EXCELLENCE IN
ENVIRONMENTAL
CONSULTING
SERVICES

XCG File No. 3-1474-17-03

June 6, 2006

FINAL
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

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 (BMP) document for the Resin, Synthetic Rubber and Artificial and Synthetic Fibres and Filaments Manufacturing Sub-Sector of the Chemical Manufacturing 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, chromium, copper, mercury, zinc, nonylphenol and its ethoxylates (NPE), and vinyl chloride in wastewater effluents of the resin, synthetic rubber and artificial and synthetic fibres and filaments manufacturing sub-sector. The two primary audiences for this document are municipal representatives and industrial facility representatives.

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.

The substances of concern addressed in this BMP are used in the production of polymers, plastics, rubber and synthetic fibres as pigments and stabilizers (cadmium, chromium, copper, mercury) and as catalysts and processing aids (cadmium, chromium, copper, mercury, zinc, NPE). Vinyl chloride is used to make the polymer polyvinyl chloride (PVC), which consists of long repeating units of vinyl chloride. Mercury can be found in many devices used in manufacturing facilities and associated quality control laboratories. The major sources of wastewater streams at plastic resin and manmade fibre facilities include equipment cleaning; leaks and spills at pumps, valves and seals; and loading and unloading operations.

In developing the BMP guidance documents, three reference criteria were considered with respect to final effluent concentrations for harmful substances. The three reference criteria are identified in Table ES.1. Reference Criteria 1 are the most stringent and Reference Criteria 3 are the least stringent. Due to the methodology applied to develop the reference criteria, as elaborated within the main text, two of the three reference criteria are the same in some instances.

Table ES.1 Reference Criteria for Substances in the Resin, Synthetic Rubber and Artificial and Synthetic Fibres and Filaments Manufacturing Sub-Sector

Substance	Reference Criteria 1 (mg/L)	Reference Criteria 2 (mg/L)	Reference Criteria 3 (mg/L)
Cadmium	0.0006	0.02	1
Chromium	0.2	1	5
Copper	0.1	1	3
Mercury	0.0001	0.001	0.1
Zinc	0.2	2	3
Nonylphenol	0.001	0.001	0.0025
Nonylphenol ethoxylates	0.001	0.01	0.025
Vinyl chloride	0.04	0.04	0.22

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. 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."[1] 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[2]	BMP Name	BMP Number
Elimination/Reduction		
All	Improve catalysts – reduce or eliminate by-product formation	BMP #1
All	Automate control systems	BMP #2
All	Recover solvents and raw materials for reuse	BMP #3
All	Optimize reaction conditions	BMP #4
All	Modify products	BMP #5
All	Optimize equipment and process design to improve mixing and reduce spills and leaks	BMP #6

[1] 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

[2] "All" refers to all substances addressed in this BMP document: cadmium, chromium, copper, mercury, zinc, nonylphenol and its ethoxylates, and vinyl chloride.

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

Substance Addressed	BMP Name	BMP Number
All	Optimize cleaning practices	BMP #7
All	Clean product from lines	BMP #8
All	Review sampling practices	BMP #9
All	Review laboratory practices	BMP #10
Cadmium	Closed loop recycle	BMP #11
Cadmium	Substitute for cadmium-containing pigments	BMP #12
Cadmium	Substitute for cadmium as a plastic stabilizer	BMP #13
Chromium	Substitute for chromium in cooling water	BMP #14
Chromium	Chromium recovery	BMP #15
Chromium	Select appropriate catalyst	BMP #16
Copper	Optimize effluent collection system design	BMP #17
Copper	Dedicated effluent collection systems	BMP #18
Mercury	Review mercury use and substitute with mercury-free equipment and products, where possible	BMP #19
Zinc	Substitute for zinc in cooling water	BMP #20
Zinc	Use of di-2-ethyl hexyl phosphoric acid in rayon production	BMP #21
Zinc	Product reformulation for rubber manufacturing	BMP #22
Zinc	Automatic dispensing	BMP #23
Zinc	Recover raw materials	BMP #24
Zinc	Select appropriate catalyst	BMP #25
NPE	Substitute for NPE in emulsion polymers	BMP #26
Vinyl chloride	Closed reactor technology	BMP #27
Vinyl chloride	Optimize effluent collection system design	BMP #28
Vinyl chloride	Dedicated effluent collection systems	BMP #29
Operating Procedures and Housekeeping		
All	Materials management and housekeeping	BMP #30
Mercury	Mercury handling	BMP #31
NPE	Know the sources and pathways of NPE	BMP #32
All	Leak detection and repair program	BMP #33
Education and Training		
All	Management and staff training	BMP #34
All	Customer education	BMP #35

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 Effectiveness 40 – 85%	
All	Improve catalysts – reduce or eliminate by-product formation	BMP #1
All	Automate control systems	BMP #2
All	Recover solvents and raw materials for reuse	BMP #3
All	Optimize reaction conditions	BMP #4
All	Modify products	BMP #5
All	Optimize equipment and process design to improve mixing and reduce spills and leaks	BMP #6
All	Optimize cleaning practices	BMP #7
All	Clean product from lines	BMP #8
All	Review sampling practices	BMP #9
All	Review laboratory practices	BMP #10
Mercury	Review mercury use and substitute with mercury-free equipment and products, where possible	BMP #19
NPE	Substitute for NPE in emulsion polymers	BMP #26
Vinyl chloride	Closed reactor technology	BMP #27
Vinyl chloride	Optimize effluent collection system design	BMP #28
Vinyl chloride	Dedicated effluent collection systems	BMP #29
	Operating Procedures and Housekeeping Effectiveness 20%	
All	Materials management and housekeeping	BMP #30
Mercury	Mercury handling	BMP #31
NPE	Know the sources and pathways of NPE	BMP #32
All	Leak detection and repair program	BMP #33
	Education and Training Effectiveness 2%	
All	Management and staff training	BMP #34
All	Customer education	BMP #35

Based on the estimated 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). For mercury, nonylphenol and its ethoxylates, and vinyl chloride treatment is required to meet all three reference criteria. For cadmium, copper, and zinc treatment is required to meet Reference Criteria 1; however, P2 measures can achieve Reference Criteria 2 and 3 concentrations. For chromium, P2 measures can achieve all reference criteria concentrations.

Cost ranges for capital and operating costs have been estimated. Cost estimates for implementation of pollution prevention measures are based on the number of persons employed at the facility as a proxy for operating budget levels. Cost estimates for treatment systems were based on a range of wastewater flow rates assumed for the sector. Table ES.4 provides a summary of estimated costs for selected P2 BMPs and Table ES.5 provides a summary of estimated costs for selected treatment BMPs.

Note that the estimates are dependent on the incoming concentrations of contaminants 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 ES.4 Estimated Pollution Prevention Costs

Type of P2 Measure	Pollution Prevention Costs*		
	Small Facilities (25 Staff)	**Medium Facilities (175 Staff)**	**Large Facilities (300 Staff)**
Pollution Elimination or Reduction	$100,000	$120,000	$140,000
Operating/Housekeeping	$28,000	$220,000	$440,000
Education and Training	$12,000	$90,000	$180,000
Total Estimate	$140,000	$430,000	$760,000

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.

The database used to develop reference concentrations for vinyl chloride (VC) was limited to a few sub-sector industries which may not be typical of the range of industries covered in this BMP document. There are industries that do not have issues with VC. Consequently, the approach taken was to consider pre-treatment through advanced oxidation technology (AOT) to lower high VC concentrations prior to subsequent treatment steps. Consideration has also been made to determine treatment processes assuming low initial VC concentrations.

Based on the representative wastewater concentrations of substances after P2 measures and an assumption that the BOD_5 is greater than 100 mg/L[3], the overall full treatment systems for all three target reference criteria including treatment for high concentrations of VC are as follows:

- Reference Criteria 1 and 2: Air Stripping, Biological Treatment, Sand/Mixed Media Filtration, Granular Activated Carbon (GAC), Microfiltration, and Deionization (DI) for the main wastewater stream. Advanced oxidation (AOT) for the high strength VC stream.
- Reference Criteria 3: Air Stripping, Biological Treatment, Sand/Mixed Media Filtration, Microfiltration, and DI for the main wastewater stream. AOT for the high strength VC stream.

Treatment would require the wastewater stream containing the high concentration of VC to be segregated from the total wastewater flow, and the VC wastewater treated with AOT. The remaining wastewater would be treated with the other treatment processes. It has been

[3] Assuming low VC concentrations and should BOD_5 concentrations after P2 measures be lower than 100mg/L, then biological treatment may not be required for VC and NPE reduction and removal and granular activated carbon (GAC) may be sufficient. Air stripping will remove the bulk of VC.

assumed that the remaining wastewater would contain a low VC concentration (i.e., less than 3 mg/L) which would be air stripped.

Capital and annual operational and maintenance (O&M) costs were developed for full treatment for the three reference criteria using a wastewater flow range of 1 m^3/h to 50 m^3/h. Costs were also developed for three other treatment scenarios where a number of substances can be considered to be reduced through aggressive P2 measures. The treatment option assuming low VC concentrations eliminates the AOT pre-treatment process. The treatment option assuming low VC, NPE and BOD_5 eliminates the AOT and the biological treatment components and uses GAC directly for the treatment and reduction of these substances. The treatment option assuming low VC and low metals eliminates the AOT and DI treatment components but retains the biological treatment for NPE. This last option assumes the aggressive reduction of metals through P2 practices, whereby DI may not be required. 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	Approximate Costs as Function of Flow Range of 1 to 50 m^3/h					
	Capital Cost Range			Annual O&M Cost Range		
	1m^3/h	25 m^3/h	50 m^3/h	1m^3/h	25 m^3/h	50 m^3/h
Full Treatment Assuming High VC						
Criteria 1 and 2	$947,000	$4,309,000	$7,693,000	$142,000	$517,000	$769,000
Criteria 3	$932,000	$4,087,000	$7,294,000	$140,000	$490,000	$729,000
Treatment Assuming Low VC (<3 mg/L)						
Criteria 1 and 2	$584,000	$1,860,000	$3,051,000	$88,000	$223,000	$305,000
Criteria 3	$569,000	$1,638,000	$2,652,000	$85,000	$197,000	$265,000
Treatment Assuming Low VC, NPE and BOD_5						
Criteria 1 and 2	$258,000	$1,173,000	$2,101,000	$39,000	$141,000	$210,000
Criteria 3	$243,000	$951,000	$1,702,000	$36,000	$114,000	$170,000
Treatment Assuming Low VC and Low Metals (i.e., No DI)						
Criteria 1 and 2	$396,000	$1,126,000	$1,698,000	$59,000	$135,000	$170,000
Criteria 3	$367,000	$795,000	$1,135 ,000	$55,000	$95,000	$114,000

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, chromium, copper, mercury, zinc, nonylphenol and its ethoxylates (NPE), and vinyl chloride in wastewater effluents of the Resin, Synthetic Rubber and Artificial and Synthetic Fibres and Filaments Manufacturing Sub-Sector of the Chemical Manufacturing Sector (NAICS[4] 3252). 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.

Resin, Synthetic Rubber, and Artificial and Synthetic Fibres and Filaments Manufacturing comprises establishments primarily engaged in manufacturing polymers, such as resins, synthetic rubber, and textile fibres and filaments. Polymerization of monomers into polymers, for example, of styrene into polystyrene, is the basic process. Definitions for this sub-sector are provided in Appendix C.

[4] 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 January 25, 2006)

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 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:

- Increased cost-effectiveness and lower long-term costs through implementation of pollution prevention (P2) 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,[5] using the Standard & Poor's 500 Index (S&P 500), compared the financial performance of "low polluter" portfolios to industry-matched "high polluter" portfolios. The study found that the "low polluter" portfolios performed as well as - and often better than - the "high polluter" group. Investors who chose the

[5] Environmental and Financial Performance: Are They Related? M. A. Cohen, S. A. Fenn, S. Konar, Vanderbilt University, Nashville, TN, 1997 (URL http://sitemason.vanderbilt.edu/files/d/dLwFkQ/Environmental%20and%20Financial%20Performance.pdf, accessed January 2006)

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 BMP 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 this BMP document.

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 used to analyze and develop the BMP and reporting requirements for the substances.
- **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 pollution prevention 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 sewer use 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

The resin and synthetic fibres industries use and manufacture polymers. Although there are thousands of types of resins and fibres that may be produced during polymerization, the basic industrial processes are similar:

1. **Preparation of reactants.** Many chemicals are used to make polymers: monomers, catalysts, and solvents. Monomers are the building blocks of polymers. Catalysts are chemicals used to speed up or initiate the polymerization reaction. Details of commercially-used catalysts are highly guarded secrets because small differences in catalyst preparation can lead to large differences in polymerization costs and polymer properties. Solvents facilitate polymer transport throughout the plant, increase heat dissipation in the reactor, and promote uniform mixing in the reactor.

2. **Polymerization.** Polymerization occurs in a reactor with a catalyst and other additives.

3. **Polymer recovery.** Following polymerization, there are three components in the reactor: polymer, monomer, and trace catalyst. The polymer must be recovered: unreacted monomer is separated from the polymer, liquids and solids are separated and residual water or solvents are purged by drying the polymer.

4. **Polymer extrusion.** The polymer is extruded into plastic pellets.

5. **Supporting operations.** Supporting operations include equipment cleaning (reactors and storage vessels), unloading and storage of reactants, conveyance, and pellet storage.

Plastic resin and manmade fibre facilities generate large amounts of wastewater from processes, cooling operations, utilities and maintenance, and air pollution control systems. Sources of wastewater include the following:

- Equipment cleaning;
- Leaks and spills at pumps, flanges, valves, seals, etc.; and
- Loading/unloading operations and bag filling operations.

2.1 Use of the Substances of Interest in This Sector

The following substances have been identified in the wastewaters discharged from facilities in the Resin, Synthetic Rubber and Artificial and Synthetic Fibres and Filaments Manufacturing Sub-Sector of the Chemical Manufacturing Sector:

- Cadmium;
- Chromium;

- Copper;
- Mercury;
- Zinc;
- NPE; and
- Vinyl chloride.

The following sections provide background on the use of and presence in wastewater of the six substances identified above.

In addition, some products manufactured in this sub-sector are comprised in part with 1,4-dichlorobenzene, 3,3-dichlorobenzidine, or hexachlorobenzene. For more information on the reduction and treatment of these compounds in wastewaters, refer to *Best Management Practices. 1,4-Dichlorobenzene, 3,3-Dichlorobenzidine, Hexachlorobenzene, and Pentachlorophenol: Non-Sector Specific Practices*.

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 resin, synthetic rubber and artificial and synthetic fibres and filaments manufacturing sub-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 Resin, Synthetic Rubber and Artificial and Synthetic Fibres and Filaments Manufacturing Sub-Sector

Substance	Representative Concentration in Wastewater (prior to pollution prevention or treatment) (mg/L)
Cadmium	0.03
Chromium	0.1
Copper	0.51
Mercury	0.9
Zinc	0.52
Nonylphenol	0.15
Nonylphenol Ethoxylates	2.3
Vinyl Chloride	540

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

Cadmium is a naturally occurring element, most often found in combination with other elements. Cadmium and its compounds are stable, with high melting points and low volatility, and it is one of the persistent, bio-accumulative and toxic (PBT) chemicals identified by the United States Environmental Protection Agency (USEPA). 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.

Cadmium is used in the manufacture of polymers as pigments and plastic stabilizers, and as a catalyst in the production of polyvinyl chloride (PVC). Cadmium pigments produce intense colours, such as yellow, orange, red, and maroon. They are insoluble in water and organic solvents and are resistant to detergents and corrosive alkaline chemicals. The plastics industry is the main consumer of cadmium pigments, which are stable at high temperature and remain strong and bright over long periods of time in the presence of strong sunlight. Organic cadmium compounds can be used in combination with barium sulphate to stabilize PVC, which is used where long-term weathering, heat, and UV resistance is required to prolong the life of a product.

2.1.2 Chromium

Chromium is a naturally occurring element found in rocks, animals, plants, soil, and volcanic dust and gases. It is present in the environment in several different forms, the most common being metal chromium (0), trivalent chromium (III) compounds, and hexavalent chromium (VI) compounds. Chromium (III) occurs naturally, whereas chromium (0) and chromium (VI) are produced by industrial processes. Chromium (III) is insoluble in water and in common organic solvents, although the solubility of chromium compounds depends on the specific compound. Chromium VI has been declared 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.

Chromium and its compounds are used as constituents of inorganic pigments, which may be used in the manufacture of resins and plastics, and as catalysts.

2.1.3 Copper

Copper is a reddish metal that occurs naturally in rock, soil, water, sediment, and at low levels in air. It can be found in nature in its elemental form. Copper is insoluble in water but soluble in methanol and slightly soluble in ethanol.

Copper is used in inorganic pigments and as a catalyst for organic reactions, particularly in the production of vinyl chloride, a precursor in PVC manufacturing.

2.1.4 Mercury

Mercury is a naturally occurring toxic metal; a shiny, silver-white, odourless liquid metal at room temperature. It is very volatile and some mercury salts and organic compounds containing mercury are soluble in water. Mercury and its components have been declared 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.

Mercury is used in catalysts, pigments and dyes and preservatives. Mercury-containing devices are commonly used in laboratories to measure temperature, pressure, liquid density, and humidity. Laboratory reagents and subsequent chemical products may contain mercury. Other potential sources of mercury in the manufacturing industry include fluorescent lights, custodial supplies and old paint, batteries, float switches, and process control and instrumentation devices, such as level meters and flow meters.

Further, sinks and floor drains may contain mercury from historical use and previous spills, as mercury was extensively used in the past. Mercury can settle at low points and continuously dissolve into the wastewater even after measures for preventing discharge of mercury into the drains have been implemented.

2.1.5 Zinc

Zinc is one of the most common elements in the earth's crust, found in air, soil, water, and all foods. Pure elemental zinc is a bluish white, shiny metal. Zinc is insoluble in water, but some zinc compounds are readily soluble in water.

Zinc compounds are used to make rubber, plastics, and synthetic fibres (e.g., zinc oxide for vulcanizing, zinc carbonate for fire proofing, zinc chloride in the manufacture of artificial silk, zinc sulphate in the manufacture of rayon, zinc sulphide as a pigment). In rubber and plastics products manufacturing, zinc is used in the rubber mixing process as vulcanizing agents, accelerator activators, and processing aids. Zinc can be released during mixing operations as spills, leaks, and fugitive emissions.

2.1.6 Nonylphenol and its Ethoxylates (NPE)

Nonylphenol ethoxylates are part of the alkyl phenol ethyoxylates (APE) group of non-ionic surfactants; they degrade to form nonylphenol. NPE accumulate in sewage sludge and sediments and bioaccumulate in aquatic species. They 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.

Nonylphenol ethoxylates are used as detergents, emulsifiers, dispersion agents, surfactants, and/or wetting agents. They are used in production of resins. Nonylphenol is used almost exclusively as an intermediate in the production of other chemicals and as an additive in polymer processing. It is also produced when nonylphenol ethoxylates degrade. The main use of nonylphenol in the plastics industry is as a monomer in the production of nonylphenol/formaldehyde resins. Other reported uses are as an intermediate in the production of tri-(4-nonylphenyl) phosphate (TNPP), as a catalyst in the curing of epoxy resins, and in plastics stabilizers.

2.1.7 Vinyl Chloride

Vinyl chloride (VC) is a manufactured substance that does not occur naturally, although it can be formed by the biodegradation of other manufactured substances, including trichloroethylene and tetrachloroethylene. VC, also known as chloroethene, chloroethylene, ethylene monochloride, or monochloroethylene, is a colourless gas that burns easily and is not stable at high temperatures. VC exists in liquid form if kept under high pressure or at low temperatures. VC has been declared 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.

Most of the VC produced is used to make PVC, which consists of long repeating units of VC. PVC is subsequently used to make a variety of plastic products including pipes, wire and cable coatings, packaging materials, furniture, automobile upholstery, wall coverings, housewares, and automotive parts. Vinyl chloride is made by reacting ethylene with chlorine and hydrochloric acid to 1,2-dichloroethane, which is then cracked to hydrogen chloride and the monomer vinyl chloride. Polymerization then occurs in the presence of catalysts and other chemicals under controlled temperature conditions to create PVC, a fine-grained, white powder, or resin. VC has a relatively low solubility in water and is a gas at ambient temperature; it therefore tends to evaporate quickly.

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 2.2, 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. Due to the methodology applied to develop the reference criteria, as elaborated below, two of the three reference criteria are the same in several instances.

Table 2.2 Reference Criteria for Substances in the Resin, Synthetic Rubber and Artificial and Synthetic Fibres and Filaments Manufacturing Sub-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
Chromium	CEPA** Toxic+	0.2	1	5
Copper	N/A	0.1	1	3
Mercury	COA Tier I	0.0001	0.001	0.1
Zinc	N/A	0.2	2	3
Nonylphenol	CEPA Toxic	0.001	0.001	0.0025
Nonylphenol Ethoxylates	CEPA Toxic	0.001	0.01	0.025
Vinyl Chloride	CEPA Toxic	0.04	0.04	0.22

Notes:
*COA: Canada-Ontario Agreement respecting the Great Lakes Basin Ecosystem
**CEPA: Canadian Environmental Protection Act
+ Hexavalent chromium has been declared CEPA Toxic

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 2.2 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 except for NPE, where Reference Criteria 1 are the threshold identified in the Canadian Environmental Quality Guidelines, Canadian Council of Ministers of the Environment (CCME), 2002.

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. In cases where the sewer use by-law limit was the same as the PWQO or RMDL, Reference Criteria 2 are the same as Reference Criteria 1.

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. In cases where only one by-law identified a limit for the substance, or where the same limit was identified in all by-laws, Reference Criteria 3 are the same as Reference Criteria 2.

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 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, National Pollutant Release Inventory (NPRI) and the federal Environmental Emergency (EE) 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:[6]

- 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

[6] *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

- 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 P2 planning and reporting by industrial facilities. Proponents are encouraged to obtain and review 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.

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[7] directly for the most recent reporting requirements, including reportable substances and reporting thresholds, as these may change over time. There are over 330 substances and substance groups reportable under NPRI; Table 2.3 identifies the substances of interest for this BMP document.

Table 2.3 NPRI Reporting Requirements (2003) for Substances in the Resin, Synthetic Rubber and Artificial and Synthetic Fibres and Filaments Manufacturing Sub-Sector

Substance	NPRI Reportable Substances	NPRI Part Designation	Reporting Threshold
Cadmium	Cadmium and its compounds	Part 1B	5 kg
Chromium	Chromium and its compounds and hexavalent chromium	Group 1A, except hexavalent chromium is Part 1B	10 tonnes except hexavalent chromium is 50 kg
Copper	Copper and its compounds	Group 1A	10 tonnes
Mercury	Mercury and its compounds	Part 1B	5 kg
Zinc	Zinc and its compounds	Group 1A	10 tonnes
Nonylphenol and Ethoxylates	Specific substances	Group 1A	10 tonnes (total in 2003)
Vinyl chloride	Vinyl chloride	Group 1A	10 tonnes

For the chemical manufacturing sector, there are companies reporting releases to the NPRI for these substances, indicating that there are currently companies meeting the reporting thresholds indicated in the above table.

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

Federal Environmental Emergency Regulation

Environmental Emergency (EE) Regulations under Part 8 of the CEPA 1999, promote prevention and planning for preparedness, response, and recovery. This regulation requires those who own or manage identified toxic and hazardous substances at or above the specified thresholds to provide required information to Environment Canada on the substance(s), their quantities and to prepare and implement environmental emergency plans. Information required includes the quantity of the substance, the facility location, information on the development of an environmental emergency plan, and a notice indicating that the emergency plan has been implemented. Practitioners are encouraged to review details of these requirements at Environment Canada's website.[8] Table 2.4 provides information on specific substances of interest in this document.

Table 2.4 Environmental Emergency Substances and Thresholds

Substance Name	CAS number	Concentration	Threshold Quantity (tonnes)	Comment
Mercury	7439-97-6	Not specified	1.00	Part 2 - Other Hazardous Substances
Vinyl chloride	75-01-4	1%	4.5	Part 1 – Flammable Substances

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 Environmental 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-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.

Pollution Prevention Plans for NPE

Environment Canada, under CEPA 1999, has set out pollution prevention planning requirements for manufacturers and importers of soap and cleaning products, processing aids used in textiles, and pulp and paper processing aids containing NPE. Facilities that have purchased or otherwise acquired a total of 2,000 kilograms or

---

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

more of NPE during one calendar year are required to prepare P2 plans and meet all related requirements of the Notice published in the Canada Gazette on this topic. Refer to the Environment Canada website for further details.

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."[9] 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 resin, synthetic rubber, and artificial and synthetic fibres and filaments manufacturing sub-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.

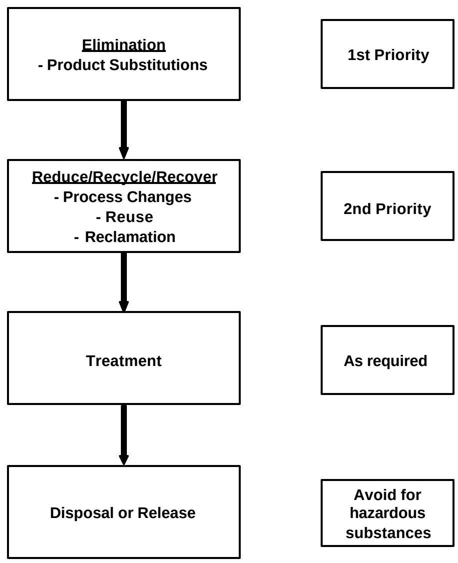
General best available techniques (BAT) for the EMS at chemical manufacturing facilities include the following:

[9] 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

- An environmental strategy and a commitment to follow the strategy.
- Organizational structures to integrate environmental issues into decision-making, including, for example, implementing a requirement that chemicals new to the facility not be purchased without undergoing an environmental review.
- Written procedures or practices for all environmentally important aspects of plant design, operation, maintenance, commissioning, and decommissioning.
- Internal audit systems to review the implementation of environmental policies and to verify compliance with procedures, standards, and legal requirements.
- Accounting practices that internalize the full costs of raw materials and wastes.
- Long-term financial and technical planning for environmental investments.
- Control systems for the core process and pollution control equipment to ensure stable operation, high yield, and good environmental performance under all operational modes.
- Systems to ensure operator environmental awareness and training.
- Inspection and maintenance strategies to optimize process performance, including implementing monitoring and reporting programs.
- Implementation of an inspection and recording program for all input and output materials, including defined chemicals labelling, storage, handling, and disposal practices.
- Defined response procedures to abnormal events.
- On-going waste minimization exercises.

The following sequence of steps (Figure 3.1) 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 water input to the process;
- Minimize process water and washwater contamination with raw material, product, or wastes;
- Maximize wastewater re-use; and
- Maximize the recovery and retention of substances from streams unfit for re-use.

The chemical manufacturing sector includes a large variety of processes and chemical reactions, depending on the type of chemical being manufactured. Consumption and emission levels are very specific to each process and are difficult to define and quantify without detailed study. P2 opportunities and BMPs are therefore site and process specific.

3.1 Overview of P2 Measures for Cadmium, Chromium, Copper, Mercury, Zinc, NPE, and Vinyl chloride in the Resin, Synthetic Rubber and Artificial and Synthetic Fibres and Filaments Manufacturing Sub-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 Summary of P2 Measures

Substance Addressed[10]	BMP Name	BMP Number
	Elimination/ Reduction	
All	Improve catalysts – reduce or eliminate by-product formation	BMP #1
All	Automate control systems	BMP #2
All	Recover solvents and raw materials for reuse	BMP #3
All	Optimize reaction conditions	BMP #4
All	Modify products	BMP #5
All	Optimize equipment and process design to improve mixing and reduce spills and leaks	BMP #6
All	Optimize cleaning practices	BMP #7
All	Clean product from lines	BMP #8
All	Review sampling practices	BMP #9
All	Review laboratory practices	BMP #10
Cadmium	Closed loop recycle	BMP #11
Cadmium	Substitute for cadmium-containing pigments	BMP #12
Cadmium	Substitute for cadmium as a plastic stabilizer	BMP #13
Chromium	Substitute for chromium in cooling water	BMP #14
Chromium	Chromium recovery	BMP #15
Chromium	Select appropriate catalyst	BMP #16
Copper	Optimize effluent collection system design	BMP #17
Copper	Dedicated effluent collection systems	BMP #18
Mercury	Review mercury use and substitute with mercury-free equipment and products, where possible	BMP #19
Zinc	Substitute for zinc in cooling water	BMP #20
Zinc	Use of di-2-ethyl hexyl phosphoric acid in rayon production	BMP #21
Zinc	Product reformulation for rubber manufacturing	BMP #22
Zinc	Automatic dispensing	BMP #23
Zinc	Recover raw materials	BMP #24
Zinc	Select appropriate catalyst	BMP #25
NPE	Substitute for NPE in emulsion polymers	BMP #26
Vinyl chloride	Closed reactor technology	BMP #27

[10] "All" refers to all substances addressed in this BMP document: cadmium, chromium, copper, mercury, zinc, nonylphenol and its ethoxylates, and vinyl chloride.

Table 3.1 (cont'd) Summary of P2 Measures

Substance Addressed	BMP Name	BMP Number
Vinyl chloride	Optimize effluent collection system design	BMP #28
Vinyl chloride	Dedicated effluent collection systems	BMP #29
Operating Procedures and Housekeeping		
All	Materials management and housekeeping	BMP #30
Mercury	Mercury handling	BMP #31
NPE	Know the sources and pathways of NPE	BMP #32
All	Leak detection and repair program	BMP #33
Education and Training		
All	Management and staff training	BMP #34
All	Customer education	BMP #35

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.

Opportunities for pollution prevention include avoidance or elimination of the pollutant from the chemical process, reduction of the amount or concentration of the pollutant used or produced as waste, the re-use of wastes impacted with the pollutant, and associated training and education of staff to carry out the identified pollution prevention techniques.

The resin and synthetic fibres industries use and manufacture polymers. Although there are thousands of types of resins and fibres that may be produced during polymerization, the basic industrial processes are similar. Plastic resin and manmade fibre facilities generate large amounts of wastewater from processes, cooling operations, utilities and maintenance, and air pollution control systems. Sources of wastewater include equipment cleaning; leaks and spills at pumps, flanges, valves, seals, etc.; and loading/unloading operations and bag filling operations.

3.2.1 Reduction Measures Common to All Substances of Interest

Sources and quantities of waste streams should be documented prior to assessment of pollution prevention measures. Determine what changes in process conditions would lower waste and if wastes can be recycled back into the process. Process inefficiencies should be reduced. Increase product yield to reduce by-product and co-product generation and raw material requirements.

BMP #1: Improve catalysts - reduce or eliminate by-product formation:

- The presence of heavy metals in catalysts can result in contaminated process wastewater from catalyst handling and separation. Catalysts comprised of noble metals, because of their cost, are generally recycled by both on-site and off-site reclaimers.
- Effluents are generated with catalyst activation or regeneration. Obtain catalyst in the active form or provide in situ activation with appropriate processing/activation facilities.
- In situ regeneration of catalysts eliminates unloading/loading effluents.
- Use a nonpyrophoric catalyst to minimize amount of water required to handle and store safely.
- Study and identify catalyst deactivation mechanisms and operate to extend the catalyst life; thereby, reducing effluents associated with catalyst handling and regeneration.
- Use a more selective catalyst which will reduce the yield of undesired by-products.

BMP #2: Automate control systems. Consider using computer controlled systems to optimize the use of chemicals and processes. Efficient process control, to achieve stable operations and high yields, will improve the quality of process wastewater, as more of the raw materials are reacted into final product. Computer-controlled systems provide results for environmental parameters on a continuous basis, allowing swift corrective action to be taken and abnormal releases prevented.

BMP #3: Recover solvents and raw materials for reuse. Provide a separate reactor for converting recycle streams with waste by-products to usable products.

BMP #4: Optimize reaction conditions:

- Control conditions (temperature, pressure, etc.) to reduce by-product formation. Use lower temperatures to reduce the water solubility of chemicals.
- Modify the reaction sequence(s) to reduce or change the composition of intermediate reaction products or properties.
- Evaluate unit operation or technologies that do not require the addition of solvents or other non-reactant chemicals.

BMP #5: Modify products:

- Substitute hazardous raw materials with less water soluble materials to minimize water contamination and reconsider the need for raw materials that end up as wastes. Reformulate products by substituting different material or using a mixture of individual chemicals that meet end-use performance specifications.

- Small containers increase shipping frequency, which increases chances of material releases and waste residues from shipping containers (including wash waters). Use bulk supply or ship by pipeline. In some cases, product may be shipped out in the same containers the material supply was shipped in without washing.

BMP #6: Optimize equipment and process design to improve mixing and reduce spills and leaks:

- Reduce spills, leaks, and upset conditions through equipment and process control. Install seamless pumps to prevent leaks.

- Optimize reactor design and/or improve reactor mixing/contacting to increase catalyst effectiveness.

- Inadequate mixing in reactors can be improved by adding baffles or changing impellers. Operationally, add ingredients in the optimum sequence to improve reaction conversion.

- Design the process facility to readily allow maintenance so as to avoid unexpected equipment failure and resultant effluent releases.

- Shutdowns and start-ups generate wastes and releases. Design on-line instrumentation and automatic start-up and shutdown. Consider operational changes such as continuous versus batch reactions and optimization of on-line run time.

BMP #7: Optimize cleaning practices. Wastes generated from cleaning operations include vessel wash waters, floor wash waters, equipment draining, sump draining, and air stripper water effluent. To minimize these wastes, consider the following:

- Initiate a water conservation program.

- Clean reactors using high-pressure water or process solvents which can be recycled into the reactor.

- Use materials with low viscosity and minimize equipment roughness to facilitate cleaning between production batches.

- Optimize the product manufacturing sequence to minimize washing operations and cross-contamination of batches.

BMP #8: Clean product from lines. Releases occur when cleaning or purging lines. Use "pigs" for cleaning, slope lines to a low point drain, and/or use heat tracing and insulation to prevent freezing. In operation, flush lines to product storage tanks to minimize product disposed as waste.

BMP #9: Review sampling practices. Quality control sampling is a potential source of emissions of contaminants, including by-products. The sampling frequency and procedure should be reviewed to reduce the number and quantity of samples. Consideration should be given to recycling samples into the process. Similarly, associated laboratory wastes can be reduced by reviewing sampling procedures, reducing sample size and number, returning unused sample to the process, and considering in-line monitoring.

BMP #10: Review laboratory practices. Laboratories located at chemical manufacturing facilities are a potential source of emissions of contaminants. Laboratories should install and maintain lips around sinks to prevent spilled chemicals from reaching the sewer system. Protocols for proper clean-up of chemical spills should be established and all individuals who may work with chemicals or respond to chemical spills be trained.

3.2.2 Reduction Measures for Cadmium

There are several different alternatives and processes that are available to eliminate or reduce the amount of cadmium used in chemical manufacturing operations, including but not limited to the following.

BMP #11: Closed loop recycle. In operations where cadmium waste is produced, a reverse osmosis (RO) filter system can be used to filter out the cadmium from process wastewater. A closed loop system can then be installed to recycle the wastewater produced back into the production processes as clean-up water.

BMP #12: Substitute for cadmium-containing pigments. Many types of cadmium-free pigments are available today for use in industry (e.g., alloy of polycarbonate and acrylonitrile-butadiene styrene terpolymer, which passed a 1000-hour UV-ray exposure test). Proposed alternatives should be evaluated to ensure that they are not more toxic than the cadmium pigments they replace.

In some applications of pigments, cadmium can be replaced by zinc (for green yellow colours), selenium (for reddish colour), or mercury (for red to brown colour). However, due to its toxic properties, mercury should not be considered a substitution for cadmium in pigments. Specific properties of cadmium (i.e., resistance to high temperatures, durability, and brilliant colour) make substitution of cadmium in plastic applications and safety systems difficult.

BMP #13: Substitute for cadmium as a plastic stabilizer. Consideration should be given to substitution of cadmium by other materials for use as plastic stabilizers. The use of cadmium stabilizers has been banned by the European Union (EU) (Directive 91/338/EEC) for some uses such as in packaging materials, stationery supplies, fittings and furniture, although cadmium pigments may be used in any polymer where the colouring is being used for safety reasons.

3.2.3 Reduction Measures for Chromium

BMP #14: Substitute for chromium in cooling water. Use of phosphates as corrosion inhibitors instead of chromates in cooling water eliminates chromium and zinc from the cooling water waste stream.

BMP #15: Chromium recovery. Install a chromium recovery unit, such as an ion exchange resin, to reduce the plant's hazardous catalyst waste.

BMP #16: Select appropriate catalyst:

- Catalysts comprised of noble metals, because of their cost, are generally recycled by both on-site and off-site reclaimers.
- Study and identify catalyst deactivation mechanisms and avoid conditions that promote thermal or chemical deactivation. By extending catalyst life, emissions and effluents associated with catalyst handling and regeneration can be reduced.
- Provide in situ activation with appropriate processing/activation facilities.
- Reduce catalyst consumption with a more active form. A higher concentration of active ingredient or increased surface area can reduce catalyst loadings.

3.2.4 Reduction Measures for Copper

Copper has been identified as a wastewater pollutant from the manufacture of VC, which is used in the production of polyvinyl chloride. The following BAT for VC plants have been identified:

BMP #17: Optimize effluent collection system design: Leaking process effluent water systems are observed as a problem at several VC plants. To reduce the risk of leaks, sewage systems should be made from corrosion resistant materials and be designed to prevent leaks. BAT for contaminated effluent water collection systems at new plants and retrofitted system are:

- Pipes and pumps placed above ground; or
- Pipes and pumps placed in ducts accessible for inspection and repair.

BMP #18: Dedicated effluent collection systems. Water pollution prevention measures at VC plants should include maximum reduction of water consumption and separate effluent collection systems for each of the following:

- Contaminated process effluent water;

- Potentially contaminated water from leaks and other sources, including cooling water and surface run-off from process plant areas; and
- Uncontaminated water.

3.2.5 Reduction Measures for Mercury

Mercury P2 in chemical manufacturing, including resin, synthetic rubber and artificial and synthetic fibres and filaments manufacturing, includes the following approaches:

- Reduce or eliminate mercury-containing reagents;
- Promote the use of non-mercury containing devices and chemical reagents; and
- Implement a mercury-free purchase policy.

Mercury can enter the wastewater stream at chemical manufacturing facilities when mercury-containing product is broken or spilled over a sink or the mercury is flushed down the drain, or when mercury-containing chemical reagents are spilled or flushed down a drain.

BMP #19: Review mercury use. The following list of BMPs can be implemented by manufacturers working with mercury-containing products or instruments:

- Replace mercury-containing devices with non-mercury substitutes if available (e.g., thermometers).
- Use alternatives for products that contain mercury. Table 3.2 provides a list of alternatives for some of the mercury-containing chemicals commonly used.
- Modify the process to eliminate the intentional use of mercury (e.g., a novel chemical pathway was developed to circumvent the sulfonation step in producing aminoanthroquinone, thereby eliminating the need for mercury as a catalyst).
- Assess all products used for mercury content and request mercury-free products from suppliers. This should include laboratory reagents, cleaners, and process chemicals. Material Safety Data Sheets (MSDS) should not be relied on, as only chemicals making up 1% or more of the products are required to be reported.
- Designate a room for mercury use and provide containment. Use mercury only in uncarpeted areas and on smooth surfaces to facilitate clean-up of spills.

- Install and maintain lips around sinks to keep spilled chemicals from reaching the sewer system and provide containment areas where mercury is being used.
- Have a mercury spill kit on site to handle small spills and train personnel on the proper use of the kit.

Table 3.2 Alternatives to Mercury-Containing Chemicals

Chemicals	Alternatives
Mercury (II) oxide	Copper catalyst
Mercury (II) chloride	Magnesium chloride/sulfuric acid or Zinc Formalin, Freeze drying
Mercury (II) sulfate	Silver Nitrate/Potassium/Chromium-(III) Sulfate
Mercury iodide	Phenate method
Mercury nitrate	Ammonia/copper sulfate; Neosporin, Mycin
Zenker's Solution	Zinc Formalin
Notes: (From: Draft Wisconsin Mercury Sourcebook: Laboratories, 1997)	

- Flush sink traps and sewer lines to remove historical mercury build-up. Whenever traps or sumps are moved or cleaned, the solid contents should be treated as a hazardous waste unless proven otherwise.
- Recycle the mercury from mercury-containing products when they can no longer be used.
- Establish protocols for proper clean-up of spills involving mercury.
- Train all individuals who may work with or respond to mercury spills or emergencies.

3.2.6 Reduction Measures for Zinc

BMP #20: Substitute for zinc in cooling water. Replace the zinc products used for corrosion and deposit control in the cooling water treatment program. Use of phosphates as corrosion inhibitors instead of chromates in cooling water eliminates chromium and zinc from the cooling water waste stream.

BMP #21: Use of di-2-ethyl hexyl phosphoric acid in rayon production. The use of a solution of di-2-ethyl hexyl phosphoric acid (DEHPA) (10%) and solvents (90%) reduces zinc required for production of rayon fibres.

General and zinc specific pollution prevention practices applicable to rubber manufacturing include the following:

BMP #22: Product reformulation for rubber manufacturing. Reduce the use of toxic chemicals via product reformulation. Use different materials that are less toxic or non-toxic. This may include the use of non-zinc containing raw materials or different equipment that does not require zinc.

BMP #23: Automatic dispensing. Use an automatic zinc oxide dispensing system, which reuses recycled super sacks instead of 50-pound paper bags.

BMP #24: Recover raw materials. For example:

- Recycle process water through a sedimentation tank designed to remove the suspended solids, so that the zinc-containing process water can be reused.
- Use an alternative two-stage precipitation process to recover zinc, which is used in the acid spinning bath process. Zinc is precipitated, treated, and returned to the spinning bath.

General and zinc specific pollution prevention practices applicable to plastic resin and manmade fibre manufacturing include the following:

BMP #25: Select appropriate catalyst:

- Catalysts comprised of noble metals, because of their cost, are generally recycled by both on-site and off-site reclaiming facilities.
- Study and identify catalyst deactivation mechanisms and avoid conditions, which promote thermal or chemical deactivation. By extending catalyst life, emissions, and effluents associated with catalyst handling and regeneration can be reduced.
- In situ regeneration eliminates unloading/loading emissions and effluents versus off-site regeneration or disposal.
- Reduce catalyst consumption with a more active form. A higher concentration of active ingredient or increased surface area can reduce catalyst loadings.

3.2.7 Reduction Measures for Nonylphenol and its Ethoxylates

Due to the concern for NPE, governments are taking action to reduce the use of NPE in the marketplace. As indicated in Section 2.3, in Canada, owners or operators of facilities that manufacture soap and cleaning products, processing aids used in textile wet processing, or pulp and paper processing aids, as well as importers and bulk purchasers of NPE, are required to prepare and implement a pollution prevention plan. The P2 plan must reduce by 50% the mass of NPE used or imported annually by the year 2007 and reduce the mass used or imported annually by 95% by the year 2010. (See Environment Canada' Canada Gazette Notice for precise requirements.)[11]

[11] website: http://www.ec.gc.ca/Ceparegistry/documents/notices/g1-13849_n4.pdf

Canada's steps are similar to those of the European Union (EU), which as of January 2005, under the 26th amendment to Directive 76/796/EC, requires that NPE may not be placed on the market or used as a substance or constituent of preparations in concentrations equal to or higher than 0.1% weight to weight in a number of applications. The exceptions to this list of applications are processes with no release into wastewater, including those with special treatment where washing liquid is recycled or incinerated. The European Community has banned the marketing and use of NPE for some sectors and issues permits containing emission limits for NPE for uses including production of phenol/formaldehyde resin, production of plastic stabilizers, and emulsion polymerisation.

BMP #26: Substitute for NPE in emulsion polymers. Substitute and reformulate products to eliminate the use of NPE in plastic stabilizers and emulsion polymers. Ensure substituted compound is not more toxic than the compound it is replacing.

3.2.8 Reduction Measures for Vinyl Chloride

Given that VC is the basic building block of PVC, avoidance and elimination from the chemical process is not appropriate. Therefore, opportunities for P2 are focused on reduction of VC produced in the waste streams and the re-use of wastes produced.

BMP #27: Closed reactor technology. The closed reactor technology is considered BAT for all new plants. The PVC slurry at the inlet to the driers at these plants should have a maximum residual VC content of 20 grams VC per tonne suspension PVC as a yearly average. BAT in terms of process selection are the following:

- For the overall production of 1,2-dichloroethane/VC, the BAT is the chlorination of ethylene;
- For the chlorination of ethylene, the BAT is either direct chlorination or oxychlorination;
- For direct chlorination, the BAT can be either low or high temperature variants;
- For ethylene oxychlorination, either fixed or fluidized bed are BAT; and
- Optimize process balancing to maximize the recycle of process streams and aim for full process balancing.

BMP #28: Optimize effluent collection system design. Leaking process effluent water systems are observed as a problem at several VC plants. To reduce the risk of leaks, sewage systems should be made from corrosion resistant materials, and be designed to prevent leaks. BAT for contaminated effluent water collection systems at new plants and retrofitted system are:

- Pipes and pumps placed above ground; or
- Pipes and pumps placed in ducts accessible for inspection and repair.

BMP #29: Dedicated effluent collection systems. Water pollution prevention measures at VC plants should include maximum reduction of water consumption and separate effluent collection systems for each of the following:

- Contaminated process effluent water;
- Potentially contaminated water from leaks and other sources, including cooling water and surface run-off from process plant areas; and
- Uncontaminated water.

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 best management practices can be expected.

A comprehensive management approach is the most effective way to reduce release of hazardous substances. The following practices outline measure to reduce cadmium, chromium, copper, mercury, zinc, NPE, and vinyl chloride through operating procedures and housekeeping.

BMP #30: Materials Management and Housekeeping

- Evaluate impurities in raw materials and use higher purity materials.
- Large inventories can lead to spills, inherent safety issues and material expiration. Minimize inventory by utilizing just-in-time delivery.
- Reduce spillage and potential damage to containers by reducing the amount of materials handled. For example, use 25 pound bags instead of 50 or 100 pound bags to minimize wastage or consider using pre-weighed bags that can be thrown directly into the mixer.
- Keep chemicals well inventoried and in well marked containers.
- Switch to less toxic cleaning materials and solvents.
- Use dry cleaning methods, where possible. Clean-up spills without washing down with water.

- Perform preventive maintenance on all equipment, valves, fittings, pumps and pipes, and repair leaky valves and fittings in a timely manner.
- Receive chemicals in closed docks in sealed containers or in bulk rail or truck shipments with a minimal history of spills.
- Storage, loading, and unloading facilities, including tanks and associated appurtenances, should be designed and maintained to prevent leaks and to contain any spills of raw materials or product.

BMP #31: Mercury handling. Mercury-containing chemicals and equipment should be identified and handled appropriately:

- Store mercury-containing reagents and waste in tightly capped and shatter-resistant containers away from sinks and drains.
- Correctly handle and dispose of mercury, mercury-containing equipment, and laboratory chemicals.
- Make a list of mercury-containing devices and reagents. Eliminate all nonessential mercury sources.
- Properly label all products and devices that contain mercury.

BMP #32: Know the sources and pathways of NPE. Pollution prevention planning, with respect to NPE, should include the following:

- Identify which imported products contain NPE;
- Establish the total quantity of NPE in these products;
- Determine the most appropriate P2 methods to reduce the quantities of NPE;
- Develop an action plan to implement the P2 activities; and
- Establish monitoring and reporting activities to evaluate P2 activities.

Monitoring is required to measure reductions in NPE, determine effectiveness of P2 plans, and determine if more action is required.

BMP #33: Leak detection and repair program. Regular inspection and instrument monitoring should be carried out to detect leaks and fugitive emissions to the wastewater system. A leak detection and repair program should be developed and maintained, and repairs scheduled to minimize emissions (e.g., at normal shutdown times). Equipment modification and/or upgrades should be routinely considered with respect to preventing leaks.

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 #34: Management and Staff Training

- Ensure every employee is fully trained before beginning his or her first employment shift and whenever new equipment is installed or new procedures implemented. They should be familiar with the hazards that accompany the material they are using and be aware of potential sources of contamination. Material safety data sheets (MSDS) should be available for all compounds used at the facility.

- Ensure employees are familiar with the site layout and catch basin locations. Ensure they employ good housekeeping practices and understand proper reporting procedures. Provide training for all employees on the established practices and protocols of materials management, including storage, cleanup and handling of materials.

- Ensure all employees are aware of the spill response plan and are properly trained to carry it out.

- Train all individuals who may work with or respond to mercury spills or emergencies and ensure that only trained employees work with mercury.

- Document all employees' training and retain the records for a minimum of two years after the employee ceases employment; i.e., date and location of training, subject(s) covered, test results if applicable, trainer's name, etc.

BMP #35: Customer Education. Educate customers about the possibility of eliminating hazardous chemicals from batch specifications.

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 resin, synthetic rubber and artificial and synthetic fibres and filaments manufacturing sub-sector, it was assumed that, where applicable, substitutions would be made and that several elimination/reduction P2 measures would be implemented at each facility. The specific BMPs applicable to each facility will depend on the product manufactured and the processes utilized at the facility. It was further assumed that all applicable operating procedures and housekeeping BMPs and all education and training BMPs would be implemented.

Because metals substitution applies only to specific products (e.g., BMP #12 and 13), pollutant concentrations due to these BMPs was not calculated. Where applied, these substitutions will reduce the pollutant concentrations in wastewater. A reduction of 40% due to process modification was estimated for cadmium, chromium, copper and zinc.

The potential for mercury substitution (BMP #19) would be low for this sub-sector; therefore, the lower end of the range was selected (50%). An additional 40% reduction of the remaining 50% was estimated due to process modifications. The total reduction for mercury is, therefore, 70%.

There is a significant potential for NPE substitution in this sub-sector (BMP #26, 32); therefore, the higher end of the range was selected (75%). An additional 40% reduction of the remaining 25% was estimated due to process modifications. The total reduction for NPE is, therefore, 85%.

Given that VC is the basic building block of PVC, avoidance and elimination from the chemical process is not appropriate. Assuming a facility has been designed using BAT, the potential for additional reduction in vinyl chloride releases due to process modifications is low. A reduction of 20% was, therefore, selected for vinyl chloride.

The effectiveness of operating procedures and housekeeping is assumed to be 20% removal of the remaining contaminants after materials substitution and process modification (i.e., the mid-range of rules of thumb P2 effectiveness of this group of BMPs, Table 3.3). For cadmium, chromium, copper, and zinc, operating procedures and housekeeping would remove 20% of the remaining 60% of contaminants, for an additional 12% net reduction prior to treatment. For mercury, an additional 6% (20% of 30%) would be removed. For NPE, an additional 3% (20% of 15%) would be removed. For vinyl chloride, an additional 16% (20% of 80%) would be removed.

The removal effectiveness of education and training practices is assumed to be 2% of the remaining contaminants after materials substitution, process modifications, and operating and housekeeping practices. This effectiveness rate is at the low end of the rules of thumb range for this group of BMPs (Table 3.3) due to the fact that the staff and supply chain should be already familiar with issues associated with these substances of concern. For mercury and NPE, education and training practices would result in negligible net reductions prior to treatment (i.e., 2% of the remaining 24% and 12%, respectively). For the remaining metals (cadmium, chromium, copper, zinc) education and training practices would remove 2% of the remaining 52% for an additional 1% net reduction prior to treatment. For vinyl chloride, education and training practices would remove 2% of the remaining 64% for an additional 1% net reduction prior to treatment.

As indicated in Tables 5.1 to 5.8 (Section 5), P2 practices are assumed to result in pollutant concentration reductions, prior to treatment, of 53% of each of cadmium, chromium, copper, and zinc; 76% of mercury; 88% of NPE; and 37% of vinyl chloride. The effectiveness of selected P2 BMPs is summarized in Table 3.5.

Table 3.5 Summary of Effectiveness of Selected P2 BMPs

Substance Addressed	BMP Name	BMP Number
	Elimination/ Reduction:[12] Effectiveness 40 – 85%	
All	Improve catalysts – reduce or eliminate by-product formation	BMP #1
All	Automate control systems	BMP #2
All	Recover solvents and raw materials for reuse	BMP #3
All	Optimize reaction conditions	BMP #4
All	Modify products	BMP #5
All	Optimize equipment and process design to improve mixing and reduce spills and leaks	BMP #6
All	Optimize cleaning practices	BMP #7
All	Clean product from lines	BMP #8
All	Review sampling practices	BMP #9
All	Review laboratory practices	BMP #10

[12] For substitutions that apply only to specific products, pollutant reduction due to these BMPs was not calculated. Where applied, these substitutions will greatly reduce the concentrations of the specific pollutants in wastewater.

Table 3.5 (cont'd) Summary of Effectiveness of Selected P2 BMPs

Substance Addressed	BMP Name	BMP Number
Mercury	Review mercury use and substitute with mercury-free equipment and products, where possible	BMP #19
NPE	Substitute for NPE in emulsion polymers	BMP #26
Vinyl chloride	Closed reactor technology	BMP #27
Vinyl chloride	Optimize effluent collection system design	BMP #28
Vinyl chloride	Dedicated effluent collection systems	BMP #29
Operating Procedures and Housekeeping Effectiveness 20%		
All	Materials management and housekeeping	BMP #30
Mercury	Mercury handling	BMP #31
NPE	Know the sources and pathways of NPE	BMP #32
All	Leak detection and repair program	BMP #33
Education and Training Effectiveness 2%		
All	Management and staff training	BMP #34
All	Customer education	BMP #35

3.5.2 P2 Costs

Acquisition costs for materials substitutions (i.e., once an acceptable substitute has been identified and selected for use) are assumed to be negligible for all sizes of facility, given relatively small materials cost impacts and positive indirect benefits, such as reduced hazardous materials handling. Where a facility is highly automated, material cost may be more significant than staff costs. Note that where a product (e.g., resin) is reformulated to eliminate a particular substance (as opposed to a direct substitution), significant research and development costs may be incurred. Estimation of these costs is product-specific and are not considered to be within the scope of this general BMP.

Estimated costs associated with process modifications are based on one-quarter to five person years per modification for research, pilot testing, implementation and operator familiarization, documentation, reporting, and assessment. The following costs are estimated for implementation of each process modification for three facility sizes:

- Small Facilities (25 staff) – $110,000 annually;
- Medium Facilities (175 staff) – $120,000 annually; and
- Large Facilities (300 staff) – $140,000 annually.

Estimated costs associated with implementation of operating procedures and housekeeping BMPs are assumed to be proportional to staff complement and to cost between 0.5% 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. For the mid-range of the cost estimates, the following costs are estimated for implementation of the operating procedures and housekeeping BMPs for three facility sizes:

- Small Facilities (25 staff) – $28,000 annually;
- Medium Facilities (175 staff) – $220,000 annually; and
- Large Facilities (300 staff) – $440,000 annually.

Estimated costs associated with implementation of education and training BMPs are assumed to be proportional to staff complement and to cost between 0.25% and 2% of the staff budget. The upper end of this range would be applicable to facilities without well-established training programs or contact with supply chain representatives. For the mid-range of the cost estimates, the following costs are estimated for implementation of the education and training BMPs for three facility sizes:

- Small Facilities (25 staff) – $12,000 annually;
- Medium Facilities (175 staff) – $90,000 annually; and
- Large Facilities (300 staff) – $180,000 annually.

Estimated P2 costs, based on the options outlined above 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

Type of P2 Measure	Pollution Prevention Costs*		
	Small Facilities (25 Staff)	**Medium Facilities (175 Staff)**	**Large Facilities (300 Staff)**
Pollution Elimination or Reduction	$100,000	$120,000	$140,000
Operating/Housekeeping	$28,000	$220,000	$440,000
Education and Training	$12,000	$90,000	$180,000
Total Estimate	$140,000	$430,000	$760,000

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 resin, synthetic rubber and fibre and filament manufacturing sector. The treatment review was based on representative wastewater data available for this sector.[13] 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

[13] Refer to Section 2.1.

assessment for cadmium removal. It is important to note that some cadmium 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, such as NPE, 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. 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 Chromium

Three types of treatment processes are potentially applicable to meet the reference criteria for chromium 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:** Unlike most heavy metals that are precipitated readily as insoluble hydroxides by pH adjustment, hexavalent chromium (Cr^{+6}) must first be reduced to the trivalent state because it forms the chromate complex that behaves as an anion and cannot form an insoluble hydroxide. Conventional chromium reduction is achieved by reaction of Cr^{+6}

with a reducing agent. The most commonly used reducing agents are sulphur dioxide gas and sodium metabisulphite. 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 chromium concentrations in excess of the sewer use by-law limit. Therefore, this treatment stage was not included in the cost assessment for chromium reduction. It is important to note that some chromium 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 chromium before biological treatment to minimize chromium accumulation in biological sludge.

- **Granular activated carbon (GAC):** GAC is not a conventional treatment option for chromium as the removal efficiency is relatively low (around 50%). However, if a GAC process is used to remove organic pollutants, such as NPE, there will also be some reduction in the chromium 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 chromium. Filtration using a sand or mixed media filter 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 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. 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 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, such as NPE, 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. Filtration using a sand or mixed media filter 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.

4.1.4 Treatment Measures for Mercury

Three types of treatment processes are potentially applicable to meet the reference criteria for mercury 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:** Mercury can be precipitated as insoluble mercury sulfide by adding a sulfide salt (e.g., sodium sulfide) to the wastewater. The precipitated metal is removed from the wastewater stream by flocculation followed 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 mercury concentrations in excess of the sewer use by-law limit. Therefore, this treatment stage was not included in the cost assessment for mercury removal. It is important to note that some mercury 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 mercury before biological treatment to minimize mercury accumulation in biological sludge.

- **Granular activated carbon (GAC):** GAC is not a conventional treatment option for mercury as the removal efficiency is relatively low (around 30%). However, if a GAC process is used to remove organic pollutants, such as NPE, there will also be some reduction in the mercury 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 treatment can be used as a polishing stage to further reduce the concentration of mercury. Filtration using a sand or mixed media filter 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.

4.1.5 Treatment Measures for Zinc

Two types of treatment processes are potentially applicable to meet the reference criteria for zinc 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:** Zinc can be precipitated as insoluble zinc 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 zinc concentrations in excess of the sewer use by-law limit. Therefore, this treatment stage was not included in the cost assessment for zinc removal. It is important to note that some zinc 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 zinc accumulation in biological sludge.

- **Reverse osmosis (RO) or Deionization (DI)**: RO or DI treatment can be used as a polishing stage to further reduce the concentration of zinc. Filtration using a sand or mixed media filter 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.

4.1.6 Treatment Measures for Nonylphenol and its Ethoxylates

Three types of treatment processes are potentially applicable to meet the reference criteria for NPE 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.

- **Aerobic biological treatment:** Biological treatment involves contacting wastewater with a microbial reactor to remove biodegradable organic pollutants. The microorganisms convert the organic material into new microbial cells, which results in a sludge that requires disposal. Aerobic biological treatment involves adding air to the process to facilitate aerobic biodegradation, which is the process required for the contaminants of concern. Treatment can be either a suspended biomass system (such as activated sludge) or an attached growth system (e.g., trickling filters, rotating biological contactors). Both types of systems require a clarification process after the biroreactor. This process requires specific environmental control to operate effectively, e.g., sufficient aeration and a limited pH range. There are limited data available on the degradation of NPE in the biological treatment process; therefore, pilot testing is recommended for this process.

- **Granular activated carbon (GAC) or powdered activated carbon (PAC):** The GAC process involves pumping wastewater through a fixed-bed column containing GAC granules. The GAC adsorbs pollutants from the wastewater. A two-stage system may be required to reduce the concentration to below the concentrations required to meet the reference criteria. 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. As an alternative to GAC, PAC can be added to the bioreactor of an activated sludge biological treatment system. PAC cannot be regenerated and is disposed of as a waste with the biological treatment sludge. Biological treatment will typically be required as a preliminary treatment stage before GAC treatment when the concentration of organic compounds in the wastewater [measured as 5-day biochemical oxygen demand (BOD_5)] is greater than 100 mg/L. For wastewater streams that have a relatively low BOD_5, GAC will be the most cost-effective treatment option. There are limited data on the removal efficiency of GAC or PAC for NPE; therefore, pilot testing is recommended for these processes.

- **Advanced Oxidation (AOT)**: The AOT process uses ultraviolet (UV) light in conjunction with an oxidant such as ozone or hydrogen peroxide. This combination achieves a significantly greater treatment performance that using the oxidant alone. UV light is used to split the oxidant molecule, producing very reactive hydroxyl radicals. These hydroxyl radicals react quickly with organic pollutants in the water, breaking them down into carbon dioxide and water. The treatment process will break down any organic contaminant; therefore, to treat the organic contaminants of concern, the removal of other organics will typically be required before this process is used.

4.1.7 Treatment Measures for Vinyl Chloride

Three types of treatment processes are potentially applicable to meet the reference criteria for VC 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.

- **Air stripping**: VC is a very volatile compound and can be easily volatilized in an air stripper. VC would also be air stripped from an aerobic biological treatment system, if used to treat other organic compounds. After volatilization the VC in the air can be sent through an air phase GAC adsorption unit to capture the VC. Air stripping and air phase GAC treatment are typically only cost-effective for relatively low VC concentrations (e.g., less than 3 mg/L) due to the large amount of GAC required. See below for more details on GAC.
- **Granular activated carbon (GAC) or powdered activated carbon (PAC):** The GAC process involves conveying wastewater or air containing VC vapour through a fixed-bed column containing GAC granules. The GAC adsorbs VC. A two-stage system may be required to reduce the concentration to below the concentrations required to meet the reference criteria. The spent can GAC is regenerated off-site or on-site in order to recover the adsorbed VC and reuse it in the industrial process. 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 wastewater pre-treatment stage for a GAC filter. As an alternative to GAC for wastewater, PAC can be added to a holding tank. PAC cannot be regenerated and is disposed of as a solid waste. There are limited data on the removal efficiency of GAC or PAC for vinyl chloride; therefore, pilot testing is recommended for these processes.
- **Advanced Oxidation (AOT):** AOT can be used to further reduce the concentration of VC. Due to the high cost of this process, AOT would typically only be used for wastewater streams with a relatively high VC concentration. As AOT will degrade any organic contaminant, it is recommended that the wastewater stream containing VC be isolated from other wastewater streams at a facility for AOT treatment, and the remaining organic treatment be provided by biological treatment and/or GAC treatment The AOT process uses ultraviolet (UV) light in conjunction with an oxidant such as ozone or hydrogen peroxide. This combination achieves a significantly greater treatment performance that using the oxidant alone. UV light is used to split the oxidant molecule, producing very reactive hydroxyl radicals. These hydroxyl radicals react quickly with organic pollutants in the water, breaking them down into carbon dioxide and water.

4.2 Treatment Options and Costs

Treatability information is provided for the individual pollutants specified in Tables 5.1 to 5.8 as a guide (Section 5).

The database used to develop reference concentrations for VC was limited to a few sub-sector industries which may not be typical of the range of industries covered in this BMP document. There are industries that do not have issues with VC. Consequently, the approach taken was to consider pre-treatment through AOT to lower high VC concentrations, preferentially in a segregated wastewater stream, prior to subsequent treatment steps. Consideration has also been made to determine treatment processes assuming low initial VC concentrations.

Based on the estimated wastewater concentrations of each pollutant identified after P2 measures provided in the tables, an assumption that all pollutants identified will be reduced, and an assumption that the BOD_5 is greater than 100 mg/L[14], the overall full treatment systems in terms of sequential process steps for each target reference criteria, including treatment for high concentrations of VC, are as follows:

- Reference Criteria 1 and 2: Air Stripping, Biological Treatment, Sand/Mixed Media Filtration, GAC, Microfiltration, and DI for the main wastewater stream. AOT for the high strength VC stream.
- Reference Criteria 3: Air Stripping, Biological Treatment, Sand/Mixed Media Filtration, Microfiltration, and DI for the main wastewater stream. AOT for the high strength VC stream.

In terms of treatment for metals and based on the estimated metal concentrations after P2 measures, chemical precipitation is not required for any of the metals. Chromium concentrations after P2 measure are sufficiently low to not require any treatment. Cadmium, copper, and zinc would require additional treatment to meet Reference Criteria 1. Mercury would require additional treatment to meet all the reference criteria.

Treatment would require the wastewater stream containing the high concentration of VC to be segregated from the total wastewater flow, and the VC wastewater treated with AOT. The remaining wastewater would be treated with the other treatment processes. It has been assumed that the remaining wastewater would contain a low VC concentration (i.e., less than 3 mg/L) which would be air stripped. Biological treatment and GAC will reduce the concentration of NPE. Removal of metals from wastewater will be provided by DI, with some removal by the GAC process (with the exception of zinc).

The proposed treatment strategies identified above serve as preliminary guidelines for the full level of treatment likely to be required. Different treatment options may be required, depending on the wastewater constituents and strength. For example, for a facility without a high strength VC wastewater stream (i.e., VC concentration of less than 3 mg/L), AOT would not be required. If VC and NPE were substantially reduced through more aggressive P2 measures, GAC and DI would be required. For

[14] Assuming low VC concentrations and should BOD5 concentrations after P2 measures be lower than 100mg/L, then biological treatment may not be required for VC and NPE reduction and removal and granular activated carbon (GAC) may be sufficient. Air stripping will remove the bulk of VC.

facilities that eliminate metals from the wastewater stream and have a low VC concentration, treatment would involve air stripping, biological treatment and GAC. For some facilities, RO may be a better option than DI for metals removal.

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 chemical manufacturing sector 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 full treatment for the three reference criteria using a wastewater flow range of 1 m^3/h to 50 m^3/h. The estimated costs are presented in Table 4.1. Costs are also presented in Table 4.1 for facilities with a low VC concentration (AOT not required), facilities with low VC, NPE and BOD_5 (GAC and DI treatment only) and for facilities that have substantially reduced or eliminated metals from the wastewater stream and have a low VC concentration (air stripping, biological and GAC treatment required).

The treatment option assuming low VC concentrations eliminates the AOT pre-treatment process. The treatment option assuming low VC, NPE and BOD_5 eliminates the AOT and biological components and uses GAC directly for the treatment and reduction of these substances. The treatment option assuming low VC and low metals eliminates the AOT and DI treatment components but retains the biological treatment for NPE. This last option assumes the aggressive reduction of metals through P2 practices whereby DI may not be required.

The costs provided in table 4.1 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	Approximate Costs as Function of Flow Range of 1 to 50 m^3/h*					
	Capital Cost Range			Annual O&M Cost Range		
	1m^3/h	25 m^3/h	50 m^3/h	1m^3/h	25 m^3/h	50 m^3/h
Full Treatment Assuming High VC						
Criteria 1 and 2	$947,000	$4,309,000	$7,693,000	$142,000	$517,000	$769,000
Criteria 3	$932,000	$4,087,000	$7,294,000	$140,000	$490,000	$729,000
Treatment Assuming Low VC (<3 mg/L)						
Criteria 1 and 2	$584,000	$1,860,000	$3,051,000	$88,000	$223,000	$305,000
Criteria 3	$569,000	$1,638,000	$2,652,000	$85,000	$197,000	$265,000
Treatment Assuming Low VC, NPE and BOD_5						
Criteria 1 and 2	$258,000	$1,173,000	$2,101,000	$39,000	$141,000	$210,000
Criteria 3	$243,000	$951,000	$1,702,000	$36,000	$114,000	$170,000
Treatment Assuming Low VC and Low Metals (i.e., No DI)						
Criteria 1 and 2	$396,000	$1,126,000	$1,698,000	$59,000	$135,000	$170,000
Criteria 3	$367,000	$795,000	$1,135,000	$55,000	$95,000	$114,000

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 4.3 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.

Figure 4.1 Resin, Synthetic Rubber and Fibre and Filament Manufacturing Reference Criteria 1

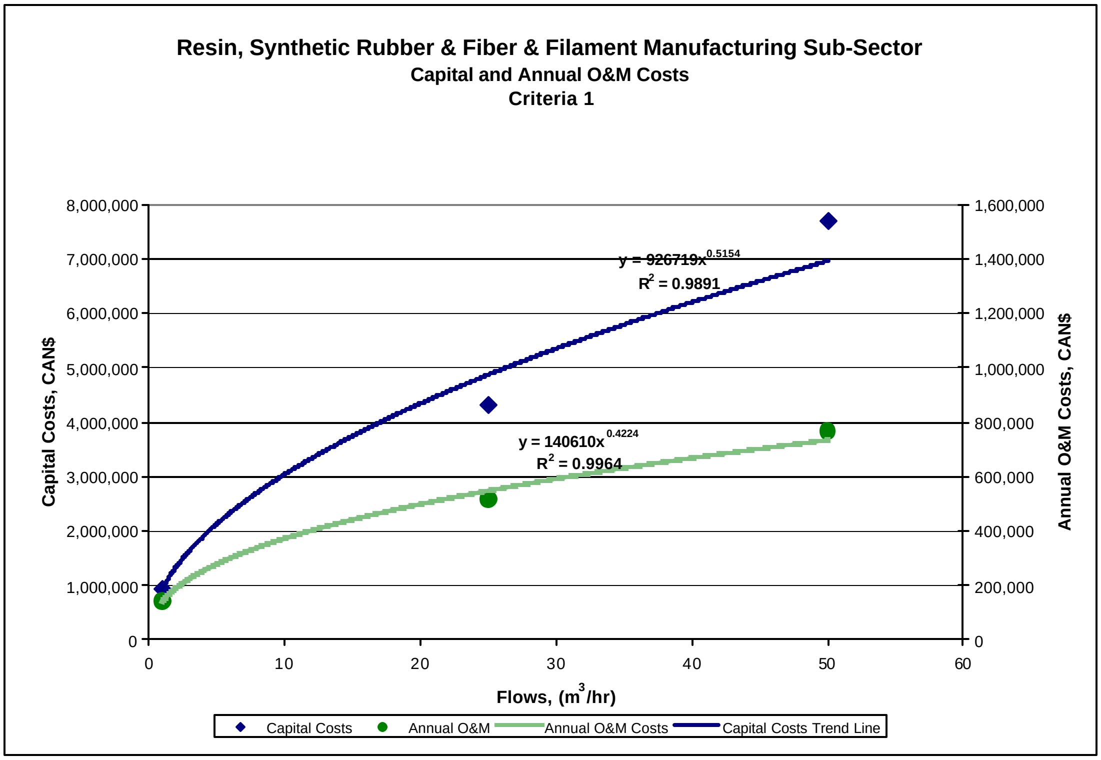


Figure 4.2 Resin, Synthetic Rubber and Fibre and Filament Manufacturing Reference Criteria 2

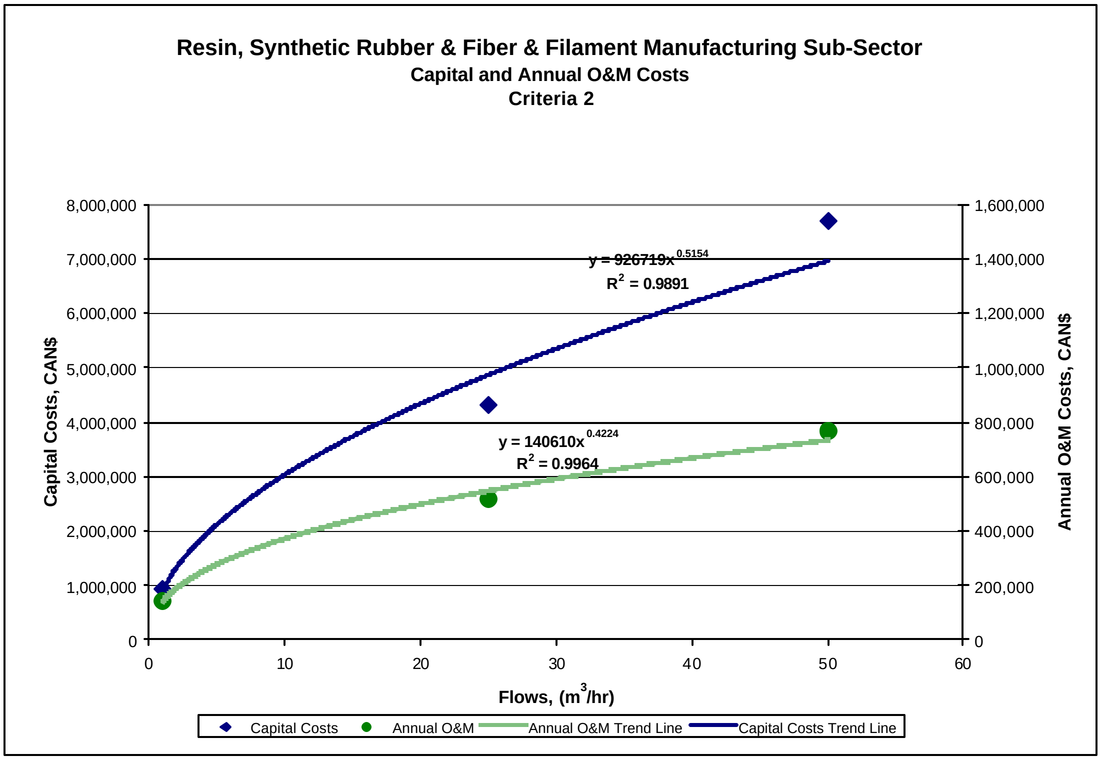
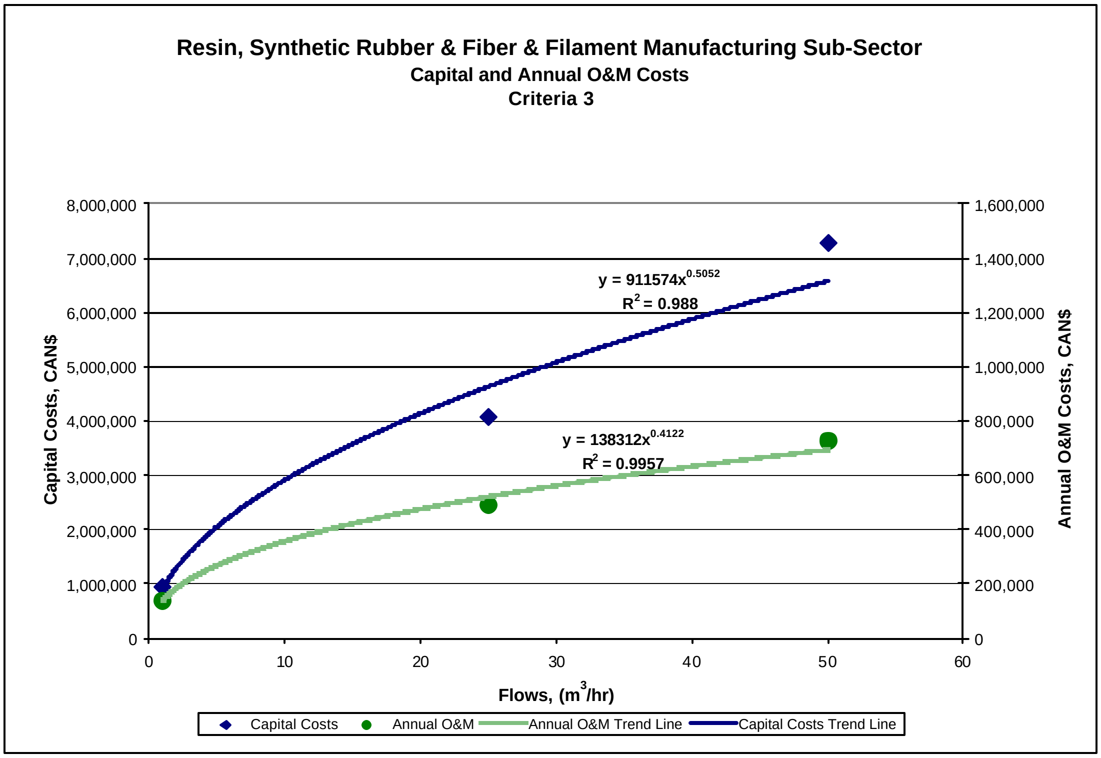


Figure 4.3 Resin, Synthetic Rubber and Fibre and Filament Manufacturing Reference Criteria 3



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: Chromium.
- Reference Criteria 2: Cadmium, chromium, copper, zinc.
- Reference Criteria 3: Cadmium, chromium, copper, zinc.

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 for P2 implementation.

Table 5.1 Summary: Cadmium

Table 5.2 Summary: Chromium

Table 5.3 Summary: Copper

Table 5.4 Summary: Mercury

Table 5.5 Summary: Zinc

Table 5.6 Summary: Nonylphenol

Table 5.7 Summary: Nonylphenol Ethoxylates

Table 5.8 Summary: Vinyl Chloride

6. REFERENCES

1. Alkylphenols and Ethoxylates (APE) Research Council, *Top Ten Treatment Tips for NPE*, 2005. Available at URL: http://www.aperc.org/toptentreatment.pdf

2. Environment Canada, *Notice requiring the preparation and implementation of pollution prevention plans in respect of nonylphenol and its ethoxylates contained in products*, December 4, 2004. Available at URL: http://www.ec.gc.ca/Ceparegistry/documents/notices/g1-13849_n4.pdf

3. Environment Canada, *Notice requiring the preparation and implementation of pollution prevention plans in respect of nonylphenol and its ethoxylates contained in products: Sample P2 Plan*, October 2004. Available at URL: http://www.c2p2online.com/documents/NPE_SampleP2Plan_Importer_English.doc

4. European Commission, *Reference Document on Best Available Techniques in the Large Volume Organic Chemical Industry*, February 2003. Available at URL: http://www.epa.ie/Licensing/IPPCLicensing/BREFDocuments/FileUpload,478,en.pdf

5. Georgia Pollution Prevention Assistance Division, *Chemical and Allied Products Sector Analysis: An Analysis of Pollution Prevention Opportunities and Impediments in the Chemical and Allied Products Sector in Georgia*. Available at URL: http://www.ganet.org/dnr/p2ad/pblcations/chemical/toc_ch.htm

6. Illinois Waste Management and Research Center, Pollution Prevention for Chemical Processes: A Handbook with Solved Problems from the Refining and Chemical Processing Industries, August 1994. Available at URL: http://www.wmrc.uiuc.edu/main_sections/ info_services/library_docs/tr/tr22.pdf

7. Joint effort by Inland Ispat Indiana Harbor Works, Bethlehem Steel Burns Harbor Division, United States Steel Gary Works, and the Delta Institute Lake Michigan Forum, *A Guide to Mercury Reduction in Industrial and Commercial Settings*, July 2001. Available at URL: http://delta-institute.org/publications/Steel-Hg-Report-0627011.pdf

8. Michigan Department of Environmental Quality, *Best Management Practices for Mercury*, 2001-2005. Available at URL: http://www.michigan.gov/deq/1,1607,7-135-3585_4127_4175-11753--,00.html

9. North Carolina Division of Pollution Prevention and Environmental Assistance, *Waste Reduction and Proper Waste Management of Products Containing Mercury*, June 1996. Available at URL: http://www.p2pays.org/ref/01/00127.htm

10. Ohio Environmental Protection Agency, *Pollution Prevention Opportunities for PBT Chemicals-Zinc and Zinc Compounds*, September 2002. Available at URL: http://www.epa.state.oh.us/ocapp/p2/mercury_pbt/fact98.pdf

11. Oslo and Paris (OSPAR) Commission, *Hazardous Substances Series: Cadmium*, 2004. Available at URL: http://www.ospar.org/documents/dbase/publications/p00151_Background%20document%20on%20Cadmium.pdf

12. Oslo and Paris (OSPAR) Commission, *Hazardous Substances Series: Nonylphenol/Nonylphenolethoxylates*, 2001 (2004 Update). Available at URL: http://www.ospar.org/documents/dbase/publications/p00136_BD%20on%20nonylphenol.pdf

13. Oslo and Paris (OSPAR) Commissions 1996, *Best Available Techniques for the Vinyl Chloride Industry*, 1996. Available at URL: http://www.ospar.org/documents/dbase/publications/p00053_PVC-E.pdf

14. Palo Alto Regional Water Quality Control Plant, *Mercury Pollution Prevention Plan*, October 1997. Available at URL: www.city.palo-alto.ca.us/cleanbay/pdf/mercp2.pdf

15. United States Environmental Protection Agency, *Profile of the Plastic Resin and Manmade Fiber Industries*, September 1997. Available at URL: http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/resfibsn.pdf

16. United States Environmental Protection Agency, *Profile of the Rubber and Plastics Industry, 2nd Edition*, February 2005. Available at URL: http://www.epa.gov/compliance/resources/publications/assistance/sectors/notebooks/rubplasn.pdf

17. United States Environmental Protection Agency, Technical Fact Sheet for Cadmium, August 2000. Available at URL: http://www.epa.gov/reg5rcra/wptdiv/wastemin/cd.pdf

18. University of California, Berkeley, Office of Environment, Health and Safety, *Hazards, Precautions, and Pollution Prevention – Mercury, Fact Sheet*, March 3, 2003. Available at URL: http://www.ehs.berkeley.edu/pubs/factsheets/19mercury.html

19. Wisconsin Department of Natural Resources, *Draft Wisconsin Mercury Sourcebook: Chemical Manufacturers/Users*, May 1997. Available at URL: http://www.epa.gov/glnpo/bnsdocs/hgsbook/chemical.pdf

20. Wisconsin Department of Natural Resources, *Draft Wisconsin Mercury Sourcebook: Laboratories*, May 1997. Available at URL: http://www.epa.gov/glnpo/bnsdocs/hgsbook/labs.pdf

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.[15] 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 concentrations 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)[16] 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 -

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

[16] 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.[17] 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."[18]

Reference Criteria are the maximum desired final effluent concentrations for the harmful substances identified. Three reference criteria 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

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

[18] 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) Fibre, Yarn, Thread Mills Fabric Mills Textile and Fabric Finishing and Fabric coating	Nonylphenol and its ethoxylates Chromium
Best Management Practices. Fabricated Metal Product Manufacturing: Cadmium, Lead and Copper	Fabricated Metal Product Manufacturing (332) Forging and Stamping Architectural and Structural Metals Manufacturing Boiler, Tank and Shipping Container Manufacturing Spring and Wire Product Manufacturing Coating, Engraving, Heat Treating and Allied Activities Other Fabricated Metal Product Manufacturing	Cadmium Lead Copper
Best Management Practices. Motor Vehicle Parts Manufacturing: Cadmium and Nonylphenol and its Ethoxylates	Motor Vehicle Parts Manufacturing (3363) Motor Vehicle Gasoline Engine and Engine Parts Manufacturing Motor Vehicle Electrical and Electronic Equipment Manufacturing Motor Vehicle Metal Stamping Motor Vehicle Steering and Suspension Components (except Spring)Manufacturing Motor Vehicle Brake System Manufacturing Motor Vehicle Transmission and Power Train Parts Manufacturing	Cadmium 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) Automotive Repair and Maintenance Automotive Body, Paint and Interior Repair and Maintenance Car Washes	Cadmium PAHs
Best Management Practices. Dry Cleaning and Laundry Services: Nonylphenol and its Ethoxylates, Cadmium, and Mercury	Dry Cleaning and Laundry Services (8123) Dry Cleaning and Laundry Services (except Coin-Operated) Linen and Uniform Supply	Nonylphenol and its ethoxylates Cadmium Mercury
Best Management Practices. Chemical Manufacturing Sector: Cadmium, Chromium, Copper, Mercury, Zinc, Nonylphenol and its Ethoxylates, and Vinyl Chloride	Chemical Manufacturing Sector (325) Basic Chemical Manufacturing (NAICS 3251); Pharmaceutical and Medicine Manufacturing (NAICS 3254); Soap, Cleaning Compound and Toilet Preparation Manufacturing (NAICS 3256) Other Chemical Product Manufacturing (NAICS 3257)	Cadmium Chromium Copper Mercury Zinc Nonylphenol and its ethoxylates 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) Resin, Synthetic Rubber, and Artificial and Synthetic Fibres and Filaments Manufacturing (NAICS 3252)	Cadmium Chromium Copper Mercury Zinc Nonylphenol and its ethoxylates 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) Pesticide, Fertilizer, and Other Agricultural Chemical Manufacturing (NAICS 3253)	Cadmium Chromium Copper Mercury Zinc 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) Paint, Coating, and Adhesive Manufacturing (NAICS 3255)	Cadmium Chromium Copper Mercury Zinc 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 3,3-Dichlorobenzidine Hexachlorobenzene 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 resin, synthetic rubber and artificial and synthetic fibres and filaments manufacturing sub-sector are provided below: [19]

Resin, Synthetic Rubber, and Artificial and Synthetic Fibres and Filaments Manufacturing: This industry group comprises establishments primarily engaged in manufacturing polymers such as resins, synthetic rubber, and textile fibres and filaments. Polymerization of monomers into polymers, for example, of styrene into polystyrene, is the basic process.

32521 Resin and Synthetic Rubber Manufacturing: This industry comprises establishments primarily engaged in manufacturing synthetic resins, plastics materials and synthetic rubber from basic organic chemicals. Excluded establishments from this NAICS group include those primarily engaged in:

- Manufacturing rubber processing chemicals and plasticizers, whether separate chemical elements or compounds (32519, Other Basic Organic Chemical Manufacturing).
- Manufacturing plastics adhesives (32552, Adhesive Manufacturing).
- Manufacturing rubber processing chemicals and plasticizers except from separate chemical elements or compounds; custom compounding of resins produced elsewhere (32599, All Other Chemical Product Manufacturing).
- Processing rubber into intermediate or final products (3262, Rubber Product Manufacturing).

32522 Artificial and Synthetic Fibres and Filaments Manufacturing [CAN]: This industry comprises establishments primarily engaged in manufacturing artificial and synthetic fibres and filaments in the form of monofilament, filament yarn, staple or tow. Artificial fibres are made from organic polymers derived from natural raw materials, mainly cellulose. Synthetic fibres are generally derived from petrochemicals. Establishments that both manufacture and texture fibres are included. Excluded establishments from this NAICS group include those primarily engaged in:

- Texturizing artificial and synthetic fibres and filaments produced elsewhere (31311, Fibre, Yarn and Thread Mills).
- Manufacturing glass fibres (32721, Glass and Glass Product Manufacturing).

[19] http://stds.statcan.ca/english/naics/2002/naics02-class-search.asp?criteria=3252 (accessed January 25, 2006)

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