EXCELLENCE IN
ENVIRONMENTAL
CONSULTING
SERVICES

**XCG File No. 3-1474-17-03**

June 6, 2006

# FINAL
# BEST MANAGEMENT PRACTICES

## FABRICATED METAL PRODUCTS SECTOR:

## CADMIUM, LEAD, AND COPPER

Prepared for:

**MINISTRY OF THE ENVIRONMENT**
Land and Water Policy Branch
135 St. Clair Avenue West, 6th Floor
Toronto, Ontario
M4V 1P5

XCG Consultants Ltd.
820 Trillium Drive
Kitchener, ON
Canada
N2R 1K4
Tel: (519) 741-5774
Fax: (519) 741-5627
E-mail:
kitchener@xcg.com

## *EXECUTIVE SUMMARY*

This Best Management Practices (BMPs) document for the Fabricated Metal Products Sector is one in a series of documents to identify BMPs to eliminate or reduce specific harmful pollutants potentially found in wastewater effluents of six industrial sectors in Ontario. These documents provide qualitative and quantitative estimates of the potential reductions achievable through pollution prevention and treatment measures for specific pollutants of concern. This BMP document is a guide only; site-specific analysis of each facility is required to identify the most effective pollution prevention and treatment measures.

This document identifies BMPs to eliminate or reduce cadmium, lead, and copper in wastewater effluents of the fabricated metal products sector. The two primary audiences for this document are municipal representatives and industrial facility representatives. Specific sub-sectors within the fabricated metal products sector addressed include Forging and Stamping (NAICS[1] 3321); Architectural and Structural Metals Manufacturing (NAICS 3323); Boiler, Tank and Shipping Container Manufacturing (NAICS 3324); Spring and Wire Product Manufacturing (NAICS 3326); Coating, Engraving, Heat Treating and Allied Activities (NAICS 3328); and Other Fabricated Metal Product Manufacturing (NAICS 3329).

Benefits of implementing BMPs, specifically pollution prevention measures, include but are not limited to, the following:

- Increased cost-effectiveness and lower long-term costs;
- Increased customer satisfaction;
- Social benefits, such as good community relations;
- Reductions in energy, water and materials used; and
- Reduced risk and liability.

Cadmium, copper and lead are widely used and released by facilities in the fabricated metal products sector. They are used in the processes of metal shaping, metal cutting, metal plating, as well as cleaning and surface preparation.

In developing the BMP guidance documents, three reference criteria were considered with respect to final effluent concentrations for harmful substances. The three reference criteria limits are identified in Table ES.1. Reference Criteria 1 are the most stringent and Reference Criteria 3 are the least stringent.

[1] North American Industry Classification System (NAICS) used by Statistics Canada.

***Table ES.1 Reference Criteria for Substances in the Fabricated Metal Products Sector***

| Substance | Reference Criteria 1 (mg/L) | Reference Criteria 2 (mg/L) | Reference Criteria 3 (mg/L) |
|---|---|---|---|
| Cadmium | 0.0006 | 0.02 | 1 |
| Copper | 0.1 | 1 | 3 |
| Lead | 0.1 | 0.5 | 5 |

BMPs are described in this document in four categories: elimination and reduction; operating and housekeeping; education and training; and treatment. The first three categories are considered pollution prevention (P2) measures; treatment is not. Pollution prevention (P2) is defined as "the use of processes, practices, materials, products, substances or energy that avoid or minimize the creation of pollutants and waste, and reduce the overall risk to the environment or human health."[2] P2 measures are more effective than treatment in reducing releases of hazardous substances and should, therefore, be implemented in preference to treatment to meet release reference criteria. Multiple P2 measures can be implemented concurrently.

Table ES.2 identifies the pollution prevention BMPs described in this document.

***Table ES.2 Summary of P2 Measures***

| Substance Addressed | BMP Name | BMP Number |
|---|---|---|
| **Elimination/ Reduction** | | |
| Cadmium, Lead, Copper | Maximize the use of recycled water | BMP #1 |
| Cadmium, Lead, Copper | Process fluid waste minimization | BMP #2 |
| Cadmium, Lead, Copper | Reduce waste from spray-painting | BMP #3 |
| Cadmium, Lead, Copper | Reduce drag-out loss in metal plating operations | BMP #4 |
| Cadmium, Lead, Copper | Drag-out return recovery technologies for metal plating operations | BMP #5 |
| Cadmium, Lead, Copper | Rinsewater reductions for metal plating operations | BMP #6 |
| Cadmium, Lead, Copper | Extending metal working fluid life with centrifuge and reuse | BMP #7 |

[2] Definition from *Guidelines for the Implementation of the Pollution Prevention Planning Provisions of Part 4 of the Canadian Environmental Protection Act, 1999 (CEPA 1999)*, National Office of Pollution Prevention, Environment Canada, 2001

### *Table ES.2 (cont'd) Summary of P2 Measures*

| Substance Addressed | BMP Name | BMP Number |
|---|---|---|
| Cadmium, Lead, Copper | Replace salt/lead bath heat treatment process | BMP #8 |
| Cadmium | Cadmium solder substitution | BMP #9 |
| Cadmium | Material substitution for cadmium plating | BMP #10 |
| Lead | Flux substitution | BMP #11 |
| Copper | Substitution for Copper Plating Baths | BMP #12 |
| Copper | Alternative Deposition Processes for Copper Plating | BMP #13 |
| Copper | Copper Strike Alternatives | BMP #14 |
| **Operating Procedures and Housekeeping** | | |
| Cadmium, Lead, Copper | Contain all above-ground tanks containing liquids, whose spillage could be harmful to the environment | BMP #15 |
| Cadmium, Lead, Copper | Effective operational and maintenance systems | BMP #16 |
| Cadmium, Lead, Copper | Accident Prevention | BMP #17 |
| **Education and Training** | | |
| Cadmium, Lead, Copper | Management and Staff Training | BMP #18 |

To achieve the three reference criteria (Table ES.1), the most effective and appropriate combinations of P2 BMPs and treatment processes were identified. These combinations were selected on the basis of ability to achieve the reference criteria, costs, and feasibility for implementation, using estimates and engineering judgment. Table ES.3 provides an overview of the estimated effectiveness of the select P2 BMPs identified. Refer to the Tables in Section 5 for details of combinations of P2 and treatment BMPs identified.

### *Table ES.3 Summary of Effectiveness of Selected P2 BMPs*

| Substance Addressed | BMP Name | BMP Number |
|---|---|---|
| **Elimination/ Reduction**<br>Effectiveness: 50-70% | | |
| Cadmium | Material substitution for cadmium plating | BMP #4 |
| Cadmium & Lead | Drag-out reduction | BMP #10 |
| Lead | Flux substitution | BMP #11 |
| Copper | Substitution for copper plating baths | BMP#12 |
| **Operating Procedures and Housekeeping**<br>Effectiveness: 20% | | |
| Cadmium, Copper & Lead | Effective operational and maintenance systems | BMP #16 |
| Cadmium, Copper & Lead | Accident prevention | BMP #17 |
| **Education & Training**<br>Effectiveness: 1 % | | |
| Cadmium, Copper & Lead | Management and Staff Training | BMP #18 |

In the case of cadmium and copper, treatment is required after implementation of P2 practices to meet two of the three reference criteria. In the case of lead, treatment is required to meet Reference Criteria 1 and 2; however, P2 measures can achieve Reference Criteria 3 concentrations (assuming a chemical precipitation system for metals removal is already in place).

Combinations of P2 measures and treatment processes needed to achieve the three reference criteria (Table ES.1) were developed using estimates and engineering judgment.

- Cost ranges for capital and operating costs are also estimated.
- Cost estimates for implementation of pollution prevention measures were based on the number of persons employed at the facility, which was used to estimate percent of operating budget required for implementation.
- Cost estimates for treatment systems were based on a range of wastewater flow rates assumed for the sector. Based on typical wastewater data for this sector and estimated reductions with P2 measures, deionization (DI) is required for removal of cadmium, copper, and lead to meet Reference Criteria 1 and for removal of cadmium and lead to meet Reference Criteria 2. However, precipitation alone can achieve the required effluent quality to meet Reference Criteria 3.

Capital and operational and maintenance (O&M) cost curves were developed for treatment of fabricated metal products sector wastewater after the implementation of P2 measures for each set of reference criteria. Cost estimates for treatment systems were based on a range of wastewater flow rates assumed for the sector. These costs for treatment were based on achieving the concentrations as defined by the reference criteria for all relevant pollutants for each set of reference criteria. Estimated capital treatment costs ranged from $231,000 for a 1 $m^3$/h plant for Reference Criteria 2 to $1.7 million for a 50 $m^3$/h plant for Reference Criteria 1, and O&M costs ranged from $35,000 to $170,000. Assuming a chemical precipitation system already in place for metals removal, there would not be additional costs for treatment to meet Reference Criteria 3.

### *Table ES 4 Estimated Pollution Prevention Costs (for selected P2 BMPs)*

| Type of P2 Measure | Small Facilities (25 Staff) | Medium Facilities (175 Staff) | Large Facilities (300 staff) |
|---|---|---|---|
| Pollution Elimination or Reduction | negligible | negligible | negligible |
| Operating/ Housekeeping | $20,000 annually | $160,000 annually | $270,000 annually |
| Education & training | $7,725 annually | $59,350 annually | $118,772 annually |
| **Total Estimate** | $27,725 annually | $219,350 annually | $388,772 annually |

**Note:**
* Estimated annual costs for each P2 measure are approximations only; facility specific wastewater quality and operating practices must be assessed prior to selection of P2 practices.

Based on typical wastewater data for this sector and estimated reductions with P2 measures, the overall full treatment system for each target reference criteria are as follows:

- Reference Criteria 1 and 2: chemical precipitation, sand/mixed media filtration, microfiltration, and deionization (DI); and
- Reference Criteria 3: chemical precipitation.

Capital and O&M costs were developed for treatment of wastewater after the implementation of P2 measures for each set of reference criteria. These costs were based on achieving the target concentration for all relevant pollutants for each set of reference criteria. Table ES.5 presents a summary of the capital and O&M cost data for wastewater treatment after P2.

***Table ES.5 Estimated Capital and Annual Operation and Maintenance Costs***

| **Reference Criteria** | **Costs as Function of Flow Range of 1 $m^3$/h to 50 $m^3$/h** | | | | | |
|---|---|---|---|---|---|---|
| | **Capital Cost Range** | | | **Annual O&M Cost Range** | | |
| | **1$m^3$/h** | **25 $m^3$/h** | **50 $m^3$/h** | **1$m^3$/h** | **25 $m^3$/h** | **50 $m^3$/h** |
| Criteria 1 | $243,000 | $951,000 | $1,702,000 | $36,000 | $114,000 | $170,000 |
| Criteria 2 | $231,000 | $916,000 | $1,667,000 | $35,000 | $110,000 | $167,000 |
| Criteria 3 | No additional treatment required assuming a chemical precipitation system is in place. | | | | | |

**Note:**
Costs exclude chemical precipitation (metals removal), which is assumed to be installed. If required, the following estimated capital costs should be added: 1 $m^3$/hr = $67,200; 25 $m^3$/hr = $371,000; 50 $m^3$/hr = $658,000.

Note that estimates are dependent on the incoming concentrations of the pollutants identified prior to P2 measures, and concentrations achieved after P2 measures. Thus, site-specific wastewater testing is necessary at all facilities to determine compliance with regulations and to implement appropriate measures.

## TABLE OF CONTENTS

## TABLES



## FIGURES

## APPENDICES

# 1. OVERVIEW OF THIS DOCUMENT

## 1.1 Objective and Audience

This document identifies best management practices (BMPs) to eliminate or reduce cadmium, copper, and lead in wastewater effluents of the fabricated metal product manufacturing sector. The benefits of undertaking BMPs are also described. This BMP document is a guide only; site-specific analysis of each facility is required to identify the most effective pollution prevention and treatment measures.

This document is one in a series of documents to identify BMPs to eliminate or reduce specific harmful pollutants potentially found in wastewater effluents of six key industrial sectors in Ontario. Appendix A identifies the other industrial sectors and substances for which similar BMP documents have been developed.

The two primary audiences for this document are:

- **Municipal representatives** interested in assisting industrial facilities with sewer discharges to eliminate or reduce harmful pollutants.
- **Industrial facility representatives** interested in implementing BMPs to eliminate or reduce harmful pollutants and to increase company reputation for implementing 'green policies', specifically operations staff and management staff.

Appendix B identifies assessment form templates for use by municipal representatives and self-assessment templates for use by industrial sector representatives.

Specific sub-sectors within the fabricated metal products sector addressed within this document include the following: [3]

- Forging and Stamping (NAICS) 3321;
- Architectural and Structural Metals Manufacturing (NAICS 3323);
- Boiler, Tank and Shipping Container Manufacturing (NAICS 3324);
- Spring and Wire Product Manufacturing (NAICS 3326);
- Coating, Engraving, Heat Treating and Allied Activities (NAICS 3328); and

[3] North American Industry Classification System (NAICS) used by Statistics Canada. The NAICS is an industry classification system developed by the statistical agencies of Canada, Mexico and the United States. Created against the background of the North American Free Trade Agreement, it is designed to provide common definitions of the industrial structure of the three countries and a common statistical framework to facilitate the analysis of the three economies. http://www.statcan.ca/english/Subjects/Standard/naics/2002/naics02-intro.htm (accessed December 20, 2005

- Other Fabricated Metal Product Manufacturing (NAICS 3329).

Definitions for these sub-sectors are provided in Appendix C.

The harmful pollutants addressed in this series of BMPs documents have been identified at both the federal and provincial government levels, as part of on-going initiatives to limit the effect of wastewater discharges on receiving waters. Appendix D provides a list of agreements and programs, as well as substances identified by the Ontario MOE to be of particular concern under these or other initiatives.

## 1.2 Benefits of Implementing Pollution Prevention

In addition to reductions in pollutants released to water, air, and soil, implementation of pollution prevention best management practices and high quality environmental performance has numerous benefits, including:

- Increased cost-effectiveness and lower long-term costs through implementation of pollution prevention measures in a planned, holistic manner;
- Increased customer satisfaction through meeting expectations for goods and services to be produced in an environmentally responsible manner;
- Social benefits, such as good community relations and potential endorsement of facility efforts and activities;
- Reductions in energy, water, and materials used, with associated operating cost savings;
- Compliance with federal and municipal regulations;
- Reduced risk and liability resulting from regulatory non-compliance, spills, and environmental emergencies;
- Increased innovation through process and materials improvements and supply chain communication;
- Better return on investment for shareholders;
- Health and safety benefits through reduced worker exposure; and
- Higher public approval ratings and improved corporate reputation.

A study of the relationship between environmental performance and financial performance,[4] using the Standard & Poor's 500 Index (S&P 500), compared the

[4] Environmental and Financial Performance: Are They Related? M. A. Cohen, S. A. Fenn, S. Konar, Vanderbilt University, Nashville, TN, 1997 (URL

financial performance of "low polluter" portfolios to industry-matched "high polluter" portfolios. The study found that the "low polluter" portfolio performed as well as - and often better than - the "high polluter" group. Investors who chose the environmental leaders in an industry-balanced portfolio were found to do as well (or better) than those choosing the environmental laggards in each industry. According to the study, a portfolio that tracked the S&P 500 and included only the environmental leaders in each industry category would be expected to meet or exceed the market returns of the S&P 500. The study concluded that greener firms are performing as well as or better than their more polluting counterparts.

Literature references on pollution prevention do not generally quantify benefits and cost savings resulting from implementation of P2 measures. Individual case studies, however, often do identify cost savings and benefits. Refer to Appendix E, Case Study Examples Demonstrating Benefits of P2 Measures for case studies of facilities that have documented the benefits of implementing P2 measures while, at the same time, reducing releases of hazardous substances.

## 1.3 Methodology

This best management practices document was developed by a consultant team with the advice of a Steering Committee of provincial and municipal representatives. A detailed review of literature was conducted by the consultant team to identify available information on specific substance–sector combinations. Sector specialists and other representatives identified through the literature review were contacted for additional information and to obtain recent data, where available. Engineering estimates and consultant team expertise also supported the analysis and development of the BMP documents.

A number of estimating procedures and assumptions were made to support the development of options and costs for both the pollution prevention and the treatment measures. These estimating procedures were developed through available data and consultant team expertise. Refer to Sections 3 and 4 for brief outlines of the estimating procedures made for pollution prevention and treatment effectiveness and costs.

## 1.4 How to Use This Document

In addition to this introductory section, this BMP document consists of the following sections:

- **Section 2, Background**, provides information on the use of substances of interest in the sector, reference criteria targets used to analyze and develop the BMPs and reporting requirements for the substances.

---

http://sitemason.vanderbilt.edu/files/d/dLwFkQ/Environmental%20and%20Financial%20Performance.pdf, accessed January 2006)

- **Section 3, Pollution Prevention**, identifies pollution prevention (P2) options, including operating, housekeeping, training and education opportunities and suggestions. Identifies specific combinations of P2 practices, including estimates of implementation costs.
- **Section 4, Treatment**, identifies the specific combinations of treatment (assuming the combinations of P2 measures identified in Section 3 are implemented) to achieve the three reference criteria levels, including underlying assumptions for the reduction analyses.
- **Section 5, Options for Reduction of Substance concentrations in Effluents,** summary tables of the P2 and treatment measures identified in Sections 3 and 4.
- **Section 6, References**, identifies key reference documents used in the development of this BMP document.
- **Section 7, Glossary**, defines terminology and acronyms used in the document.
- **Appendices** provide information on other documents in this series, templates for assessment of facilities, sector definitions, a list of harmful substances of particular interest, and case studies.

Once having read this document, practitioners are encouraged to:

- Assess the concentration of identified substances in the effluent of their facility versus the three reference criteria analyzed (Section 2.2).
- Identify potential sources of these substances in their effluent and assess P2 and treatment options, as well as broader management practices (Sections 3 and 4).
- Review the estimating procedures and assumptions stated in Sections 3 and 4 and information presented in the Tables of Section 5 for an indication of measures that could potentially be implemented to meet the target reference criteria.
- Refer to municipal by-laws or other requirements applicable to the facility with respect to control requirements for the substances.
- Refer to the companion template documents that provide guidance on assessment (for municipal representatives) and self-assessment (for industrial representatives) of facilities.

# 2. BACKGROUND

## 2.1 Use of the Substances of Interest in this Sector

For the purposes of assessing the effectiveness of pollution prevention measures and treatment technologies, representative raw wastewater concentrations of the substances addressed in this document have been estimated as summarized in Table 2.1. The raw wastewater concentrations in Table 2.1 were determined from an extensive review of available data for the fabricated metal products manufacturing sector. In the data reviewed, concentrations of pollutants in wastewaters for this sector varied greatly. Each facility should assess its wastewater components, as the compounds listed in Table 2.1 may be found at higher, lower or negligible concentrations, depending on operating conditions and existing pollution prevention and treatment practices.

**Table 2.1 Wastewater Concentrations in the Fabricated Metal Products Manufacturing Sector**

| Substance | Representative Concentration in Wastewater (prior to pollution prevention or treatment) (mg/L) |
|---|---|
| Cadmium | 10 |
| Copper | 514 |
| Lead | 14 |

This BMP document addresses specifically the compounds listed in Table 2.1. Other compounds that may be present in the wastewater should be identified as they may be reduced by practices identified herein or by other practices.

### 2.1.1 Cadmium[5,6]

Cadmium is an elemental metal and can enter wastewater from the fabricated metal products industry through the processes of metal shaping and metal cutting when metal working fluids are used, metal plating operations in bath and rinse water and possibly cleaning and surface preparation. It is also used in solder and brazing. In some proprietary formulations for autocatalytic nickel-plating systems, a trace quantity of a brightener based on a cadmium salt is used. Cadmium and its compounds have been declared toxic substances under Section 64 of the *Canadian Environmental Protection Act, 1999* (CEPA 1999), and added to the List of Toxic Substances in Schedule 1 of CEPA 1999.

[5] Pollution Prevention Assistance Division – Georgia Department of Natural Resources. (1996). *An Analysis of Pollution Prevention Opportunities and Impediments in the Fabricated Metal Products Manufacturing Sector in Georgia.* Retrieved May, 20, 2005 from http://www.p2ad.org/Assets/Documents/ma_fabmetal.htm

[6] National Centre for Manufacturing Sciences and National Association of Metal Finishers. (1994). Blue *Book: Pollution Prevention Control Technologies for Plating Operations.* Retrieved May, 20, 2005 from http://www.nmfrc.org/bluebook/tocmain.htm

Cadmium is soluble and binds in oily waste. If exposed to an aqueous medium, the oily waste containing cadmium will emulsify in the water.

#### *Metal Shaping Processes*

Metal working fluids are typically used to cool the part, aid lubrication, provide a good finish, wash away chips, and inhibit corrosion. This fluid waste may be considered hazardous due to contamination by metals like cadmium and lead. Typically, the scrap metal and metalworking fluids are disposed of or recycled.

#### *Metal Plating Operations*

Electrocoating produces a thin surface coating of one metal on another by electrodeposition. Ferrous and non-ferrous materials are typically coated with copper, nickel, chromium, brass, zinc, and cadmium among other metals. All of these metal deposition finishing operations take place using plating baths with cleaning and rinsing baths, typically upstream and downstream of the metal deposition procedure.

The principal cause of waste in this sector is drag-out loss in transferring the work being surface treated from one process fluid to another or from process fluid to water-rinse prior to further processing. Other causes are mechanical loss from filtration systems and leakage or overfilling of process tanks. Spent or contaminated treatment solutions together with spillage and leakage are removed by a licensed waste disposal contractor either directly or after treatment in an on-site effluent treatment facility.

#### *Cleaning and Surface Preparation*

Depending on the stage of the process, aqueous degreasing operations may also produce metal wastes. Table 2.2 illustrates where cadmium can be found in the fabricated metal products sub-sectors profiled in this document.

### *Table 2.2 Cadmium in the Fabricated Metal Products Sector*

| Sector | Where cadmium may be found in process |
|---|---|
| Forging and Stamping (NAICS 3321) | Improper disposal practices of metal working fluids such as coolants and lubricants not removed by a licensed waste disposal contractor. |
| Architectural and Structural Metals Manufacturing (NAICS 3323) | Improper disposal practices of metal working fluids such as cutting oils, metal plating solutions and rinse not removed by a licensed waste disposal contractor. |
| Coating, Engraving, Heat Treating and Allied Activities (NAICS 3328) | Surface preparation and resurfacing operations including metal plating solutions leaking or spilling.<br><br>Aqueous degreasing. |
| Other Fabricated Metal Product Manufacturing (NAICS 3329) | Improper disposal practices of metal working fluids such as cutting oils, metal plating solutions and rinse not removed by a licensed waste disposal contractor.<br><br>Surface preparation and resurfacing operations including metal plating solutions leaking or spilling.<br><br>Aqueous degreasing. |
| Spring and Wire Product Manufacturing (NAICS 3326) | Improper disposal practices of metal working fluids such as coolants and lubricants not removed by a licensed waste disposal contractor. |
| Boiler, Tank and Shipping Container Manufacturing (NAICS 3324) | Improper disposal practices of metal working fluids such as coolants and lubricants not removed by a licensed waste disposal contractor. |
| Metal finishing – surface treatment | Surface preparation and resurfacing operations including metal plating solutions leaking or spilling.<br><br>Aqueous degreasing. |

BMP literature references identified processes where cadmium is a generated waste but did not clearly outline if cadmium was a unique input at that stage or carried over from an input during an earlier stage.

### *2.1.2 Lead [7,8]*

Lead is a bluish-white heavy elemental metal. It is very soft, highly malleable, ductile, and a relatively poor conductor of electricity. It is very resistant to corrosion

[7] Environment Agency (2004). "Guidance for the Surface Treatment of Metals and Plastics by Electrolytic and Chemical Processes. Environment Agency- Scientific and Technical Information services. Bristol, England.

[8] NEWMOA (2001) "Pollution Prevention in Machining and Metal Fabrication: A Manual for Technical Assistance Providers." Accessed May 20, 2005 from:http://www.newmoa.org/Newmoa/htdocs/prevention/topichub/23/NEWMOAmanual.pdf

but tarnishes upon exposure to air. This metal is found in rolled and extruded products, alloys, pigments and compounds, cable sheathing, shot and ammunition, leaded etch-resist used in manufacture of printing wire boards (PWB), and leaded glass in cathode ray tubes. The surface of metallic lead is protected by a thin layer of lead oxide, PbO. It does not react with water under normal conditions. Lead and most of its compounds are only slightly soluble in water. Lead has been declared a toxic substance under Section 64 of the *Canadian Environmental Protection Act, 1999* (CEPA 1999), and added to the List of Toxic Substances in Schedule 1 of CEPA 1999.

Lead can enter wastewater from the fabricated metal products industry through the processes of metal shaping and metal cutting when metal working fluids are used, metal plating operations in bath and rinse water and possibly cleaning and surface preparation. In some autocatalytic nickel-plating, a tin-lead process is used for electrical and electronics applications. Some fluxes for soldering contain lead. In larger ferrous processing industries, wire drawing and hot-dip coatings employ acid pickling as a pre-treatment; lead anodes are used because of the 50 g/L (max) concentration of the sulphuric acid electrolyte. Metal shaping processes including conductive heating may produce spent salt/lead baths.

#### *Metal Shaping Processes*

Metal working fluids are typically used to cool the part, aid lubrication, provide a good finish, wash away chips, and inhibit corrosion. This fluid waste may be considered hazardous due to contamination by metals like cadmium and lead. Typically, the scrap metal and metalworking fluids are disposed of or recycled.

Soldering, much like brazing, involves the joining of two metal pieces by applying fluxes to the substrates prior to heating, and allowing filler metal to flow into the space between the pieces. There are a variety of fluxes, solders, and flux/solder pastes available, which may be applied to the joint using a variety of application techniques. Modern application techniques, such as metered nozzles, are much more precise than manual methods delivering flux and solder, or solder paste, and thereby reduce the waste associated with flux removal and the formation of solder balls from excess solder. Fluxes present a problem because they require cleaning after soldering and because some fluxes contain lead.

#### *Metal Plating Operations*

Electrocoating produces a thin surface coating of one metal on another by electrodeposition. Ferrous and non-ferrous materials are typically coated with copper, nickel, chromium, brass, zinc, tin, cadmium, and lead among other metals. All of these metal deposition finishing operations take place using plating baths with cleaning and rinsing baths, typically upstream and downstream of the metal deposition procedure.

The principal cause of waste in this sector is drag-out loss in transferring the work being surface treated from one process fluid to another or from process fluid to water-rinse prior to further processing. Other causes are mechanical loss from filtration systems and leakage or overfilling of process tanks. Spent or contaminated treatment solutions together with spillage and leakage are typically removed by a licensed waste disposal contractor either directly or after treatment in an on-site effluent treatment facility.

Electroplating processes where lead may be used include the following:

- Continuous Electrolytic lead coating of steel.
  - **Resist Stripping** - Resist Strippers are designed to strip fully aqueous dry film and liquid photoresists. The resist strippers have been formulated in order to remove the resist rapidly without attacking the copper or the tin/tin-lead.
  - **Etching** - Etching is undertaken to completely remove the base copper, thus leaving only the circuit pattern which is protected by the tin/tin-lead deposit (etch resist).
  - **Trivalent chromium electroplating processes** – plating bath - lead vat lining, lead/antimony anodes with carbon. An ion exchange system is required for controlling metal contamination, and the resin requires changing at approximately three year intervals.[9]
- Other processes where lead may be used include the following:
  - **Brass** - Brass is predominantly an alloy of copper and zinc although nickel, tin, or lead may be added. A mixture of copper and zinc cyanides in solution are widely used to deposit copper and zinc alloys for decorative purposes.
  - **Bronze** - Bronze is a copper alloyed with tin and zinc. Lead is used in low concentrations as a brightener in some electrolytes. Its use in the future in many products is banned by new directives.
  - **Tin and alloy plating** - Tin lead plating is the most commonly tin plated alloy. It is used as a solder coat in different alloy ratios. Non-fluoroboric tin lead electrolytes are now available as organic acid base (MSA) methane sulphonate acid systems. They have improved stability, low sludge formation, better deposit properties, and structure of the deposit. They are widely-used in reel-to-reel machines, as well as in barrel processing.
  - **Gold** - Very pure gold deposits can also be achieved from neutral electrolytes, based on potassium-gold cyanide. Traces of arsenic,

[9] European Commission, Integrated Pollution prevention Control. (2003). “Draft Reference Document on Best Available Techniques for the Surface Treatment of Metals and Plastics.” Directorate-General Joint Research Centre – Institute for Prospective Technological Studies. Seville, Spain.

thallium, lead, and bismuth provide the fine grain structure needed for electronic devices and printed circuit boards.[10]

#### *Cleaning and Surface Preparation*

Although the strip as it leaves the cleaner rinse should be free of surface oil and dirt, oxides formed during the various stages of steel processing are not removed. The purpose of acid pickle is to remove these oxides and lightly etch the strip to present as clean a steel surface as possible to the plating section. Strip pickling can be carried out by immersion, spraying, or more commonly by eletrolysis. Acid pickling as a pre-treatment to subsequent processing steps is used for:

- Continuous cold-rolling of hot-rolled coils where thickness and other technological characteristics are charged solely by compression;
- Wire-drawing of hot-rolled coils of rod or wire for diameter reduction;
- Continuous hot-dip coating of wire or sheet steel;
- Batch hot-dip galvanising of iron or steel fabrications;
- Lead-tin (terne) coating of steel sheet;
- Continuous electroplating of steel sheet; and
- Batch pickling.

#### *Chemical Aqueous (soak) degreasing*

The workpieces are placed in this process solution for several minutes. The solution may be acid, neutral, or alkaline and normally working at increased temperatures (50-90 degrees C) because of the improved cleaning effect. The main components of the aqueous cleaning system are alkalis or acids, silicates, phosphates and complexing, and wetting agents. Aqueous cleaning systems work either by forming unstable emulsions (known as a demulgating system) or stable emulsions. Aqueous chemical systems avoid the use of solvents. The cleaned items can remain wet if the subsequent treatment is water-based, such as electroplating. Process solutions have a short life dependent on throughput and the amount of oil or grease on the workpieces.

Metals can be stripped from the substrate surface (including trace elements such as lead, which may have toxic effects). They can be separated after pH adjustment. Cleaning solutions may need to be separated from other process effluents to avoid interference with the effluent treatment plant by excess surfactants

During electrolytic degreasing, insoluble anodes are used to repel the positive ions towards the steel strip (cathode). They are constructed of current carrying materials that do not take part in the solution reaction. Two materials are used for the anode

[10] Ibid.

plate: a plate substrate in titanium coated with a thin layer of tantalum oxides or iridium oxides; and, a plate in lead alloyed with tin, or with silver and indium.

Table 2.3 illustrates where lead can be found in the fabricated metal products sector.

### *Table 2.3 Lead in the Fabricated Metal Products Sector*

| Sector | Where lead may be found in process |
|---|---|
| Forging and Stamping (NAICS 3321) | Improper disposal practices of metal working fluids such as coolants and lubricants not removed by a licensed waste disposal contractor. |
| Architectural and Structural Metals Manufacturing (NAICS 3323) | Improper disposal practices of metal working fluids such as cutting oils, metal plating solutions and rinse not removed by a licensed waste disposal contractor. |
| Coating, Engraving, Heat Treating and Allied Activities (NAICS 3328) | Surface preparation and resurfacing operations including metal plating solutions leaking or spilling.<br><br>Aqueous degreasing. |
| Other Fabricated Metal Product Manufacturing (NAICS 3329) | Improper disposal practices of metal working fluids such as cutting oils, metal plating solutions and rinse not removed by a licensed waste disposal contractor.<br><br>Surface preparation and resurfacing operations including metal plating solutions leaking or spilling.<br><br>Aqueous degreasing. |
| Spring and Wire Product Manufacturing (NAICS 3326) | Improper disposal practices of metal working fluids such as coolants and lubricants not removed by a licensed waste disposal contractor. |
| Boiler, Tank and Shipping Container Manufacturing (NAICS 3324) | Improper disposal practices of metal working fluids such as coolants and lubricants not removed by a licensed waste disposal contractor. |
| Metal finishing – surface treatment | Surface preparation and resurfacing operations including metal plating solutions leaking or spilling.<br><br>Aqueous degreasing. |

### *2.1.3 Copper* [11, 12]

In the fabrication of metal products, copper is used as a base metal and for plating other metals. Copper is an elemental metal and can enter wastewater from the fabricated metal products industry through the processes of metal shaping and metal cutting when metal working fluids are used, metal plating operations in bath and rinse water and possibly cleaning and surface preparation. It is also used in solder, as a metal colouring, in printed circuit board manufacturing and forming copper products, such as wire, buttons, zippers, coins, and fittings.

Copper (I) oxide or cuprous oxide ($Cu_2O$) is an oxide of copper. It occurs naturally as the red mineral cuprite. It has a melting point of 1230 °C. $Cu_2O$ is insoluble in water and organic solvents. Copper (I) oxide dissolves in concentrated ammonia solutions, hydrochloric acid, dilute sulfuric acid, and nitric acid to produce copper metal, copper (II) sulfate, or copper (II) nitrate, respectively.[13]

#### *Metal Shaping Processes*

Metal working fluids are typically used to cool parts, aid lubrication, provide a good finish, wash away chips, and inhibit corrosion. This fluid waste may be considered hazardous due to contamination by metals like copper, cadmium and lead. Typically, the scrap metal and metalworking fluids are disposed of or recycled.

#### *Metal Plating Operations*

Electrocoating produces a thin surface coating of one metal on another by electrodeposition. Ferrous and non-ferrous materials are typically coated with copper, nickel, chromium, brass, zinc, and cadmium among other metals. All of these metal deposition finishing operations take place using plating baths with cleaning and rinsing baths typically upstream and downstream of the metal deposition procedure.

The principal cause of waste in this sector is drag-out loss in transferring the work being surface treated from one process fluid to another or from process fluid to water-rinse prior to further processing. Other causes are mechanical loss from filtration systems, and leakage or overfilling of process tanks. Spent or contaminated treatment solutions together with spillage and leakage are removed by a licensed waste disposal contractor either directly or after treatment in an on-site effluent treatment facility.

---

[11] Illinois Waste Management and research Centre. (nd). *Metal Finishing Industry Pollution Prevention Notebook.* Retrieved May 20, 2005 from http://www.wmrc.uiuc.edu/main_sections/info_services/library_docs/manuals/finishing/toc1.htm

[12] European Commission, Integrated Pollution prevention Control. (2003). "Draft Reference Document on Best Available Techniques for the Surface Treatment of Metals and Plastics." Directorate-General Joint Research Centre – Institute for Prospective Technological Studies. Seville, Spain.

[13] Wikipedia. Copper Oxide. Retrieved October 3, 2005 from http://en.wikipedia.org/wiki/Copper(I)_oxide

#### *Cleaning and Surface Preparation*

Depending on stage of process, aqueous degreasing operations may also produce metal wastes.

Table 2.4 illustrates where copper can be found in the fabricated metal products sector.

### *Table 2.4 Copper in the Fabricated Metal Products Sector*

| Sector | Where copper may be found in process |
|---|---|
| Forging and Stamping (NAICS 3321) | Improper disposal practices of metal working fluids<br><br>Plating baths |
| Architectural and Structural Metals Manufacturing (NAICS 3323) | Improper disposal practices of metal working fluids<br><br>Plating baths |
| Coating, Engraving, Heat Treating and Allied Activities (NAICS 3328) | Surface preparation and resurfacing operations<br><br>Plating baths |
| Other Fabricated Metal Product Manufacturing (NAICS 3329) | Improper disposal practices of metal working fluids<br><br>Surface preparation and resurfacing operations<br><br>Plating baths |
| Spring and Wire Product Manufacturing (NAICS 3326) | Improper disposal practices of metal working fluids<br><br>Plating baths |
| Boiler, Tank and Shipping Container Manufacturing (NAICS 3324) | Improper disposal practices of metal working fluids<br><br>Plating baths |
| Metal finishing – surface treatment | Surface preparation and resurfacing operations<br><br>Plating baths |

## *2.2 Reference Criteria for Concentrations of Substances of Interest in Discharges to Sewers*

This sub-section identifies the reference criteria for substances of concern. In developing the BMP guidance documents, three reference criteria were considered with respect to final effluent concentrations for harmful substances. In Table 2.5, Reference Criteria 1 are the most stringent; that is, Reference Criteria 1 are the lowest reference criteria, whereas Reference Criteria 3 are the least stringent reference criteria.

***Table 2.5 Reference Criteria for Substances in the Fabricated Metal Products Sector***

| Substance | Designation | Reference Criteria 1 (mg/L) | Reference Criteria 2 (mg/L) | Reference Criteria 3 (mg/L) |
|---|---|---|---|---|
| Cadmium | COA* Tier II | 0.0006 | 0.02 | 1 |
| Copper | N/A | 0.1 | 1 | 3 |
| Lead | CEPA** Toxic | 0.1 | 0.5 | 5 |

**Note:**
*COA: Canada-Ontario Agreement respecting the Great Lakes Basin Ecosystem
**CEPA Canadian Environmental Protection Act, 1999

The *Canadian Environmental Protection Act, 1999* (CEPA) is the cornerstone of the Government of Canada's environmental legislation aimed at preventing pollution and protecting the environment and human health. CEPA recognizes the contribution of pollution prevention and the management and control of toxic substances and hazardous waste to reducing threats to Canada's ecosystems and biological diversity. CEPA acknowledges the need to virtually eliminate the most persistent toxic substances that remain in the environment for extended periods of time before breaking down, and bioaccumulative toxic substances that accumulate within living organisms.

From a regulatory perspective, pollution prevention planning becomes one of the tools Environment Canada risk managers can use to address Schedule 1 CEPA toxic substances. Facilities that use Schedule 1 CEPA toxic substances should be aware of the impact that CEPA may have on them.

#### *Reference Criteria 1*

Substances identified in the Canada-Ontario Agreement respecting the Great Lakes Basin Ecosystem (COA) are either Tier I substances, subject to virtual elimination, or Tier II substances, targeted for reduction. Column 2 of Table 2.5 identifies substances subject to the COA. For substances identified in the COA, Reference Criteria 1 are the more stringent of the recommended method detection limit (RMDL) or the Provincial Water Quality Objective (PWQO).

For other substances not subject to COA, Reference Criteria 1 are the more stringent of 20 times the PWQO or 20 times the RMDL.

#### *Reference Criteria 2*

Reference Criteria 2 were established by the minimum values identified in municipal sewer use by-laws in Ontario for the identified substances.

#### *Reference Criteria 3*

Reference Criteria 3 were established by the median values identified in municipal sewer use by-laws in Ontario for the identified substances.

## 2.3 Select Regulatory Requirements for the Substances Addressed

Toxic and hazardous substances may be subject to several regulations at the federal, provincial and municipal levels, in addition to international agreements and protocols. It is incumbent on owners and operators of industrial facilities to be knowledgeable of all management and reporting requirements for specific substances used in, produced by, transported to and from, or otherwise used at, or released from, their facilities and operations.

The following section is intended as a guide only regarding specific regulations. Proponents are advised to consult these regulations directly to ensure they have all information they require. Requirements discussed in this section include municipal sewer use by-laws, the National Pollutant Release Inventory (NPRI), and the federal Environmental Emergency requirements.

### *Municipal Sewer Use By-laws*

The majority of municipalities in the province of Ontario have municipal sewer use by-laws. A wide range of materials, chemicals, and conditions for discharge are identified in the sewer use by-laws with corresponding objectives that may include the following:[14]

- Protection of the environment;
- Protection of municipal staff and infrastructure;
- Efficient use of the system;
- Prevention of stormwater and 'clear' water from entering the system;
- Protection of sludge or biosolids quality; and
- Protection of public health and safety and protection of public property.

Some municipal sewer use by-laws include an option for entering into over-strength agreements with industrial dischargers, although these agreements are typically limited to substances intended for treatment by the community wastewater treatment facility and do not include the toxic substances addressed in this document. Some municipal sewer use by-laws also require pollution prevention planning and reporting by industrial facilities. Proponents are encouraged to access the municipal sewer use by-law pertaining to the community sewer system into which they discharge to ensure they are in compliance with all discharge and reporting requirements of the by-law.

[14] Review of Existing Municipal Wastewater Effluent (MWWE) Regulatory Structures in Canada, Marbek Resource Consultants for the Canadian Council of Ministers of the Environment (CCME), 2005

#### *Canada's National Pollutant Release Inventory*

The NPRI has several reporting thresholds, including number of employee hours, quantities, and concentrations of reportable substances manufactured, processed, or otherwise used, with requirements pertaining to specific cases where substances are produced as by-products. Practitioners are encouraged to reference the NPRI website[15] directly for the most recent reporting requirements, including reportable substances and reporting threshold, as these may change over time. There are over 330 substances and substance groups reportable under NPRI; Table 2.6 identifies the substances of interest for this BMP document.

**Table 2.6 NPRI Reporting Requirements (2003) for Substances in the Fabricated Metal Products Sector**

| Substance | NPRI Reportable Substances | NPRI Part Designation | Reporting Threshold |
|---|---|---|---|
| Cadmium | Cadmium and its compounds | Part 1B | 5 kg |
| Copper | Copper and its compounds | Group 1A | 10 tonnes |
| Lead | Lead and its compounds | Part 1B | 50 kg |

The likelihood of the sector meeting the NPRI reporting requirements is fairly high because of the scale of most operations of this nature. The limiting factor is expected to be whether the quantities of reportable substances used at the facilities are high enough.

#### *Federal Environmental Emergency (EE) Regulation*

Environmental Emergency (EE) Regulations under Part 8 of the *Canadian Environmental Protection Act*, *1999* (CEPA 1999) promote prevention and planning for preparedness, response and recovery. None of the three substances discussed in this document are identified in the federal emergency regulation at this time. Practitioners are encouraged to reference the regulatory requirements at Environment Canada's website.[16]

#### *MOE Spills Action Centre*

When a spill occurs, it is the responsibility of the owner and the person who had control of the pollutant at the time it was spilled to clean up and dispose of the pollutants and ameliorate any adverse effects in a timely manner. It is the Ministry's role to ensure that those responsible take preventative measures and use proper clean up, disposal, and amelioration practices. Under the Environment Protection Act, the Ministry can order those responsible for the spill to clean up the site.

The MOE should be contacted (Spill Action Centre 1-800-268-6060) if the spill is discharged to a storm water system and into the natural environment, migrates off-

---

[15] NPRI website: http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm

[16] Environment Canada EE Regulatory Requirements website: http://www.ec.gc.ca/ee-ue/default.asp?lang=En&n=8A6C8F31-1

site, or where the spill occurs off-site. In such a situation, the MOE, the municipality and the controller, and/or owner of the pollutant, if different, are to be notified.

# 3. POLLUTION PREVENTION

Pollution prevention (P2) is defined as "the use of processes, practices, materials, products, substances or energy that avoid or minimize the creation of pollutants and waste, and reduce the overall risk to the environment or human health."[17] P2 practices therefore include elimination of hazardous substances through materials substitutions (Section 3.2); reduction of hazardous substances through process or equipment modifications (Section 3.2); operating procedures and housekeeping practices (Section 3.3); and education and training of staff, suppliers, customers, and the public (Section 3.4). P2 measures can be undertaken concurrently. The most effective actions are those that eliminate hazardous substances, through substitution, for example.

Treatment (Section 4) is not a pollution prevention activity. For many substances, treatment moves pollutants from one media to another (e.g., removal of a metal from the water effluent to a solids residue) and does not avoid or minimize the creation of the pollutant or waste.

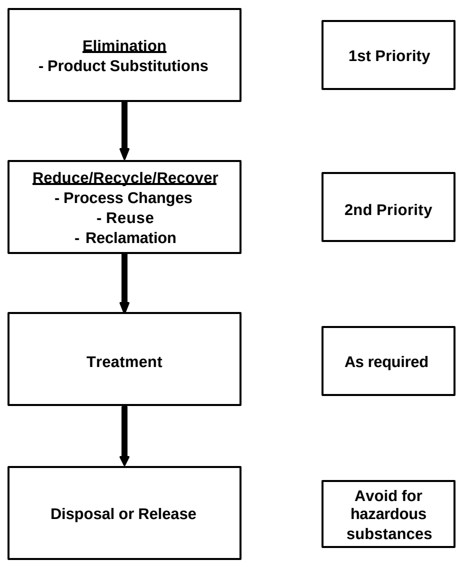
Pollution prevention and treatment BMPs must be assessed and implemented based on specific site and process conditions and characteristics; however, some overall observations can be made about effective ways to proceed with assessment and implementation of BMPs. Specific options for the fabricated metal products sector for P2 are outlined in the sub-sections following.

The best way to improve environmental management issues is to use a systematic approach. One key first step is to develop an environmental policy and strategy that is formally supported through senior management's commitment to the strategy. An Environmental Management System (EMS) is a tool that organizations in a variety of sectors have implemented to systematically identify, prioritize, and take action to address the environmental impacts of their operations and services. In addition, an EMS can establish the record-keeping and reporting required to ensure facility management has the necessary information for continuous improvements. It is recommended that all facilities consider developing, adopting, and implementing an EMS. One example of such a system is the ISO 14001 standard. Pollution prevention, product stewardship, and social responsibility are important aspects of a comprehensive, integrated environmental approach. Employee engagement and training, communication throughout the supply chain, and customer education may be appropriate elements for a successful, integrated approach to long-term sustainability.

[17] Definition in: Guidelines for the Implementation of the Pollution Prevention Planning Provisions of Part 4 of the *Canadian Environmental Protection Act*, 1999 (CEPA 1999), National Office of Pollution Prevention, Environment Canada, 2001

The following sequence of steps presents a hierarchy of techniques for undertaking pollution prevention and waste minimization:

### *Figure 3.1 Environmental Management Options Hierarchy*




- Eliminate generation of waste streams through process development and design;
- Reduce waste streams at source through process-integrated changes to raw materials, equipment and operating procedures;
- Recycle waste streams by direct re-use or reclamation and re-use;
- Recover any resource value from waste streams; and
- Treat and dispose of waste streams using end-of-pipe techniques.

The sequence of general techniques to prevent and minimize release of water pollutants includes the following steps:

- Identify all wastewater streams and characterize their quality, quantity, and variability;
- Minimize quantity of water used in the process;
- Minimize contamination of process water and washwater with hazardous raw materials, product, or wastes;
- Maximize wastewater re-use; and
- Maximize the recovery and retention of substances from streams unfit for re-use.

## *3.1 Overview of P2 Measures for Cadmium, Lead, and Copper in the Fabricated Metal Products Sector*

This sub-section provides an overview of the P2 measures discussed in the following three sub-sections: 3.2 Pollution Elimination or Reduction; 3.3 Operating Procedures and Housekeeping; and 3.4 Education and Training.

***Table 3.1 Overview of P2 Measures for Cadmium, Lead, and Copper in the Fabricated Metal Products Sector***

| P2 Type | Substance Addressed | BMP Name | BMP Number |
|---|---|---|---|
| **Elimination/ Reduction** | Cadmium, Lead, Copper | Maximize the use of recycled water | BMP #1 |
| | Cadmium, Lead, Copper | Process fluid waste minimization | BMP #2 |
| | Cadmium, Lead, Copper | Reduce waste from spray-painting | BMP #3 |
| | Cadmium, Lead, Copper | Reduce drag-out loss in metal plating operations | BMP #4 |
| | Cadmium, Lead, Copper | Drag-out return recovery technologies for metal plating operations | BMP #5 |
| | Cadmium, Lead, Copper | Rinsewater reductions for metal plating operations | BMP #6 |
| | Cadmium, Lead, Copper | Extending metal working fluid life with centrifuge and reuse | BMP #7 |
| | Cadmium, Lead, Copper | Replace salt/lead bath heat treatment process | BMP #8 |
| | Cadmium | Cadmium solder substitution | BMP #9 |
| | Cadmium | Material substitution for cadmium plating | BMP #10 |
| | Lead | Flux substitution | BMP #11 |
| | Copper | Substitution for Copper Plating Baths | BMP #12 |
| | Copper | Alternative Deposition Processes for Copper Plating | BMP #13 |
| | Copper | Copper Strike Alternatives | BMP #14 |
| **Operating Procedures and Housekeeping** | Cadmium, Lead, Copper | Contain all above-ground tanks containing liquids, whose spillage could be harmful to the environment | BMP #15 |
| | Cadmium, Lead, Copper | Effective operational and maintenance systems | BMP #16 |
| | Cadmium, Lead, Copper | Accident Prevention | BMP #17 |
| **Education and Training** | Cadmium, Lead, Copper | Management and Staff Training | BMP #18 |

### *3.2 Pollution Elimination or Reduction*

P2 opportunities to eliminate or reduce hazardous substances include material substitutions and process alterations. Changes in operating costs will depend on the cost differential of the substitute in comparison with the hazardous material. Where the cost of the substitute is higher, operating costs will increase; however, where the cost of the substitute is lower, operating costs will decrease. Some capital investment in equipment modifications or replacements to accommodate any differences in properties of the substitute substances may also be required. Alterations to processes to reduce use of hazardous substances may entail changes in operating budget, including possible reductions in costs due to more efficient operations. Capital investment for equipment modification or replacement may also be required.

### 3.2.1 Reduction Measures Common to All Substances of Interest

The following BMPs outline measures to reduce the release of cadmium, lead, and copper in the Fabricated Metal Products Manufacturing process.

**BMP #1: Maximize the use of recycled water.** Water should be recycled within the process from which it issues, by treating it first if necessary. Filtration/osmosis or other techniques which allow the effluent water to be cleaned for return to the process. This reduces the need for new solution to be added to the original process.

**BMP #2: Process fluid waste minimization.** There are various methods to improve the efficiency of process fluid, such as using lower concentration process fluids, using process fluids of lower viscosity, using drag-out minimization techniques, and using multistage cascade rinsing. These methods extend the life of the process fluids.

**BMP #3: Reduce waste from spray-painting**. Establishing a standardized procedure for cleaning paint spraying equipment and paint booths during colour changes in combination with a schedule to reduce the number of cleanings required is effective in reducing waste volumes.

#### *Metal Plating Operations*

**BMP #4: Reduce Drag-out loss:** Many devices and procedures are used successfully to reduce drag-out. These techniques usually are employed to alter viscosity, chemical concentration, surface tension, velocity of withdrawal, and temperature. Also used are drag-out tanks and similar equipment for capturing lost plating solution and for returning it to the bath. Drag-out techniques include the following:

- Control the plating solutions, workpiece position on rack, workpiece withdrawal, and the design and maintenance of racks and barrels. Design racks for maximum drainage by encouraging clients to provide drainage holes in hollow or tubular work.
- Minimize drag-out by maximizing the drainage time of the work over the plating tank or in a separate drainage tank. Drainage times should not be less than 20 seconds for rack plant and 30 seconds for barrel plant.
- Allow longer drip/draining times in the transfer of work from one tank to the next.
- Mechanical recovery and return of drag-out solution upstream.

- Recovery of anode metals from drag-out that cannot be returned upstream.

Drag-out recovery will reduce drag-out losses by 50% or more. Two-stage drag-out will reduce drag-out losses by 70% or more and multiple drag-out tanks will reduce drag-out losses by up to 100%.[18] Ensure that the drain time for pieces is at least 10 seconds to reduce drag-out by 40+%, as compared to the industry average of three seconds.

**BMP #5: Drag-out return recovery technologies**. Technologies can reduce chemical consumption, as well as the amount of rinsewater. The technologies range from simple, cost effective systems, such as the use of drain boards, to use of electrochemical metals recovery technology for unreturned drag-out. More elaborate technologies include ion exchange; reverse osmosis; electrodialysis; evaporation; draining, such as drip shield (tilted surface), air knife (intensive air stream), drip tank (empty tank), and drag-out tank (filled with pure water); and rinsing over the plating tank (such as flood rinsing, spray rinsing, or fog rinsing).

The use of air-swept evaporation technology in conjunction with 3-5 stage cascade rinsing allows closed loop operation for hot (35°C plus) plating processes, i.e., 100% return of drag-out.[19]

**BMP #6: Rinsewater Reductions**: The proper design of rinsing systems is essential for water conservation and for the prolongation of process fluid life. Adequate rinsing is necessary to ensure that the finished work is chemically clean, especially when the final treatment (plating or passivation) uses, or is based on, hexavalent chromium. Rinsing quality is defined as the ratio of the concentration of a metal or other ion in the preceding process tank to its concentration in the final rinse tank. Effective rinsing ratios depend on the process concentration, and the quality of rinsing required. Single rinse tanks, whether used for interstage rinsing or as a final rinse, are ineffective unless a very large volume of water is used, or the rinse water is recirculated by use of an ion exchange (or other treatment) unit. Cascade (counterflow) rinsing in two or more stages reduces the water requirement to a low level, whilst improving the quality of rinsing.

In order to maximize opportunities for rinsewater reduction, the facility should have optimal rinse tank design. Various other techniques such as: flow restrictions, manual control of water flow, conductivity controls, solenoid valve on automated plating machines, timer rinse controls, flow meters, and accumulators, help control the flow rate of rinsewater use. Alternative rinse configurations such as: counterflow rinsing, cascade reactive and dual purpose rinsing, chemical rinsing, spray rinsing, or combined drag-out/rinsewater reduction rinsing arrangements also help to maximize opportunities for rinsewater reduction. Multi-stage cascade rinsing is a must for facilities looking to achieve significant wastewater reduction. Two stages, up to

[18] National Centre for Manufacturing Sciences and National Association of Metal Finishers. (1994).
[19] Environment Agency. (2004). Guidance *for the Surface Treatment of Metals and Plastics by Electrolytic and Chemical Processes.* Bristol. Environment Agency.

multistage cascade rinsing, with agitation, is considered optimal for achieving adequate to significant rinsewater reduction.

***Other Fabricated Metal Products Manufacturing and Spring and Wire Manufacturing Sub-Sectors***

**BMP #7: Extending metal working fluid life with centrifuge and reuse**: One key objective in effective waste management is to segregate the waste streams as they often have greater value (or lower cost) as separate materials. One common example for metal fabricators is the waste mixture of an oil coolant and metal shavings found in many shops due to milling, cutting, drilling, and similar operations. With the use of a "chipwringer", or centrifuge, oil and metal shavings can be separated to obtain a high degree of purity of the oil. Once separated out, the oil can be reused as a coolant and the metal can be recycled. Unless this is done, this waste is typically landfilled or sent to a recycler at a cost to the company. Depending on the amounts of waste, the reduction in coolant oil purchases and recycling prices for steel, the purchase of a chipwringer often has a quick payback. As the oil is reused, biocides may need to be added to extend the coolant life.

Spent high performance hydraulic fluids can often be downgraded and used as cutting oils, reducing purchasing and waste amounts for cutting fluids. Additional methods besides centrifugation for recycling oils include filtration, ultrafiltration for water removal, skimming, and coalescing. A plant may consider listing materials on a waste exchange which gives buyers and sellers of miscellaneous wastes a networking opportunity to connect with other companies that can use their wastes. The opportunity may also exist for the company to sell their used oil for burning purposes, reducing their disposal costs while contributing to a reduction in fossil fuel usage.[20]

***Coating, Engraving and Heat Treating Activities Sub-Sector***

**BMP #8: Replace salt/lead bath heat treatment process:**

Direct resistance heating may be used to replace salt/lead bath heat treating, fossil/electric (indirect resistance) furnace, flame hardening, and torch welding. Wastes reduced or eliminated by switching to direct resistance heating include: combustion pollutants, such as reactive organic gases (ROG), SOx, NOx, COx, and particulate; material oxidation (slag, scale); and spent salt/lead baths.

Direct resistance heating, also referred to as conductive heating, involves passing an alternating current through the workpiece to heat the workpiece. In addition to heat treating, direct resistance may be used for hot metal working (i.e., forging, stamping, extruding, rolling, and upsetting), and metal joining (i.e., spot, seam, and flash welding). Clamp or roll type electrodes are used to deliver the current to the workpiece. The resistance of the workpiece to the current being passed through it generates the heat. Low frequency current (60 Hz) is used to heat the part

[20] FMP Sector Assessment

throughout, while high frequency current (400 Hz) is used to heat the surface of the part.

Indirect resistance heating, is used to replace salt/lead bath heat treating, and fuel-fired furnace or flame hardening. Heat is transferred to the workpiece via conduction, convection, and/or radiation. This is usually carried out in a well-insulated enclosure, such as an electric oven. In addition to heat treating, indirect resistance may be used for forming, drying, joining, sintering, or curing. Wastes reduced by using indirect resistance include combustion pollutants (ROG, SOx, NOx, COx, particulate) and spent salt/lead baths.

### *3.2.2 Reduction Measures for Cadmium*

Measures to avoid or eliminate the use of hazardous substances are the most desirable P2 measures since these are the most effective means to ensure environmental protection. Substitutions of process materials that contain cadmium with materials that do not contain cadmium should be considered whenever possible.

The cadmium emission to sewer based on the use of best available technique (BAT) is zero; however, an acceptable level of detection has been established as 0.01 mg/l.[21] The typical process efficiency with BAT implementation for cadmium is 99%.[22] Filtration to remove fine suspended solids to achieve effluent limits for metals of 1-3 mg/l is common. Effluent, whether filtered or not, may be recycled to the less critical rinsing steps and thus reduce input water usage by up to 30%.[23]

**BMP #9: Solder Substitution**: Certain silver brazing fillers give off cadmium and zinc fumes; many users are changing to cadmium-free filler metals. There are suitable alternatives for many existing applications using cadmium-bearing solders.

**BMP #10: Material substitution for cadmium plating**: Full consideration of substitutions for cadmium plating should be made, e.g., zinc-nickel and tin–zinc alloy processes, where available, proprietary plating systems can be used, such as 1) Proprietary plating electrolytes that have a low concentration of dissolved solids and operate with minimum energy requirements for heating or cooling; and/or 2) Proprietary systems which provide a long process fluid life, which do not contain cadmium and which require relatively simple effluent treatment.

### *3.2.3 Reduction Measures for Lead*

***Coating, Engraving, and Heat Treating Activities, Other Fabricated Metal Products Manufacturing and Spring and Wire Manufacturing Sub-Sectors***

**BMP #11: Flux Substitution:** Alternatives to the use of traditional fluxes, containing lead include the following:

---

[21] Environment Agency. (2004). Guidance *for the Surface Treatment of Metals and Plastics by Electrolytic and Chemical Processes.* Bristol. Environment Agency.
[22] Ibid.
[23] Ibid.

- Fluxless applications developed to eliminate the need for cleaning; and
- Lead-free solders, which are available for various applications.

### *3.2.4 Reduction Measures for Copper*

#### *Metal Finishing Specific Measures*

Copper plating is widely used as an underplate in multi-plate systems and as stop-offs for carburizing, as well as in electroforming and the production of printed circuit boards. Copper plating is used generally as an underplate or pre-plate before a final finishing operation, such as nickel or gold. Bright copper is used as a protective underplate in multiple layer systems or when a decorative finish is desired. The copper finish often is protected against tarnishing and staining by the application of a clear lacquer. Copper plating can change the appearance, dimensions, or electrical conductivity of a metal part. Jewellery manufacturing, aerospace, and electronics often use copper plating.

**BMP #12: Substitution for Copper Plating Baths:** Cyanide copper low temperature electrolytes are necessary for strike plating on steel and zinc die casts to prevent spontaneous cementation of copper and poor adhesion of the subsequent metal deposit. This type of solution is based on copper cyanide and sodium cyanide, with a copper concentration of 15-20 g/L. Copper strike layers are usually no thicker than 2-3 micrometers.

The benefits of replacing cyanide-based copper plating baths with a non-cyanide solution include reduced environmental exposure and employee health risks. Non-cyanide copper plating requires more frequent bath analysis and adjustment than cyanide-based plating. Cyanide-based copper plating baths are relatively forgiving to bath composition because they remove impurities. Non-cyanide baths are less tolerant of poor surface cleaning so thorough cleaning and activation of the surface is critical to obtain a quality finish. Personnel should be capable of operating the non-cyanide process as easily as the cyanide-based process.

For plating copper, certain non-cyanide alkaline baths of proprietary composition have been developed. Four widely known alternatives to copper cyanide plating are copper acid sulfate, copper acid fluoroborate, copper alkaline, and copper pyrophosphate.

***Table 3.2 Overview of Alternatives for Copper Cyanide Plating***

| Alternatives | Finish Appearance | Ductility | Plating Uniformity | Process Considerations | General Comments |
|---|---|---|---|---|---|
| **Copper Alkaline** | (+) Good appearance | (+) Good | (+) Better throwing than cyanide | (+) Operating pH 8.0 to 8.8 | (+) Can be used as heat treating maskants<br>(+) Less corrosive<br>(+) Might be used as a strike bath |
| **Copper Acid Sulfate or Fluoroborate** | (+) Good appearance<br>(+) Excellent levelling | (+) Good to excellent | (-) Less macrothrowing power than alkaline<br>(+) More microthrowing power than alkaline | (-) Lined tanks and appropriate anode baskets required<br>(+) Fluoroborate allows use of higher current densities | (+) Good use data available |
| **Copper Pyrophosphate** | (+) Good, fine grained, and semi-bright | (+) Good | (+) Good throwing power | (+) Operating pH of 8.0 to 9.8<br>(-) More sensitive to organic contaminants than acid copper<br>(-) Might require longer plating time | (+) Might be used as strike bath<br>(-) Might contain ammonia |

**BMP #13: Alternative Deposition Processes for Copper Plating:** Methods for depositing metal coatings such as chromium, nickel, cadmium, and copper in traditional electroplating processes have inherent pollution problems. Several alternative technologies exist to coat a substrate with metal without using electrolytic solutions or plating baths. The following could reduce the amount of metal-contaminated wastewater and sludge that is generated from plating:

- Electric Arc Spraying – During electric arc spraying, an electric arc forms between the ends of two wires that are made of coating material. The arc continuously melts the ends of the wire while a jet of gas (e.g., air or nitrogen) blows the molten droplets toward the substrate.

- Plasma Spraying – Plasma spraying involves the introduction of a flow of gas (usually argon-based) between a water-cooled copper anode and a tungsten cathode. A direct current arc passes through and is ionized to form a plasma. The plasma heats the powder coating to a molten state.

- Ion Plating is plasma based.
- Sputtering and Sputter Deposition is an etching process that alters the physical properties of a surface. In this process, a gas plasma discharge is set up between two electrodes: a cathode plating material and an anode substrate.

***Opportunities for Pollution Prevention in Copper Strike Process*** [24,25]

Copper strikes often are used to deposit a thin intermediate layer (strike) of copper over a variety of substrates including steel and zinc die castings before those metals are plated with other metals. This layer is required for successful plating because it promotes adhesion on difficult-to-plate metals and protects some substrates from degradation in subsequent plating solutions. Because copper strikes are applied frequently, finding replacements for cyanide solutions can greatly assist facilities in reducing the amount of cyanide that they use.

**BMP #14: Copper Strike Alternatives:**

- Copper Pyrophosphate.

Dilute copper pyrophosphate has been viewed as a feasible replacement for the cyanide strike because the solution does not degrade substrates. The main disadvantage of this chemistry is that it usually takes three times longer to plate than traditional cyanide solutions.

- High-pH Nickel.

High-pH nickel plating solutions have been available for a long time as a substitute for cyanide copper strike on zincated surfaces and zinc die castings. To obtain optimum results with high-pH nickel, the plater must balance the ratio between nickel sulfate and sodium sulfate. The proper ratio depends on several factors, including part geometry; parts with complex shapes require higher sodium sulfate concentrations than parts with simple geometry. For plating operations above a 5.4 pH, platers use ammonium hydroxide and sulfuric acid for pH control. Cleaning parts prior to plating is more critical in high-pH nickel plating than traditional copper cyanide strikes.

Substituting high-pH nickel for a copper cyanide strike will eliminate a cyanide wastestream. However, the ammonium ion present in the high-pH nickel formulation can cause waste treatment problems unless the concentration can be minimized through drag-out recovery techniques. Another disadvantage of this technique is that

---

[24] Illinois Waste Management and research Centre. (nd). *Metal Finishing Industry Pollution Prevention Notebook.* Retrieved May 20, 2005 from http://www.wmrc.uiuc.edu/main_sections/info_services/library_docs/manuals/finishing/toc1.htm

[25] European Commission, Integrated Pollution prevention Control. (2003). “Draft Reference Document on Best Available Techniques for the Surface Treatment of Metals and Plastics.” Directorate-General Joint Research Centre – Institute for Prospective Technological Studies. Seville, Spain.

the bath contains a higher metal content than the cyanide copper process and twice the metal content of the alkaline non-cyanide process. Sludge volume from wastewater treatment would be affected accordingly.

#### *Electroless Plating*

Nickel, copper, cobalt, and gold are the most common metals plated in the electroless plating process. In electroless plating, metals are deposited onto the surface of a part without the use of electricity as a source of electrons. Instead, the bath solution supplies the electrons for the deposition reaction. These baths are extremely complex using a variety of chelating and/or complexing agents that hold the metals in solution. Common chelating agents include ethylenediaminetetraacetic acid (EDTA), citrates, oxalates, cyanides, and 1,2 diaminocyclohexanetetraacetic acid (DCTA).

Electroless copper is used commonly to plate parts for engineering applications, particularly to provide conductivity for electronics, and printed circuit boards or plastics that are going to receive further plates for decorative applications.

Electroless solutions are especially susceptible to impurities affecting the process solution. Impurities in the solution can cause reduced ductility and corrosion resistance, as well as pitting, adhesion, and roughness problems. Facilities should identify sources of contamination and take steps to avert them including worker training or equipment modifications. Common sources of contamination include cleaners, pickling solutions, airborne particulates, hard water, and defective equipment.

Electroless copper uses copper salt as the metal salt, often cupric chloride, EDTA as a chelating agent, and formaldehyde (a suspected carcinogen) as the reducing agent. The reductive reaction is favored at high pHs, so caustic soda is used to keep the pH above 11.0. Reducing agents often react with the bath, resulting in slower deposition rates and poorer deposit quality. This also can mean that the bath will need to be rejuvenated after several metal turnovers.

This solution also is subject to spontaneous decomposition. Copper built up on the tanks from the process solution must be stripped with an etching solution (e.g., sulfuric acid/hydrogen peroxide etchant). This results in an additional waste stream of copper and etching solution.

#### *Coating, Engraving, and Heat Treating Activities, Other Fabricated Metal Products Manufacturing and Spring and Wire Manufacturing Sub-Sectors*

Chromate solutions to treat copper and copper alloys are prepared with proprietary materials. The treatment not only passivates the surface but also provides effective chemical surface polishing. Consequently, chromate treatments on copper and copper alloys are used both as a final finish and as a whole or partial substitute for mechanical buffing prior to nickel or chromium plating. Increased effluent treatment may be required because of the dissolution of copper in the process.

### *3.3 Operating Procedures and Housekeeping*

Operating procedures and housekeeping BMPs are P2 measures that can be implemented concurrently with elimination/reduction BMPs and education/training BMPs. Some operating costs may be incurred to initiate improved operating and housekeeping practices, for example to establish an inventory control system. Once implemented, however, these costs can be expected to be off-set by optimized performance, reduced losses of time and materials, reduced liability, better-informed staff and management, and, potentially, improved customer satisfaction. Reliable record-keeping systems are needed to realize the full benefits of operating procedures and housekeeping BMPs. Minimal capital investment to implement operating and housekeeping BMPs can be expected.

**BMP # 15: Contain all above-ground tanks containing liquids whose spillage could be harmful to the environment:** Containers should:

- Be impermeable and resistant to stored materials;
- Have no outlet and drain to a blind collection point;
- Have pipework routed within contained areas with no penetration of contained surfaces;
- Be designed to catch leaks from tanks or fittings;
- Have a capacity greater than 110% of the largest tank or 25% of the total tankage, whichever is larger;
- Be subject to regular visual inspection;
- Where not inspected, be fitted with probe and alarm; and
- Be subject to engineering inspection.

**BMP #16: Effective operational and maintenance systems.** Effective operational and maintenance systems should be employed on all aspects of the process whose failure could impact on the environment. In particular, there should be:

- Documented procedures to control operations that may have an adverse impact on the environment.
- A defined procedure for identifying, reviewing, and prioritizing items used in the plant for which a preventative maintenance regime is appropriate.
- Documented procedures for monitoring emissions or impacts.
- A preventative maintenance program covering all plant processes, whose failure could lead to impact on the environment, including regular inspection of major 'non productive' items, such as tanks, pipework, retaining walls, containing ducts, and filters.

- The maintenance system should include auditing of performance against requirements arising from the above and reporting the result of audits to top management.

**BMP #17: Accident Prevention**. There should be plans for accidents/incidents/non-conformance which:

- Identify the likelihood and consequence of accidents;
- Identify actions to prevent accidents and mitigate any consequences; and
- Outline written procedures for handling, investigating, communicating, and reporting actual or potential non-compliance with operating procedures or emission limits, reporting environmental complaints, and investigating incidents (and near misses), including identifying suitable corrective action and following up.

### *3.4 Education and Training*

Education and training are P2 measures that can be implemented concurrently with elimination/reduction BMPs and operating/housekeeping BMPs. Investments in education and training for management and staff can return significant benefits, including improved staff motivation, an improved health and safety record, reduced material losses, improved productivity, and, potentially, improved customer satisfaction. Communication and education of the supply chain, including material and equipment suppliers, can result in improved working relationships, as well as environmental benefits resulting from reduced pollution release.

It is important to keep education and training current and to ensure a management system is in place to maintain the relevance of education and training delivered. As mentioned above, a comprehensive management approach is important for effective reduction of releases of hazardous substances, including reductions through education and training.

Some operating costs may be incurred to initiate education and training practices, for example, time required to discuss improved materials specifications with suppliers. Once implemented, however, these costs can be expected to be off-set by the benefits of education and training. Capital investment is not typically required for implementation of education and training practices.

**BMP #18: Management and Staff Training**

- Employee Education
  - Training systems, covering the following items, should be in place for all relevant staff:
    - Awareness of the regulatory implications of the activity and their work activities;

  - Awareness of all potential environmental effects from operation under normal and abnormal circumstances;
  - Awareness of the need to report deviation from the regulation; and
  - Prevention of accidental emissions and action to be taken when accidental emissions occur.
- The skills and competencies necessary for key posts should be documented and records of training needs and training received for these post maintained.
- The key posts should include contractors and those purchasing equipment and materials.
- The potential environmental risks posed by the work of contractors should be assessed and instructions provided to contractors about protecting the environment while working on site.
- Where industry standards or codes of practice for training exist they should be complied with.

### 3.5 P2 Options and Costs

The rationale for selection of BMPs and associated cost estimates is outlined in this section. In general, information on the effectiveness and cost of P2 measures is not well documented in literature. Therefore, a number of estimating procedures were made with respect to the effectiveness and costs of implementing BMPs to eliminate or reduce the substances of concern. In the absence of specific information, rules of thumb were developed for each type of P2 measure, as summarized below.

Data in literature with respect to substance removal effectiveness of P2 measures is very sparse. Where data is provided, there is wide variability in results. Further, costs and cost savings information are not provided with sufficient context to be useful for this analysis. In the absence of directly relevant data, several rules of thumb were developed for P2 effectiveness and cost estimations were based on available literature information. Case study information from a range of literature sources for the six sectors of interest was researched to identify P2 effectiveness experience for any substance. These case study results were grouped by type of P2 measure and the data was assessed to derive a reasonable range of substance removal effectiveness. The following Table provides a summary of the rules of thumb for P2 effectiveness.

***Table 3.3 Rules of Thumb for P2 Effectiveness***

| Type of P2 Measure | Percent Reductions in Releases | | | |
|---|---|---|---|---|
| | **Material Substitution** | **Process Modification** | **Operating/ Housekeeping** | **Education and Training** |
| Sub-Section title in BMP Document | Pollution Elimination or Reduction | Pollution Elimination or Reduction | Operating Procedures and Housekeeping | Education and Training |
| Rule of Thumb to Apply (in absence of specific information) | 50% to 75% | 10% to 40% | 10% to 30% | 1% to 30% |

In the absence of directly relevant data for P2 costs, it was assumed that P2 costs primarily impact operating budgets, except in the case of process modifications where capital investments were also assumed to be required. Extrapolations of operating costs were derived from Statistics Canada data on annual average earnings by company size for manufacturing and service sector groups.

***Table 3.4 Rules of Thumb for P2 Costs***

| P2 Rules of Thumb | Range of Costs | | | |
|---|---|---|---|---|
| **Type of P2 Measure** | **Material Substitution** | **Process Modification** | **Operating/ Housekeeping** | **Education and Training** |
| Rule of Thumb to Apply (in absence of specific information) | Materials budget implications of –2% to 4%; negligible for typical materials | ¼ person year to 5 person year per modification, plus capital investment (annualized $5,000 per year for manufacturing sectors; $1,000 per year for service) | ½% to 5% increase in operating budget staff time (off-set over time as a result of reduced liability, materials losses, etc.) | ¼% to 2% increase in staff time (based on 240 workdays per year). |

### *3.5.1 P2 Removal Effectiveness*

For the Fabricated Metal Products Sector, it was assumed that the most effective Elimination/Reduction P2 measure would be implemented for each substance of concern. In addition, it was expected that all applicable measures in the Operating Procedures and Housekeeping group of BMPs and all applicable measures in the Education and Training group of BMPs would also be implemented.

The most effective Elimination/Reduction P2 measures for cadmium, copper, and lead are as follows:

- Cadmium: Material Substitution for Cadmium plating, Drag-out reduction-BMP #4 and #10;

- Copper: Substitution for copper plating baths - BMP #12; and
- Lead: Drag-out reduction, Flux Substitution, - BMP #4 and #11.

Effectiveness of materials substitution for cadmium is estimated to be 50 - 75%, based on rules of thumb developed for application where no specific industry data was available. For the purposes of this exercise a reduction value of 62.5% will be used. To reach the least stringent reference criteria, the BMP for drag-out reduction could be utilized as opposed to substitution to achieve a reduction of 50%. Effectiveness for materials reduction for copper is estimated to be 62.5% removal, based on rules of thumb, developed for application where no specific industry data was available. Effectiveness of flux substitution in combination with drag-out reduction is estimated to achieve 62.5% removal for lead, based on rules of thumb developed for application where no specific industry data was available.

Applicable Operating Procedures and Housekeeping BMPs are:

- Effective operational and maintenance systems - BMP #16; and
- Accident Prevention - BMP #17.

The effectiveness of Operating Procedures and Housekeeping is estimated to be 20% removal of the remaining contaminants after materials substitution (i.e., the mid-range of expected effectiveness of this group of BMPs). In the case of cadmium, Operating Procedures and Housekeeping are assumed to remove 20% of the remaining 37.5% of contaminants, for an additional 7.5% net reduction in cadmium prior to treatment. Therefore, with the combination of substance substitution/process modification and operating procedures and housekeeping, a cumulative removal of 70% of cadmium in the wastewater effluent from fabricated metal products manufacturing facilities is estimated.

For copper, Operating Procedures and Housekeeping are estimated to remove 20% of the remaining 37.5 % of the remaining concentration, for an additional 7.5% net reduction in copper concentration in the wastewater effluent from fabricated metal products manufacturing facilities, prior to treatment.

For lead, Operating Procedures and Housekeeping are estimated to remove 20% of the remaining 37.5% of the remaining concentration, for an additional 7.5% net reduction in lead concentration in the wastewater effluent from fabricated metal products manufacturing facilities, prior to treatment.

The effectiveness of Education and Training practices in removing cadmium, copper & lead is expected to be 1% removal of the remaining contaminants after materials substitution/process modification. This effectiveness rate is relatively low because staff within the Fabricated Metal Products Sector are generally already familiar with these types of practices. Education and Training is an integral component of a comprehensive pollution prevention program and is needed to ensure the success of the other recommended BMPs. The combination of substance substitution/process modification, operating procedures and housekeeping, and education/training in the wastewater effluent for the fabricated metal products sector is estimated to result in a cumulative removal of 70%.

In summary, the effectiveness of P2 BMPs in achieving reductions of the pollutants examined is estimated to be 70% removal of each of cadmium, copper and lead prior to treatment. Table 3.5 provides a summary of the estimated effectiveness discussed in this section. Refer to Tables 5.1 to 5.3 (Section 5) for a summary of P2 BMP effectiveness and treatment measures to achieve the reference criteria.

***Table 3.5 Summary of Effectiveness of BMPs***

| Substance Addressed | BMP Name | BMP Number |
|---|---|---|
| **Elimination/ Reduction**<br>Effectiveness: 50-70% | | |
| Cadmium | Material Substitution for Cadmium plating | BMP #4 |
| Cadmium & Lead | Drag-out reduction | BMP #10 |
| Copper | Substitution for copper plating baths | BMP#12 |
| Lead | Flux Substitution | BMP #11 |
| **Operating Procedures and Housekeeping**<br>Effectiveness: 20% | | |
| Cadmium, Copper & Lead | Effective operational and maintenance systems | BMP #16 |
| Cadmium, Copper & Lead | Accident Prevention | BMP #17 |
| **Education & Training**<br>Effectiveness: 1 % | | |
| Cadmium, Copper & Lead | Management and Staff Training | BMP # 18 |

### 3.5.2 P2 Costs

Costs for elimination/reduction measures are expected to be negligible for all sizes of facility. Products produced will not be adversely affected by implementation of BMPs. Various positive indirect benefits, such as reduced hazardous materials handling costs and reduced costs from worker health and safety claims due to cadmium exposure.

Costs associated with implementation of Operating Procedures and Housekeeping BMPs are expected to be proportional to staff complement and to cost between 1/2% and 5% of the staff budget. The upper end of this range would be applicable to facilities without well-established operating procedures and record-keeping practices. Assuming mid-range of the cost estimates, costs are estimated for implementation of the Operating Procedures and Housekeeping BMPs for three facility sizes for all three substances.

Costs associated with implementation of Education and Training are expected to be proportional to staff complement and to cost between ¼% and 2% of the staff budget. The upper end of this range would be applicable to facilities without well-established training programs. Assuming the low-range of the cost estimates, costs are estimated for implementation of the Education and Training.

Estimated costs for implementation of the P2 BMPs are summarized in Table 3.6. Clearly, these estimates constitute a first-cut high-level estimate in the absence of facility-specific data and circumstances.

### *Table 3.6 Estimated Pollution Prevention Costs (for selected P2 BMPs)*

| Type of P2 Measure | Small Facilities (25 Staff) | Medium Facilities (175 Staff) | Large Facilities (300 staff) |
|---|---|---|---|
| Pollution Elimination or Reduction | negligible | negligible | negligible |
| Operating/ Housekeeping | $20,000 annually | $160,000 annually | $270,000 annually |
| Education & training | $7,725 annually | $59,350 annually | $118,772 annually |
| **Total Estimate** | $27,725 annually | $219,350 annually | $388,772 annually |

**Note:**

* Estimated annual costs for each P2 measure are approximations only; facility specific wastewater quality and operating practices must be assessed prior to selection of P2 practices.

# 4. TREATMENT

Treatment is not a P2 measure and it is not as effective as P2 in preventing the release of hazardous substances since it occurs after the hazardous substance has been used or created and subsequently becomes part of the facility's wastewater. With some treatment, the hazardous substance may be simply transferred from the water to the air or the sludge. Operating and capital costs of treatment can be significant. As a result, treatment should only be considered after P2 measures have been implemented and after all efforts have been taken to reduce or eliminate the substance first through P2 practices.

## 4.1 Treatment Measures

Treatment measures and BMPs must be assessed and implemented based on specific site and process conditions and characteristics. The following subsections present treatment processes to be considered where P2 alone does not meet the reference criteria.

The reference criteria outlined in Section 2.2 are provided for the purpose of assessing the potential for application of select treatment technologies for the select substances identified in this BMP document.

The following subsections provide a brief overview of typical treatment systems for the removal of individual pollutants. The processes described were based on estimated wastewater constituents for the fabricated metal products sector. The treatment review was based on representative wastewater data available for this sector.[26] Other treatment processes may be more applicable at facilities that have a wastewater stream significantly different from that used in this assessment.

### 4.1.1 Treatment Measures for Cadmium

Three types of treatment processes are potentially applicable to meet the reference criteria for cadmium outlined in Section 2.2. The treatment processes provided are presented in sequential order of treatment requirements, with the process required to achieve the lowest concentration presented last. These treatment processes can be used alone or in combination, depending on specific wastewater properties.

- **Chemical precipitation:** Cadmium can be precipitated as insoluble cadmium hydroxide by pH adjustment. The precipitated metal is removed from the wastewater stream by settlement. Filtration using a sand or mixed media filter may be used after settlement to further reduce the concentration. It is assumed that chemical precipitation and settlement is in place for facilities with raw wastewater cadmium concentrations in excess of the sewer use by-law limit. Therefore, this treatment stage was not included in the cost assessment for cadmium removal. It is important to note that some cadmium

[26] Refer to Section 2.1.

may accumulate in the sludge of a biological treatment system, which could be released during sludge treatment. Therefore, facilities using a biological treatment system should chemically precipitate cadmium before biological treatment to minimize cadmium accumulation in biological sludge.

- **Granular activated carbon (GAC):** GAC is not a conventional treatment option for cadmium as the removal efficiency is relatively low (around 30%). However, if a GAC process is used to remove organic pollutants, there will also be some reduction in the cadmium concentration. The GAC process involves pumping wastewater through a fixed-bed column containing GAC granules. The GAC adsorbs pollutants from the wastewater. The spent GAC is regenerated off-site. The type of pollutants adsorbed and the extent of adsorption are a function of the source material for the GAC and the preparation procedure for the GAC granules. Typically, a sand or mixed media filter is required to remove suspended solids as a pre-treatment stage for a GAC filter.

- **Reverse osmosis (RO) or Deionization (DI)**: RO or DI processes can be used as a polishing stage to further reduce the concentration of cadmium. Sand or mixed media filtration followed by microfiltration is typically used as a pre-treatment stage. The RO process separates water from dissolved materials in solution by filtering through a semipermeable membrane under pressure. The basic components of an RO system are the membrane, a membrane support structure, a containing vessel, and a high-pressure pump. The permeability of the membrane used, level of wastewater pre-treatment and membrane cleaning are the key criteria for the performance of this process. RO results in a waste stream, or reject, that must be disposed of. For the DI process, specific ions are displaced from an insoluble exchange material (or resin) by different ions in solution. The spent resin is regenerated and reused. The waste stream from regeneration must be disposed of. The type of resin, level of wastewater pre-treatment and frequency of regeneration are the key criteria for effectiveness of treatment for DI.

### *4.1.2 Treatment Measures for Copper*

Three types of treatment processes are potentially applicable to meet the reference criteria for copper outlined in Section 2.2. The treatment processes provided are presented in sequential order of treatment requirements, with the process required to achieve the lowest concentration presented last. These treatment processes can be used alone or in combination, depending on specific wastewater properties.

- **Chemical precipitation:** Copper can be precipitated as insoluble copper hydroxide by pH adjustment. The precipitated metal is removed from the wastewater stream by settlement. Filtration using a sand or mixed media filter may be used after settlement to further reduce the concentration. It is assumed that chemical precipitation and settlement is in place for facilities with raw wastewater copper concentrations in excess of the sewer use by-law limit. Therefore, this treatment stage was not included in the cost assessment for copper removal. Filtration using a sand filter or mixed media filter can be used after chemical precipitation and settlement to further reduce the copper concentration. It is important to note that some copper may accumulate in the sludge of a biological treatment system, which could be released during sludge treatment. Therefore, facilities using a biological treatment system should chemically precipitate copper before biological treatment to minimize copper accumulation in biological sludge.

- **Granular activated carbon (GAC):** GAC is not a conventional treatment option for copper as the removal efficiency is relatively low (around 50%). However, if a GAC process is used to remove organic pollutants, there will also be some reduction in the copper concentration. The GAC process involves pumping wastewater through a fixed-bed column containing GAC granules. The GAC adsorbs pollutants from the wastewater. The spent GAC is regenerated off-site. The type of pollutants adsorbed and the extent of adsorption are a function of the source material for the GAC and the preparation procedure for the GAC granules. Typically, a sand or mixed media filter is required to remove suspended solids as a pre-treatment stage for a GAC filter.

- **Reverse osmosis (RO) or Deionization (DI)**: RO or DI processes can be used as a polishing stage to further reduce the concentration of copper. Sand or mixed media filtration followed by microfiltration is typically used as a pre-treatment stage. The RO process separates water from dissolved materials in solution by filtering through a semipermeable membrane under pressure. The basic components of an RO system are the membrane, a membrane support structure, a containing vessel, and a high-pressure pump. The permeability of the membrane used, level of wastewater pre-treatment and membrane cleaning are the key criteria for the performance of this process. RO results in a waste stream, or reject, that must be disposed of. For the DI process, specific ions are displaced from an insoluble exchange material (or resin) by different ions in solution. The spent resin is regenerated and reused. The waste stream from regeneration must be disposed of. The type of resin, level of wastewater pre-treatment and frequency of regeneration are the key criteria for effectiveness of treatment for DI.

### 4.1.3 Treatment Measures for Lead

Three types of treatment processes are potentially applicable to meet the reference criteria for lead outlined in Section 2.2. The treatment processes provided are presented in sequential order of treatment requirements, with the process required to achieve the lowest concentration presented last. These treatment processes can be used alone or in combination, depending on specific wastewater properties.

- **Chemical precipitation:** Lead can be precipitated as insoluble lead hydroxide by pH adjustment. The precipitated metal is removed from the wastewater stream by settlement. Filtration using a sand or mixed media filter may be used after settlement to further reduce the concentration. It is assumed that chemical precipitation and settlement is in place for facilities with raw wastewater lead concentrations in excess of the sewer use by-law limit. Therefore, this treatment stage was not included in the cost assessment for lead removal. It is important to note that some lead may accumulate in the sludge of a biological treatment system, which could be released during sludge treatment. Therefore, facilities using a biological treatment system should chemically precipitate lead before biological treatment to minimize lead accumulation in biological sludge.

- **Granular activated carbon (GAC):** GAC is not a conventional treatment option for lead as the removal efficiency is relatively low (around 40%). However, if a GAC process is used to remove organic pollutants, there will also be some reduction in the lead concentration. The GAC process involves pumping wastewater through a fixed-bed column containing GAC granules. The GAC adsorbs pollutants from the wastewater. The spent GAC is regenerated off-site. The type of pollutants adsorbed and the extent of adsorption are a function of the source material for the GAC and the preparation procedure for the GAC granules. Typically, a sand or mixed media filter is required to remove suspended solids as a pre-treatment stage for a GAC filter.

- **Reverse osmosis (RO) or Deionization (DI)**: RO or DI processes can be used as a polishing stage to further reduce the concentration of lead. Sand or mixed media filtration followed by microfiltration is typically used as a pre-treatment stage. The RO process separates water from dissolved materials in solution by filtering through a semipermeable membrane under pressure. The basic components of an RO system are the membrane, a membrane support structure, a containing vessel, and a high-pressure pump. The permeability of the membrane used, level of wastewater pre-treatment and membrane cleaning are the key criteria for the performance of this process. RO results in a waste stream, or reject, that must be disposed of. For the DI process, specific ions are displaced from an insoluble exchange material (or resin) by different ions in solution. The spent resin is regenerated and reused. The waste stream from regeneration must be disposed of. The type of resin, level of wastewater pre-treatment and frequency of regeneration are the key criteria for effectiveness of treatment for DI.

## *4.2 Treatment Options and Costs*

Treatability information is provided for the individual pollutants specified in Tables 5.1 to 5.3 as a guide (Section 5). Based on the estimated wastewater concentrations of each pollutant identified after P2 measures that are provided in the tables, the overall treatment systems in terms of sequential process steps for each target reference criteria are as follows:

- Reference Criteria 1 and 2: chemical precipitation, sand/mixed media filtration, microfiltration, and DI.
- Reference Criteria 3: chemical precipitation.

It is assumed that facilities will have in place a chemical precipitation process for metals to meet sewer use bylaws; therefore, there will be no additional treatment required to meet Reference Criteria 3.

The proposed treatment strategies identified above serve as preliminary guidelines for the level of treatment likely to be required. For example, RO may be more suitable than DI at some facilities. Site and facility specific information is needed to determine what treatment trains and components are required to achieve the reference criteria. A typical total treatment process for fabricated metal production manufacturing wastewater after P2 measures will provide treatment for all pollutants identified in the wastewater. A comprehensive analysis of the wastewater stream is required and bench-scale and/or pilot testing of treatment may be needed to verify the optimum treatment system for a specific facility.

Capital and annual O&M costs were developed for the three treatment scenarios using a wastewater flow range of 1 $m^3$/h to 50 $m^3$/h. The estimated costs are presented in Table 4.1. These costs are conceptual level only, normally considered to be accurate to a range of –35 percent to + 50 percent.

***Table 4.1 Estimated Capital and Annual Operation and Maintenance Costs***

| **Reference Criteria** | **Costs as Function of Flow Range of 1 $m^3$/h to 50 $m^3$/h*** | | | | | |
|---|---|---|---|---|---|---|
| | **Capital Cost Range** | | | **Annual O&M Cost Range** | | |
| | 1$m^3$/h | 25 $m^3$/h | 50 $m^3$/h | 1$m^3$/h | 25 $m^3$/h | 50 $m^3$/h |
| Criteria 1 | $243,000 | $951,000 | $1,702,000 | $36,000 | $114,000 | $170,000 |
| Criteria 2 | $231,000 | $916,000 | $1,667,000 | $35,000 | $110,000 | $167,000 |
| Criteria 3 | No additional treatment required assuming a chemical precipitation system is in place. | | | | | |

**Note:**
* Refer to Figures 4.1 to 4.3 for capital and O&M costing curves to estimate full treatment costs for a specific flow rate. Costs exclude chemical precipitation (metals removal), which is assumed to be installed. If required, the following estimated capital costs should be added: 1 $m^3$/hr = $67,200; 25 $m^3$/hr = $371,000; 50 $m^3$/hr = $658,000.

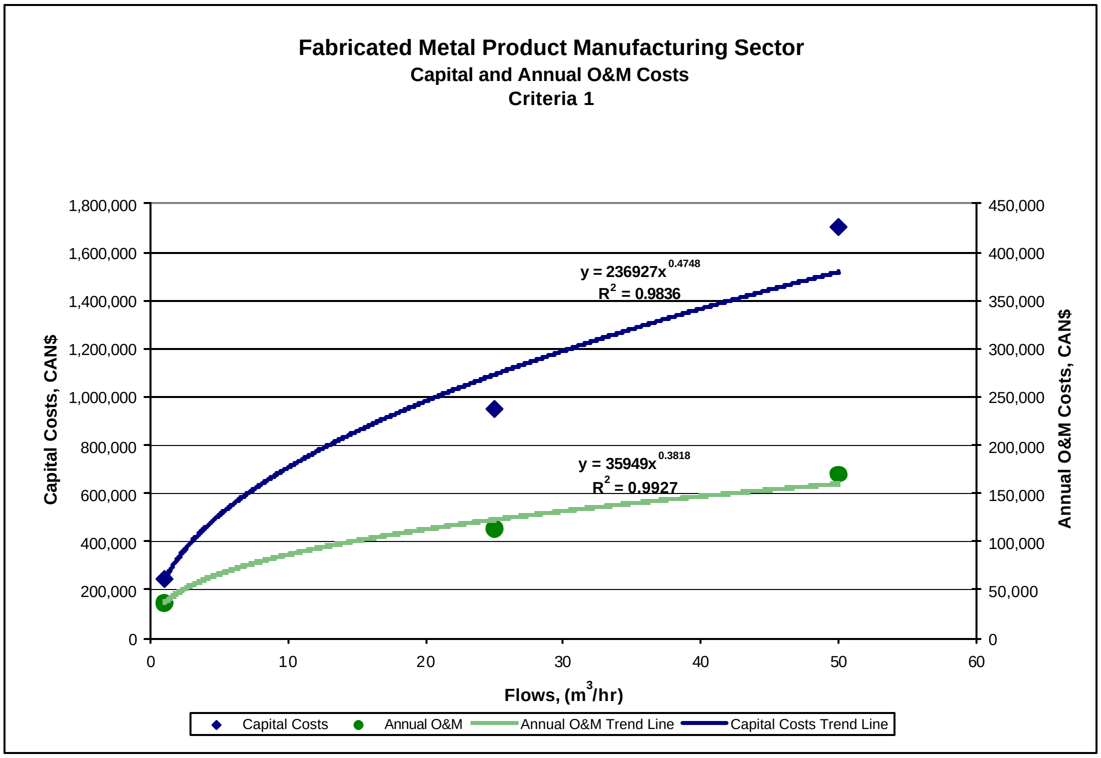
The capital costs presented in Table 4.1 do not include chemical precipitation for metals pre-treatment and removal, as it is assumed that this would be a treatment process already installed and operating. Should a particular plant or facility not have a chemical precipitation system installed, then the capital costs should be increased accordingly, as shown in Table 4.1. Costing includes engineering, equipment, piping and instrumentation, electrical and controls, installation, and construction costs.

The annual O&M costs were determined as a function of percentage of capital costs, assuming 15% for the 1 $m^3$/h flow condition, 12% for the intermediate 25 $m^3$/h flow condition, and 10% for the 50 $m^3$/h flow condition. Annual O&M costs include a consideration of the following:

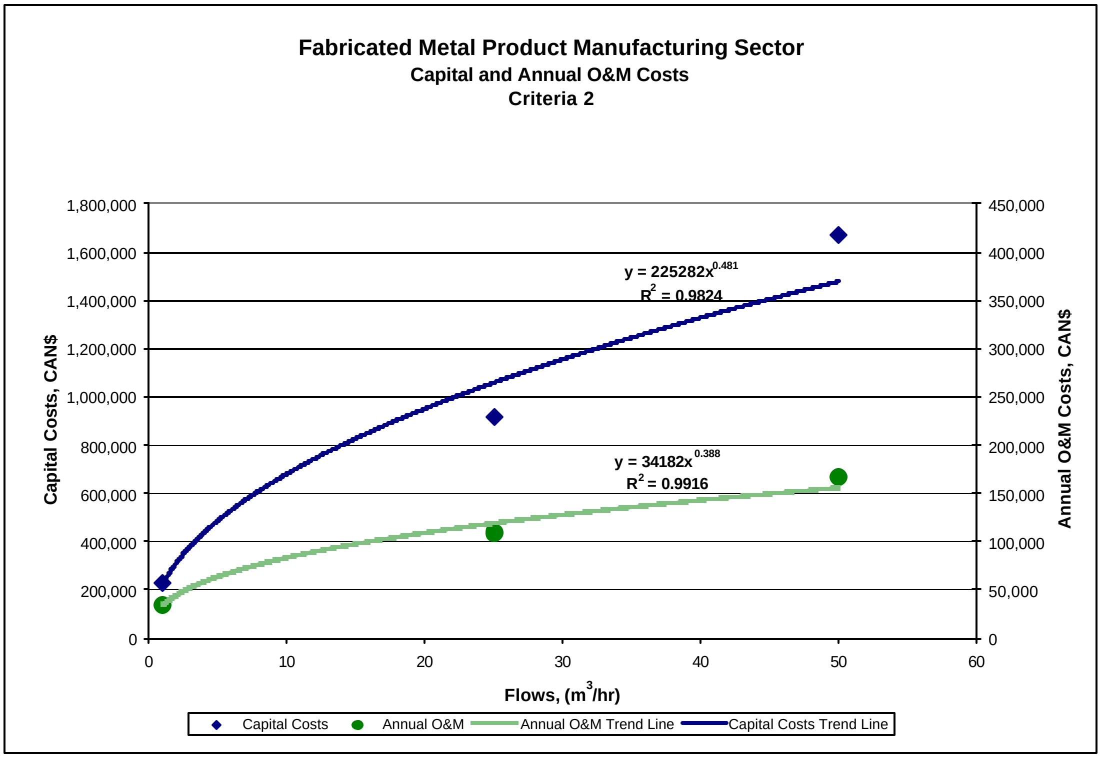
- Increased power and energy costs to operate the additional treatment processes;
- Chemical costs for treatment chemicals, where required;
- Additional labour costs for operation;
- Sampling and monitoring costs for the specific substances requiring treatment; and
- Disposal costs for residues and waste streams generated from treatment.

Figures 4.1 to 4.2 show capital and annual O&M costing curves for the estimated full treatment cost ranges presented in Table 4.1 for each set of reference criteria. Assuming a chemical precipitation system is in place, there are no additional costs for treatment to meet Reference Criteria 3.

## *Figure 4.1 Fabricated Metal Product Manufacturing Sector Capital and O&M Costs for Reference Criteria 1*



## *Figure 4.2 Fabricated Metal Product Manufacturing Sector Capital and O&M Costs for Reference Criteria 2*



# 5. OPTIONS FOR REDUCTION OF SUBSTANCE CONCENTRATIONS IN EFFLUENTS

The following tables outline the combination of P2 measures and treatment evaluated for substance removal effectiveness. These measures were chosen on the basis of ability to achieve the reference criteria, costs, and feasibility for implementation.

Based on the estimating procedures used to determine initial concentrations and percent removal resulting from implementation of P2 measures, some reference criteria may be met with P2 alone (i.e., no additional treatment required):

- Reference Criteria 1: No substances.
- Reference Criteria 2: No substances.
- Reference Criteria 3: Lead.

For lead, chemical precipitation should not be necessary, as an overall 70% reduction through P2 measures will result in a concentration less than the Reference Criteria 3 concentration of 5 mg/L. However, chemical precipitation is indicated in Table 5.3 as this process will be required to reduce or remove other metals present in the wastewater.

Site and facility specific analysis of the wastewater stream is required to determine which pollutants can be reduced to the reference criteria by implementation of P2 measures.

Information provided in the tables is based on assumptions for the concentration of each substance in wastewater before and after P2 measures. Treatability information is also based on estimated removal rates for treatment processes. A detailed analysis of the waste streams and the wastewater would be required for each facility to determine the optimum treatment system should this be required after P2 implementation.

***Table 5.1 Summary: Cadmium***

***Table 5.2 Summary Copper***

***Table 5.3 Summary Lead***

# 6. KEY REFERENCES

The following documents were key in preparing this BMP:

1. Bray, Andy. (March 2001). *Pollution Prevention in Machining and Metal Fabrication: A Manual for Technical Assistance Providers*. Available at URL: http://www.newmoa.org/Newmoa/htdocs/prevention/topichub/23/NEWMOAmanual.pdf

2. Department of Planning and Environmental Protection, Pollution Prevention and Remediation Programs – Broward County. (n.d.). *Pollution Prevention and Best Management Practices for Metal Finishing Facilities.* Available at URL: http://www.co.broward.fl.us/ppi00500.htm

3. Environment Agency. (2004). *Guidance for the Surface Treatment of Metals and Plastics by Electrolytic and Chemical Processes.* Bristol, United Kingdom: Environment Agency.

4. European Commission Directorate-General. (August 2003). *Draft Reference Document on Best Available Techniques for the Surface Treatment of Metals and Plastics***.** Sevilla, Spain: Technologies for Sustainable Development European Commission Integrated Pollution Prevention and Control Bureau.

5. Garruto, Mike. (September 1996). *An Analysis of Pollution Prevention Opportunities and Impediments in the Fabricated Metal Products Manufacturing Sector in Georgia*. Available at URL:http://www.p2ad.org/Assets/Documents/ma_fabmetal.htm

6. Illinois Waste Management and Research Centre. (n.d.). *Metal Finishing Industry Pollution Prevention Notebook.* Available at URL: http://www.wmrc.uiuc.edu/main_sections/info_services/library_docs/manuals/finishing/toc1.htm

7. National Center for Manufacturing Sciences. (1994). *Blue Book: Pollution Prevention Control Technologies for Plating Operations*. Available at URL: http://www.nmfrc.org/bluebook/tocmain.htm

# 7. GLOSSARY OF TERMS

**Best Management Practices** (BMPs) to reduce or eliminate pollutants encompass a wide range of activities including changes to materials or processes, operating procedures, housekeeping activities, and treatment techniques. BMPs may also include management activities, such as education and training, record-keeping and reporting, information systems, and communication with stakeholders, customers, and supply chain partners. BMPs can also include management approaches such as loss control programs and environmental management systems.

**Canadian Environmental Protection Act 1999** (CEPA 1999) is federal legislation that was first created in 1988 and consolidated various pieces of 1970s environmental legislation.[27] In addition, CEPA 1999 added many new Ministerial authorities and obligations, including new requirements for risk assessment and risk management of toxic substances and a strengthened pollution prevention approach.

**Criteria** are the reference criteria identified for analysis. There are three reference criteria, with Reference Criteria 1 being the most stringent and Reference Criteria 3 the least stringent.

**Environmental Management System** (EMS)[28] refers to management systems focussed on the minimization of harmful effects on the environment caused by corporate activities. Management systems in general are part of an organization's structure for managing its processes or activities that transform inputs of resources into a product or service, which meet the organization's objectives, such as satisfying the customer's quality requirements, complying with regulations, or meeting environmental objectives. Environmental management is what the organization does to minimize harmful effects and to achieve continual improvement of its environmental performance.

**Hazardous Substances** refers to substances that are potentially harmful to the environment or human health and safety. Hazardous substances include substances considered toxic under the Canadian Environmental Protection Act 1999, as well as other substances of interest subject to international agreement and reporting requirements. Refer to the Appendices for a list of substances of particular interest in this series of BMP documents.

**Industrial Facility Representatives** may include any industrial employee or contractor of an industrial sector with responsibility, for example, for facility operations, facility design, public relations, compliance.

**National Pollution Release Inventory** (NPRI) is a database of information on annual releases to air, water, land, and disposal or recycling from all sectors -

[27] Refer to the CEPA 1999 Environmental Registry for more information at URL: http://www.ec.gc.ca/CEPARegistry/default.cfm

[28] Definition adapted from definitions by the International Organization for Standardization, URL: http://www.iso.org/iso/en/iso9000-14000/understand/inbrief.html

industrial, government, commercial, and others.[29] The NPRI is a national reporting system legislated under the Canadian Environmental Protection Act 1999.

**Municipal Representatives** may include any municipal employee or contractor with responsibility, for example, wastewater quality, wastewater infrastructure management, industrial sewer use programs, industrial relations, public outreach, and/or by-law enforcement.

**NAICS Code** is the North American Industry Classification System (NAICS), which assigns numerical codes to industrial sectors and sub-sectors in North America. This system has replaced an older system of classification, known as the U.S. Standard Industrial Classification (SIC) system. Statistics Canada uses the NAICS classification system in its analysis of industrial activities in Canada.

**Pollution Prevention** (P2) is "the use of processes, practices, materials, products, substances or energy that avoids or minimizes the creation of pollutants and waste, and reduces the overall risk to the environment or human health."[30]

**Reference Criteria** are the maximum desired final effluent concentrations for the harmful substances identified. Three reference criteria limits were identified for analysis in terms of pollution prevention measures and treatment measures required to achieve the reference criteria.

**Rules of Thumb** are sets of engineering estimates based on similar or related datasets, professional judgement, and stated assumptions. Rules of Thumb are applied where specific information is not available. In the absence of specific information, Rules of Thumb can be used to develop reasonable ranges of potential outcomes or effects resulting from actions taken (such as implementation of certain P2 or treatment measures, for example).

**Substances of Interest** are the potentially hazardous substances or toxic substances examined within this series of best management practices. Refer to the Appendices for a list of substances of particular interest in this series of BMP documents.

**Supply Chain** refers to the network of organizations that provide materials, products, and services to industrial sectors in order that the industry can produce, market, and sell its products. The supply chain can include organizations selling raw materials, organizations selling semi-finished and finished goods, retail outlets, customers, etc.

**Treatment** in this document refers to wastewater treatment processes used to remove or transform pollutants in the wastewater stream. Treatment is not

[29] See the NPRI website at URL: http://www.ec.gc.ca/pdb/npri/npri_home_e.cfm

[30] Definition in Guidelines for the Implementation of the Pollution Prevention Planning Provisions of Part 4 of the *Canadian Environmental Protection Act*, 1999 (CEPA 1999), National Office of Pollution Prevention, Environment Canada, 2001

considered a pollution prevention measure since it occurs after pollutants have been introduced or used in a process; pollutants that are present in a wastewater stream indicate that opportunities to prevent pollution have passed and treatment must therefore be used to reduce release of the pollutants to the environment.

# *APPENDIX A*

# *BEST MANAGEMENT PRACTICES DOCUMENTS*

## *APPENDIX A: BEST MANAGEMENT PRACTICES DOCUMENTS*

Table A.1 identifies the available Best Management Practices Documents in this series, and the industrial sectors and harmful pollutants which are addressed in each.

***Table A.1 Industrial Sectors and Substances Addressed in BMP Documents***

| Document Name | Sector and Sub-Sector Titles and NAICS Codes | Harmful Pollutants |
|---|---|---|
| *Best Management Practices. Textiles Sector: Nonylphenol and its Ethoxylates and Chromium* | Textiles Sector (313)<br>Fibre, Yarn, Thread Mills<br>Fabric Mills<br>Textile and Fabric Finishing and Fabric coating | Nonylphenol and its ethoxylates<br>Chromium |
| *Best Management Practices. Fabricated Metal Product Manufacturing: Cadmium, Lead and Copper* | Fabricated Metal Product Manufacturing (332)<br>Forging and Stamping<br>Architectural and Structural Metals Manufacturing<br>Boiler, Tank and Shipping Container Manufacturing<br>Spring and Wire Product Manufacturing<br>Coating, Engraving, Heat Treating and Allied Activities<br>Other Fabricated Metal Product Manufacturing | Cadmium<br>Lead<br>Copper |
| *Best Management Practices. Motor Vehicle Parts Manufacturing: Cadmium and Nonylphenol and its Ethoxylates* | Motor Vehicle Parts Manufacturing (3363)<br>Motor Vehicle Gasoline Engine and Engine Parts Manufacturing<br>Motor Vehicle Electrical and Electronic Equipment Manufacturing<br>Motor Vehicle Metal Stamping<br>Motor Vehicle Steering and Suspension Components (except Spring)Manufacturing<br>Motor Vehicle Brake System Manufacturing<br>Motor Vehicle Transmission and Power Train Parts Manufacturing | Cadmium<br>Nonylphenol and its ethoxylates |

| Document Name | Sector and Sub-Sector Titles and NAICS Codes | Harmful Pollutants |
|---|---|---|
| *Best Management Practices. Automotive Repair and Maintenance: Cadmium and PAHs* | Automotive Repair and Maintenance (8111)<br>Automotive Repair and Maintenance<br>Automotive Body, Paint and Interior Repair and Maintenance<br>Car Washes | Cadmium<br>PAHs |
| *Best Management Practices. Dry Cleaning and Laundry Services: Nonylphenol and its Ethoxylates, Cadmium, and Mercury* | Dry Cleaning and Laundry Services (8123)<br>Dry Cleaning and Laundry Services (except Coin-Operated)<br>Linen and Uniform Supply | Nonylphenol and its ethoxylates<br>Cadmium<br>Mercury |
| *Best Management Practices. Chemical Manufacturing Sector: Cadmium, Chromium, Copper, Mercury, Zinc, Nonylphenol and its Ethoxylates, and Vinyl Chloride* | Chemical Manufacturing Sector (325)<br>Basic Chemical Manufacturing (NAICS 3251);<br>Pharmaceutical and Medicine Manufacturing (NAICS 3254);<br>Soap, Cleaning Compound and Toilet Preparation Manufacturing (NAICS 3256)<br>Other Chemical Product Manufacturing (NAICS 3257) | Cadmium<br>Chromium<br>Copper<br>Mercury<br>Zinc<br>Nonylphenol and its ethoxylates<br>Vinyl chloride |
| *Best Management Practices. Chemical Manufacturing Sector: Resin, Synthetic Rubber, and Artificial and Synthetic Fibres and Filaments Manufacturing: Cadmium, Chromium, Copper, Mercury, Zinc, Nonylphenol and its Ethoxylates, and Vinyl Chloride* | Chemical Manufacturing Sector (325)<br>Resin, Synthetic Rubber, and Artificial and Synthetic Fibres and Filaments Manufacturing (NAICS 3252) | Cadmium<br>Chromium<br>Copper<br>Mercury<br>Zinc<br>Nonylphenol and its ethoxylates<br>Vinyl chloride |

| Document Name | Sector and Sub-Sector Titles and NAICS Codes | Harmful Pollutants |
|---|---|---|
| *Best Management Practices. Chemical Manufacturing Sector: Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing: Cadmium, Chromium, Copper, Mercury, Zinc, and Nonylphenol and its Ethoxylates* | Chemical Manufacturing Sector (325)<br>Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing (NAICS 3253) | Cadmium<br>Chromium<br>Copper<br>Mercury<br>Zinc<br>Nonylphenol and its ethoxylates |
| *Best Management Practices. Chemical Manufacturing Sector: Paint, Coating, and Adhesive Manufacturing: Cadmium, Chromium, Copper, Mercury, Zinc, and Nonylphenol and its Ethoxylates* | Chemical Manufacturing Sector (325)<br>Paint, Coating, and Adhesive Manufacturing (NAICS 3255) | Cadmium<br>Chromium<br>Copper<br>Mercury<br>Zinc<br>Nonylphenol and its ethoxylates |
| *Best Management Practices. 1,4-Dichlorobenzene, 3,3-Dichlorobenzidine, Hexachlorobenzene, and Pentachlorophenol: Non-Sector Specific Practices* | Not applicable. | 1,4-Dichlorobenzene<br>3,3-Dichlorobenzidine<br>Hexachlorobenzene<br>Pentachlorophenol |

## *APPENDIX B*

## *TEMPLATES (TASK 5)*

## *APPENDIX B – TEMPLATES (TASK 5)*

To be provided upon completion of Task 5.

# *APPENDIX C*

# *SUB-SECTOR DEFINITIONS*

## *APPENDIX C – SUB-SECTOR DEFINITIONS*

Definitions for the fabricated metal products sub-sectors are: [31]

- Forging and Stamping (NAICS 3321):

  This industry group comprises establishments primarily engaged in shaping hot metal by forging to produce a part near its final size and shape; or pressing and cutting sheet metal stock to form stampings. These establishments generally operate on a job or order basis, manufacturing metal stampings or forgings for sale to others or for inter-plant transfer. These establishments may surface-finish the forgings and stampings produced, by such activities as deburring and grinding, but they do not further process them.

- Architectural and Structural Metals Manufacturing (NAICS 3323):

  This industry group comprises establishments primarily engaged in fabricating metal products for structural or architectural purposes.

- Boiler, Tank and Shipping Container Manufacturing (NAICS 3324):

  This industry group comprises establishments primarily engaged in cutting, forming, and joining metal to manufacture products, such as power boilers, heat exchangers, and tanks of heavy gauge metal, and cans, boxes and other light gauge metal containers.

- Spring and Wire Product Manufacturing (NAICS 3326):

  This industry group comprises establishments primarily engaged in manufacturing wire products made from purchased wire.

- Coating, Engraving, Heat Treating and Allied Activities (NAICS 3328):

  This industry group comprises establishments primarily engaged in coating, engraving, heat treating, and similarly processing metal. These activities often involve heating the metal, and the purpose is often to harden it. In general, the hardening of metal is included. Other activities of this industry include tempering, brazing, plating (including electroplating and re-chroming), polishing, sand-blasting, and colouring metal and metal products. Establishments primarily engaged in plating with precious metal for the trade are included.

- Other Fabricated Metal Product Manufacturing (NAICS 3329):

  This industry group comprises establishments, not classified to any other industry group, primarily engaged in fabricating metal products.

[31] http://stds.statcan.ca/english/naics/2002/naics02-class-search.asp?criteria=332 (accessed December 20, 2005)

## *APPENDIX D*

## *AGREEMENTS FOR TOXIC REDUCTION AND SUBSTANCES OF CONCERN*

## *APPENDIX D – AGREEMENTS FOR TOXIC REDUCTION AND SUBSTANCES OF CONCERN*

Following is the list of agreements and programs identified by the Ontario MOE to be of particular concern. These agreements and programs were the impetus behind the development of this series of BMP documents.

- The 2002 Canada-Ontario Agreement respecting the Great Lakes Basin Ecosystem (COA), which identifies the goal of virtual elimination Tier I substances, reductions of Tier II substances and virtual elimination of 17 PAHs.
- The *Canadian Environmental Protection Act, 1999* (CEPA)
- The 1997 Bi-National Toxics Strategy (BNTS), signed by Environment Canada and the USEPA.
- The Ontario government's commitment to implement recommendation #32 of Commissioner O'Connor's Report on the Walkerton Inquiry Part 2 to support major wastewater plant operators to identify practical methods to reduce or remove heavy metals and priority organics that are not removed by conventional treatment.

The following hazardous substances are subject of the agreements identified above and/ or subject of potential concern due to environmental and human health effects. (Note that not all of these substances have been addressed in the series of BMP documents for the six sectors.)

***Table D.1 Substances of Concern Subject to Agreements***

| Substance | COA | CEPA | BNTS |
|---|---|---|---|
| 1,4-dichlorobenzene | Tier II | n/a | Level II |
| 3,3-dichlorobenzidine | Tier II | Schedule 1 | Level II |
| alkyl-lead | Tier I | n/a | Level I |
| cadmium | Tier II | n/a | Level II |
| chromium | n/a | n/a | n/a |
| copper | n/a | n/a | n/a |
| dioxins and furans | Tier I | n/a | Level I |
| hexachlorobenzene | Tier I | Schedule 1 | Level I |
| hexachlorobutadiene/hexachloro-1,3-butadiene | n/a | Schedule 1 | Level II |
| hexachlorocyclohexane | Tier II | n/a | Level II |
| lead | n/a | Schedule 1 | n/a |
| mercury | Tier I | Schedule 1 | Level I |
| nonylphenol and ethoxylates | n/a | Schedule 1 | n/a |
| octachlorostyrene | Tier I | n/a | Level I |
| polynuclear aromatic hydrocarbons (PAHs) | Tier II | Schedule 1 | Level II |
| pentachlorophenol | Tier II | n/a | Level II |
| vinyl chloride | n/a | Schedule 1 | n/a |
| zinc | n/a | n/a | n/a |

# *APPENDIX E*

# *CASE STUDY EXAMPLES DEMONSTRATING BENEFITS OF P2 MEASURES*

## *APPENDIX E: CASE STUDY EXAMPLES DEMONSTRATING BENEFITS OF P2 MEASURES*

The following case studies pertain to facilities among the six industrial sectors of interest for this BMP series. The case studies demonstrate the reduction effectiveness of P2 measures for specific applications while, at the same time, demonstrating the benefits of undertaking P2 measures. Reference information is provided for further investigation of the case study experience.

Proponents are encouraged to document their experience with P2 measures for publication as case studies. Several organizations recognize leadership in Canada in the area of P2 implementation, including the Canadian Council of Ministers of the Environment (CCME).

**Case Study for P2 Measure: Material Substitution**

Hafner Inc., with four facilities in Granby, Quebec, is the largest Canadian manufacturer of furniture fabric and stretch knitted fabric. Material substitution enabled the company to reduce its nonylphenol and nonylphenol ethoxylated derivatives load from 6,800 kilograms in 2001 to 68 kilograms in 2003. The chemical oxygen demand (COD) of the wastewater was reduced from 210,000 kilograms per year to 110,000 kilograms per year. The reduction in COD reduced the annual effluent disposal costs by $15,000. For further information, see the following:

Environment Canada's Pollution Prevention Success Stories website: Hafner Inc.
http://www.ec.gc.ca/pp/en/storyoutput.cfm?storyid=111

**Case Study for P2 Measure: Process Modification**

Monsanto Company, Muscatine, Iowa Plant, is a large agricultural herbicide manufacturing facility. Through internal recycling and process modifications, the facility reduced wastewater biochemical oxygen demand (BOD) loading by 97 %. For further information, see the following:

U.S. Environmental Protection Agency's National Environmental Performance Track website: Performance Track Case Study Monsanto Company – Muscatine, Iowa Plant
http://www.epa.gov/performancetrack/tools/casestudies/MonsantoCaseStudy.pdf

**Case Study for P2 Measure: Operating Procedures and Housekeeping**

Hendersons Automotive Group, a major supplier of seating components, has implemented several good housekeeping measures which have helped raise pollution prevention consciousness among the 180 employees at the company's Melrose Park plant in South Australia. Cleaner production measures introduced have resulted in annual savings of $270,000. The measures cost a total of $309,000 and paid for themselves in only 18 months after implementation. For more information, see the following:

Australian Department of the Environment and Heritage's Eco-Efficiency and Cleaner Production website: Hendersons Automotive Group Cleaner Production – Continuous Improvement Programs
http://www.deh.gov.au/settlements/industry/corporate/eecp/case-studies/hendersons.html

**Case Study for P2 Measure: Process Modification**

Monroe Australia is a leading Adelaide-based manufacturer of shock absorbers and strut suspension units for the automotive industry. The company has implemented a major waste minimization strategy that has enabled it to process liquid waste, reduce water usage, reduce chemical and waste disposal costs, and eliminate pollution. It installed new equipment which treats wastewater to remove emulsified fats and oils, grease, heavy metals and all forms of suspended, colloidal and some dissolved solids. Monroe's mains water usage has been reduced by over 10 ML per year; wastewater discharge to sewer has been reduced by 50 percent. The new technology has produced a savings of $250,000 per year with total outlay of $530,000 for a payback period of approximately two years. For more information, see the following:

Australian Department of the Environment and Heritage's Eco-Efficiency and Cleaner Production website: Monroe Australia Pty Ltd Cleaner Production – Waste Minimisation Strategy
http://www.deh.gov.au/settlements/industry/corporate/eecp/case-studies/monroe.html

**Case Study for P2 Measure: Process Modification and Operating Procedures**

Specific Plating is a small metal finishing company where parts are plated with metals such as copper, nickel, zinc, silver, and gold. Specific Planting has dramatically reduced its sewer discharges of copper and nickel through pollution prevention efforts including both modifications of industrial processes and improved waste handling and treatment techniques. After the completion of the P2 projects, a reduction of approximately 88% for copper discharges and 85% for nickel discharges was achieved. Wastewater discharge flow has been reduced 27% and off-site sludge disposal has been reduced 53%.

Installation of equipment or changes in operating procedures required an investment of $63,000. Annual savings of $30,000 was realized with the payback period ranging from 1.5 years to just under 3 years. For more information, see the following:

City of Palo Alto's website: Pollution Prevention at Specific Plating Company
http://www.city.palo-alto.ca.us/public-works/documents/cb-specific.pdf