
General Metals	This subcategory was created as a catch-all for facilities that discharge metal-bearing wastewater (with or without oil-bearing wastewater) but do not fall under the other MP&M subcategories. It may cover more than just facilities in the Metal Finishing Category.	10,484
Metal Finishing Job Shops	This subcategory included facilities covered under 40 CFR Part 413.	1,491
Non-Chromium Anodizing	This subcategory includes facilities that perform aluminum anodizing without using chromic acid or dichromate sealants.	93
Printed Wiring Boards[a]	This subcategory covers wastewater discharges from the manufacture, maintenance, and repair of printed wiring boards (i.e., circuit boards), excluding IPCB manufacturers that are job shops.	609
Total Number of Facilities		**12,677**

Source: (U.S. EPA, 2000)

a Also known as IPCB manufacturers in Parts 413 and 433.

The scope of facilities included in the Metal Finishing Category is based on process operations rather than industry sectors; therefore, facilities to which the Metal Finishing ELGs may apply can be classified under various metal processing and metal forming industry classifications. The *Guidance Manual for Electroplating and Metal Finishing Pretreatment*

Standards identified the following two-digit Standard Industrial Classification (SIC) codes under which regulated facilities generally fall (U.S. EPA, 1984):[13]

- 34: Fabricated Metal Products, Except Machinery and Transportation;
- 35: Machinery, Except Electrical;
- 36: Electrical and Electronic Machinery, Equipment and Supplies;
- 37: Transportation Equipment;
- 38: Measuring, Analyzing and Controlling Instruments: Photograph; Optical Goods; Watches and Clocks; and
- 39: Miscellaneous Manufacturing Industries.

In the conversion of the SIC system to the North American Industry Classification System (NAICS) in the late 1990s, EPA reviewed these SIC codes and determined that they corresponded to 200 NAICS codes under which facilities for the Metal Finishing Category could be identified. See EPA's *Technical Support Document for the Annual Review of Existing Effluent Guidelines and Identification of Potential New Point Source Categories,* known as the 2009 Screening-Level Analysis or SLA Report, for additional details (U.S. EPA, 2009).

As part of the 2014 Annual Review, EPA searched for more recent data to determine the number of facilities that fall into the Metal Finishing Category. The 2007 Economic Census provides a general industry description for each NAICS code under which these facilities may fall; however, it does not detail facility-specific process operations or wastewater discharge practices, which is the basis for determining whether the Metal Finishing ELGs would apply to specific facilities. In the 2011 Annual Review, EPA identified 166,356 facilities included in the 2007 Economic Census for the 200 NAICS codes. However, this number includes establishments that are distributors or sales facilities, not just manufacturers (U.S. EPA, 2012). It may also include facilities that do not conduct the six core operations and would not be regulated under the Metal Finishing ELGs. In previous annual reviews, EPA has identified the number of facilities submitting discharge monitoring reports (DMRs) and reporting to EPA's TRI. However, EPA determined that these data sources include only a fraction of the facilities that would fall under the applicability of the Metal Finishing Category due to the limitations of the data sets. For example, small establishments (less than 10 employees) are not required to report to TRI, and DMR data are limited concerning indirect discharges from industrial facilities to POTWs. See the 2009 SLA Report (U.S. EPA, 2009) for more details on the limitations of these data sets. Therefore, these data sources do not provide a complete picture of the metal finishing industry. The scope of facilities reporting to DMR and TRI is further discussed in Section 5.1.2.3.

Some EPA regions have maintained lists of industrial users subject to 40 CFR Part 433 that discharge metal finishing wastewater to POTWs; however, a national inventory of metal finishing facilities does not exist. For the 2014 Annual Review, EPA was not able to determine how the industry is currently distributed between job shops, IPCB manufacturers, and captive

[13] Although facilities performing metal finishing operations generally fall under these SIC codes, not all facilities under the codes may be subject to the Metal Finishing ELGs. These facilities may not perform the six electroplating operations that would require them to comply with the Metal Finishing ELGs. Additionally, these facilities may be subject to other metal ELGs that take precedence over the Metal Finishing ELGs.

integrated and non-integrated facilities based on available information. This is primarily because the applicability of the ELGs are based on operations not industry sectors; therefore, it is difficult to identify how many of the estimated facilities would be covered by the rule and how the distribution of facilities may have changed over time. EPA did not conduct a survey as part of the 2014 Annual Review to obtain updated industry profile information.

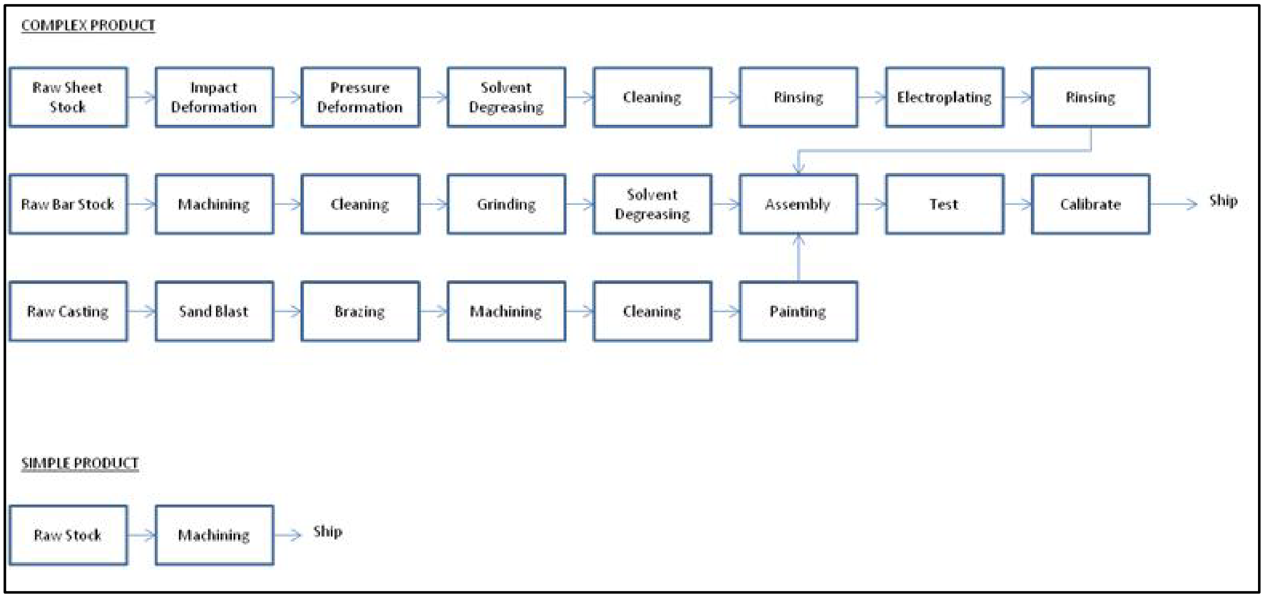
Based on a recent 2008 National Center for Manufacturing Sciences review of the surface finishing industry (including metal finishing), the industry has trended toward an extremely fragmented market since 1983, with market competition dispersed among many companies. With expanding global markets, U.S. firms have more recently attempted to concentrate the industry (i.e., incorporate the smaller job shops into larger companies) to achieve economies of scale, expand niche markets, and provide a larger range of finishing services in a global market. Many firms have also shifted surfacing operations to non-U.S. locations such as Asia, India, Mexico, Canada, and Europe to further reduce costs (Chalmer, 2008).

5.1.2.2 Metal Finishing Operations

Metal finishing is the process of changing the surface of an object by creating a thin layer of metal or metal precipitate on the surface to impart the desired surface characteristics to the final product, such as corrosion resistance, wear resistance, and hardness. The operations performed and the sequence of operations at a metal finishing facility can vary and depend on a number of factors (e.g., raw materials used, industry sector, product specifications) and may result in significant wastewater generation (U.S. EPA, 2000).

The Metal Finishing ELGs cover wastewater discharges from six primary metal finishing operations and where these operations apply; the ELGs also cover wastewater discharges from 40 supplemental metal finishing operations (as listed in Table 5-2, and further described in Appendix C). Metal finishing operations usually begin with materials in the form of raw stock (rods, bars, sheets, castings, forgings, etc.) and can progress to the most sophisticated surface finishing operations. Because of the differences in facility size and processes, production facilities are custom-tailored to the specific needs of each individual plant. Figure 5-1 illustrates the variation in the number of unit operations that can be performed in facilities within the metal finishing industry, depending upon the complexity of the product. The possible variations of unit operations within the metal finishing industry are extensive and could require the use of nearly all unit operations, while a simple product might require only a single operation (U.S. EPA, 1983).

Many different raw materials are used by facilities in the Metal Finishing Category. During the development of the 1983 Metal Finishing ELGs, the basis materials were almost exclusively metals which range from common copper and steel to extremely expensive high grade alloys and precious metals, but may also include glass, plastic, and other non-conductive materials. The materials used in metal finishing unit operations can contain acids, bases, cyanide, metals, complexing agents, organic additives, oils and detergents. All of the basis materials and finishing raw materials can potentially enter wastewater streams during the production sequence.



Adapted from (U.S. EPA, 1983)

Figure 5-1. Metal Finishing Process Application

Since the promulgation of the Metal Finishing ELGs, process technologies and chemistries have evolved. Materials currently used in industry include the following:

- *Transition metal coatings (TMCs) with oxides of zirconium, vanadium, and titanium* (Dunham, 2013; Hopwood, 2012). Environmental regulations restricting phosphate and chromium discharges make traditional metal coatings, which include iron and zinc phosphate and chromium conversion coatings, less desirable. The application of TMCs uses a fluorozirconic or fluorotitanic acid or the more commonly used nitric acid (in place of phosphoric acid solvent) (Hopwood, 2012; LaFlamme, 2009). Application of TMCs generates less volume of sludge and less toxic sludge that is not subject to hazardous waste disposal regulations (Dunham, 2013). Application of TMCs also generates wastewater that is phosphate-free; however, the wastewater may contain metals that do not have specific discharge effluent limits in the Metal Finishing ELGs (e.g., zirconium, vanadium, and titanium).

- *Trivalent chromium coatings,* to replace hexavalent chromium coatings for conventional chromium plating on aluminum, stainless steel, nickel, zinc-nickel alloys, and magnesium alloys (Manavbasi, 2012; U.S. EPA, 2013). Trivalent chromium is a less toxic oxidation state of chromium. Use of trivalent coatings also provides operational cost savings because it eliminates the need for wastewater pretreatment to reduce hexavalent chromium to its more treatable trivalent form (Weber, 2013).

- *Electrodeposited aluminum, zinc-nickel finish, and nickel fluorocarbon polymer* as alternate finishes to cadmium plating for aerospace applications. These alternative finishes are applied to aluminum objects using electrodeposition and eliminate cadmium in wastewater generated during this process (Ogundiran, 2011). Metal Finishing ELGs contain limitations for cadmium, zinc, and nickel, but do not contain limitations for aluminum.

- *Molybdate-based self-healing coatings,* to replace self-healing hexavalent chromium coatings on aluminum in the defense and aerospace industry. The coating formulation performs comparably to hexavalent chromium coatings and can be applied to all aluminum products to provide a corrosion protective surface that will heal itself when damaged (Wolterbeek, 2012). Use of this alternative coating eliminates hexavalent chromium in wastewater generated during this process.

- *Graphene nanocomposite coatings,* to replace hexavalent chromium for hard chromium plating applications. Use of this process technology eliminates the use and subsequent handling of hexavalent chromium in spent plating baths and rinsewater (Dennis, 2014).

- *High-velocity oxygen-fueled thermal spray application,* to replace hard chromium electroplating. This process technology provides a dry coating application process, which eliminates the need for spent chromium plating baths and reduces the amount of wastewater generated. Use of this process may generate additional waste streams, including overspray powder and post-treatment grinding coolant wastes (Legg, n.d.).

These emerging processes have not yet been widely applied for many metal finishing operations, and Chalmer anticipates that many operations will continue to use traditional inputs through 2020 (Chalmer, 2008).

5.1.2.3 Discharge Practices

Metal finishing wastewater comprises primarily rinsewater from rinsing and drying steps during the metal finishing process. In the Metal Finishing Rulemaking development, EPA identified 10,561 out of 13,470 facilities (or 78 percent) that indirectly discharge to surface water via POTWs. These facilities were evenly distributed between job shops, non-integrated captive facilities, and integrated captive facilities. The remaining 2,909 facilities (or 22 percent) directly discharged to surface water, with captive facilities (both integrated and non-integrated) predominantly performing this practice (U.S. EPA, 1983). The 1983 rule did not capture the number of facilities in the industry that reused wastewater.

During the MP&M Rulemaking development, EPA looked at a broad range of industries, including the metal finishing industry, and estimated that 92 percent of the facilities to which the rule would apply were indirect dischargers and 7 percent were direct dischargers. A small percentage of facilities performed both direct and indirect discharge practices (U.S. EPA, 2000). As with the Metal Finishing ELGs, EPA did not evaluate the number of facilities reusing wastewater.

Using the DMR Pollutant Loading Tool, EPA reviewed the number of facilities with NPDES permits that allow them to directly discharge to surface waters as well as the number of facilities reporting direct and indirect discharges to EPA's TRI program, which may provide a relative indication of current discharge practices. Table 5-5 provides a summary of the facilities reporting to DMR and TRI from 2010 to 2012. The DMR data represent the universe of direct dischargers reporting under the 200 NAICS codes that generally cover facilities in the Metal Finishing Category. Compared to the approximate 12,700 facilities in the Metal Finishing Category (see Section 5.1.2.1), fewer than 6 percent of the facilities had permits to directly discharge in 2012. Additionally, nearly 90 percent of the direct dischargers are classified as minor dischargers.[14] The majority of facilities reporting to TRI are indirect dischargers, which is consistent with the historic profiles of the Metal Finishing industry. However, the number of facilities and estimated discharges associated with both indirect and direct discharging facilities reporting to TRI provide an incomplete representation of the industry. TRI data are limited because reporting is required for a select number of facilities depending on the industry sector, number of employees, and activity thresholds (see the 2009 SLA Report (U.S. EPA, 2009) for additional details on limitations of the data sets).

Table 5-5. Number of Metal Finishing Facilities by Discharge Practice

Year	DMR[a]			TRI			
	Minor Dischargers	Major Dischargers	Total	Indirect Discharge Only	Direct Discharge Only	Both Indirect and Direct Discharge	Total
2010	807	79	886	1,290	276	268	1,834
2011	714	76	790	1,241	279	270	1,790
2012	639	72	711	1,218	267	247	1,732

Source: DMR Pollutant Loading Tool.

a Facilities reporting to DMR are direct dischargers only.

Because facilities reusing wastewater are not required to report metal finishing operations and wastewater handling practices under DMR or TRI, EPA could not determine the number of facilities engaged in and the currently employed practices for wastewater recovery and reuse. However, according to regional EPA pretreatment coordinators, efforts to minimize and eliminate wastewater discharges are becoming more common for the industry.

5.1.2.4 Metal Finishing Wastewater Characteristics

Water is used for rinsing workpieces, washing away spills, air scrubbing, process fluid replenishment, cooling and lubrication, washing of equipment and workpieces, quenching, spray booths and assembly and testing during the metal finishing process. Plating and cleaning operations are typically the biggest water users. While the majority of metal finishing operations use water, some of them are completely dry. Table 5-6 provides a summary of the anticipated water usage by unit operation, as evaluated during the development of the 1983 Metal Finishing

[14] To provide an initial framework for permitting priorities, EPA developed a major/minor classification system for industrial and municipal wastewater discharges. Major discharges usually have the capability to impact receiving waters if not controlled and, therefore, have received more regulatory attention than minor discharges. Major/minor classifications are determined by permitting authorities and vary state to state. See Section 3.2.4 from EPA's *2013 Annual Review Report* for more information (U.S. EPA, 2014b).

ELGs. The type of rinsing can have a marked effect on water use as can the flow rates within the particular rinse types. Product quality requirements often dictate the amount of rinsing needed for specific parts. Parts requiring extensive surface preparation will generally necessitate the use of larger amounts of water (U.S. EPA, 1983). This wastewater may require further treatment before discharge and can be directly discharged to surface water, indirectly discharged through POTWs, or recycled/reused.

Table 5-6. Water Use by Unit Operation

Unit Operation		Major Water Use	Minimal Water Use	Zero Discharge
1	Electroplating	x		
2	Electroless Plating	x		
3	Anodizing	x		
4	Conversion Coating	x		
5	Etching (Chemical Milling)	x		
6	Cleaning	x		
7	Machining	x		
8	Grinding	x		
9	Polishing		x	
10	Tumbling (Barrel Finishing)	x		
11	Burnishing		x	
12	Impact Deformation		x	
13	Pressure Deformation		x	
14	Shearing		x	
15	Heat Treating	x		
16	Thermal Cutting		x	
17	Welding	x		
18	Brazing		x	
19	Soldering		x	
20	Flame Spraying		x	
21	Sand Blasting	x		
22	Other Abrasive Jet Machining		x	
23	Electric Discharge Machining		x	
24	Electrochemical Machining		x	
25	Electron Beam Machining			x
26	Laser Beam Machining			x
27	Plasma Arc Machining			x
28	Ultrasonic Machining			x
29	Sintering			x
30	Laminating		x	
31	Hot Dip Coating		x	
32	Sputtering			x
33	Vapor Plating			x
34	Thermal Infusion			x
35	Salt Bath Descaling	x		
36	Solvent Degreasing		x	
37	Paint Stripping	x		
38	Painting	x		
39	Electrostatic Painting	x		
40	Electropainting	x		

Table 5-6. Water Use by Unit Operation

Unit Operation		Major Water Use	Minimal Water Use	Zero Discharge
41	Vacuum Metalizing			x
42	Assembly		x	
43	Calibration			x
44	Testing	x		
45	Mechanical Plating	x		
46	Printed Circuit Board Manufacturing	x		

Source: (U.S. EPA, 1983)

Although wastestream characteristics may vary depending on the unit operations used in the metal finishing process, according to the 1983 Metal Finishing ELGs, wastestreams were generally characterized by the types of inorganic and organic constituents, as listed in Table 5-7 (U.S. EPA, 1983).

Table 5-7. Waste Characteristics by Unit Operation

Waste Characteristics		Inorganics				Organics		
		Common Metals	Precious Metals	Complexed Metals	Chromium (Hexavalent)	Cyanide	Oils	Toxic Organics
Unit Operation								
1	Electroplating	x	x		x	x		
2	Electroless Plating	x	x	x		x		
3	Andodizing	x			x			
4	Conversion Coating	x	x		x	x		
5	Etching (Chemical Milling)	x	x	x	x			
6	Cleaning	x	x	x	x	x	x	x
7	Machining	x					x	
8	Grinding	x					x	
9	Polishing	x	x				x	
10	Tumbling	x			x	x	x	
11	Burnishing	x	x			x	x	
12	Impact Deformation	x					x	
13	Pressure Deformation	x					x	
14	Shearing	x					x	
15	Heat Treating	x				x	x	x
16	Thermal Cutting	x						
17	Welding	x						
18	Brazing	x						
19	Soldering	x		x				
20	Flame Spraying	x						
21	Sand Blasting	x						
22	Other Abrasive Jet Machining	x					x	
23	Electric Discharge Machining	x					x	
24	Electrochemical Machining	x				x	x	x

Table 5-7. Waste Characteristics by Unit Operation

Waste Characteristics		Inorganics				Organics		
		Common Metals	Precious Metals	Complexed Metals	Chromium (Hexavalent)	Cyanide	Oils	Toxic Organics
Unit Operation								
25	Electron Beam Machining	x						
26	Laser Beam Machining	x						
27	Plasma Arc Machining	x						
28	Ultrasonic Machining	x						
29	Sintering	x						
30	Laminating	x						
31	Hot Dip Coating	x						
32	Sputtering	x						
33	Vapor Plating	x						
34	Thermal Infusion	x						
35	Salt Bath Descaling	x					x	
36	Solvent Degreasing	x					x	x
37	Paint Stripping	x					x	x
38	Painting	x					x	x
39	Electrostatic Painting	x			x		x	x
40	Electropainting	x						x
41	Vacuum Metalizing	x						
42	Assembly	x					x	x
43	Calibration	x					x	
44	Testing	x					x	
45	Mechanical Plating	x			x			
46	Printed Circuit Board Manufacturing	x	x	x	x	x		x

Source: (U.S. EPA, 1983)

During the 2012 Annual Review, EPA's review of the TNSSS, combined with available TRI indirect discharge data, identified the Metal Finishing Category (40 CFR Part 433) as potentially discharging high concentrations of metals, particularly chromium, nickel, and zinc, to POTWs. These metals could transfer to sewage sludge and diminish its beneficial use (U.S. EPA, 2014a). For the 2014 Annual Review, EPA reviewed 2011 DMR and TRI facility pollutant discharge data for the Metal Finishing Category and identified the top pollutants discharged by the industry in terms of TWPE, as listed in Table 5-8 and Table 5-9, respectively. Table 5-8 and Table 5-9 also identify whether the pollutants are currently regulated under 40 CFR Part 433. This analysis confirms discharges of nickel and zinc, which are currently regulated by the Metal Finishing ELGs. As stated above, however, TRI reporting is only required for select facilities. In addition, TRI discharges may be estimated, not actually measured. Therefore, the number of facilities and estimated discharges associated with both indirect- and direct-discharging facilities reporting to TRI is an incomplete representation of the industry; see the 2009 SLA Report (U.S. EPA, 2009) for additional details on limitations of TRI.

Table 5-8. Metal Finishing Category Top 2011 DMR Pollutants

Reported Pollutant	Number of Facilities Reporting Pollutant Discharges	TWPE	% of TWPE	Regulated Pollutant Under 40 CFR Part 433
PCB-1248[a]	2	44,200	29.1	No
Polychlorinated biphenyls (PCBs)[a]	3	28,200	18.5	No
Chrysene	8	24,400	16.0	No
Silver, total (as Ag)	13	10,700	7.0	Yes
PCB-1268[a]	1	9,310	6.1	No
Zinc, total (as Zn)	113	5,560	3.7	Yes
Chlorine, total residual	83	3,570	2.3	No
PCB-1260[a]	1	3,220	2.1	No
Lead, total (as Pb)	41	3,040	2.0	Yes
Copper, total (as Cu)	111	2,950	1.9	No
Copper, total recoverable	28	2,870	1.9	Yes
Top Pollutant Total		**138,000**	**90.7**	**NA**
Metal Finishing Category Total		**152,000**	**100.0**	**NA**

Source: DMR Pollutant Loading Tool.

NA: Not applicable.

[a] "Polychlorinated biphenyls (PCBs)" refers to the grouping of PCB compounds; PCB-1248, PCB-1268, and PCB-1260 are individual PCB compounds. Facilities may report PCBs as a grouping or as individual compounds, depending on what is specified in their permits.

Table 5-9. Metal Finishing Category Top 2011 TRI Pollutants

Reported Pollutant	Number of Facilities Reporting Pollutant Discharges	TWPE	% of TWPE	Regulated Pollutant Under 40 CFR Part 433
Copper and copper compounds	692	13,600	18.7	Yes (as total copper)
Lead and lead compounds	734	11,100	15.1	Yes (as total lead)
Silver and silver compounds	15	10,800	14.9	Yes (as total silver)
Mercury and mercury compounds	13	5,160	7.1	No
Nitrate compounds	208	2,710	3.7	No
Manganese and manganese compounds	357	2,070	2.8	No
Zinc and zinc compounds	268	1,640	2.2	Yes (as total zinc)
Nickel and nickel compounds	599	1,400	1.9	Yes (as total nickel)
Top Pollutant Total		**48,500**	**94.3**	**NA**
Metal Finishing Category Total		**51,700**	**100**	**NA**

Source: *TRILTOutput2011_v1*.

NA: Not applicable.

As discussed in Section 5.1.2.2, EPA determined that new chemical alternatives in the industry could generate wastewater containing pollutants that are not currently regulated under the Metal Finishing ELGs (40 CFR Part 433). Existing processes have used base metals such as aluminum, calcium, magnesium, manganese, iron, and tin. Some emerging processes use titanium, zirconium, vanadium, and nanocomposites that were not considered in the Metal Finishing ELGs (Dennis, 2014; Dunham, 2013). Additionally, there are new chemical formulations used in cleaning, surface treatment, and post-treatment operations, including fluorides, sulfides, borates, phosphates, nitrates, and sulfates. These potential new pollutants of concern are not currently regulated by the Metal Finishing ELGs and are not currently reported to DMR or TRI; therefore, EPA is uncertain at this point about the extent of their presence in metal finishing wastewater.

In EPA's discussions with regional EPA pretreatment coordinators, the coordinators did not identify any issues related to the treatability of metal finishing wastewater at POTWs, particularly related to chromium, nickel, and zinc. However, the pretreatment coordinators did note concern about potential new pollutants introduced by more recent chemical alternatives used in metal finishing. For example, coordinators were concerned about the increasing use of nanotechnologies in metal finishing processes, which involve nanoscale metal particles that may not have existing methods of detection, regulation, and treatment. (EPA's review of engineered nanomaterials in industrial wastewater is discussed in Section 6.1 of this report). In addition, pretreatment coordinators expressed concern about new pollutants generated as a result of the use of wet air pollution controls on metal finishing operations to comply with air regulations. Specifically, chemical additives used in wet air pollution controls may be introduced into facility wastewater, which is subsequently sent to POTWs or is discharged directly to surface water. EPA did not further explore the impact of wet air pollution controls during the 2014 Annual Review.

The regional EPA pretreatment coordinators also mentioned the need for hexavalent chromium limits for metal finishing wastewaters. In the Metal Finishing ELGs, total chromium limits are set without any specific limits for the discharge of hexavalent chromium, chromium's more toxic form. The pretreatment coordinators indicated that smaller metal finishing facilities generally do not employ chromium reduction operations to reduce hexavalent chromium to its less toxic form (i.e., trivalent chromium) if the total chromium limits are met before discharge. Some POTWs are setting more stringent local limits on hexavalent chromium from metal finishing wastewater. Several pretreatment coordinators suggested that EPA consider developing limits specific to hexavalent chromium to reduce its potential discharge to POTWs and surface water.

5.1.2.5 Review of Metal Finishing Wastewater Treatment Technologies

In 1983, EPA set BAT and PSES limits to control discharges of toxic metals, toxic organics, and cyanide from the Metal Finishing Category. These standards were based on the best practicable control technology (BPT) for the industry at that time and include physical-chemical precipitation followed by clarification with additional cyanide oxidation and chromium reduction pretreatment steps where these pollutants are present in the wastewater stream (U.S. EPA, 1983). This section further discusses the wastewater treatment technologies that are prevalent in the industry, as well as advanced treatment technologies and zero-discharge or reuse practices that are emerging within the industry for the treatment and/or recycling of metal finishing wastewater.

5.1.2.5.1 Commonly Used Technologies for the Treatment of Metal Finishing Wastewater

EPA's review indicates that physical-chemical precipitation, clarification, chromium reduction, and cyanide oxidation are prevalent technologies for the treatment of metal finishing wastewater. The regional EPA pretreatment coordinators have observed that a vast majority of metal finishing operations that treat metal finishing wastewater for discharge can meet the current Metal Finishing ELGs using these treatment technologies. Industry literature also confirms the prevalence of these technologies, with minor modifications to improve the solids separation stage. Facilities may also add a filtration/polishing step or replace the flocculation and clarification steps with direct microfiltration to improve solids removal (Weber, 2013).

During the development of the MP&M rule in 2003, EPA identified more advanced technologies for reducing metal discharges from metal finishing operations than those used as the basis for limitations in the Metal Finishing ELGs. The proposed rule's technology options for the subcategories encompassing the Metal Finishing Category included chemical precipitation with clarification, microfiltration, and ion exchange (to target removal of colloidal particles, heavy metal particulates, and their hydroxides).

EPA further reviewed the technologies that are prevalent for the treatment of metal finishing wastewater and identified limitations associated with their current application.

Chromium reduction means reducing the oxidation state of hexavalent chromium to trivalent chromium, which is less toxic and more amenable to chemical precipitation and clarification. Metal finishing operations using hexavalent chromium generally include a chromium reduction pretreatment step prior to chemical precipitation (U.S. EPA, 2000) . Recent efforts to replace hexavalent chromium with trivalent chromium in metal finishing operations (such as those described in Section 5.1.2.2) would eliminate this pretreatment step; however, according to industry literature, trivalent chromium may cause its own problems in wastewater treatment. Operations using trivalent chromium may generate chromium complexes in the wastewater that would require a separate pretreatment step to breakdown these complexes into treatable constituents prior to chemical precipitation (Weber, 2013).

Cyanide oxidation most commonly uses an alkaline chlorination process that treats simple cyanides in the process wastewater prior to the chemical precipitation step. Complexed cyanides must be treated separately using a high-pressure, high-temperature thermal process. Industry sources indicate that complexed cyanides are generally the cause of pretreatment violations (Weber, 2013).

Metal finishing wastewater may contain complexing and chelating agents, which are important constituents of some plating operations, especially electroless plating, immersion plating, and printed circuit board manufacturing. These agents may also produce metal complexes that present a problem for effective metal removal, since they hinder the formation of precipitates in the chemical precipitation system (U.S. EPA, 1979; U.S. EPA, 1984). During the development of the Metal Finishing ELGs, EPA recommended segregated treatment of the complexed metal wastes. Among the proposed technologies were high-pH precipitation to break down the complexes and precipitate the metal ions, sulfide precipitation, and ferrous sulfate precipitation. In the MP&M proposed rule, EPA identified pretreatment steps to break down the chelates using reducing agents such as sodium borohydride, hydrazine, dithiocarbamate (measured analytically as ziram), or sodium hydrosulfite; using high-pH precipitation with calcium hydroxide or ferrous sulfate addition; or filtering the chelated metals out of solution prior to chemical precipitation (U.S. EPA, 2000). EPA is not certain which current technologies are most commonly used to treat complexed metal waste from metal finishing operations.

Regional EPA pretreatment coordinators indicate that some smaller facilities can meet pretreatment standards without implementing chemical precipitation and clarification treatment of metal finishing wastewater. These smaller facilities may generate small volumes of metal finishing wastewater for which they can store, monitor, and control the frequency of discharge. The smaller facilities may also discharge dilute rinse water, but use other management practices for plating baths, such as wastewater disposal at centralized waste treatment facilities or in onsite evaporations tanks or they may use advanced closed-loop/reuse practices. The practice of diluting rinse water as a partial or total substitute for adequate treatment to achieve compliance with discharge limits is in violation of the National Pretreatment Standards: Categorical Standards (40 CFR Part 403.6(d)). See below for more discussion on advanced closed-loop/reuse practices.

5.1.2.5.2 Emerging Technologies for the Treatment of Metal Finishing Wastewater

In most cases, the use of chemical precipitation and clarification with optional pretreatment of chromium and cyanide has been sufficient to meet the Metal Finishing ELGs. However, more advanced treatment technologies are emerging. Based on more recent observations from the regional EPA pretreatment coordinators and industry sources, emerging technologies are being used to some extent, but are not yet widespread within the industry.

To identify emerging technologies that are being evaluated and/or implemented, EPA reviewed recent literature gathered to develop and populate the Industrial Wastewater Treatment Technology (IWTT) database (for more information on the IWTT database, see Section 6.2 of this report). A query of the IWTT database produced nine articles with performance data on the treatment of metal finishing wastewater. A majority of these articles document the performance of pilot-scale systems that facilities are implementing to evaluate treatment performance. Table 5-10 summarizes these systems' treatment effectiveness.

As the table shows, a variety of wastewater treatment technologies (or combinations of technologies) have been tested to treat metal finishing wastewater, including electrocoagulation and membrane bioreactors. These systems target a range of regulated pollutants such as cadmium, chromium, nickel, and zinc, as well as non-regulated pollutants such as iron, manganese, and tin. The majority of the treatment performance data for these technologies target metal removals and show a percent removal of greater than 90 percent, reaching effluent concentrations sometimes orders of magnitude below current effluent limitations.

Table 5-10. Summary of Wastewater Treatment Technologies for End-of-Pipe Discharge of Metal Finishing Wastewater

Wastewater Treatment (Order of Unit Processes)	Type of Wastewater Treated	Treatment Scale (Pilot- or Full-Scale)	Metals Treated	Effluent Concentration (mg/L)	Percent Removal	Metal Finishing Monthly Average ELG Limit (40 CFR Part 433)		Article Source
						NSPS/PSNS	BAT/PSES	
Adsorptive media	Electroplating process wastewater	Pilot	Chromium, hexavalent	Not provided	79	NA	NA	(Lv, 2013)
Aerobic fixed film biological treatment, chemical precipitation, powdered activated carbon	Electroplating process wastewater	Pilot	Chromium, hexavalent	<0.05	>99.8	NA	NA	(Ahmad, 2010)
			Chromium, total	0.7	98.6	1.71	1.71	
			Iron	0.2	67.21	NA	NA	
			Manganese	0.15	53.13	NA	NA	
			Tin	<0.1	>66.67	NA	NA	
			Zinc	0.02	81.82	1.48	1.48	
Biological activated filters[a]	Chromium plating process wastewater	Pilot	Chromium, hexavalent	30,000	45.75	NA	NA	(Colica, 2012)
Electrocoagulation	Aircraft maintenance operations wastewater subject to 40 CFR Part 433 and 40 CFR Part 413 effluent limits	Pilot	Cadmium	0.012–0.126	75-99.9	0.07	0.26	(Firouzi, 2009a; Firouzi, 2009b; Firouzi, 2010)
			Chromium	0.031–7.204	84-99.91	1.71	1.71	
			Nickel	0.022–1.317	65.1-99.77	2.38	2.38	
Electrocoagulation followed by membrane filtration	Aircraft maintenance operations wastewater subject to 40 CFR Part 433 and 40 CFR Part 413 effluent limits	Pilot	Cadmium	0.004	98.58	0.07	0.26	(Firouzi, 2009b)
			Chromium	0.018	99.94	1.71	1.71	
			Nickel	0.07	99.48	2.38	2.38	
Flow equalization, anaerobic fixed film biological treatment, aerobic fixed film biological treatment	Metal working process wastewater	Pilot	Not provided	Not provided	Not provided	NA	NA	(Schuch, 2000)
Liquid extraction[a]	Metal plating wastewater	Pilot	Chromium, hexavalent	0.06	99.50	NA	NA	(Usinowicz, 2005)
			Chromium, total	0.72	96.57	1.71	1.71	

Table 5-10. Summary of Wastewater Treatment Technologies for End-of-Pipe Discharge of Metal Finishing Wastewater

Wastewater Treatment (Order of Unit Processes)	Type of Wastewater Treated	Treatment Scale (Pilot- or Full-Scale)	Metals Treated	Effluent Concentration (mg/L)	Percent Removal	Metal Finishing Monthly Average ELG Limit (40 CFR Part 433)		Article Source
						NSPS/PSNS	BAT/PSES	
Membrane bioreactor	Barge cleaning wastewater	Pilot	Copper	0.0105	70.60	2.07	2.07	(Buckles, 2003)
			Lead	0.001	77.30	0.43	0.43	
Membrane bioreactor, aerobic digestion[b]	Metal fabrication process wastewater from the automotive industry	Pilot and Full	Not provided	Not provided	Not provided	NA	NA	(Sutton, 2001)

NA: Not applicable.

[a] The article discusses wastewater treatment technology as applicable for end-of-pipe discharge and zero discharge.

[b] The article presents treatment information for pollutants such as chemical oxygen demand and oil and grease, but provides no treatment information for metals.

5.1.2.5.3 Technologies to Achieve a Zero-Discharge, Closed-Loop Process

A closed-loop process is a system that treats process wastewater to an acceptable quality to be returned back to the process for reuse (Candiloro, 2012). Unwanted contaminants removed from the wastewater are disposed of as solid waste; no wastewater is discharged. During the development of the MP&M rule EPA identified technology options that included wastewater management alternatives such as closed-loop and reuse practices using reverse osmosis and evaporation (U.S. EPA, 2000). Recent industry literature also identified technologies to purify process wastewater for recycling, which minimizes overall wastewater generation and discharge (McLay, 2013). Table 5-11 summarizes these waste minimization technologies and practices available to reduce the volume of wastewater discharged from metal finishing operations and to recover other process waste streams, such as plating baths, to be reused in the process.

Table 5-11. Summary of Waste Minimization Technologies for Reuse

Technology	Technology Description	Types of Wastewater Treated
Evaporation	An energy-intensive process of concentrating and returning a stream back to process by converting some of the liquid to vapor. The only process that can treat plating rinse waters back to or beyond original strength.	Plating baths, rinse waters, pretreated wastewater (brine for disposal)
Reverse osmosis	Separation of solutes from solvent using a high-pressure differential across a membrane. Limited application due to the high pressure requirement to overcome the significant osmotic pressure from the feed solution. Limited application to nickel plating rinsewater because the water returned is at too low a concentration to be completely recycled.	High total dissolved solids wastewater, nickel plating rinsewater (limited)
Electrodialysis	Configuration of stacked ion exchange membranes with two electrodes at both ends of the stacks to separate desirable compounds across a concentration (voltage) gradient with minimal energy consumption. Requires careful maintenance and periodic membrane regeneration.	Gold, silver, nickel, tin-containing solutions; nickel electroplating bath (slow circulation process)
Membrane electrolysis	Single-membrane process driven by electrolytic potential across an ion exchange membrane or diaphragm to remove metallic impurities.	Plating, anodizing, etching, stripping, and other metal-finishing process solutions, chromium plating baths, chrome conversion coating solutions
Diffusion dialysis	Multi-membrane technology to recover clean acid from spent acid solutions using a concentration gradient between deionized water and the process acid. Also generates an acidic waste stream that requires treatment.	Spent acid solutions, hydrofluoric/nitric acids, sulfuric/nitric and sulfuric/hydrochloric acids, battery acids
Ion exchange	Separation process for removing low concentrations of ionic compounds from dilute wastewater.	Noble metal recovery (including gold), chromate baths, rinse water

Table 5-11. Summary of Waste Minimization Technologies for Reuse

Technology	Technology Description	Types of Wastewater Treated
Electrowinning	Consists of three main components to recover metals from electroplating rinse water: an electrolytic cell, a rectifier, and a pump. The electrolytic cell is a tank in which cathodes and anodes are typically arranged in alternating order, attached to their respective bus bars, which supply the electrical potential to the unit.	Electroplating rinse water containing gold, silver, copper, cadmium, and zinc
Electrodeposition/ electrocoagulation	Metals recovery though cathodic deposition. Types of reactors include tank cells, plate and frame cells, rotating cells, fluidized beds, packed bed cells, and porous carbon packing cells.	Manganese-phosphate coating wastewater; cadmium-, copper-, zinc, and hexavalent chromium-containing water
Electroflotation	A process that floats pollutants to the surface of a water body by tiny bubbles of hydrogen and oxygen gases generated from water electrolysis.	Heavy-metal-containing wastewaters, gold and silver recovered from cyanide solutions

Sources: (Adhoum, 2004; Bloch, 2000; Chen, 2004; Firouzi, 2009a; Ince, 2013; Mahvi, 2007; McLay, 2013; U.S. EPA, 2000).

In addition, EPA identified six articles in a query of the IWTT database that presented performance data for the treatment of metal finishing wastewater for reuse. Table 5-12 summarizes the treatment effectiveness of these systems. A majority of the articles document the performance of pilot-scale systems that facilities are implementing to evaluate treatment performance and the quality of reuse water. As the results show, a variety of technologies (or combinations of technologies) have been tested to treat metal finishing wastewater for reuse, targeting a range of regulated pollutants such as chromium and nickel, as well as non-regulated pollutants such as calcium, magnesium, and sodium. The treatment technologies discussed in Table 5-12 do not always result in zero discharge: in some cases, they produce a concentrated waste stream that is handled as a hazardous waste.

Table 5-12. Summary of Wastewater Treatment Technologies for Reuse of Metal Finishing Wastewater

Wastewater Treatment (Order of Unit Processes)	Type of Wastewater Treated	Treatment Scale (Pilot- or Full-Scale)	Metals Treated	Effluent Concentration (mg/L)	Percent Removal	Metal Finishing Monthly Average ELG Limit (40 CFR Part 433)		Article Source
						NSPS/PSNS	BAT/PSES	
Biological activated filters[a]	Chromium plating process wastewater	Pilot	Chromium, hexavalent	30,000	45.75	NA	NA	(Colica, 2012)
Clarification, granular-media filtration, membrane filtration, bag and cartridge filtration, ultraviolet, reverse osmosis	Electroless nickel-plating process wastewater	Pilot	Calcium	0.02	99.90	NA	NA	(Qin, 2004)
			Nickel	<0.003	>99.90	2.38	2.38	
			Sodium	1.45	98.70	NA	NA	
Flow equalization, ion exchange, chemical precipitation, membrane filtration, reverse osmosis, evaporation	Automotive components manufacturing process wastewater	Full	Calcium	<1	>99.67	NA	NA	(Chan, 2011)
			Magnesium	<0.5	>99.8	NA	NA	
			Sodium, total (as Na)	<60	>95.00	NA	NA	
Granular-media filtration, bag and cartridge filtration, ultraviolet, granular activated carbon unit, membrane filtration, nanofiltration, ion exchange	Final rinse process wastewater from electroless plating operations	Pilot	Not provided	Not provided	Not provided	NA	NA	(Wong, 2002)
Liquid extraction[a]	Metal plating wastewater	Pilot	Chromium, hexavalent	0.06	99.50	NA	NA	(Usinowicz, 2005)
			Chromium, total	0.72	96.57	1.71	1.71	
Membrane filtration	Solvent cleaning rinse water from nickel-plating operations	Pilot	Not provided	Not provided	Not provided	NA	NA	(Qin, 2006)

NA: Not applicable.

a The article discusses wastewater treatment technology as applicable for end-of-pipe discharge and zero discharge.

b The article presents treatment information for pollutants such as chemical oxygen demand and oil and grease, but provides no treatment information for metals.

EPA regional pretreatment coordinators noted they have observed that smaller facilities, with smaller volumes of wastewater, can achieve zero discharge by implementing cost-effective alternatives. These alternatives include technologies such as evaporation tanks, which combined with storage and reuse, eliminate wastewater discharges. A 2008 study observed an increasing trend towards wastewater minimization practices during metal finishing operations at both small and large facilities throughout the industry (Chalmer, 2008). Larger facilities may use some of these practices, but because of the larger volumes of water used, they may not completely eliminate discharges. The extent of the use of the technologies identified in Table 5-11 is unknown.

5.1.3 Potential ELG Applicability Issues and Other Considerations

As part of the 2014 Annual Review, EPA discussed with regional EPA pretreatment coordinators any noticeable changes to the metal finishing industry over time and whether those changes may be impacting the POTW treatability of metal finishing wastewater. The regional pretreatment coordinators indicated that they have not encountered recent issues with POTW treatability of metal finishing wastewater; this includes issues involving nickel, chromium, and zinc, which were identified as pollutants of concern in the 2012 Annual Review (U.S. EPA, 2014a).

However, the regional pretreatment coordinators provided observations on issues arising from the implementation of the Metal Finishing ELGs. They noted some key topic areas for EPA's consideration:

- *Misapplication of the limits in permit applications.* Unlike other metal-related industries (e.g., aluminum forming, iron and steel), the Metal Finishing ELGs are concentration-based and are easier to apply in wastewater permits than the production-based standards. As a result, the regional pretreatment coordinators have observed the application of the Metal Finishing ELGs for wastewater generated from operations that should be regulated by other ELGs. Additionally, the pretreatment coordinators noted that POTWs may still be implementing 40 CFR Part 413 pretreatment standards for metal finishing wastewater. Most metal finishing facilities should be covered by 40 CFR Part 433 pretreatment standards, not 40 CFR Part 413 standards. The scope of facilities still regulated under 40 CFR Part 413 should be limited to job shops and IPCB manufacturers that were considered existing at the time of the 1983 promulgation of the Metal Finishing ELGs.

- *Applicability of the 46 metal finishing unit operations.* The regional pretreatment coordinators also noted that there is uncertainty about the applicability of the existing ELGs and how to determine which of the 46 metal finishing operations listed in the 1983 Metal Finishing ELGs would apply to current industry practices, including:

- Whether using acid for cleaning and preparing metal surfaces prior to metal finishing would constitute "acid cleaning" or "acid etching";

- When the use of phosphoric acid or chromic acid constitutes "cleaning" and when it is "conversion coating";
- Whether the use of brighteners during cleaning would be considered "acid cleaning" or "bright dipping," which is identified in the Metal Finishing ELGs as a form of etching; and
- How the rule applies to new processes and process chemistries.
- *New source criteria development.* The Metal Finishing ELGs identify new sources as new sites that are discharging wastewater. Pretreatment coordinators suggested that additional guidance is needed to specify the criteria for identifying new sources. Existing facilities that develop new or revise existing processes question whether certain process changes classify them as new sources. Similarly, ACWA commented that a facility covered under the PSES for the Electroplating Category (40 CFR Part 413) may upgrade its plant incrementally, which makes it difficult to determine when the plant is a new source and subject to the Metal Finishing ELGs (40 CFR Part 433) (ACWA, 2013). Additionally, metal finishing operations have expanded to product markets that did not exist during the development of the ELGs. Pretreatment coordinators noted products such as solar panels and cell phone screens as newer metal finishing applications that require interpretation as to their applicability under the Metal Finishing ELGs.

5.1.4 Summary of Findings from EPA's Continued Review of the Metal Finishing Category

Based on EPA's continued preliminary category review, the Metal Finishing Category has not experienced significant growth in the last 30 years. However, an industry source suggests that the industry is consolidating into larger companies that tend to compete better with the expanding global market; this consolidation may have slightly reduced the size of the U.S. metal finishing industry (Chalmer, 2008).

Discussions with regional EPA pretreatment coordinators and a review of literature on existing process technologies and advances in wastewater treatment show that a portion of the industry is employing new technologies. These new technologies include improved technologies for reusing baths and other metal finishing chemicals that reduce the quantities of pollutants discharged. The new technologies also include improved wastewater treatment technologies that reduce the concentration of pollutants in treated metal finishing wastewater. Implementation of these new technologies results in effluent concentrations that are well below the limits established in the Metal Finishing ELGs. However, the regional pretreatment coordinators reported that despite the emergence of these new technologies, a majority of the industry seems to be continuing to meet the ELGs using common treatment technologies (described in Section 5.1.2.5). Further, they have not observed any notable issues with pass-through or interference at POTWs receiving metal finishing wastewater, which would indicate that the industry can achieve pretreatment standards for the nine pollutants currently regulated in the Metal Finishing ELGs even with the change in surface finishing chemistries over the past three decades.

At the time the existing ELGs were developed, metal finishers used base metals such as aluminum, magnesium, iron, and tin. In addition to those metals, they are now using metals such as titanium, zirconium, vanadium, and also nanocomposites. Metal finishers are also employing alternative metal finishing processes and chemicals. These changes may introduce additional pollutants into metal finishing wastewater that EPA did not consider in the development of the 1983 Metal Finishing ELGs.

EPA's continued review of the Metal Finishing Category identified several topics that require further review:

- Potential new pollutants of concern not currently regulated, including transition metal coatings and nanoscale particles that are becoming more common in metal finishing operations.
- The characteristics of current metal finishing wastewater discharges, including:
  - — The need for hexavalent chromium limits in addition to total chromium limits to explicitly limit the discharge of the more toxic form of chromium.
  - — Treatment technologies available for metal finishing wastewater and the more stringent discharge concentrations these technologies can achieve.
- The prevalence of and the potential pollutants of concern associated with wastewater generated from the use of wet air pollution control devices, which may contribute additional pollutants to metal finishing wastewater.
- The need for clarifying descriptions of metal finishing operations listed in the ELGs to help permit writers properly apply the Metal Finishing ELGs, specifically:
  - — Providing guidance to help distinguish between metal finishing operations, such as etching and chemical milling, acid cleaning, chemical conversion coating, and similar cases in which the same acid is used for different functions.
  - — Clarifying how the Metal Finishing ELGs apply to current industry practices (i.e., practices that evolved after the promulgation of the Metal Finishing ELGs) that may use chemical alternatives (e.g., alternatives to hexavalent chromium, phosphate-free formulations) and are not specifically identified in the ELGs.
  - — Clarifying applicability of the Metal Finishing ELGs to newer manufacturing operations that use metal finishing, such as solar panel manufacturing and cell phone manufacturing.
- How advanced wastewater treatment technologies are used and the prevalence of zero discharge practices in the industry.

5.1.5 References for the Continued Review of the Metal Finishing Category

1. ACWA, 2013. Association of Clean Water Administrators. Public Comment Submitted by the Association of Clean Water Administrators on the Preliminary 2012 Effluent Guidelines Program Plan. Re: Docket ID No. EPA-HQ-OW-2010-0824/Preliminary 2012 Effluent Guidelines Program Plan and 2011 Annual Effluent Guidelines Review Report. (October 7). EPA-HQ-OW-2010-0824-0218-A2.

2. Adhoum, N. L. Monser, N. Belakal, and J-E Belgaied. 2004. Treatment of electroplating wastewater containing Cu2+, Zn2+ and Cr(vi) by electrocoagulation. *Journal of Hazardous Materials. B112:* 207-213. EPA-HQ-OW-2014-0170. DCN 08004.

3. Ahmad, W.A. Z.A. Zakaria, A.R. Khasim, M.A. Alias, and S.M.H.S. Ismail. 2010. Pilot-scale removal of chromium from industrial wastewater using the chromebac system. *Bioresource Technology. 101* (12): 4371-4378. (June). EPA-HQ-OW-2014-0170. DCN 08005.

4. Bloch, L. 2000. Metal recovery and wastewater reduction using electrowinning. *Products Finishing.* (January 1). Available online at: http://www.pfonline.com/articles/metal-recovery-and-wastewater-reduction-using-electrowinning. EPA-HQ-OW-2014-0170. DCN 08007.

5. Buckles, J. A. Kuljian, K. Olmstead, and J. Merritt. 2003. *Treatment of oily wastes by membrane biological reactor*. Water Environment Federation's 2003 Technical Exibition and Conference. Los Angeles, CA. (October 11-15). EPA-HQ-OW-2014-0170. DCN 08008.

6. Candiloro, S. 2012. Close loop for zero waste water discharge, Epner Technology Inc. (May 17). EPA-HQ-OW-2014-0170. DCN 08009.

7. Chalmer, P. 2008. The future of finishing. *National Center for Manufacturing Services.* (January 1). EPA-HQ-OW-2014-0170. DCN 08010.

8. Chan, M. 2011. *Recovery and recycling of industrial side-stream wastewater*. International Water Conference. Orlando, FL. (November 13-17). EPA-HQ-OW-2014-0170. DCN 08011.

9. Chen, G. 2004. Electrochemical technologies in wastewater treatment. *Separation and Purification Technology. 38:* 11-41. (January 1). EPA-HQ-OW-2014-0170. DCN 08012.

10. Colica, G. P.C. Mecarozzi, and R. DePhilippis. 2012. Biosorption and recovery of chromium from industrial wastewaters by using saccharomyces cerevisiae in a flow-through system. *Industrial & Engineering Chemistry Research. 51* (11): 4452-4457. (March 8). EPA-HQ-OW-2014-0170. DCN 08013.

11. Dennis, R. L.T. Viyannalage, A.V. Gaikwad, T.K. Rout, and S. Banerjee. 2014. Graphene nanocomposite coatings for protecting low-alloy steels from corrosion.

American Ceramic Society Bulletin. 92 (5): 18-24. EPA-HQ-OW-2014-0170. DCN 08014.

12. Dunham, B. D. Chalk. 2013. Non-phosphate transition metal coatings, 81st universal metal finishing guidebook. *Metal Finishing Magazine. 111* (7): 116-122. (Fall). (September 1). EPA-HQ-OW-2014-0170. DCN 08015.

13. Firouzi, F. M.A. Ross, G. Champneys and M.J. McFarland. 2009a. Treatment of metal finishing wastewater from aircraft maintenance operations using an electrocoagulation treatment process. *Microconstituents and Industrial Water Quality. 8:* 473-480. EPA-HQ-OW-2014-0170. DCN 08017.

14. Firouzi, F. M.A. Ross, G. Champneys and M.J. McFarland. 2009b. *Treatment of metal finishing wastewaters in the presence of chelating substances*. Water Environment Federation's 2009 Technical Exibition and Conference. Orlando, FL. (October 10-14). EPA-HQ-OW-2014-0170. DCN 08018.

15. Firouzi, F. M.A. Ross, G. Champneys and M.J. McFarland. 2010. Needs more work. *Industrial Wastewater.* 10-12. (April/May). EPA-HQ-OW-2014-0170. DCN 08019.

16. Hopwood, D. 2012. Zirconium pretreatments: Not just for early adopters anymore. *Metal Finishing: The Plating and Coating Industries' Technology Magazine. 110* (6): 18-21. (July/August). EPA-HQ-OW-2014-0170. DCN 08021.

17. Ince, M. 2013. Treatment of manganese-phosphate coating wastewater by electrocoagulation. *Separation Science and Technology. 48:* 515-522. (January 18). EPA-HQ-OW-2014-0170. DCN 08023.

18. LaFlamme, D. 2009. Going low-temp. *Products Finishing.* (January 1). Available online at: http://www.pfonline.com/articles/going-low-temp. EPA-HQ-OW-2014-0170. DCN 08025.

19. Legg, K. n.d. Rowan Technology Group. Chrome replacements for internals and small parts. Available online at: http://www.asetsdefense.org/documents/DoD-Reports/Cr_Plating_Alts/Cr_Rplcmnt-IDs&Sm_Parts.PDF. EPA-HQ-OW-2014-0170. DCN 08026.

20. Lv, X. Z. Chen, Y. Wang, F. Huang, and Z. Lin. 2013. Use of high-pressure CO_2 for concentrating Cr^{VI} from electroplating wastewater by Mg-Al layered double hydroxide. *Applied Materials & Interfaces. 5* (21): 11271-11275. (October 1). EPA-HQ-OW-2014-0170. DCN 08027.

21. Mahvi, A.H. E. Bazrafshan. 2007. Removal of cadmium from industrial effluents by electrocoagulation process using aluminum electrodes. *World Applied Sciences Journal. 2* (1): 34-39. EPA-HQ-OW-2014-0170. DCN 08028.

22. Manavbasi, A. 2012. Non-chromated conversion coating for magnesium alloys and zinc-nickel plated steel. *Products Finishing.* (November 13). Available online at:

http://www.pfonline.com/articles/non-chromated-conversion-coating-for-magnesium-alloys-and-zinc-nickel-plated-steel. EPA-HQ-OW-2014-0170. DCN 08029.

23. McLay, W.J. 2013. Waste minimization and recovery technologies, 81st universal metal finishing guidebook. *Metal Finishing Magazine. 111* (7): 595-619. (Fall). (September 1). EPA-HQ-OW-2014-0170. DCN 08030.

24. Ogundiran, O. 2011. A Study of Zinc-Nickel as an Alternate Coating to Cadmium for Electrical Connector Shells Used in Aerospace Applications. A Thesis Submitted to the Graduate Faculty of Rensselaer Polytechnic Institute. (April). EPA-HQ-OW-2014-0170. DCN 08032.

25. Qin, J-J. M.N. Wai, M.H. Oo, and H. Lee. 2004. A pilot study for reclamation of a combined rinse from a nickel-plating operation using a dual-membrane UF/RO process. *Desalination. 161* (2): 155-167. (February 20). EPA-HQ-OW-2014-0170. DCN 08033.

26. Qin, J-J. M.H. Oo and F.S. Wong. 2006. Pilot study on the treatment of spent solvent cleaning rinse in metal plating. *Desalination. 191:* 359-364. (May 10). EPA-HQ-OW-2014-0170. DCN 08034.

27. Schuch, R. R. Gensicke, K. Merkel, and J. Winter. 2000. Nitrogen and DOC removal from wastewater streams of the metal-working industry. *Water Research. 34* (1): 295-303. (January). EPA-HQ-OW-2014-0170. DCN 08037.

28. Sutton, P.M. P. Mishra, J. Roberts, L. Abreu, and P. Gignac. 2001. *Optimization of oily wastewater membrane bioreactor treatment: Pilot to full scale results*. Water Environment Federation's 2001 Technical Exposition and Conference. Atlanta, GA. (October 13-17). EPA-HQ-OW-2014-0170. DCN 08038.

29. U.S. EPA. 1979. *Development Document for Existing Source Pretreatment Standards for the Electroplating Point Source Category*. Washington, D.C. (August). EPA-HQ-OW-2014-0170-0007.

30. U.S. EPA. 1981. *Federal Register Notice: Effluent Guidelines and Standards; Electroplating Point Source Category Pretreatment Standards for Existing Sources*. Washington, D.C. (January). EPA-HQ-OW-2014-0170. DCN 08039.

31. U.S. EPA. 1983. *Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Metal Finishing Point Source Category*. Washington, D.C. (June). EPA-HQ-OW-2004-0032-0110.

32. U.S. EPA. 1984. *Guidance Manual for Electroplating and Metal Finishing Pretreatment Standards*. Washington, D.C. (February). EPA-HQ-OW-2014-0170. DCN 08040.

33. U.S. EPA. 2000. *Development Document for the Proposed Effluent Limitations Guidelines and Standards for the Metal Products & Machinery Point Source Category*. Washington, D.C. (December). EPA-HQ-OW-2014-0170-0005.

34. U.S. EPA. 2009. *Technical Support Document for the Annual Review of Existing Effluent Guidelines and Identification of Potential New Point Source Categories.* Washington, D.C. (October). EPA-821-R-09-007. EPA-HQ-OW-2008-0517-0515.

35. U.S. EPA. 2012. *The 2011 Annual Effluent Guidelines Review Report*. Washington, D.C. (December). EPA-821-R-12-001. EPA-HQ-OW-2010-0824-0195.

36. U.S. EPA. 2013. EPA *Small Business Innovation Research (SBIR) Program. 2013 Presidential Green Chemistry Award Winner – Faraday Technology, Inc. Functional Trivalent Chromium Plating Process to Replace Hexavalent Chromium Plating*. Available online at: http://www.epa.gov/ncer/sbir/success/pdf/faraday_success.pdf. EPA-HQ-OW-2014-0170. DCN 08041.

37. U.S. EPA. 2014a. *The 2012 Annual Effluent Guidelines Review Report*. Washington, D.C. (September). EPA-821-R-14-004. EPA-HQ-OW-2010-0824-0320.

38. U.S. EPA. 2014b. *The 2013 Annual Effluent Guidelines Review Report*. Washington, D.C. (September). EPA-821-R-14-003. EPA-HQ-OW-2014-0170-0077.

39. Usinowicz, P.J. B.F. Monzyk, H.N. Conkle, J.K. Rose, and S.P. Chauhan. 2005. *The use of liquid-liquid extraction for heavy metals recovery and reuse from plating wastewaters*. Water Environment Federation's 2005 Technical Exposition and Conference. Washington D.C. (October 30 - November 2). EPA-HQ-OW-2014-0170. DCN 08042.

40. Weber, T. 2013. Wastewater treatment, 81st universal metal finishing guidebook. *Metal Finishing Magazine. 111* (7): 582-594. (Fall). (September 1). EPA-HQ-OW-2014-0170. DCN 08043.

41. Wolterbeek, M. 2012. New coating for aluminum developed to replace cancer-causing product. Nevada Today. University of Nevada, Reno. EPA-HQ-OW-2014-0170. DCN 08044.

42. Wong, F.S. J.-J. Qin, M.N. Wai, A.L. Lim, and M. Adiga. 2002. A pilot study on a membrane process for the treatment and recycling of spent final rinse water from electroless plating. *Separation and Purification Technology. 29* (1): 41-51. (October). EPA-HQ-OW-2014-0170. DCN 08045.

5.2 Targeted Review of Pesticide Active Ingredients Without Pesticide Chemical Manufacturing Effluent Limits (40 CFR Part 455)

As part of the 2012 Annual Review, EPA reviewed analytical methods it had recently developed or revised to facilitate its identification of unregulated pollutants in industrial wastewater discharges. This review included the EPA Office of Water's 2012 updates to the test procedures for analysis of pollutants under the Clean Water Act (CWA) (2012 Method Update Rule) (77 FR 29758). Under the authority of the CWA, EPA publishes laboratory methods at 40 CFR Part 136 (U.S. EPA, 2012a). Industries and municipalities use these methods to analyze the chemical, physical, and biological properties of wastewater and other environmental samples that require measurement by regulation. As part of the 2012 Method Update Rule, EPA added some of the methods for pesticide active ingredients (PAIs) from Table IG in Part 136 to applicable parameters listed in Table ID for general use. EPA reviewed these methods and identified 30 PAIs (listed below in Table 5-13) that are measured by existing analytical methods listed in 40 CFR Part 136, but discharges of which from manufacturers are not currently regulated under the Pesticide Chemicals effluent limitation guidelines and standards (ELGs) (40 CFR Part 455) (U.S. EPA, 2014a).

The Pesticide Chemicals ELGs regulate wastewater discharges from four subcategories:

1. Subpart A: Organic Pesticide Chemicals Manufacturing;
2. Subpart B: Metallo-Organic Pesticide Chemicals Manufacturing;
3. Subpart C: Pesticide Chemicals Formulating and Packaging; and
4. Subpart E: Repackaging of Agricultural Pesticides Performed at Refilling Establishments.

EPA established specific limitations for the discharge of PAIs from pesticide chemicals manufacturing under Subparts A and B in Tables 2 and 3 of 40 CFR Part 455. EPA also established specific limitations for discharge of PAIs from pesticide formulating, packaging, and repackaging (PFPR) under Subparts C and E. The PAIs with limitations under Subparts C and E are limited to zero discharge unless the facility decides to incorporate certain pollution prevention alternative practices (see Table 10 in 40 CFR Part 455). For the purposes of this review, EPA is focusing on the list of 30 PAIs of interest (listed below in Table 5-13) as they relate to Subparts A and B.

The Pesticide Chemicals ELGs regulate PAIs, but several other terms can refer to pesticides. The ELG defines these terms as:

1. *Pesticide:* any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest.
2. *Active ingredient:* an ingredient of a pesticide that is intended to prevent, destroy, repel, or mitigate any pest.
3. *Pesticide chemicals:* the sum of all active ingredients manufactured at each facility covered by 40 CFR Part 455.

4. *Formulation of pesticide products:* the process of mixing, blending, or diluting one or more PAIs with one or more active or inert ingredients, without an intended chemical reaction to obtain a manufacturing use product or an end use product.

For the 2014 Annual Review, EPA began investigating whether U.S. manufacturers produced the 30 PAIs of interest, listed in Table 5-13, and whether these ingredients may be present in industrial wastewater discharges from pesticide chemical manufacturing. For reference, Table 5-13 also indicates whether each PAI is regulated under Subparts C and E in the Pesticide Chemicals ELGs (discharges are prohibited under Subparts C and E unless certain pollution prevention alternatives are employed). As previously stated, EPA is focusing these 30 PAIs as they relate to Subparts A and B.

Table 5-13. PAIs Measured by EPA-Approved Methods Without Limits in Subparts A and B of the Pesticide Chemicals ELGs (40 CFR Part 455)

EPA Method	Chemical	CAS Number	Limitations Under Subparts A and B in 40 CFR Part 455?	Limitations Under Subparts C and E in 40 CFR Part 455?[a]
608.1	Chlorobenzilate	510-15-6	No	Yes
	Chloropropylate	5836-10-2	No	No
	Dibromochloropropane	96-12-8	No	No
	Etridiazole	2593-15-9	No	Yes
614.1	EPN	2104-64-5	No	Yes
615	Dalapon	75-99-0	No	Yes
617	Carbophenothion	786-19-6	No	Yes
	Endosulfan sulfate	1031-07-8	No	No
	Endrin aldehyde	7421-93-4	No	No
	Heptachlor epoxide	1024-57-3	No	No
	Isodrin	465-73-6	No	No
	Strobane	8001-50-1	No	No
619	Atraton	1610-17-9	No	No
	Secbumeton	26259-45-0	No	No
	Simetryn	1014-70-6	No	No
622	Chlorpyrifos methyl	5598-13-0	No	Yes
	Coumaphos	56-72-4	No	Yes
	Ethoprop	13194-48-4	No	Yes
	Ronnel	299-84-3	No	Yes
	Tokuthion	34643-46-4	No	No
	Trichloronate	327-98-0	No	No
622.1	Aspon	3244-90-4	No	Yes
	Dichlofenthion	97-17-6	No	No
	Famphur	52-85-7	No	Yes
	Fenitrothion	122-14-5	No	Yes

Table 5-13. PAIs Measured by EPA-Approved Methods Without Limits in Subparts A and B of the Pesticide Chemicals ELGs (40 CFR Part 455)

EPA Method	Chemical	CAS Number	Limitations Under Subparts A and B in 40 CFR Part 455?	Limitations Under Subparts C and E in 40 CFR Part 455?[a]
	Fonophos	944-22-9	No	No
	Thionazin	297-97-2	No	No
632	Fluometuron	2164-17-2	No	Yes
	Neburon	555-37-3	No	Yes
	Oxamyl	23135-22-0	No	Yes

Source: 40 CFR Part 455, 2012 Method Update Rule (77 FR 29758).

[a] Limits under Subparts C and E are zero discharge unless the facility decides to incorporate pollution prevention alternative practices (see Table 10 in 40 CFR Part 455).

5.2.1 Targeted Review of Pesticide Active Ingredients Without Pesticide Chemical Manufacturing Effluent Limits

To determine if U.S. manufacturers are producing the 30 PAIs of interest and identify if they are present in industrial wastewater discharges from pesticide chemicals manufacturing, EPA's Office of Water contacted EPA's Office of Pesticide Programs (OPP) to review the registration status for each active ingredient. Section 3 of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) governs pesticide registration and provides the authority to regulate the content and labeling of pesticide products (U.S. EPA, 2012b). Registration is required when a pesticide product is produced in the U.S. for distribution, sale, or use within the U.S. (Keigwin, R., 2014). The pesticide product may contain PAIs (U.S. EPA, 2014b).

FIFRA Section 4 requires that pesticide product registrations be reviewed every 15 years and requires EPA to reregister all pesticide products that were registered before 1984 in order to update labeling and use requirements. EPA may cancel a registration if it determines that the pesticide product does not comply with any of the FIFRA requirements. After cancellation, any production of the pesticide product for distribution, sale, or use within the U.S. is prohibited (U.S. EPA, 2012b). OPP provided the registration status for each of the 30 PAIs of interest, shown in Table 5-14 (Keigwin, R., 2014).

Table 5-14. Registration Status for the 30 PAIs of Interest

EPA Method	Chemical	CAS Number	Registration Status
608.1	Chlorobenzilate	510-15-6	All U.S. registrations have been canceled.
	Chloropropylate	5836-10-2	All U.S. registrations have been canceled.
	Dibromochloropropane	96-12-8	Never registered in the U.S.
	Etridiazole	2593-15-9	First registered in 1962; under registration review.
614.1	EPN	2104-64-5	All U.S. registrations have been canceled.
615	Dalapon	75-99-0	All U.S. registrations have been canceled.
617	Carbophenothion	786-19-6	All U.S. registrations have been canceled.
	Endosulfan sulfate	1031-07-8	Never registered in the U.S.

Table 5-14. Registration Status for the 30 PAIs of Interest

EPA Method	Chemical	CAS Number	Registration Status
	Endrin aldehyde[a]	7421-93-4	Never registered in the U.S. All U.S. registrations of the parent compound, endrin, have been canceled.
	Heptachlor epoxide[b]	1024-57-3	Never registered in the U.S. All U.S. registrations of the parent compound, heptachlor, have been canceled.
	Isodrin	465-73-6	Never registered in the U.S.
	Strobane	8001-50-1	All U.S. registrations have been canceled.
619	Atraton	1610-17-9	Never registered in the U.S.
	Secbumeton	26259-45-0	Never registered in the U.S.
	Simetryn	1014-70-6	Never registered in the U.S.
622	Chlorpyrifos methyl	5598-13-0	First registered in 1985; under registration review.
	Coumaphos	56-72-4	First registered in 1958; under registration review.
	Ethoprop	13194-48-4	First registered in 1967; under registration review.
	Ronnel	299-84-3	All U.S. registrations have been canceled.
	Tokuthion	34643-46-4	Never registered in the U.S.
	Trichloronate	327-98-0	Never registered in the U.S.
622.1	Aspon	3244-90-4	All U.S. registrations have been canceled.
	Dichlofenthion	97-17-6	All U.S. registrations have been canceled.
	Famphur	52-85-7	All U.S. registrations have been canceled.
	Fenitrothion	122-14-5	First registered in 1975; under registration review. Only product registered in the U.S. is for formulating other insecticides. No end-use products registered in the U.S.
	Fonofos	944-22-9	All U.S. registrations have been canceled.
	Thionazin	297-97-2	All U.S. registrations have been canceled.
632	Fluometuron	2164-17-2	First registered in 1974; under registration review.
	Neburon	555-37-3	All U.S. registrations have been canceled.
	Oxamyl	23135-22-0	First registered in 1974; under registration review.

Source: (Keigwin, R., 2014).

[a] Endrin aldehyde has never been a registered pesticide, but is an impurity and breakdown product of a previously registered pesticide, endrin. Endrin is also a regulated PAI under the Pesticide Chemicals ELGs (40 CFR Part 455).

[b] Heptachlor epoxide has never been a registered pesticide, but is a metabolite of a previously registered pesticide, heptachlor. Heptachlor is also a regulated PAI under the Pesticide Chemicals ELGs (40 CFR Part 455).

Although FIFRA Section 3 provides authority to regulate the content and labeling of pesticide products through registration, it does not provide the authority to regulate pesticide production or production facilities. Manufacturers can only produce pesticide products in the U.S. for distribution within the U.S. or for export. As stated above, pesticide products manufactured for distribution within the U.S. require registration. However, pesticide products manufactured solely for export do not require U.S. registration. Therefore, the registration status of a particular PAI (e.g., canceled, never registered) may not indicate which pesticide products are produced in the U.S., especially if produced only for export (Keigwin, R., 2014).

Under FIFRA Section 7, establishments producing pesticides, PAIs, or devices must register with the appropriate EPA Regional office and report the types and amounts of pesticide products they produce. This includes facilities manufacturing pesticide products solely for export (Keigwin, R., 2014; U.S. EPA, 2012b). The FIFRA Section 7 data are compiled in the Pesticide Registration Information System (PRISM), Section Seven Tracking System (SSTS). The SSTS database contains the following information, which may be useful for determining whether any of the 30 PAIs of interest are produced in the U.S. (U.S. EPA, 2013):

1. General establishment and company information (name, contact information);
2. Product registration status and information;
3. Product name (common brand names, alternate brand names);
4. Product classification (e.g., insect repellant, herbicide, rodenticide);
5. Product type (technical formulation or active ingredient, end-use product, repackaged or relabeled, device);
6. Market status in the U.S. (marketed in the U.S., marketed in the U.S. and exported, solely exported);
7. "Restricted Use" pesticide status;
8. Amount produced;
9. Amount sold or distributed in the U.S.;
10. Amount sold or distributed to foreign markets; and
11. Amount estimated to be produced in the following year.

5.2.2 Summary of Findings from EPA's Targeted Review of Pesticide Active Ingredients Without Pesticide Chemical Manufacturing Effluent Limits

EPA's review identified that only seven of the 30 PAIs of interest are currently registered or are under registration review in accordance with FIFRA Section 3. The remaining 23 have either never been registered or had their registrations canceled. However, discussions with OPP suggest that registration status may not be an indicator of whether the PAI is produced in the U.S. (and potentially present in industrial wastewater discharge), as unregistered pesticides may still be produced in the U.S. for export. Therefore, EPA was not at this time able to prioritize for further review a subset of the PAIs of interest that are produced in the U.S. However, EPA did identify follow up questions and types of information that will indicate which of the 30 PAIs of interest are produced in the U.S. and are thus potentially present in industrial wastewater discharges. These sources of information include examining the SSTS production data in conjunction with reviews of permit applications, fact sheets, and permits for the facilities that produce the PAIs of interest. The information will help EPA answer the following questions and determine whether revisions to the Pesticide Chemicals ELGs are warranted:

- Are any of the 30 PAIs of interest produced in the U.S.? If so, which facilities produce the PAIs?
- What is the manufacturing process of the PAIs at a particular facility?
- Does the manufacturing process of the PAIs produce a wastewater discharge?

- Are the PAIs at treatable concentrations in the wastewater discharge?
- Are discharge data available for the PAIs?
- Does the permit have any limitations for the PAIs?
- Is permitting support necessary for plants identified as likely discharging the PAIs?

5.2.3 References for EPA's Targeted Review of Pesticide Active Ingredients Without Pesticide Chemical Manufacturing Effluent Limits

1. Keigwin, R. 2014. Email Communication Between Richard Keigwin, U.S. EPA Office of Pesticide Programs, and William Swietlik, U.S. EPA Office of Water. Re: Questions for OPP About Pesticides. (April 30). EPA-HQ-OW-2014-0170. DCN 07996.

2. U.S. EPA. 2012a. *Clean Water Act Analytical Methods*. Available online at: http://water.epa.gov/scitech/methods/cwa/index.cfm. EPA-HQ-OW-2010-0824. DCN 07746.

3. U.S. EPA. 2012b. *Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA)*. Washington, D.C. . (March 30). Available online at: http://www.epa.gov/agriculture/lfra.html. EPA-HQ-OW-2014-0170. DCN 07997.

4. U.S. EPA. 2013. Instructions for Completing EPA Form 3540-16 Pesticide Report for Pesticide-Producing and Device-Producing Establishments, Reporting Year 2013. Available online at: http://www.epa.gov/compliance/resources/publications/monitoring/fifra/estabreportinst.pdf. EPA-HQ-OW-2014-0170. DCN 07998.

5. U.S. EPA. 2014a. *The 2012 Annual Effluent Guidelines Review Report*. Washington, D.C. (September). EPA-821-R-14-004. EPA-HQ-OW-2010-0824-0320.

6. U.S. EPA. 2014b. *Pesticide Registration Manual: Chapter 1: Overview of Requirements for Pesticide Registration and Registrant Obligations*. (June 26). Available online at: http://www2.epa.gov/pesticide-registration/pesticide-registration-manual-chapter-1-overview-requirements-pesticide. EPA-HQ-OW-2014-0170. DCN 07999.

5.3 Continued Review of Brick and Structural Clay Products Manufacturing

As part of the 2012 Annual Review, EPA reviewed air quality regulations, including New Source Performance Standards (NSPS) and National Emission Standards for Hazardous Air Pollutants (NESHAP), to determine if they result in the generation of unregulated wastewater discharges or changes to currently regulated wastewater streams (containing new pollutants of concern) (U.S. EPA, 2014). From that review, EPA identified brick and structural clay products manufacturing as an industry that is not currently regulated by effluent limitations guidelines (ELGs) and that may have industrial wastewater discharges resulting from air pollution control requirements.

The brick and structural clay products production process consists of preparing the raw materials (primarily clay and shale), forming the processed materials into bricks or other shapes, and drying and frying the bricks and shapes (U.S. EPA, 2005). During its review of this industry sector in 2012 (U.S. EPA, 2014), EPA identified 93 facilities associated with brick and structural clay products manufacturing Standard Industrial Classification (SIC) codes[15] reporting discharge monitoring report (DMR) data in 2009. Only 37 of the facilities had reported pollutant discharges greater than zero. However, none of the facilities holds an individual National Pollutant Discharge Elimination System (NPDES) permit; all reported discharges were associated with general stormwater permits.

Because a majority of the brick and structural clay manufacturers reporting DMR data in 2009 were in Alabama, EPA contacted the Alabama Department of Environmental Management (ADEM). The ADEM contact stated that the brick manufacturing facilities have general permits for stone, glass, and clay that cover stormwater discharges; they do not have individual NPDES permits (Warren, L., 2012). The 2012 review suggested that brick and structural clay products manufacturers may have only stormwater discharges, and may not have wastewater discharges associated with manufacturing or wet air pollution control systems. However, EPA continued its review of the brick and structural clay products manufacturing industry because the evaluation of 2009 data may not have fully captured the potential impacts of the NESHAP. This possibility arises due to the time allowed for implementation of the NESHAP requirements (through 2006) and the timing of the NPDES permit renewal schedule (every five years).

5.3.1 Air Regulations for Brick and Structural Clay Products Manufacturing

On May 16, 2003, EPA promulgated the NESHAP for brick and structural clay products manufacturing, as well as the NESHAP for clay ceramics manufacturing (68 FR 26689). The NESHAP for brick and structural clay products manufacturing requires affected manufacturers to control the following substances, beginning in 2006: hydrogen fluoride, hydrogen chloride, sulfur dioxide, and some metal emissions, including antimony, arsenic, beryllium, cadmium, chromium, cobalt, mercury, manganese, nickel, lead, and selenium (68 FR 26692). The

[15] SIC codes associated with the Brick and Structural Clay Products Manufacturing industry include: SIC 1455, Kaolin & Ball Clay (NAICS 212324); SIC 1459, Clay, Ceramic & Refractory Minerals (NAICS 212325); 3251, Brick and Structural Clay Tile (NAICS 327121); SIC 3255, Clay Refractories (NAICS 327120); SIC 3259, Structural Clay Products (NAICS 327123); SIC 3271, Concrete Block and Brick (NAICS 327331); and SIC 5032, Brick, Stone, and Related Materials (NAICS 423320).

NESHAP states that entities potentially affected are those industrial facilities that manufacture brick and structural clay products, specifically those classified under the following SIC codes:

- 3251 (NAICS 327121): Brick and structural clay tile manufacturing facilities;
- 3253 (NAICS 327122): Extruded tile manufacturing facilities; and
- 3259 (NAICS 327123): Other structural clay products manufacturing facilities.

The NESHAP for brick and structural clay products manufacturing mentions wet air pollution control devices, such as wet scrubbers, as one of three methods to comply with the standard. The other two potential methods are dry lime injection fabric filters (DIFF) and dry lime scrubbers/fabric filters (DLS/FF) (68 FR 26694). Wet scrubbers have the potential to generate new wastewater discharges not regulated by ELGs.

The Clay Ceramics Manufacturing NESHAP states that potentially affected facilities are manufacturers of ceramic wall and floor tile or vitreous plumbing fixtures, specifically those classified under the following SIC codes:

- 3253 (NAICS 327122): Ceramic wall and floor tile manufacturing facilities; and[16]
- 3261 (NAICS 327111): Vitreous plumbing fixtures (sanitaryware) manufacturing facilities.

However, EPA did not review the Clay Ceramics Manufacturing NESHAP as part of its initial review of air quality regulations in 2012 because the preamble states that no water or solid waste impacts are projected for existing or new sources (68 FR 26717).

Brick and structural clay products manufacturing facilities were required to comply with the 2003 NESHAP by May 2006. However, in 2007, in response to a complaint filed by the Sierra Club, the U.S. District Court for the District of Columbia vacated the rule. The lawsuit claimed EPA failed to meet its obligations under the Clean Air Act by not including all technologies in developing the standards, including technologies that were not necessarily achievable by all sources (Sierra Club vs. EPA, 2007). Currently, EPA is planning to propose a revised rule in August 2014 and issue final regulations by June 2015 (OMB, 2014).

5.3.2 2014 Annual Review of Brick and Structural Clay Products Manufacturing

EPA's review of the brick and structural clay products manufacturing industry, as part of the 2012 Annual Review, suggested that the majority of brick and structural clay manufacturing facilities only have stormwater discharges, not process discharges, associated with manufacturing or wet air pollution control. However, because of the timing allowed for implementation of the NESHAP requirements (through 2006) and the NPDES permit renewal schedule (every five years), EPA's evaluation of 2009 DMR data may not have fully captured

[16] Facilities in SIC Code 3253 (ceramic wall and floor tile manufacturing facilities and extruded tile manufacturing facilities) are subject to both the Clay Ceramics Manufacturing NESHAP and the Brick and Structural Clay Products Manufacturing NESHAP (68 FR 26690).

the potential impact of the NESHAP. Therefore, EPA continued its investigation of brick and structural clay manufacturing facilities during the 2014 Annual Review.

As part of this 2014 Annual Review, EPA's Office of Water contacted EPA's Office of Air and Radiation (OAR) and the Brick Industry Association (BIA) to learn more about the NESHAP and the potential impacts on the industry, specifically regarding the installation of wet air pollution controls. Both contacts stated that wet scrubbers are not a common air pollution control method within the industry and that only a small number of brick and structural clay manufacturing facilities have them installed (Miller, S., 2014; Telander, J., 2014). OAR also provided information on the number of brick manufacturing facilities and clay ceramics facilities that have installed wet scrubbers, as discussed in the sections below.

5.3.2.1 Review of Brick Manufacturing Facilities

As of 2014, only two of the 345 brick manufacturing facilities in the U.S. (as identified by SIC Codes 3251, 3253, and 3259) have wet scrubbers (Telander, J., 2014; U.S. Census, 2011). Table 5-15 presents these facilities. However, both facilities are synthetic minor sources and would not be subject to the brick and structural clay products manufacturing NESHAP (Telander, J., 2014). Synthetic minor sources are those facilities using some emission control device (or devices) required by a Federally Enforceable State Operating Permit (FESOP) and which thereby emit fewer than 10 tons per year of any hazardous air pollutants (HAP) and fewer than 25 tons per year of any combination of HAP. In the absence of such controls, these sources would be major[17] (68 FR 26697).

The first facility, Interstate Brick, in West Jordan, UT, has two wet scrubbers, the first installed in 1996, and the second in 2000 (Telander, J., 2014). Interstate Brick manufactures a full line of standard brick products used in residential and commercial construction (Interstate Brick, 2014). The facility is included in the DMR Loading Tool, but it has no reported wastewater discharges between 2007 and 2011.

The second facility, Glen-Gery Corporation's Hanley Plant in Summerville, PA, has one wet scrubber, installed in 2003 (Telander, J., 2014). Glen-Gery produces high quality architectural brick at the Hanley Plant, which the company has owned since 1986 (Glen-Gery Brick, 2014). The facility is not included in the DMR Loading Tool and has no reported wastewater discharges between 2007 and 2011.

Table 5-15. Brick Manufacturing Facilities in the U.S.

Company Name	Facility Name	Facility Location	Type of Source	DMR Discharges	Facility SIC Codes
Pacific Coast Building Products	Interstate Brick	West Jordan, UT	Kiln	None	3271 – Concrete Block and Brick 3251 – Brick and Structural Clay Tile

[17] A major source is any stationary source or group of stationary sources that emits or has the potential to emit 10 tons per year or more of any hazardous air pollutant, or 25 tons per year or more of any combination of hazardous air pollutants.

Table 5-15. Brick Manufacturing Facilities in the U.S.

Company Name	Facility Name	Facility Location	Type of Source	DMR Discharges	Facility SIC Codes
Glen-Gery Corporation	Hanley Plant	Summerville, PA	Kiln	None	3251 – Brick and Structural Clay Tile

Source: (EPA Envirofacts; Telander, J., 2014).

5.3.2.2 Review of Clay Ceramics Facilities

EPA did not review the Clay Ceramics Manufacturing NESHAP as part of the initial review of air quality regulations in 2012 because the preamble of the rule stated that no water or solid waste impacts were projected for existing or new sources (68 FR 26717). However, OAR indicated and provided information regarding several clay ceramics facilities in the U.S. that have installed wet scrubbers. Table 5-16 presents these facilities.

As of 2014, two out of 24 facilities in the clay ceramics industry, SIC code 3261, have wet scrubbers, both of which are at major sources. Kohler, Co. owns both facilities and each facility has one wet scrubber (Telander, J., 2014). Neither facility has reported DMR discharge data for years 2007 to 2011 (DMR Loading Tool).

Three out of 127 facilities in the ceramic tile category, SIC code 3253, have wet scrubbers. Dal Italia and the Dal-Tile Dallas Plant each have two wet scrubbers to control air emissions from kilns. Florim USA has three wet scrubbers and the Dal-Tile Dallas Plant has two wet scrubbers to control air emissions from glaze lines (Telander, J., 2014). None of the facilities has reported DMR discharge data for years 2007 to 2011 (DMR Loading Tool). In addition, all three of the facilities are synthetic area sources and are therefore not subject to the clay ceramics manufacturing NESHAP (Telander, J., 2014).

Table 5-16. Clay Ceramics Facilities in the U.S.

Category	Company Name	Facility Name	Facility Location	Type of Source	DMR Discharges	Facility SIC Codes
Clay Ceramics	Kohler Co.	Spartanburg Plant	Spartanburg, SC	Kiln	None	3088 – Plastics Plumbing Fixtures 3261 – Vitreous China Plumbing Fixtures and China and Earthenware Fittings and Bathroom Accessories
Clay Ceramics	Kohler Co.	Wisconsin Plant	Kohler, WI	Glaze spray booth	None	3261 – Vitreous China Plumbing Fixtures and China and Earthenware Fittings and Bathroom Accessories[a] 3431 – Enameled Iron and Metal Sanitary Ware 3432 – Plumbing Fixtures and Trim 3519 – Internal Combustion Engines, not elsewhere classified 3541 – Machine Tools, Metal Cutting Types 3471 – Electroplating, Plating, Polishing, Anodizing, and Coloring
Ceramic Tile	Dal-Tile Corporation	Dal Italia	Muskogee, OK	Kiln	None	3253 – Ceramic Wall and Floor Tile
Ceramic Tile	Mohawk Industries	Dal-Tile Dallas Plant	Dallas, TX	Kiln & Glaze spray booth	None	3253 – Ceramic Wall and Floor Tile 3251 – Brick and Structural Clay Tile
Ceramic Tile	Florim Ceramiche S.p.A.	Florim USA	Clarksville, TN	Glaze Spray Booth	None	3253 – Ceramic Wall and Floor Tile

Source: (EPA Envirofacts; Telander, J., 2014).

[a] Kohler Co. is major plant with many operations. This analysis focused on operations related to SIC 3261 – Vitreous China Plumbing Fixtures and China and Earthenware Fittings and Bathroom Accessories, which corresponds to the SIC code covered by the Clay Ceramics Manufacturing NESHAP.

5.3.3 Summary of Findings from EPA's Review of Brick and Structural Clay Products Manufacturing

EPA's investigation of the brick and structural clay products manufacturing industry, outlined above, determined that only seven out of approximately 496 facilities producing brick, structural clay, and clay ceramics currently have wet scrubbers installed. Some of these were installed prior to the 2003 NESHAPs. EPA also found that the seven facilities with wet scrubbers did not report any DMR discharges for reporting years 2007 through 2011. These findings suggest that wet scrubbers are not a common air pollution control method within the industry and not expected to increase; therefore, they are not a potential new source of industrial wastewater discharge warranting regulation.

5.3.4 References for the Continued Review of Brick and Structural Clay Manufacturing

1. Glen-Gery Brick. 2014. History of Glen-Gery Brick. Available online at: http://www.glengery.com/about-us/history. Accessed: June 20, 2014. EPA-HQ-OW-2014-0170. DCN 07988.

2. Interstate Brick. 2014. Interstate Brick History. Available online at: http://www.interstatebrick.com/history.html. Accessed: June 20, 2014. EPA-HQ-OW-2014-0170. DCN 07989.

3. Miller, S. 2014. Telephone Communication Between Susan Miller, Brick Industry Assocoation, and Amie Aguiar, Eastern Research Group, Inc. Re: Brick Manufacturing Process. (April 17). EPA-HQ-OW-2014-0170. DCN 07990.

4. OMB. 2014. Office of Management and Budget. *RIN data for National Emission Standards for Hazardous Air Pollutants (NESHAP): Brick and Structural Clay Products Manufacturing and Clay Ceramics Manufacturing*. Available online at: http://www.reginfo.gov/public/do/eAgendaViewRule?pubId=201404&RIN=2060-AP69. EPA-HQ-OW-2014-0170. DCN 07991.

5. Sierra Club vs. EPA, 2007. U.S. Court of Appeals for the District of Columbia Circuit, No. 03-1202. March 13, 2007. Available online at: http://www.cadc.uscourts.gov/internet/opinions.nsf/3DE6EA395F4B40A685257440004537C7/$file/03-1202a.pdf. EPA-HQ-OW-2014-0170. DCN 07992.

6. Telander, J. 2014. Email Communication Between Jeff Telander, U.S. EPA Office of Air and Radiation, and William Swietlik, U.S. EPA Office of Water. Re: Brick and Clay Follow-up. (May 21). EPA-HQ-OW-2014-0170. DCN 07993.

7. U.S. Census. 2011. U.S. Economic Census: 2011 County Business Patterns. Available online at: http://factfinder2.census.gov/faces/nav/jsf/pages/searchresults.xhtml?refresh=t. Accessed: March 26, 2014. EPA-HQ-OW-2014-0170. DCN 07994.

8. U.S. EPA. 2005. *Fact Sheet for National Emission Standards for Hazardous Air Pollutants for Brick and Structural Clay Products Manufacturing: Reconsideration*. Washington, D.C. (April 22). EPA-HQ-OW-2014-0170. DCN 07995.

9. U.S. EPA. 2014. *The 2012 Annual Effluent Guidelines Review Report*. Washington, D.C. (September). EPA-821-R-14-004. EPA-HQ-OW-2010-0824-0320.

10. Warren, L. 2012. Telephone Communication Between Lee Warren, Alabama Department of Environmental Management, and Kimberly Landick, Eastern Research Group, Inc. Re: Brick Manufacturing Process. (March 21). EPA-HQ-OW-2010-0824. DCN 07737.

6. NEW DATA SOURCES AND ADDITIONAL SUPPORTING ANALYSES

For the 2014 Annual Review, EPA initiated a review of engineered nanomaterials, which are an emerging pollutant group of concern, and continued its review of industrial wastewater treatment technology performance data and population of the Industrial Wastewater Treatment Technology (IWTT) Database. EPA's goals in conducting these reviews were to identify new wastewater discharges or pollutants not previously regulated and to identify wastewater discharges that can be eliminated or treated more effectively.

EPA documented the usability and quality of the data supporting these reviews, analyzed how the data could be used to improve the characterization of industrial wastewater discharges (detection or monitoring of pollutants, wastewater treatment available for new industries/concentrations), and prioritized the findings for further review. See Appendix B of this report for more information on data usability and quality of the data supporting these reviews.

Sections 6.1 and 6.2 of this report provide details of each of these reviews.

6.1 Review of Engineered Nanomaterials in Industrial Wastewater

As part of the 2014 Annual Review, EPA began evaluating engineered nanomaterials (ENMs) as a potential emerging industrial wastewater pollutant category. Nanotechnology is a rapidly advancing field of research and commerce and offers potential benefits for health, consumer products, and electronics applications. According to the Woodrow Wilson International Center for Scholars' Project on Emerging Nanotechnology's *Nanotechnology Consumer Product Inventory*, ENMs are currently used in over 800 consumer products in the U.S. (Project on Emerging Nanotechnologies, 2014).

In its *Final 2010 Effluent Guidelines Program Plan,* EPA solicited data and information for future annual reviews on the manufacture, use, and environmental release of silver materials, including nanosilver, due to their anti-microbial activity and potential to create a source of silver in associated industrial wastewater discharges (U.S. EPA, 2011a). Several commenters indicated that EPA should investigate the impact of nanosilver; a few in particular indicated that EPA should investigate all nanomaterials (U.S. EPA, 2013c). In addition, recent research presented at the Society of Environmental Toxicology and Chemistry (SETAC) North America 33rd Annual Meeting in November 2012 indicates that ENMs may impact human health and the environment. Although researchers have conducted little direct sampling and analysis of industrial wastewater discharges, they have identified industrial discharges as a possible route for ENMs to enter the environment (Gottschalk and Nowack, 2011; Hendren et al., 2011; Musee, 2011).

As part of the 2014 Annual Review, EPA responded to the recent interest, research, and concerns raised in comments by reviewing current literature about the fate, transport, and effects of nanomaterials on the environment and human health and about the presence and discharge of nanomaterials in industrial wastewater. This review summarizes EPA's current knowledge of, and outstanding data gaps related to, characterizing and quantifying the presence and impact of ENMs in industrial wastewater discharges.

6.1.1 Literature Review and Research Methodology

EPA assessed available information to support the evaluation of potential industrial wastewater discharges and associated risks of discharged ENMs. EPA's review focused on:

- Production methods and potential aqueous waste streams from manufacturing and processing ENMs;
- Fate, transport, and potential effects of nanomaterials on human health and the environment;
- Analytical techniques available to detect nanomaterials in industrial wastewater;
- Presence of nanomaterials in industrial wastewater; and
- Treatment technologies to remove nanomaterials from wastewater.

SETAC's 2012 conference proceedings included over 125 presentations and posters about nanomaterial-related research, which primarily focused on fate and transport, toxicity, and analytical techniques (SETAC, 2012). EPA reviewed this nanomaterial-related research and catalogued relevant abstracts as a starting point for further research.

Next, EPA identified (partly through the SETAC abstracts) principal government and university researchers and organizations that focus on studying the environmental impacts of ENMs. Several EPA offices are currently assessing the potential effects of ENMs on human health and the environment through research into chemical safety, characterization techniques, life cycle assessment, and risk assessment of these nanomaterials in air, water, and soil (U.S. EPA, 2013a). EPA identified additional stakeholders based on nanomaterials-related research conducted by these EPA offices, including the Office of Pollution Prevention and Toxics (OPPT) and the Office of Research and Development's (ORD's) National Exposure Research Laboratory (NERL).

EPA communicated with the following researchers and government stakeholders between March and June 2013:

- Mark Wiesner, James L. Meriam Professor, Department of Civil and Environmental Engineering, Duke University; Director of the Center for the Environmental Implications of Nanotechnology (CEINT).

- Michael Hochella Jr., University Distinguished Professor, Department of Geosciences, Virginia Tech; member of CEINT.

- Paul Westerhoff, Professor, School of Sustainable Engineering and the Built Environment, Associate Dean for Research and Graduate Affairs, Ira A. Fulton Schools of Engineering, Arizona State University.

- David Meyer, Chemical Engineer, EPA ORD National Risk Management Research Laboratory (NRMRL), Sustainable Technologies Division.

- Thabet Tolaymat, Environmental Engineer, EPA ORD NRMRL.

- Katrina Varner, Research Chemist, EPA ORD NERL–Las Vegas/Environmental Sciences Division/Environmental Chemistry Branch.
- Steve Diamond, EPA National Health and Environmental Effects Research Laboratory, Mid-Continent Ecology Division–Duluth.
- Jeff Morris, Deputy Director for Programs, EPA OPPT.
- Phil Sayre, EPA Deputy National Program Director for the Chemical Safety for Sustainability Research Program.
- Jim Alwood, Program Manager and Toxic Substances Control Act Nanotechnology Coordinator, EPA OPPT, Chemical Control Division.
- Barbara Karn, Program Director, National Science Foundation; Vice President, Sustainable Nanotechnology Organization.
- Suzanne Davis, Hazardous Substances Engineer, California Department of Toxic Substances Control.

EPA reviewed literature and research identified using the following search engines:

- American Chemical Society Publications (http://pubs.acs.org), a comprehensive collection of the most-cited peer-reviewed journals in chemistry and related sciences;
- ScienceDirect (http://www.sciencedirect.com/), a full-text scientific database offering over 2,500 peer-reviewed journals; and
- Google Scholar (http://scholar.google.com), which provides a broad search of scholarly literature across disciplines, publishers, and online databases.

In addition, EPA searched for articles written by SETAC 2012 conference participants and scanned titles and abstracts to identify relevant articles, using various keyword combinations to further focus the literature search. From the articles identified, EPA performed additional searches to find other relevant articles from co-authors and references.

EPA created a comprehensive EndNote® reference library to store and organize references (ERG, 2014). Because nanotechnology is an emerging field of study, EPA strived to collect the most recent research, gathering material published from 2006 to December 2013. All articles are government publications, peer-reviewed, or conference proceedings and meet the data quality objectives outlined in the *Environmental Engineering Support for Clean Water Regulations Programmatic Quality Assurance Project Plan* (ERG, 2013).

EPA's literature review and research methodology are further documented in the memorandum *Engineered Nanomaterials in Industrial Wastewater: Literature Review and Implications for 304m* (ERG, 2015).

6.1.2 Overview of Nanomaterials

Nanomaterials are generally defined as engineered or naturally occurring materials composed of primary particles, with sizes on the order of 1 to 100 nanometers (nm) in at least one dimension, that show physical, chemical, and biological properties not found in bulk samples of the same material (U.S. EPA, 2011b). These primary particles, termed nanoparticles, may exhibit novel, size-dependent characteristics such as increased strength, chemical reactivity, and conductivity due to their high surface area-to-volume ratio. This proportionally large surface area makes nanoparticles more reactive and responsive to their surroundings and influences mobility, aggregation, and stability in soil and water (Gavankar et al., 2012).

Naturally occurring nanomaterials are ubiquitous in the environment, but have only recently been discovered due to advances in microscopy (Hochella et al., 2008). Their background levels and mass distribution are largely unknown. In some cases, nanomaterials may also be incidental, meaning that they are unintentionally produced through industrial activities, notably through emissions from fossil fuel combustion and manufacturing (Wiesner et al., 2009).

Engineered nanomaterials are produced to serve a particular purpose and represent a new or additional input to the environment. The most common ENMs are classified into two categories: carbon-based and inorganic or metal-containing ENMs. Table 6-1 lists common types of ENMs.

Table 6-1. Common Types of Engineered Nanomaterials

Category	Engineered Nanomaterial
Carbon-based ENMs	Carbon nanotubes
	Fullerenes
	Graphene
Inorganic `or metal-containing ENMs	Silver
	Titanium dioxide
	Quantum Dots
	Cerium Oxide
	Zinc Oxide
	Iron
	Copper
	Silicon
	Gold
	Bi- and tri-metallic alloys

Source: SETAC (2012) and U.S. EPA (2013a).

Some ENMs, such as cadmium selenide quantum dots and some complex carbon-based nanomaterials, are completely novel and do not occur in nature. Any of these materials detected in the environment can be assumed to be anthropogenic (ERG, 2008; Hochella, 2013). However, many types of nanomaterials that can be engineered also occur naturally in the environment, particularly silver and metal oxides. Silver ENMs are used extensively as an antimicrobial agent in consumer products, but silver particles on the nanoscale are also found in nature. In addition, titanium dioxide (TiO_2) nanoparticles that are identical to engineered nanoparticles have been found in rivers that do not receive wastewater discharges and are remote from industrial activities (Hochella, 2013).

Based on the recommendation of several leading researchers, EPA's review of current research focused on three classes of ENMs: silver, TiO_2, and carbon-based nanomaterials (Hochella, 2013; Wiesner, 2013). Researchers estimate that these three classes are produced in the largest volumes and are commonly used in commercial and consumer products. In addition, research has more fully classified their impact on human health and the environment relative to the impacts of other types of ENMs (for which there is little information).

6.1.3 Engineered Nanomaterial Production Methods, Volumes, and Potential Sources of Industrial Discharge

To understand the potential sources and magnitude of ENMs in industrial wastewater discharges, EPA gathered available information on both ENM manufacturing and ENM processing into nano-enabled products (products containing nanomaterials). *Manufacturing* is the synthesis of ENMs; *processing* (or *formulating*) includes any industrial transformation or processing of ENMs into a form that could be used to make nano-enabled products, as well as manufacturing of nano-enabled products. EPA also collected information about the generation and handling of aqueous waste streams produced during manufacturing and processing.

ENM manufacturing occurs by both wet (chemical) and dry (gas) phase processes. Wet-phase chemical synthesis, including chemical reduction, sulfate, sol-gel, and hydrothermal methods (Fabrega et al., 2011; Liu et al., 2013; Mulfinger et al., 2007; Robichaud et al., 2009), may generate aqueous waste streams (Eckelman et al., 2012; Musee, 2011). Wet-phase processes are more common in the manufacture of silver and nano-TiO_2, though research suggests that about 60 percent of the world's manufactured nano-TiO_2 is synthesized through a gas-phase chloride process (Liu et al., 2013). Carbon nanotubes (CNTs) are most commonly manufactured using dry-phase processes, including chemical vapor deposition, arc ablation, or high-pressure carbon monoxide (Eckelman et al., 2012; Healy et al., 2008). Although dry-phase processes do not generate an aqueous waste stream, common procedures following both wet- and dry-phase synthesis, such as purification and washing, may also generate aqueous waste.

ENMs are formulated into industrial and domestic products, chemicals, and other materials to create nano-enabled products for many industrial sectors. Nano-TiO_2 is used as a catalyst and incorporated into paints, coatings, plastics, paper, and cosmetics. Nano-TiO_2 is also used as a semiconductor and in water treatment and remediation applications. Silver ENMs are widely used in consumer products, textiles, and biomedical applications for their antimicrobial properties (U.S. EPA, 2013a). CNTs are used in the electronics, polymer, and biomedical industries, with ongoing research into their applications for the energy and consumer goods sectors (Mueller and Nowack, 2008).

Researchers indicate that processing ENMs into nano-enabled products may be more likely to produce an aqueous waste stream than manufacturing ENMs because many of the nano-enabled products may be formulated with the ENMs in solution (Wiesner, 2013). The extent of processing, however, is likely proprietary and could be highly variable, depending on the intended use. As a result, EPA could not identify adequate information to characterize and quantify the waste streams generated from ENM processing.

Although available literature suggests that aqueous waste streams are likely generated through manufacturing and processing of ENMs, it is unclear how these waste streams are managed and ultimately disposed, particularly from industrial manufacturing and processing. In laboratory synthesis of ENMs, unused reagents and chemical wastes are strictly managed, and are likely to be handled as hazardous waste and not released as wastewater (Eckelman et al., 2012). In addition, researchers suggest that laboratory-generated waste streams are probably recovered or reused due to the high cost of producing ENMs (Wiesner, 2013).

To understand the magnitude of potential industrial wastewater discharges, EPA searched for information on the number of facilities manufacturing and processing ENMs and the production quantities and waste volumes generated. Commercial ENM manufacturing methods, processing methods, and production volumes are often proprietary in nature. The EPA Nanoscale Materials Stewardship Program solicited voluntary reports from U.S. companies producing ENMs in 2008 (U.S. EPA, 2013b). The program estimated that about 600 companies manufactured, processed, or used nanotechnology in 2005; although the program expected reports from 240 entities, it received only 31. Of the companies that responded, only two publicly reported any production data. These two companies reported manufacturing capacity, but not the actual quantities of nanomaterials manufactured (Hendren et al., 2011). In a separate effort, Duke University researchers, using data from patents, company websites, and requests, identified 30 companies producing either silver, nano-TiO_2, or CNTs (provided in Appendix D) (Hendren et al., 2011).

EPA's OPPT recently promulgated Significant New Use Rules (SNURs) for CNTs under the authority of the Toxic Substances Control Act, which became effective in August and October 2013 (U.S. EPA, 2013d, 2013e). These SNURs require entities that intend to manufacture, process, or use certain CNTs to notify EPA at least 90 days before engaging in a significant new use. Any Significant New Use notices made under these SNURs will give EPA the opportunity to evaluate the intended new uses of the CNTs and, if necessary, to limit or prohibit activity to mitigate any unreasonable risks to human health and the environment.

In general, EPA found that manufacturing and processing ENMs, particularly silver nanoparticles, is likely to generate aqueous waste streams; however, very little publically available information exists to characterize the waste streams or describe how the aqueous wastes are managed and disposed. Further, the universe of facilities manufacturing and processing ENMs and the associated production volumes are not well understood.

6.1.4 Fate, Wastewater Treatment, and Toxicity

ENMs are likely to be transformed and exist in different forms in the environment than the original form in which they were created. ENMs undergo complex and dynamic transformations in aqueous media, the extent of which are not fully understood (Lowry et al., 2012b). The different forms in which a nanomaterial may exist will influence its fate, reactivity, and toxicity in the environment.

6.1.4.1 Fate and Environmental Transformations

Particle size and surface area influence the degree of interaction ENMs will have with substances and organisms in the environment. A larger surface area (smaller particle) allows for greater reaction rates (Healy et al., 2008). Surface coatings that are either engineered onto the nanomaterial or attached through transformations can strongly influence the solubility and reactivity of the ENM. Nanoparticles may be transformed in water through any of the following mechanisms (Lowry et al., 2012b; Wiesner et al., 2011):

- Nanoparticle aggregation;
- Formation of complexes with other molecules in water, soil, or biological systems;
- Sorption processes;
- Degradation; and
- Dissolution of coatings or the core particle.

The interactions and transformations that occur are also dependent on the chemistry of the environment, which will affect the mobility and bioavailability of the nanomaterial. In addition, most nanomaterials in the environment tend to aggregate and do not exist as single, dispersed nanoparticles in water (Zhang et al., 2008). The fate and common interactions of silver, CNTs, and nano-TiO_2 with the aqueous environment are discussed below.

Silver nanoparticles readily form complexes with sulfur in various aqueous media, which can transform the nanoparticle into many different forms. The nanoparticle can be oxidized into silver ions or remain a nanoparticle and form complexes with other chemicals in the environment, such as sulfur (Dale et al., 2013). Silver nanoparticle sulfidation has been demonstrated in many environmental media, notably during activated sludge treatment in wastewater treatment plants (WWTPs) (Doolette et al., 2013; Kim et al., 2010), in the laboratory (Levard et al., 2011), and in the natural environment (Levard et al., 2012; Lowry et al., 2012a). Researchers at CEINT constructed wetland mesocosms to study the long-term behavior of silver nanoparticles. A study of polyvinylpyrrolidone-coated silver nanoparticles indicated that a majority of the silver nanoparticles were transformed to silver-sulfide compounds and primarily partitioned to soils and sediments (70 percent by weight) (Lowry et al., 2012a). Researchers at Carnegie Mellon University reported that silver nanoparticles are transformed to similar chemical forms as bulk silver in a pilot WWTP (Ma et al., 2013).

TiO_2 nanoparticles are highly reactive with sunlight and can act as catalysts. This behavior can vary depending on the form and surface coatings of nano-TiO_2, which has certain implications for toxicity (U.S. EPA, 2010b). Nano-TiO_2 is fairly soluble in water and solubility increases when organic material is present. Studies on environmental transformations of nano-TiO_2 are limited (Liu et al., 2013). The nanoparticles have a strong tendency to form aggregates at neutral pH, but aggregation strongly depends on the chemistry of the medium (Liu et al., 2013).

Carbon nanotubes have a high affinity to partition to solid phases. However, CNTs may stay suspended in water in aqueous environments with high concentrations of dissolved organic matter. The environmental transformations CNTs undergo are not well understood, and may vary depending on the structure of the CNTs (Petersen et al., 2011). The chemistry of the environment can also change the physiochemical properties of CNTs, which can affect their behavior. For example, high-salinity environments increase CNT aggregation (Eckelman et al., 2012).

6.1.4.2 Wastewater Treatment

The transformation, fate and behavior, and treatment of nanomaterials in industrial wastewaters have not been studied. However, their presence and fate has been studied in municipal wastewater, in part to determine how well current municipal treatment systems remove ENMs from wastewater. Common treatment technologies employed in municipal WWTPs, such as activated sludge, settling, and filtration, are effective at removing nanomaterials from the wastewater, although nanoparticles likely partition to the sewage sludge (biosolids generated as a byproduct of wastewater treatment). More than 90 percent of nanomaterials may leave wastewater by sorption to biomass and subsequent settling or filtration during wastewater treatment; however, removal efficiency strongly depends on the size of the nanomaterials (Westerhoff et al., 2011).

In addition, nanomaterials tend to aggregate in water, so conventional sedimentation processes can be effective in removing nanomaterials from wastewater. Conventional coagulation and sedimentation can remove 20 to 60 percent of total nanoparticles, as measured by mass (Zhang et al., 2008). After conventional treatment, tertiary filtration processes can further remove nanomaterials from the water. For example, WWTPs using microfiltration removed TiO_2 nanoparticles more effectively than those using conventional settling methods (Westerhoff et al., 2011).

The applicability of municipal wastewater research to industrial wastewater is unknown. Nanomaterial reactions and transformations may vary depending on the aqueous environments, and industrial wastewater tends to have higher concentrations and varieties of constituents than either municipal wastewater or the ambient environment. In addition, industrial wastewater quality varies greatly between point source categories and industrial processes. For these reasons, the behavior of nanomaterials in industrial wastewater treatment systems warrants further study.

6.1.4.3 Toxicity and Exposure

Though toxicity studies have been conducted, research has focused on ENM toxicity in controlled laboratory environments using ENMs in the form in which they were created. To date, EPA has not identified any studies on toxicity from exposures to ENMs in industrial wastewater. Research on ENM toxicity, described below, largely has not considered relevant forms and concentrations of nanomaterials that may be present in complex media, such as industrial wastewater (Gottschalk and Nowack, 2011; Lowry et al., 2012b). In addition, few toxicity studies have been conducted within complex media and ecosystems, where exposures will likely be at lower concentrations and where a diversity of organisms is present (Colman et al., 2013). The complex interactions and interdependencies within an ecosystem, especially at the microbial level, will influence the hazardous effects of ENMs. Some researchers recommend that fate and toxicity measurements should be made in complex, natural systems in order to accurately assess hazards (Lowry et al., 2012b; Wiesner et al., 2009).

ENM toxicity testing has shown adverse effects on aquatic organisms and the environment. The primary toxicity mechanism for **silver nanomaterials** is their dissolution into silver ions (Arnaout and Gunsch, 2012; Nowack et al., 2011). Silver ions cause oxidative stress in microorganisms and aquatic organisms (Yang et al., 2012), but toxic impacts in humans are only observed at very high concentrations (Nowack et al., 2011). However, it is unclear whether silver nanoparticles exhibit novel toxicity mechanisms, outside of generating silver ions. Therefore, the observed toxicity effects in silver nanoparticles may not differ from those of bulk or colloidal silver (Nowack et al., 2011).

Titanium dioxide nanomaterials may exhibit ecotoxicity impacts because of their catalytic surfaces (Hochella, 2013). Nano-TiO_2 can be activated by sunlight to produce reactive oxygen species, which cause cellular damage. Nano-TiO_2 has been shown to suppress the growth of freshwater green algae, which is a concern for freshwater habitats (Cardinale et al., 2012). Researchers have observed photo-dependent mortality effects in model organisms exposed to nano-TiO_2 in the part per billion range (Alloy and Roberts, 2012; Heideman et al., 2012). This implies that exposure to sunlight in ecosystems with nano-TiO_2 may threaten organisms in shallow surface waters and soils. However, more research is needed to determine nano-TiO_2 impacts on aquatic ecosystems and microorganisms in particular.

A main mechanism for **carbon nanotubes** toxicity is the production of reactive oxygen species, which is strongly affected by nanotube structure, as the ability to generate reactive oxygen species may increase as the size of the nanotubes decrease (Chae et al., 2011). Various studies have shown that exposure to CNTs can cause growth inhibition, hatching delays, and mortality in some aquatic organisms (Petersen et al., 2011).

Though the majority of toxicity studies to date were conducted using untransformed nanoparticles in laboratory environments, toxicity studies conducted in simulated natural environments (mesocosms) and natural environments have reported fewer toxic effects. This suggests that ENM impacts are affected and potentially dampened by environmental transformations, microbial activity, and the physical and chemical properties of the environment (Colman et al., 2012; Unrine et al., 2012). For example, researchers at CEINT have shown that the short-term impacts of silver nanoparticles on microbes are attenuated by stream water and sediment (Colman et al., 2012). However, even low doses of silver nanoparticles may have appreciable effects on an environment, such as shifting wetland microorganism populations (Colman et al., 2013).

Currently, human health effects of nanomaterials in any environmental medium are not fully understood, but risks are presumed to be rather low. However, there have been recent efforts to minimize airborne exposure to nanomaterials in the workplace due to concern for inhalation hazards. In 2013, the National Institute for Occupational Safety and Health (NIOSH) published guidelines to minimize workplace exposure to nanomaterials (NIOSH, 2013). In addition, the Occupational Safety and Health Administration (OSHA) published recommended best practices and exposure limits for airborne CNTs and nano-TiO_2 (OSHA, 2013). While airborne exposure is not a direct concern for the Effluent Guidelines Program, concerns about airborne ENM concentrations may increase future use of wet scrubbers for air pollution control, with possible generation of an ENM-containing wastewater.

Biosolids generated from wastewater treatment are often used as fertilizers, and land application of biosolids is considered a potential major source of environmental exposure to ENMs (Lowry et al., 2012b; Westerhoff et al., 2013). Researchers have identified and characterized silver and TiO_2 nanoparticles in U.S. municipal wastewater sludge samples, which raises concerns about this potential exposure pathway (Kim et al., 2010; Kim et al., 2012).

To estimate the potential exposure and risk to aquatic organisms, researchers have developed models that predict the ENM concentrations in the environment. Researchers at the Swiss Federal Laboratories for Materials Testing and Research (Empa) calculated predicted environmental concentrations (PECs) of several ENMs in WWTP effluent (from a combination of industrial and domestic sources) and surface waters in the U.S. based on probabilistic material flow analysis of current production volumes (Gottschalk et al., 2009). As shown in Table 6-2, the PECs of ENMs in WWTP effluent are orders of magnitude larger than what is predicted for surface waters. The researchers then compared the PECs to predicted no effect concentrations (PNEC) from ecotoxicological studies and concluded that silver and TiO_2 ENMs in WWTP effluent may pose a risk to aquatic organisms based on their risk quotients (Table 6-2). A risk quotient greater than one indicates a need to further evaluate the risks posed to aquatic organisms.

Table 6-2. Calculated Model Values for Predicted Environmental Concentrations of Engineered Nanomaterials in the U.S.

Engineered Nanomaterial	Predicted Environmental Concentration (PEC) (ng/L)		WWTP Effluent Risk Quotient (PEC/PNEC)	
	WWTP Effluent	Surface Water	WWTP Effluent	Surface Water
Silver	21.0	0.116	**30.1**	0.17
Nano-TiO_2	1,750	2.0	**1.8**	0.002
CNTs	8.6	0.001	<0.0005	<0.0005
Fullerenes	4.6	0.003	0.023	<0.0005

Source: Gottschalk et al. (2009)

Risk quotients greater than one are indicated in bold.

The Empa model was based on estimated worldwide production volumes, which are incomplete and uncertain. Therefore, the significance of the Empa study's results to the U.S. is uncertain. The results do suggest, however, that aquatic ecosystems may be at risk from exposure to silver and TiO_2 ENMs released into the environment, though the study did not clearly distinguish between the impact of potential inputs from manufacturing, processing, and dissolution or degradation of ENMs from end-use products. In the absence of discharge data, quantifying production and waste volumes for industrial ENM manufacturing and processing is critical for developing models that accurately assess the risk associated with environmental releases.

6.1.5 Analytical Methods

Methods for detecting, quantifying, and characterizing nanomaterials in complex environmental media, like industrial wastewater, are not fully developed; many of the analytical methods developed to date characterize pure nanomaterials in simple media. With additional research, some of these methods may be refined and adapted to characterize ENMs in complex environmental media. Table 6-3 lists some of the current efforts to develop analytical methods for ENMs. The organizations listed (among others) are currently researching and developing analytical methods to characterize ENMs in both simple and complex media. There is also significant effort under way to develop new tools to characterize nanomaterials in the environment. Currently, more research characterizing analytical method development for metal-containing nanomaterials in complex media has been published than for carbon-based nanomaterials.

Table 6-3. Research Organizations Developing Analytical Methods for ENMs

Organization	Analytical Method	Nanomaterial
EPA Office of Research and Development, National Exposure Research Laboratory Environmental Sciences Division (EPA ORD/NERL/ESD)	Screening and characterization methods	Metal-containing nanomaterials
Swiss Federal Institute of Aquatic Science and Technology (Eawag)	Electron microscopy, mobile laser-induced breakdown detection	Not specified
Center for the Environmental Implications of Nanotechnology (CEINT)	Testing protocols; hyperspectral imagery with enhanced darkfield microscopy	Silver, TiO_2 and other metal-oxides
University of California's Center for Environmental Implications of Nanotechnology (UC-CEIN)	Testing protocols; microscopic and spectroscopic methods	Metal oxides, CNTs, and others not specified
Arizona State University (ASU)	Detection and characterization of ENMs during water treatment and monitoring in complex media	Silver, TiO_2, CNTs
Trent University (Ontario, Canada)	Monitoring in complex media	Silver
Binghamton University, State University of New York	Membrane sensor to detect and quantify ENMs	Silver, TiO_2, and quantum dots

Many U.S. and international organizations are working to develop guidance and standards for ENM characterization. These organizations include, but are not limited to, standard-setting groups such as the International Standardization Organization, ASTM International, and the American National Standards Institute; U.S. federal research led by the National Institute of Standards and Technology (NIST) is also relevant (NNI, 2013b). The Organization for Economic Co-operation and Development has published guidance for safety testing and characterization of toxicological properties of ENMs. It is recognized as a living document, subject to refinement as research into the development of nanomaterial test methods progresses (OECD, 2012).

Because method development is in its infancy, EPA has not approved standardized methods for sampling, detecting, monitoring, quantifying, or characterizing nanomaterials in aqueous media. This is a critical area of research because the ability to detect and characterize nanomaterials is essential to understanding the implications of their release into the environment (U.S. EPA, 2010a). The National Nanotechnology Initiative (NNI) identified the development of devices to detect and identify ENMs across their life cycles as a priority; through its initiatives, NNI aims to accelerate research. The NNI strategic plan and research priorities are further described in Section 6.1.6. Standard method development will also support research into the environmental implications of nanomaterials and especially aid in fate and transport research needed for more accurate exposure and risk assessments. EPA-approved methods are also needed before EPA can consider regulating discharges of ENMs in industrial wastewater.

Once standardized methods are developed to detect, characterize, and quantify ENMs discharges to, and concentrations in, the environment, strategies will be needed to distinguish between engineered and naturally occurring nanomaterials to fully inform monitoring. Engineered and naturally occurring nanoparticles are often indistinguishable under a microscope (Hochella, 2013; Wiesner et al., 2011). For example, TiO_2 nanoparticles that are identical to engineered nanoparticles have been found in rivers that do not receive wastewater discharges and are remote from industrial activities (Hochella, 2013). In addition, background levels of naturally occurring nanomaterials, as well as nanomaterials incidentally generated during nanomaterial processing as a result of chemical transformations, may need to be considered as part of any future potential regulatory structure for industrial discharges of ENMs.

6.1.6 Federal Research and the National Nanotechnology Initiative

The NNI is a collaborative, interagency U.S. government research and development initiative. The NNI provides a framework for individual and cooperative nanotechnology-related activities for 20 federal department and agency units, including EPA, with a range of research and regulatory roles and responsibilities. The NNI expedites the discovery, development, and deployment of nanoscale science and technology to serve the public good; this is accomplished through a program of coordinated research and development aligned with the missions of the participating agencies (NNI, 2013a). NNI agencies and academic research centers coordinate research that may facilitate EPA's understanding of the potential for wastewater discharges from ENM manufacture and processing and potential impacts on the environment.

The 2014 NNI Strategic Plan describes the high-level goals, priorities, and specific objectives, for at least the next three years, related to nanotechnology research but does not provide performance measures or timeframes for meeting the objectives (NSET, 2014). The NNI Strategic Plan describes several areas of research focused on the environmental, health, and safety implications of nanotechnology (NSET, 2014). A subset of these research areas, listed below, may inform EPA's understanding of the presence and impact of nanomaterials in industrial wastewater discharge:

- Nanomaterial measurement infrastructure;
- Predictive modeling and informatics;
- Human exposure and health;
- Environmental health; and
- Risk assessment and risk management.

The NNI Strategic Plan also establishes Nanotechnology Signature Initiatives to spotlight topical areas that exhibit particular promise, existing effort, and significant opportunity, and to accelerate their development (NSET, 2014). One initiative in particular applies to the needs of the Effluent Guidelines program: Nanotechnology for Sensors and Sensors for Nanotechnology. This initiative aims, in part, to support research and development methods and devices to detect and identify ENMs across their life cycles; this will allow researchers to assess the potential human health and environment impacts of ENMs.

NNI member agencies also fund much of the ongoing research discussed in this section (e.g., research by the National Science Foundation, NIST, NIOSH, OSHA, and others). In particular, EPA supports research on environmental exposure, impacts, risk assessment, and analytical method development through the National Center for Environmental Research and extramural grant, fellowship, and research contract programs (NNI, 2013c).

6.1.7 Summary of Findings

Nanotechnology is a rapidly progressing field, expected to continue to grow as the number of products and technological applications increases. Some manufacturing and processing methods likely generate wastewater, potentially for each of the ENMs of interest (silver, nano-TiO_2, and CNTs), but the quantity generated and waste management practices are not documented. ENM manufacturing and processing span multiple industrial categories, but little progress has been made to date to quantify production volumes.

While some exposure hazards have been demonstrated, the environmental and human health risks associated with these materials are largely unknown. Fate and toxicity assessments for ENMs, in the forms and relevant concentrations to which organisms will be exposed, are needed to accurately determine risk. Industrial wastewater releases of ENMs to the environment have not been studied.

The growth in ENM manufacturing has been accompanied by some research into ENMs' presence and fate in wastewater. Methods for detecting and characterizing nanomaterials in complex media, including industrial wastewater, are under development. Research has also shown that common treatment technologies employed in municipal WWTPs are effective at removing nanomaterials from the wastewater, and some nanomaterials (e.g., silver, nano-TiO_2) have been detected in U.S. WWTP biosolids.

Despite the body of current research, ENMs present a challenge for environmental monitoring, risk assessment, and regulation due to their small size, unique properties, and complexity. EPA has not approved any standardized methods for sampling, detection, or quantification of nanomaterials in aqueous media. New methods and means of quantification need to be developed to understand the environmental implications of ENMs and inform future regulatory decisions.

From its review of current literature and research, EPA has identified the following data gaps and research appropriate to better assess the potential presence and impact of ENMs in industrial wastewater:

- Development of standard methods and sampling techniques to detect and characterize nanomaterials in industrial wastewater;
- Development of methods to distinguish between naturally occurring and engineered nanomaterials in aqueous media;

- Evaluation of ENM toxicity impacts and potential occurrence in industrial wastewater, taking into consideration relevant forms and concentrations of ENMs;
- Identification of the universe of facilities, production volumes, and waste generated and disposed of from ENM manufacturing and processing; and
- Evaluation and characterization of the fate, transformation, and treatment of ENMs in industrial wastewaters.

While EPA, academic institutions and research centers, and international organizations are currently researching many of these areas, more focused research is needed to understand the hazards and implications from the environmental release of nanomaterials via industrial wastewater discharges.

6.1.8 References for the Review of Engineered Nanomaterials in Industrial Wastewater

1. Alloy, M., and A. Roberts. 2012. *Photo-enhanced toxicity of nano-titanium dioxide (anatase) on freshwater zooplankton*. Proceedings from the SETAC 33rd Annual Meeting. Long Beach, California. (November 15). EPA-HQ-OW-2014-0170. DCN 08046.

2. Arnaout, C. L., and C.K. Gunsch. 2012. Impacts of silver nanoparticle coating on the nitrification potential of nitrosomonas europaea. *Environmental Science & Technology.* 46(10): 5387-5395. www.dx.doi.org/10.1021/es204540z. EPA-HQ-OW-2014-0170. DCN 08047.

3. Cardinale, B. J., R. Bier, and C. Kwan. 2012. Effects of TiO_2 nanoparticles on the growth and metabolism of three species of freshwater algae. *Journal of Nanoparticle Research.* 14(8): 1-8. www.dx.doi.org/10.1007/s11051-012-0913-6. EPA-HQ-OW-2014-0170. DCN 08048.

4. Chae, S. R., M. Therezien, J.F. Budarz, L. Wessel, S.H. Lin, Y. Xiao, and M.R. Wiesner. 2011. Comparison of the photosensitivity and bacterial toxicity of spherical and tubular fullerenes of variable aggregate size. *Journal of Nanoparticle Research.* 13: 5121-5127. EPA-HQ-OW-2014-0170. DCN 08049.

5. Colman, B. P., C.L. Arnaout, S. Anciaux, C.K. Gunsch, M.F. Hochella, B. Kim, G.V. Lowry, B. M. McGill, B.C. Reinsch, C.J. Richardson, J.M. Unrine, J.P. Wright, L. Yin, and E.S. Bernhardt. 2013. Low concentrations of silver nanoparticles in biosolids cause adverse ecosystem responses under realistic field scenario. *PLoS ONE.* 8(2): e57189. Available online at: http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0057189. EPA-HQ-OW-2014-0170. DCN 08050.

6. Colman, B. P., S.Y. Wang, M. Auffan, M.R. Wiesner, and E.S., Bernhardt. 2012. Antimicrobial effects of commercial silver nanoparticles are attenuated in natural streamwater and sediment. *Ecotoxicology.* 21(7): 1867-1877. www.dx.doi.org/10.1007/s10646-012-0920-5. EPA-HQ-OW-2014-0170. DCN 08051.

7. Dale, A. L., G.V. Lowry, and E.A. Casman. 2013. Modeling nanosilver transformations in freshwater sediments. *Environmental Science & Technology.* 47(22): 12920-12928. www.dx.doi.org/10.1021/es402341t. EPA-HQ-OW-2014-0170. DCN 08052.

8. Doolette, C. L., M.J. McLaughlin, J.K. Kirby, D.J. Batstone, H. H. Harris, H. Ge, and G. Cornelis. 2013. Transformation of PVP coated silver nanoparticles in a simulated wastewater treatment process and the effect on microbial communities. *Chemistry Central Journal.* 7(1): 46. (March 4). EPA-HQ-OW-2014-0170. DCN 08053.

9. Eckelman, M. J., M.S. Mauter, J.A. Isaacs, and M. Elimelech. 2012. New perspectives on nanomaterial aquatic ecotoxicity: Production impacts exceed direct exposure impacts for carbon nanotoubes. *Environmental Science & Technology.* 46(5): 2902-2910. www.dx.doi.org/10.1021/es203409a. EPA-HQ-OW-2014-0170. DCN 08054.

10. ERG. 2008. Eastern Research Group, Inc. *Sampling and Analysis of Nanomaterials in the Environment: A State-Of-The-Science Review* [Final Report]. (August). EPA-HQ-OW-2014-0170. DCN 08055.

11. ERG. 2013. Eastern Research Group, Inc. Environmental Engineering Support for Clean Water Regulations Programmatic Quality Assurance Project Plan (PQAPP, Rev. 1, Approved October 20, 2013). EPA-HQ-OW-2010-0824. DCN 07754.

12. ERG. 2014. Eastern Research Group, Inc. *Engineered Nanomaterials EndNote Reference Library*. (August). EPA-HQ-OW-2014-0170. DCN 08056.

13. ERG. 2015. Eastern Research Group, Inc. Engineered Nanomaterials in Industrial Wastewater: Literature Review and Implications for 304m. (January). EPA-HQ-OW-2014-0170. DCN 08108.

14. Fabrega, J., S.N. Luoma, C.R. Tyler, T.S. Galloway, and J.R. Lead. 2011. Silver nanoparticles: Behaviour and effects in the aquatic environment. *Environment International.* 37(2): 517-531. www.dx.doi.org/10.1016/j.envint.2010.10.012. EPA-HQ-OW-2014-0170. DCN 08058.

15. Gavankar, S., S. Suh, and A. Keller. 2012. Life cycle assessment at nanoscale: Review and recommendations. *The International Journal of Life Cycle Assessment.* 17(3): 295-303. www.dx.doi.org/10.1007/s11367-011-0368-5. EPA-HQ-OW-2014-0170. DCN 08059.

16. Gottschalk, F., and B. Nowack. 2011. The release of engineered nanomaterials to the environment. *Journal of Environmental Monitoring.* 13(5): 1145-1155. EPA-HQ-OW-2014-0170. DCN 08060.

17. Gottschalk, F., T. Sonderer, R.W. Scholz, and B. Nowack. 2009. Modeled environmental concentrations of engineered nanomaterials (TiO_2, ZnO, Ag, CNT, fullerenes) for different regions. *Environmental Science & Technology.* 43(24): 9216-9222. www.dx.doi.org/10.1021/es9015553. EPA-HQ-OW-2014-0170. DCN 08061.

18. Healy, M. L., L.J. Dahlben, and J.A. Isaacs. 2008. Environmental assessment of single-walled carbon nanotube processes. *Journal of Industrial Ecology.* 12(3): 376-393. www.dx.doi.org/10.1111/j.1530-9290.2008.00058.x. EPA-HQ-OW-2014-0170. DCN 08062.

19. Heideman, W., O. Bar-Ilan, R. Peterson, J. Pedersen, and H. Robert. 2012. *TiO_2 nanoparticle exposure and illumination during zebrafish development: Mortality at parts per billion concentrations*. Proceedings from the SETAC 33rd Annual Meeting. Long Beach, California. Available online at: http://longbeach.setac.org/sites/default/files/SETAC-abstract-book-2012.pdf EPA-HQ-OW-2014-0170. DCN 08063.

20. Hendren, C. O., X. Mesnard, J. Droge, and M.R. Wiesner. 2011. Estimating production data for five engineered nanomaterials as a basis for exposure assessment. *Environmental Science & Technology.* 45: 2562-2569. EPA-HQ-OW-2014-0170. DCN 08064.

21. Hochella, M. F. 2013. Telephone Communication between Michael Hochella, Virginia Tech, and Eva Knoth and Kim Wagoner, Eastern Research Group, Inc. Re: Request for Information on Nanomaterials Research.(March 15). EPA-HQ-OW-2014-0170. DCN 08065.

22. Hochella, M. F., S.K. Lower, P.A. Maurice, R.L. Penn, N. Sahai, D. Sparks, and B.S. Twining. 2008. Nanominerals, mineral nanoparticles, and earth systems. *Science.* 319(5870): 1631-1635. www.dx.doi.org/10.1126/science.1141134. EPA-HQ-OW-2014-0170. DCN 08066.

23. Kim, B., M. Murayama, B.P. Colman, and M.F. Hochella. 2012. Characterization and environmental implications of nano- and larger TiO2 particles in sewage sludge, and soils amended with sewage sludge. *Journal of Environmental Monitoring.* 14(4): 1128-1136. www.dx.doi.org/10.1039/C2EM10809G. EPA-HQ-OW-2014-0170. DCN 08067.

24. Kim, B., C.S. Park, M. Murayama, and M.F. Hochella. 2010. Discovery and characterization of silver sulfide nanoparticles in final sewage sludge products. *Environmental Science & Technology.* 44(19). www.dx.doi.org/10.1021/es101565j. EPA-HQ-OW-2014-0170. DCN 08068.

25. Levard, C., E.M. Hotze, G.V. Lowry, and G.E. Brown. 2012. Environmental transformations of silver nanoparticles: Impact on stability and toxicity. *Environmental Science & Technology*. www.dx.doi.org/10.1021/es2037405. EPA-HQ-OW-2014-0170. DCN 08069.

26. Levard, C., B.C. Reinsch, F.M. Michel, C. Oumahi, G.V. Lowry, and G.E. Brown. 2011. Sulfidation processes of PVP-coated silver nanoparticles in aqueous solution: Impact on dissolution rate. *Environmental Science & Technology. 45*(12): 5260-5266. www.dx.doi.org/10.1021/es2007758. EPA-HQ-OW-2014-0170. DCN 08070.

27. Liu, X., G. Chen, A.A. Keller, and C. Su. 2013. Effects of dominant material properties on the stability and transport of TiO_2 nanoparticles and carbon nanotubes in aquatic

environments: from synthesis to fate. *Environmental Science: Processes & Impacts.* 15(1): 169-189. EPA-HQ-OW-2014-0170. DCN 08071.

28. Lowry, G. V., B.P. Espinasse, A.R. Badireddy, C.J. Richardson, B.C. Reinsch, L.D. Bryant, A.J. Bone, A. Deonarine, S. Chae, M. Therezien, B.P. Colman, H. Hsu-Kim, E.S. Bernhardt, C.W., Matson, and M.R. Wiesner. 2012a. Long-term transformation and fate of manufactured Ag nanoparticles in a simulated large scale freshwater emergent wetland. *Environmental Science & Technology.* 46(13): 7027-7036. www.dx.doi.org/10.1021/es204608d. EPA-HQ-OW-2014-0170. DCN 08072.

29. Lowry, G. V., K.B. Gregory, S.C. Apte, and J.R. Lead. 2012b. Transformations of nanomaterials in the environment. *Environmental Science & Technology.* 46(13): 6893-6899. www.dx.doi.org/10.1021/es300839e. EPA-HQ-OW-2014-0170. DCN 08073.

30. Ma, R., C. Levard, J.D. Judy, J.M. Unrine, M. Durenkamp, B. Martin, B. Jefferson, and G.V. Lowry. 2013. Fate of zinc oxide and silver nanoparticles in a pilot wastewater treatment plant and in processed biosolids. *Environmental Science & Technology*. www.dx.doi.org/10.1021/es403646x. EPA-HQ-OW-2014-0170. DCN 08074.

31. Mueller, N. C., and B. Nowack. 2008. Exposure modeling of engineered nanoparticles in the environment. *Environmental Science & Technology.* 42(12): 4447-4453. www.dx.doi.org/10.1021/es7029637. EPA-HQ-OW-2014-0170. DCN 08075.

32. Mulfinger, L., S.D. Solomon, M. Bahadory, A.V. Jeyarajasingam, S.A. Rutkowsky, and C. Boritz. 2007. Synthesis and study of silver nanoparticles. *Journal of Chemical Education.* 84(2): 322. EPA-HQ-OW-2014-0170. DCN 08076.

33. Musee, N. 2011. Nanowastes and the environment: Potential new waste management paradigm. *Environment International.* 37(1): 112-128. www.dx.doi.org/10.1016/j.envint.2010.08.005. EPA-HQ-OW-2014-0170. DCN 08077.

34. NIOSH. 2013. National Institute for Occupational Safety and Health. *Current Strategies for Engineering Controls in Nanomaterial Production and Downstream Handling Processes*. Cincinnati, OH. (November). DHHS (NIOSH) Publication No. 2014–102. EPA-HQ-OW-2014-0170. DCN 08078.

35. NNI. 2013a. National Nanotechnology Initiative. About the NNI. Available online at: http://nano.gov/about-nni. EPA-HQ-OW-2014-0170. DCN 08079.

36. NNI. 2013b. National Nanotechnology Initiative. Standards for nanotechnology. Available online at: http://nano.gov/you/standards. EPA-HQ-OW-2014-0170. DCN 08080.

37. NNI. 2013c. NSI: Nanotechnology for sensors and sensors for nanotechnology: Improving and protecting health, safety, and the environment. Available online at: http://www.nano.gov/NSISensors. EPA-HQ-OW-2014-0170. DCN 08081.

38. Nowack, B., H.F. Krug, and M. Height. 2011. 120 years of nanosilver history: Implications for policy makers. *Environmental Science & Technology.* 45(4): 1177-1183. www.dx.doi.org/10.1021/es103316q. EPA-HQ-OW-2014-0170. DCN 08082.

39. NSET. 2014. National Science and Technology Council, Committee on Technology, Subcommittee on Nanoscale Science, Engineering, and Technology. *National Nanotechnology Initiative Strategic Plan*. Washington, D.C. (February). Available online at: http://www.nano.gov/sites/default/files/pub_resource/2014_nni_strategic_plan.pdf. EPA-HQ-OW-2014-0170. DCN 08083.

40. OECD. 2012. Organisation for Economic Co-operation and Development. *Guidance on Sample Preparation and Dosimetry for the Safety Testing of Manufactured Nanomaterials Series on the Safety of Manufactured Nanomaterials.* (December 18). Available online at: http://search.oecd.org/officialdocuments/displaydocumentpdf/?cote=env/jm/mono(2012)40&doclanguage=en. EPA-HQ-OW-2014-0170. DCN 08084.

41. OSHA. 2013. Occupational Saftey and Health Administration. *OSHA Fact Sheet: Working Safely with Nanomaterials*. Available online at: https://www.osha.gov/Publications/OSHA_FS-3634.pdf. EPA-HQ-OW-2014-0170. DCN 08085.

42. Petersen, E. J., L. Zhang, N.T. Mattison, D.M. O'Carroll, A.J. Whelton, N. Uddin, T. Nguyen, Q. Huang, T.B. Henry, R.D. Holbrook, and K.L. Chen. 2011. Potential release pathways, environmental fate, and ecological risks of carbon nanotubes. *Environmental Science & Technology.* 45(23): 9837-9856. www.dx.doi.org/10.1021/es201579y. EPA-HQ-OW-2014-0170. DCN 08086.

43. Project on Emerging Nanotechnologies. 2014. Consumer Products Inventory. Available online at: http://www.nanotechproject.org/cpi. EPA-HQ-OW-2014-0170. DCN 08087.

44. Robichaud, C. O., A.E. Uyar, M.R. Darby, L.G. Zucker, and M.R., Wiesner. 2009. Estimates of upper bounds and trends in nano-TiO_2 production as a basis for exposure assessment. *Environmental Science & Technology.* 43: 4227-4233. EPA-HQ-OW-2014-0170. DCN 08088.

45. SETAC. 2012. Society of Environmental Toxicology and Chemistry. *SETAC North America 33rd Annual Meeting Abstract Book.* Long Beach, California. (November 15). Available online at: http://longbeach.setac.org/sites/default/files/SETAC-abstract-book-2012.pdf. EPA-HQ-OW-2014-0170. DCN 08089.

46. U.S. EPA. 2010a. Characterizing Concentrations and Size Distributions of Metal-Containing Nanoparticles in Waste Water. Washington, D.C. EPA/600/R-10/117. EPA-HQ-OW-2014-0170. DCN 08090.

47. U.S. EPA. 2010b. Nanomaterial Case Studies: Nanoscale Titanium Dioxide in Water Treatment and in Topical Sunscreen. Washington, D.C. EPA/600/R-09/057F. EPA-HQ-OW-2014-0170. DCN 08091.

48. U.S. EPA. 2011a. *Final 2010 Effluent Guidelines Program Plan*. Washington, D.C. (October). EPA-HQ-OW-2008-0517-0575.

49. U.S. EPA. 2011b. Nanotechnology basic information. Available online at: http://epa.gov/ncer/nano/questions/. EPA-HQ-OW-2014-0170. DCN 08092.

50. U.S. EPA. 2013a. Nanomaterials EPA is assessing. (February 12). Available online at: http://www.epa.gov/nanoscience/quickfinder/nanomaterials.htm#carnan. EPA-HQ-OW-2014-0170. DCN 08093.

51. U.S. EPA. 2013b. Nanoscale Materials Stewardship Program. Available online at: http://epa.gov/oppt/nano/stewardship.htm. EPA-HQ-OW-2014-0170. DCN 08094.

52. U.S. EPA. 2013c. *Response to Comments for the Final 2010 Effluent Guidelines Program Plan.* Washington, D.C. (May) EPA-HQ-OW-2010-0824-0196.

53. U.S. EPA. 2013d. *Significant New Use Rules on Certain Chemical Substances*. Washington, D.C. (August 7). EPA-HQ-OPPT-2013-0399-0001.

54. U.S. EPA. 2013e. *Significant New Use Rules on Certain Chemical Substances*. Washington, D.C. (June 26). EPA-HQ-OPPT-2010-0279-0134.

55. Unrine, J. M., P. Bertsch, O. Tsyusko, W.A. Shoults-Wilson, G.V. Lowry, B.P. Colman, and E.S. Bernhardt. 2012. *Fate and effects of silver nanoparticles in terrestrial environments*. Proceedings from the SETAC 33rd Annual Meeting, Long Beach, California. (November 15). EPA-HQ-OW-2014-0170. DCN 08095.

56. Westerhoff, P., G. Song, K. Hristovski, and M.A. Kiser. 2011. Occurrence and removal of titanium at full scale wastewater treatment plants: implications for TiO_2 nanomaterials. *Journal of Environmental Monitoring.* 13(5): 1195-1203. www.dx.doi.org/10.1039/c1em10017c. EPA-HQ-OW-2014-0170. DCN 08096.

57. Westerhoff, P. K., M.A. Kiser, and K. Hristovski. 2013. Nanomaterial removal and transformation during biological wastewater treatment. *Environmental Engineering Science.* 30(3): 109-117. www.dx.doi.org/10.1089/ees.2012.0340. EPA-HQ-OW-2014-0170. DCN 08097.

58. Wiesner, M. 2013. Telephone Communication between Mark Wiesner, Duke University, and Eva Knoth and Kim Wagoner, Eastern Research Group, Inc. Re: Request for Information on Nanomaterials Research.(March 13). EPA-HQ-OW-2014-0170. DCN 08098.

59. Wiesner, M. R., G.V. Lowry, E. Casman, P.M. Bertsch, C.W. Matson, R.T. Di Giulio, J. Liu, and M.F. Hochella. 2011. Meditations on the ubiquity and mutability of nano-sized materials in the environment. *ACS Nano.* 5(11): 8466-8470. www.dx.doi.org/10.1021/nn204118p. EPA-HQ-OW-2014-0170. DCN 08099.

60. Wiesner, M. R., G.V. Lowry, K.L. Jones, M.F. Hochella, R.T. Di Giulio, E. Casman, and E.S. Bernhardt. 2009. Decreasing uncertainties in assessing environmental exposure, risk, and ecological implications of nanomaterials. *Environmental Science & Technology.* 43(17): 6458-6462. www.dx.doi.org/10.1021/es803621k. EPA-HQ-OW-2014-0170. DCN 08100.

61. Yang, X., A.P. Gondikas, S.M. Marinakos, M. Auffan, J. Liu, H. Hsu-Kim, and J.N. Meyer. 2012. Mechanism of silver nanoparticle toxicity is dependent on dissolved silver and surface coating in Caenorhabditis elegans. *Environmental Science & Technology.* 46(2): 1119-1127. www.dx.doi.org/10.1021/es202417t. EPA-HQ-OW-2014-0170. DCN 08101.

62. Zhang, Y., Y. Chen, P. Westerhoff, K. Hristovski, and J.C. Crittenden. 2008. Stability of commercial metal oxide nanoparticles in water. *Water Research.* 42(8–9): 2204-2212. EPA-HQ-OW-2014-0170. DCN 08102.

6.2 Review of Industrial Wastewater Treatment Technologies

The Clean Water Act (CWA) directs EPA to establish Effluent Limitations Guidelines and Standards (ELGs) based on the performance of particular treatment technologies, application of best management practices, or implementation of process changes. As described in EPA's 2002 Draft National Strategy (67 FR 71165), EPA considers several factors when developing its Effluent Guidelines Program Plans, including the availability of wastewater treatment technologies. EPA may choose to revise existing ELGs for a point source category if it identifies an applicable and demonstrated technology, process change, or pollution prevention approach that would reduce the concentrations of pollutants in the discharged wastewater and, consequently, reduce the hazard to human health or the environment associated with the pollutant discharges.

Traditionally, EPA has reviewed the use and availability of improved treatment technologies when conducting specific facility, industry, and/or pollutant evaluations. In 2012, the Government Accountability Office (GAO) examined the Effluent Guidelines Program, including 1) the process EPA follows to screen and review industrial categories potentially needing new or revised guidelines, 2) any limitations to the process that could hinder EPA's effectiveness in advancing CWA goals, and 3) EPA's actions to address any such limitations (U.S. GAO, 2012). GAO's review determined that EPA focused its screening phase on the hazards associated with industrial categories without considering the availability of treatment technologies or process changes that could reduce those hazards. As a result, GAO concluded that the screening phase of the process might exclude some industrial categories for which treatment technologies or production changes may be available to serve as the basis for new or revised effluent guidelines.

EPA recognizes the need for a more coordinated approach to considering advances in treatment technologies across all industries as part of its initial screening of effluent guidelines. Furthermore, EPA believes it is important to consider technology advances when evaluating the effectiveness of older ELGs, some of which date back to the late 1970s or early 1980s. In some cases, more advanced treatment may be available that would allow EPA to establish ELGs for new pollutants or to strengthen existing requirements for regulated pollutants. As a result, in its *Final 2012 and Preliminary 2014 Effluent Guidelines Program Plans* (79 FR 55472), EPA announced that it had initiated a review of relevant literature to document the performance of new and improved industrial wastewater treatment technologies. This included plans to capture these performance data in a searchable Industrial Wastewater Treatment Technology (IWTT) Database. EPA intends to use IWTT as part of its annual reviews to quantify the effectiveness of technologies for removing pollutants of concern from specific industrial wastewater discharges. EPA will use the database, in part, to answer the following questions:

- What new technologies or changes to existing technologies are specific industries using to treat their waste streams?
- Are there technologies that can reduce or eliminate wastewater pollutants not currently regulated by ELGs, or remove pollutants to a greater degree than industries currently achieve?

The IWTT Database, which is responsive to GAO's recommendation for the Effluent Guidelines Program, will be a critical tool for enhancing EPA's ability to identify industrial categories or pollutants that warrant further review for new or revised ELGs, particularly based on improvements in treatment technologies.

This section summarizes the literature EPA has evaluated to date for inclusion in IWTT, describes the database structure and data elements captured, and provides an overview and detailed output of the data collected thus far. The data collection methodology, data sources, data quality assurance and control criteria, and the proposed plan for data storage are described in detail in EPA's *2012 Annual Effluent Guidelines Review Report* (2012 Annual Review Report) (U.S. EPA, 2014a).

6.2.1 Industrial Wastewater Treatment Technologies Data Collection Results

To date, EPA's efforts to build and populate IWTT have included two literature reviews to collect information on wastewater treatment performance (U.S. EPA, 2014a). EPA first conducted a brief and general literature search for studies that documented pilot- or full-scale performance data for industrial wastewater treatment technologies in 2011. This initial literature search assessed the availability and quality of industrial treatment technology performance data. In addition, EPA evaluated the feasibility of developing a searchable database that it could use as a tool to screen industrial wastewater discharges based on advances in treatment.

As described in EPA's 2012 Annual Review Report, a follow-on literature search in 2012 and 2013 yielded more comprehensive wastewater treatment performance data related to a few key industries of interest (U.S. EPA, 2014a). These industries included petroleum refining (40 CFR Part 419), metal finishing (40 CFR Part 433), and electroplating (40 CFR Part 413), as well as metals removal in general. Using the key words indicated in Appendix E, EPA reviewed data on new or improved treatment technology performance related to these industries from the following technical literature sources:

- *Conference proceedings.* EPA reviewed references from three key technical conferences on wastewater that included presentations across a broad range of industries: the Water Environment Federation's Technical Exhibit and Conference (2000–2013), the International Water Conference (2011), and the Water Environment Federation's Industrial Wastewater Seminar (2011).

- *Water-related journals.* EPA reviewed peer-reviewed journal articles from water-related societies that may provide information on new, more effective industrial wastewater treatment technologies.

- *Industry-specific organizations.* EPA reviewed industry trade organization publications, such as treatment publications from the American Petroleum Institute and the American Chemical Society.

EPA screened all identified literature and data sources against the established data quality criteria described in Section 6.6.1.3 of the 2012 Annual Review Report (U.S. EPA, 2014a) and the *Supplemental Quality Assurance and Control Plan for Development and Population of the Industrial Wastewater Treatment Database* (ERG, 2013).

To date, EPA has identified and screened 283 articles. Of those, 163 met the quality criteria and were entered into IWTT (See Appendix F for a bibliography of the articles currently included in the database). Table 6-4 provides an overview of the number of industries represented in IWTT as well as the degree to which EPA has collected relevant literature describing new or improved treatment technologies.

Table 6-4. Frequency of Industries Represented in IWTT

Industry	PSC	Number of Articles[a]
Petroleum refining	419	31
Metal finishing	433	21
Nonclassifiable establishments (industry not provided)	--	14
Coal mining	434	13
Oil and gas extraction	435	13
Steam electric power generating	423	11
Ore mining and dressing	440	9
Miscellaneous foods and beverages	--	9
Meat and poultry products	432	5
Pharmaceutical manufacturing	439	5
Pulp, paper and paperboard	430	4
Organic chemicals, plastics and synthetic fibers	414	4
Electrical and electronic components	469	3
Iron and steel manufacturing	420	3
Textile mills	410	3
Nonferrous metals manufacturing	421	3
Aluminum forming	467	2
Canned and preserved fruits and vegetables processing	407	2
Centralized waste treatment	437	2
Dairy products processing	405	2
Inorganic chemicals manufacturing	415	2
Grain mills	406	1
Fertilizer manufacturing	418	1
Mineral mining and processing	436	1
Hospital	460	1
Leather tanning and finishing	425	1
Transportation equipment cleaning	442	1
Agricultural services	--	1
CAFO	412	1
Wholesale trade - durable goods	--	1

Table 6-4. Frequency of Industries Represented in IWTT

Industry	PSC	Number of Articles[a]
Airport deicing	449	1
Ferroalloy manufacturing	424	1

a Some articles may describe wastewater treatment technologies for more than one industry.

6.2.2 Industrial Wastewater Treatment Technologies Database Structure and Data Elements

IWTT captures wastewater treatment technology data identified from the reviewed data sources. This section describes the structure of the database and data elements in detail. EPA structured IWTT in Microsoft Access[TM] to collect data on the following:

- Treatment systems (i.e., treatment units included in the system, unit order, chemical additions, system operating conditions and costs, and process diagrams);
- Industries implementing the technologies or industries for which the technology has been tested;
- Pollutants removed, including influent and effluent quality, and percent removals achieved; and
- Specific industry motivations for evaluating and employing new technologies.

6.2.3 Database Structure

EPA created several data tables in IWTT to organize article information and minimize redundancy and dependency within the database (ERG, 2013). Table 6-5 provides a brief description of the primary data input tables. EPA also established several lookup tables, which provide guidance or selection options for populating specific data input fields. Appendix H contains each of the key lookup tables.

Table 6-5. List of Data Input Tables

Table Name	Table Description	Where to Find More Information
Input Data (Data Obtained from the Articles)		
1_INPUT_Reference_Information	Contains article bibliographical information.	Export of IWTT Database Tables (ERG, 2014)
2_INPUT_Treatment_Technology	Contains information on treatment design, operations, and costs.	
2_INPUT_Treatment_Technology_Codes	Crosswalk between treatment technology operations codes and each treatment system reported.	
3_INPUT_Detection_Limits	Contains information on pollutant sample detection limits.	
4_INPUT_Performance_Data	Contains influent and effluent pollutant concentration data and percent removal.	

Table 6-5. List of Data Input Tables

Table Name	Table Description	Where to Find More Information
Lookup		
KEY_Document_Types	Identifies the list of document types.	Table H-2
KEY_Lab_Scale	Identifies the scale in which the measurements were conducted.	Table H-3
KEY_Motivation	Identifies the motivation categories for the implementation of the treatment system.	Table H-4
KEY_NAICS	Identifies the NAICS code in which the treatment technology is used.	2012 NAICS Index File (U.S. Census, 2012)
KEY_PerformStat	Identifies the value type reported (e.g., average, minimum, maximum).	Table H-5
KEY_Parameter_Code	Identifies the parameter names and Chemical Abstract Service (CAS) numbers.	EPA DMR Pollutant Loading Tool (U.S. EPA, 2014c)
KEY_PSCSIC_Crosswalk	Identifies the PSCs and respective SIC codes.	2013 Annual Review Report Table B-1 (U.S. EPA, 2014b)
KEY_TreatmentTechCode	Identifies the treatment technology codes.	Table H-6

EPA developed four data entry forms to facilitate data entry, promote standardization of data fields, and improve data security. The forms populate the corresponding fields in each of the input tables with relevant information. The purpose of each form is described below:

- *Form 0, "Main Menu."* Contains a listing of the existing articles entered into the database and allows data entry staff to edit an existing article entry or create a new article entry. Form 0 provides access to Form 1.

- *Form 1, "Reference Information."* Contains all of the data fields that identify and summarize the article reference, including bibliographical information, abstract, and key findings. Form 1 provides access to Form 2.

- *Form 2, "Treatment Technology."* Contains all of the data fields that capture the treatment system design, unit order, operating conditions, and cost information. If an article discusses more than one treatment system, an additional Form 2 is populated for each system. Form 2 provides access to Form 3.

- *Form 3, "Removal Performance."* Contains all of the data fields that capture performance data for each parameter removed by each treatment system. If an article discusses the removal of more than one parameter, an additional Form 3 is populated for each parameter.

Figure 6-1 illustrates the overall database structure and navigation between the forms.

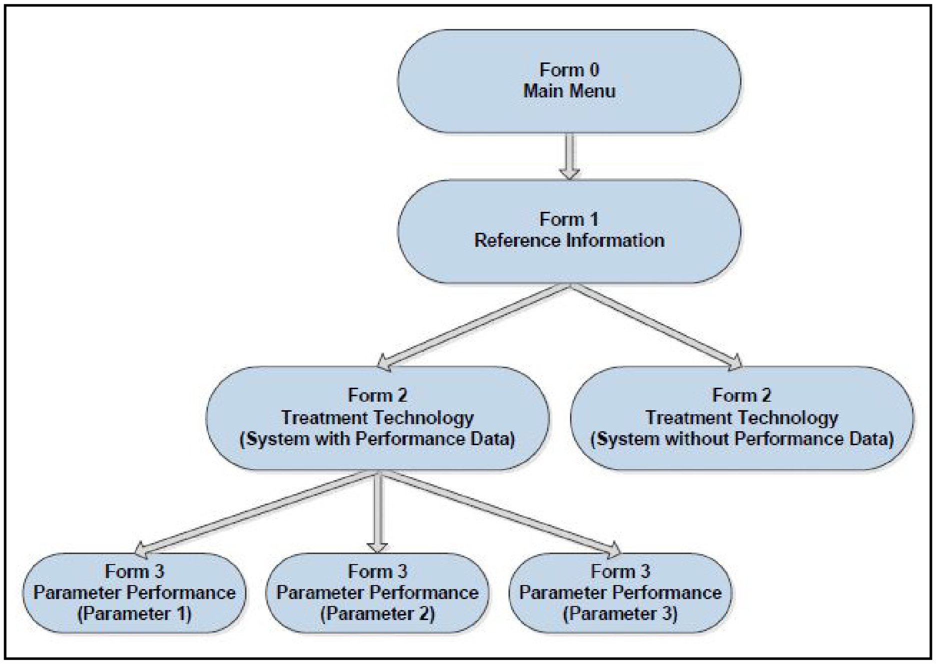


Figure 6-1. IWTT Structure

6.2.4 Data Elements Captured

Table 6-6 below provides an overview of the type of specific information captured in IWTT. For a complete list and description of the captured data elements, see Table H-1.

Table 6-6. Overview of Information Captured in IWTT

Form 1	Form 2	Form 3
Reference Information	**Treatment Technology Information**	**Parameter Performance**
• Title • Publication year • Number of pages • Authors/affiliation • Country • Source (journal, publisher, conference) • Document type (e.g., conference proceedings, peer-reviewed journal, government report) • Abstract • Key findings • Motivation (e.g., effluent limits, cost savings, water reuse, capacity increase, environmental impairment, resource recovery) • Key parameters treated	• Relevant point source category, SIC, and NAICS codes • Scale (pilot or full) • Treatment system units comprising the system (in order of the treatment train) • Operating parameters (e.g., pH, media) • Narrative description of the system • Chemical additions required • Notes on other relevant parameters • Process diagrams • Wastewater discharge type (direct or indirect, if identified)	• Pollutant parameter (each system may have performance data for multiple parameters) • Analytical method (if identified) • Influent and effluent detection limits (if identified) • Influent and effluent concentrations and qualifier flags (if identified) • Reported percent removal (if identified) • Information about what the data represent (e.g., average, maximum, median) • Effluent limits required for discharge (if identified)

Table 6-6. Overview of Information Captured in IWTT

Form 1	Form 2	Form 3
Reference Information	**Treatment Technology Information**	**Parameter Performance**
• Type of wastestream (e.g., process wastewater, commingled stormwater and process water) • Scale (lab, full, pilot)	• System manufacturer (if identified) • Capital costs (if identified) • Operation and maintenance costs (if identified)	

6.2.5 Summary of Data Captured in IWTT

EPA began populating IWTT in 2012 and continues to collect literature and populate the database. As of September 2014, there were 163 captured articles. While EPA focuses on capturing data about pilot- and full-scale treatment systems, it also documents limited information about lab-scale systems. Of the 163 articles, 98 have both treatment system information and pollutant removal information. Table 6-7 through Table 6-9 summarize the treatment technologies, industries, and parameters captured in the database. The spreadsheet *IWTT_Export.xls* provides a detailed output of the data captured in the IWTT Database (ERG, 2014).

EPA conducted specific quality assurance and control measures to validate the quality of the data as they were entered into IWTT. For more information on the quality assurance and control measures, see the methodology documented in the *Supplemental Quality Assurance and Control Plan for the Development and Population of the Industrial Wastewater Treatment Database* (ERG, 2013).

There are currently 53 pilot- or full-scale treatment technologies captured in IWTT. Table 6-7 lists the number of articles and treatment systems that include each technology. Twenty-eight treatment technologies, or 53 percent of those included in the database, are described in five or more articles. Appendix H provides additional reference tables on the treatment technologies. Table H-6 provides descriptions of each treatment technology. Table H-7 provides definitions of the treatment categories.

Table 6-7. Pilot- or Full- Scale Treatment Technologies Captured in IWTT

Treatment Technology	Category[a]	Code	Article Count	Treatment Systems Count
Chemical Precipitation	Chemical	ChemPre	32	42
Clarification	Physical, NEC	CLAR	25	29
Membrane Bioreactor	Biological	MBR	24	33
Flow Equalization	Physical, NEC	EQ	24	26
Membrane Filtration	Membrane	MF	19	25
Dissolved Air Flotation	Physical, NEC	DAF	19	25
Reverse Osmosis	Membrane	RO	18	20
Ion Exchange	Chemical	ION	16	20

Table 6-7. Pilot- or Full- Scale Treatment Technologies Captured in IWTT

Treatment Technology	Category[a]	Code	Article Count	Treatment Systems Count
Granular-Media Filtration	Filtration	FI	16	18
Mechanical Pre-Treatment	Physical, NEC	MPT	15	21
Aerobic Suspended Growth	Biological	ASG	13	13
Aeration	Physical, NEC	AIR	12	13
Bag and Cartridge Filtration	Filtration	BCF	9	10
Oil/Water Separation	Physical, NEC	OW	8	8
Anaerobic Fixed Film Biological Treatment	Biological	ANFF	7	11
Aerobic Fixed Film Biological Treatment	Biological	AFF	7	9
Electrocoagulation	Physical, NEC	EC	6	9
Anaerobic Biological Treatment	Biological	AND	6	8
Granular Activated Carbon Unit	Sorption	GAC	6	7
Liquid Extraction	Chemical	LE	6	7
UV	Chemical	UV	6	7
Adsorptive Media	Sorption	ADSM	6	6
Biologically Active Filters	Biological	BAC	6	6
Moving Bed Bioreactor	Biological	MBBR	6	6
Evaporation	Physical, NEC	EVAP	5	10
Constructed Wetlands	Biological	WET	5	8
Aerobic Biological Treatment	Biological	AD	5	6
Biological Nutrient Removal	Biological	BNR	5	5
Advanced Oxidation Processes, NEC	Chemical	AOP	4	4
Chemical Oxidation	Chemical	CO	3	4
Stripping	Physical, NEC	ST	3	4
Chemical Disinfection	Chemical	CD	3	3
Ballasted Clarification	Physical, NEC	BCLAR	3	3
Degasification	Physical, NEC	DGS	3	3
Nanofiltration	Membrane	NANO	3	3
Crystallization	Physical, NEC	CYS	2	7
Centrifugal Separator	Physical, NEC	CS	2	3
Anaerobic Suspended Growth	Biological	ANSG	2	2
Biological Treatment	Biological	BIO	2	2
Controlled Hydrodynamic Cavitation	Physical, NEC	CHC	2	2
Denitrification Filters	Biological	FDN	2	2
Ozonation	Chemical	OZ	2	2
Powdered Activated Carbon	Sorption	PAC	2	2
Dechlorination	Chemical	DCL	2	2
Hydrolysis, Acid or Alkaline	Chemical	AKH	1	2
Cloth Filtration	Filtration	CF	1	1
Biofilm Airlift Suspension Reactor	Biological	BASR	1	1

Table 6-7. Pilot- or Full- Scale Treatment Technologies Captured in IWTT

Treatment Technology	Category[a]	Code	Article Count	Treatment Systems Count
Zero Valent Iron	Chemical	ZVI	1	1
Anaerobic Membrane Bioreactor	Biological	AnMBR	1	1
Dissolved Gas Flotation	Physical, NEC	DGF	1	1
Distillation	Physical, NEC	DST	1	1
Granular Sludge Sequencing Batch Reactor	Biological	GSBR	1	1
Integrated Fixed-Film Activated Sludge	Biological	IFAS	1	1

a See Table H-7 for descriptions of each category.

Table 6-8 presents the number of full- and pilot-scale systems that have performance data for the industries captured in IWTT. Of the 163 articles entered in the database, 98 have wastewater treatment system and performance data for end-of-pipe treatment (i.e., parameter influent concentration, effluent concentration, and/or percent removal). IWTT captured removal performance of 142 parameters for these wastewater treatment systems. Table 6-9 lists the parameters with the greatest number of systems for which EPA documented treatment performance. Table G-1, in Appendix G presents the complete list of parameters with documented treatment performance.

Table 6-8. Industries with Performance data in IWTT

Industry	PSC	Scale of Treatment System	Number of Treatment Systems
Dairy products processing	405	Full	1
Canned and preserved fruits and vegetables processing	407	Full	1
Textile mills	410	Pilot	2
CAFO	412	Full	2
Petroleum refining	419	Full	6
		Pilot	12
Iron and steel manufacturing	420	Pilot	1
Nonferrous metals manufacturing	421	Pilot	3
Steam electric power generating	423	Full	1
		Pilot	3
Ferroalloy manufacturing	424	Pilot	1
Leather tanning and finishing	425	Full	4
Pulp, paper and paperboard	430	Pilot	1
Meat and poultry products	432	Full	4
		Pilot	2
Metal finishing	433	Full	2
		Pilot	18
Coal mining	434	Full	2
		Pilot	7

Table 6-8. Industries with Performance data in IWTT

Industry	PSC	Scale of Treatment System	Number of Treatment Systems
Oil and gas extraction	435	Full	2
		Pilot	8
Centralized waste treatment	437	Full	1
Pharmaceutical manufacturing	439	Full	1
		Pilot	1
Ore mining and dressing	440	Full	1
		Pilot	2
Transportation equipment cleaning	442	Full	1
Hospital	460	Pilot	1
Aluminum forming	467	Full	1
Electrical and electronic components	469	Pilot	2
Agricultural services	--	Pilot	1
Miscellaneous foods and beverages	--	Full	3
		Pilot	6
Nonclassifiable establishments	--	Full	1
		Pilot	5

Table 6-9. Top Parameters with Performance Data in IWTT

Parameter[a]	Frequency
Chemical oxygen demand	43
Total suspended solids	38
BOD	21
Solids, total dissolved (TDS)	17
Carbon, total organic (TOC)	13
Chemical oxygen demand, total	12
Nickel	12
Phosphorus, total	12
Conductivity	11
Chloride	11
Oil and grease	10
Selenium, total	10
Ammonia (as NH3)	10
Nitrogen, total	10
Cadmium	10
Chromium	9
Ammonia (as N)	9
Copper	9

Table 6-9. Top Parameters with Performance Data in IWTT

Parameter[a]	Frequency
Zinc	9
Sulfate	9
BOD5	9
Nitrogen, Kjeldahl total (TKN)	9
Calcium	8
Turbidity	8
Iron	7
Fats, oils and grease (FOG)	7
Ammonia, total	6
Nitrate (as N)	6
Arsenic	6
Dissolved oxygen (DO)	6
Naphthenic acid	5
Phenol	5
Nitrate	5
Magnesium	5
Ammonia-nitrogen	5
Phosphorus	5
Solids, volatile suspended	5
Chromium, hexavalent	5
Chemical oxygen demand, soluble	5
Selenium	5
Sodium	5

[a] Parameter names are only as specific as the names stated in each article.

6.2.6 References for the Review of Industrial Wastewater Treatment Technologies

1. ERG. 2013. Eastern Research Group, Inc. Supplemental Quality Assurance and Control Plan for the Development and Population of the Industrial Wastewater Treatment Technology Database. Chantilly, VA. (November 22). EPA-HQ-OW-2010-0824-0263.

2. ERG. 2014. Eastern Research Group, Inc. *Export of Industrial Wastewater Treatment Technology (IWTT) Database Tables.* Chantilly, VA. (September). EPA-HQ-OW-2014-0170. DCN 08000.

3. U.S. Census. 2012. 2012 NAICS Index File. Available online at: http://www.census.gov/cgi-bin/sssd/naics/naicsrch?chart=2012. EPA-HQ-OW-2014-0170. DCN 08001.

4. U.S. EPA. 2014a. *The 2012 Annual Effluent Guidelines Review Report*. Washington, D.C. (September). EPA-821-R-14-004. EPA-HQ-OW-2010-0824-0320.

5. U.S. EPA. 2014b. *The 2013 Annual Effluent Guidelines Review Report*. Washington, D.C. (September). EPA-821-R-14-003. EPA-HQ-OW-2014-0170-0077.

6. U.S. EPA. 2014c. DMR Pollutant Loading Tool. DMR Pollutant Parameters Used and Not Used by the Loading Tool (CSV). Available online at: http://cfpub.epa.gov/dmr/technical-support-documents.cfm. Accessed: June 24, 2014. EPA-HQ-OW-2014-0170. DCN 08002.

7. U.S. GAO. 2012. United States Government Accountability Office. Water Pollution: EPA Has Improved Its Review of Effluent Guidelines but Could Benefit from More Information on Treatment Technologies. (September). EPA-HQ-OW-2010-0824 -0264.

PART III: RESULTS OF EPA’s 2014 ANNUAL REVIEW

7. RESULTS OF THE 2014 ANNUAL REVIEW

For the 2014 Annual Review, EPA evaluated public comments and stakeholder input received on the *Preliminary 2014 Effluent Guidelines Program Plan*, and initiated its review of industrial categories identified as warranting further investigation during the previous annual reviews (U.S. EPA, 2014). Additionally, EPA initiated a review of an emerging pollutant group of concern and continued its review of industrial wastewater treatment technology performance data. This section presents a summary of the findings from the 2014 Annual Review.

7.1 Continued Review of Select Industrial Categories

During previous annual reviews, EPA identified several industrial categories warranting further review: Metal Finishing (40 CFR Part 433), Pesticide Chemicals (40 CFR Part 455), and brick and structural clay products manufacturing (not currently regulated). EPA continued its review of these categories as part of the 2014 Annual Review. Below are the findings from the 2014 continued category reviews.

- *Continued Review of the Metal Finishing Category (40 CFR Part 433).* EPA's continued review of the Metal Finishing Category in 2014 indicates that the industry has not experienced significant growth in the last 30 years. However, research suggests that the industry is consolidating into larger companies that tend to compete better with the expanding global market. This consolidation may have slightly reduced the size of the U.S. metal finishing industry. Further, the industry is exploring the use of new chemicals that improve surface finishing quality and/or eliminate the need for toxic chemicals that generate wastewater requiring further treatment to meet discharge requirements. These alternatives may be changing the characteristics of metal finishing wastewater over time. In addition, at least some portion of the industry is employing more advanced wastewater treatment technologies, including reuse, although a majority of the industry continues to meet the effluent limitations guidelines and standards (ELGs) using the more common treatment technologies, based on best available technology economically achievable as defined in the ELGs.

EPA's continued preliminary review of the Metal Finishing Category identified several topics that warrant further review, including:

- Potential new pollutants of concern not currently regulated that are increasingly used in metal finishing processes.
- Prevalence of potential pollutants of concern associated with wastewater generated from the use of wet air pollution control devices to control air emissions from metal finishing operations.
- The application of advanced wastewater treatment technologies and the prevalence of zero discharge practices in the industry.

- In addition there are several questions that are often raised regarding the applicability of the metal finishing requirements, such as the distinction between cleaning and etching of the base material.

- *Targeted Review of Pesticide Active Ingredients (PAIs) without Pesticide Chemical Manufacturing Effluent Limits (40 CFR Part 455)*. EPA's 2014 review identified that only seven of the 30 PAIs of interest for which discharges from manufacturing are not currently regulated under 40 CFR Part 455 are currently registered or are under registration review in accordance with Section 3 of FIFRA. The remaining 23 PAIs of interest have either never been registered or have had their registrations canceled. However, discussions with EPA's Office of Pesticide Programs suggested that registration status may not be an indicator of whether the PAI is manufactured in the U.S. (and hence potentially present in industrial wastewater discharge), as unregistered pesticides may still be manufactured in the U.S. for export. Therefore, based on the information reviewed in 2014, EPA was not able to prioritize for further review a subset of the PAIs of interest that are produced in the U.S. However, EPA did identify several follow-up questions and sources of information that will indicate whether any of the PAIs of interest are produced in the U.S. and are thus potentially present in industrial wastewater discharge. These sources of information include the Pesticide Registration Information System (PRISM), Section Seven Tracking System (SSTS) production data, and permit applications, fact sheets, and facility permits for producers of the PAIs in the U.S.

- *Continued Review of Brick and Structural Clay Products Manufacturing.* EPA's review of the current National Emission Standards for Hazardous Air Pollutants (NESHAP) for the brick and structural clay products manufacturing industry, and discussions with EPA's Office of Air and Radiation and the Brick Industry Association, identified only two of the 345 brick manufacturing facilities, two of the 24 clay ceramics facilities, and three of 127 ceramic tile facilities in the U.S. as currently having wet scrubbers installed. The findings suggest that the use of wet scrubbers to control air pollution is limited in this industry; therefore, the brick and structural clay products manufacturing industry is not generating a potential new source of industrial wastewater discharge that warrants regulation.

7.2 New Data Sources and Additional Supporting Analyses

EPA initiated a review of emerging pollutants of concern and continued its review of industrial wastewater treatment technology performance data as part of the 2014 Annual Review. Below are the findings from these analyses.

- *Review of Engineered Nanomaterials (ENMs) in Industrial Wastewater.* EPA identified outstanding data gaps related to characterizing and quantifying the presence and impact of ENMs in industrial wastewater discharges. EPA focused its review on three classes on ENMs: silver, titanium dioxide, and carbon-based nanomaterials. These are estimated to be produced in the largest volumes, and research has more fully classified their impacts on human health and the environment relative to the impacts of other types of ENMs (for which there is little information). EPA's review determined the following:

- Some ENM manufacturing and processing methods likely generate wastewater, but the quantity generated and waste management practices are not documented.
- Toxicity hazards from ENMs have been demonstrated, but the environmental and human health risks are largely unknown.
- Fate and exposure to industrial wastewater releases of ENMs to the environment have not been studied.
- The small size, unique properties, and complexity of ENMs present a challenge for environmental monitoring, risk assessment, and regulation.
- Methods for detecting and characterizing nanomaterials in complex media like industrial wastewater are under development.
- EPA has not approved any standardized methods for sampling, detecting, or quantifying nanomaterials in aqueous media.
- Research has shown that common treatment technologies employed at municipal wastewater treatment plants are effective at removing nanomaterials from the wastewater.

- From its review of the current body of research, EPA has identified several areas of further research appropriate to better assess the potential presence and impact of ENMs in industrial wastewater. Much of this research may be addressed by ongoing academic and government research, including research coordinated through the National Nanotechnology Initiative.

- *Review of Industrial Wastewater Treatment Technologies.* From its review of literature regarding the performance of industrial wastewater treatment technologies, EPA has identified and captured treatment information from 163 articles in its IWTT Database, as of September 2014. Of the 163 articles, 98 provide both treatment system information and performance data (i.e., pollutant removal efficiencies). The 98 articles with performance data represent 35 industrial categories; however most of the literature reviews conducted to date have focused on collecting treatment technology information for the petroleum refining and metal finishing industries. IWTT documents the removal efficiencies relating to 142 parameters, including many metals, chemical oxygen demand, total suspended solids, and total dissolved solids. Though performance data are captured for pilot- and full-scale treatment systems as a whole, 53 individual treatment technologies (which constitute the various treatment systems) are currently included in IWTT, with chemical precipitation, membrane bioreactors, and clarification described in the greatest number of articles.

7.3 References for Results of the 2014 Annual Review

1. U.S. EPA. 2014. *Final 2012 and Preliminary 2014 Effluent Guidelines Program Plans*. Washington, D.C. (September). EPA-820-R-14-001. EPA-HQ-OW-2014-0170-0002.