BACKGROUND DOCUMENT ON THE REDUCTION OF POTENTIALLY TOXIC DISCHARGES FROM THE CANADIAN METAL FINISHING INDUSTRY

Prepared for:

ENVIRONMENT CANADA

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INTRODUCTION

BACKGROUND

The Canadian Environmental Protection Act (CEPA; promulgated in 1988) provides a mandate for the assessment of the toxicity of substances placed on the *Priority Substances List*. Substances deemed toxic will then be placed on the *Toxic Substances List*, which already includes arsenic, lead and mercury among others. CEPA also authorizes the collection of information on uses and releases to the environment of PSL and TSL substances.

Additionally, the federal government's Green Plan (released in 1991) states that reports summarizing strategic options for the control of toxic discharges in various industrial sectors will be released by 1994. These strategic options reports will then be used as supporting documentation to justify promulgation of regulations or implementation of other controls on toxic discharges in each industrial sector.

In May of 1992, Environment Canada initiated a study for the *Development of a Background Document on the Reduction of Potentially Toxic Discharges from the Canadian Metal Finishing Industry*. This report is the result of this study and will be used by Environment Canada as supporting documentation in the development of a strategic options report for the metal finishing sector.

STUDY SCOPE AND OBJECTIVES

The scope of this study specifically encompasses the following metal finishing operations:

- Electroplating
- Electroless plating (including immersion plating)
- Anodizing
- Hot dip coating (including galvanizing)
- Printed circuit board (PCB) manufacturing
- Chemical conversion coating (including chromating, passivating and phosphating)
- Chemical milling and etching, and bright dipping.

Solvent degreasing and painting operations were specifically excluded from the Terms of Reference, since these operations are being addressed under other initiatives.

A direct survey of the industry was not conducted as part of this study. Information available through other government agencies at the provincial and municipal levels, as well as through contact with industry, was used to develop the summary profile of the industry presented in this report.

Specifically, the study objectives were:

- To describe the economic and physical dimensions of the metal finishing industry in Canada by updating the information contained in a previous Environment Canada report entitled *Overview of the Canadian Surface Finishing Industry* (EPS 2/SF/1, released in 1987).
- To identify the sources of priority substance releases to all media in the metal finishing industry. Waste streams to be considered included process wastewaters, spent process solutions, sludges and air emissions.
- To quantify priority substance releases in the metal finishing sector. In addition, the total quantity was to be broken down by substance and media of release.
- To describe available technologies and practices for environmental control in the metal finishing industry, as well as the extent to which they are currently used.
- To review national and international regulations, guidelines and other requirements for the metal finishing industry, including discharge compliance requirements, reporting requirements and enforcement strategies.

DOCUMENT OVERVIEW

The organization of this document closely mirrors the study objectives listed above. Section 2, Scope of the Metal Finishing Industry in Canada, presents information regarding current trends in the sector resulting from market, environmental and other forces. In addition, available data describing the scale of the industry are also presented.

Section 3, Sources and Releases of Priority Substances in the Metal Finishing Sector, documents the estimation methodologies used to quantify releases of priority substances from various process sources, and presents summaries of results along with discussion.

Environmental control technologies are described in Section 4. Information regarding application, performance, cost and current use in Canada is provided for technologies used in waste, wastewater and air emission control.

Section 5, Regulations Affecting the Metal Finishing Sector, summarizes national and international regulations. Where available, information regarding compliance, reporting requirements and enforcement strategies has been included.

Section 6 presents a summary of study findings. This is a background document that will provide information to Environment Canada to enable the development of a strategic options report for the metal finishing sector and, as such, contains no recommendations.

Section 7 is a bibliography of published materials referred to throughout the text, and the appendixes contain supplementary information as appropriate.

Section 2
SCOPE OF THE METAL FINISHING INDUSTRY IN CANADA

INTRODUCTION

OBJECTIVES

This section presents the results of a review of the scope of the metal finishing industry in Canada. The objectives of this review were:

1. To develop a description of the metal finishing sector in Canada with regard to current economic status.
2. To identify both general industry trends and trends in selected, key individual markets such as automotive parts and electronics.
3. To provide an economic context for the consideration of environmental issues in the metal finishing sector which will be addressed in subsequent sections of this report.

These objectives were also part of Environment Canada's previous review of the metal finishing industry (Environment Canada, 1987). The results presented here provide an update to that information.

METHODOLOGY

The information in this section has been developed based on the following:

- Input from representatives of several metal finishing companies and suppliers, including those listed in Appendix A.
- Information made available by the Canadian Metal Finishing Suppliers Association (CMFSA) and members of the executive of the Canadian Association of Metal Finishers (CAMF).

This information is compared with data from previous Environment Canada studies (Environment Canada, 1975 and 1987) and with data from studies conducted recently in Ontario (MOE, 1989) and in Alberta (Alberta Environment, 1992), where appropriate. The information is used to assist in the appreciation of industry trends and is organized under the following headings:

- Current Status of the Industry
- General Industry Trends
- Trends in Individual Sectors
- Summary

CURRENT STATUS OF THE INDUSTRY

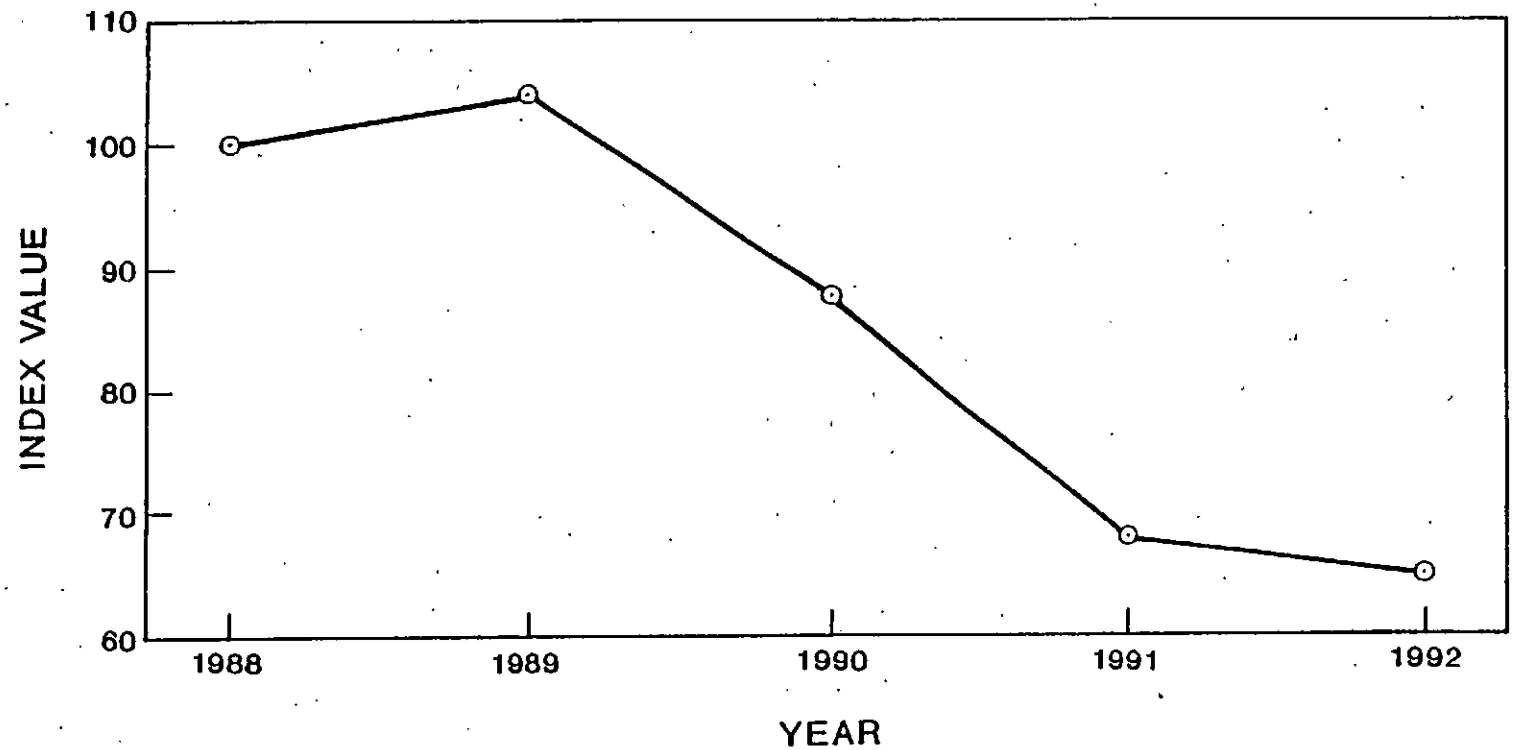
Along with other industries, the Canadian metal finishing industry has been severely hurt during the current recession. As an indicator of this decline, data on sales to the metal finishing industry by suppliers were sought. The Canadian Metal Finishers Suppliers Association is composed of the major suppliers of chemicals and equipment to the metal finishing industry. Members of the association report their sales figures to a central body on a confidential basis and then these figures are used to calculate an index. The index reflects the degree of activity in the metal finishing industry. As depicted in Figure 2-1, sales for the first quarter of 1992 are only 52.4 percent of the index high point value of 124 reached in the first quarter of 1989. These data are believed to be indicative of current production levels in the industry.

The decorative nickel-chrome sector of the industry has been particularly hard hit with the average loss of one company per month over the past 2 years according to the CAMF. Functional finishes, such as zinc and hard chrome, have fared better than decorative coatings during this time period.

A number of metal finishing shops have gone out of business during the recession and numerous other companies are reporting financial difficulties. There are a number of contributing factors to this situation including the recession, the movement of business to the U.S.A. and Mexico, more strict environmental regulations such as the Municipal Industrial Strategy for Abatement (MISA) Model Sewer Use Bylaw which has been adopted by many major municipalities in Ontario, and more extensive enforcement of the regulations. This latter factor is especially true at the municipal level where indirect dischargers are being more closely monitored in the interest of protection of municipal water pollution control plants. According to the CAMF, these effects have hit the Ontario and Quebec sectors of the industry hardest since:

- The recession has affected Ontario and Quebec more severely than other regions of the country.
- The Ontario and Quebec sector of the industry is in more direct competition with facilities in the U.S.A. and Mexico.
- Municipalities in Ontario and Quebec have focused indirect discharge abatement efforts on a few industrial sectors perceived to be significant, including metal finishing.

Table 2.1 presents estimates of the total number of metal finishing plants in Canada as compared to data from previous studies (Environment Canada, 1975 and 1987). The 1992 estimate was developed based on contact with industry associations as well as individual industry representatives. For this reason, it is possible that job shops are more completely accounted for than captive shops and that a small number of smaller facilities may have been missed. The complete listing of 541 companies identified



Note: 1992 data are first quarter results only.

FIGURE 2-1:
CMFSA SALES INDEX

Table 2.1
Distribution of Canadian Metal Finishing Plants Identified

Year	Nova Scotia	New Brunswick	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	British Columbia	Canada
1973 (Env. Can. 1975)	3	1	62	217	11	2	15	30	341
1983/84 (Env. Can. 1987)	11	7	130	266	32	1	8	59	514[1]
1992	7	5	82[2]	326	12	5	45	59	541[3]

Note:
1. Total size of the industry estimated at 644 plants. Data presented represent only survey respondents.
2. According to the Montreal Urban Community a more reasonable estimate for Quebec may be 100 to 120 facilities.
3. Based on the uncertainties in developing estimates a reasonable total for Canada may be 600 facilities.

appears in Appendix B. A complete list of 109 surface finishing facilities discharging to the municipal sewer system was made available by the Montreal Urban Community (MUC). This list indicates that as many as 85 additional surface finishing facilities exist in Montreal. However, this list may include facilities performing work other than the metal finishing processes of interest to this study. A more accurate total figure for Quebec may be in the range of 100 to 120 facilities.

The general perception in the industry is that the total number of plants is decreasing. This is supported by the data in Table 2.1, which indicate a total number of plants in 1983/84 of 644 (of which 514 responded to the survey) and in 1992 of 541. The number of facilities most likely peaked during the late 1980s, so the decline in the number of facilities has probably been most dramatic within the last three to four years. It should also be noted that given the fact that some smaller and/or captive facilities may have been missed in this study, a reasonable estimate of the total number of facilities in Canada would be 600 in 1992.

Figure 2-2 presents data in a pie graph format for three years: 1973, 1983, and 1992. Distribution trends show a slight shift of companies from Quebec and Ontario to Alberta and British Columbia. Ontario has retained the major share of all metal finishing operations, at approximately 60 percent, and probably a much larger share of total production, estimated at approximately 70 percent by the CAMF.

There appears to have been a significant decrease in the ratio of captive shops to jobs shops. In 1983/84, the apparent ratio was three captive shops to every two jobs shops. In 1992, the apparent ratio is estimated to be one captive shop to every three job shops based on a sample of approximately 100 Ontario facilities. This trend is consistent with the current restructuring of the industry and the increasing practice of contracting work out. It should be noted, however, that complete data on the ratio of captive shops to job shops were not available to this study since a survey was not conducted. It is likely that the trend toward job shops is most pronounced in the automotive sector, and therefore is most prevalent in Ontario and Quebec. In addition, as noted earlier, job shops may be more completely accounted for in this study than are captive shops. The combined result of these factors is that the ratio reported here may be biased toward job shops.

Production processes in use in the metal finishing sector were reviewed in a previous study (Environment Canada, 1987) and according to CAMF representatives have changed little since that time. Of the 541 companies identified in this study, information regarding finishing processes used was readily available from industry representatives for 72 percent, or 390, of the facilities. This information is summarized in Table 2.2, Table 2.3, and Table 2.4 for electrolytic, non-electrolytic and chemical treatment processes, respectively. Figures in these tables are not additive to the total number of plants since each facility most often uses more than one of the listed processes.

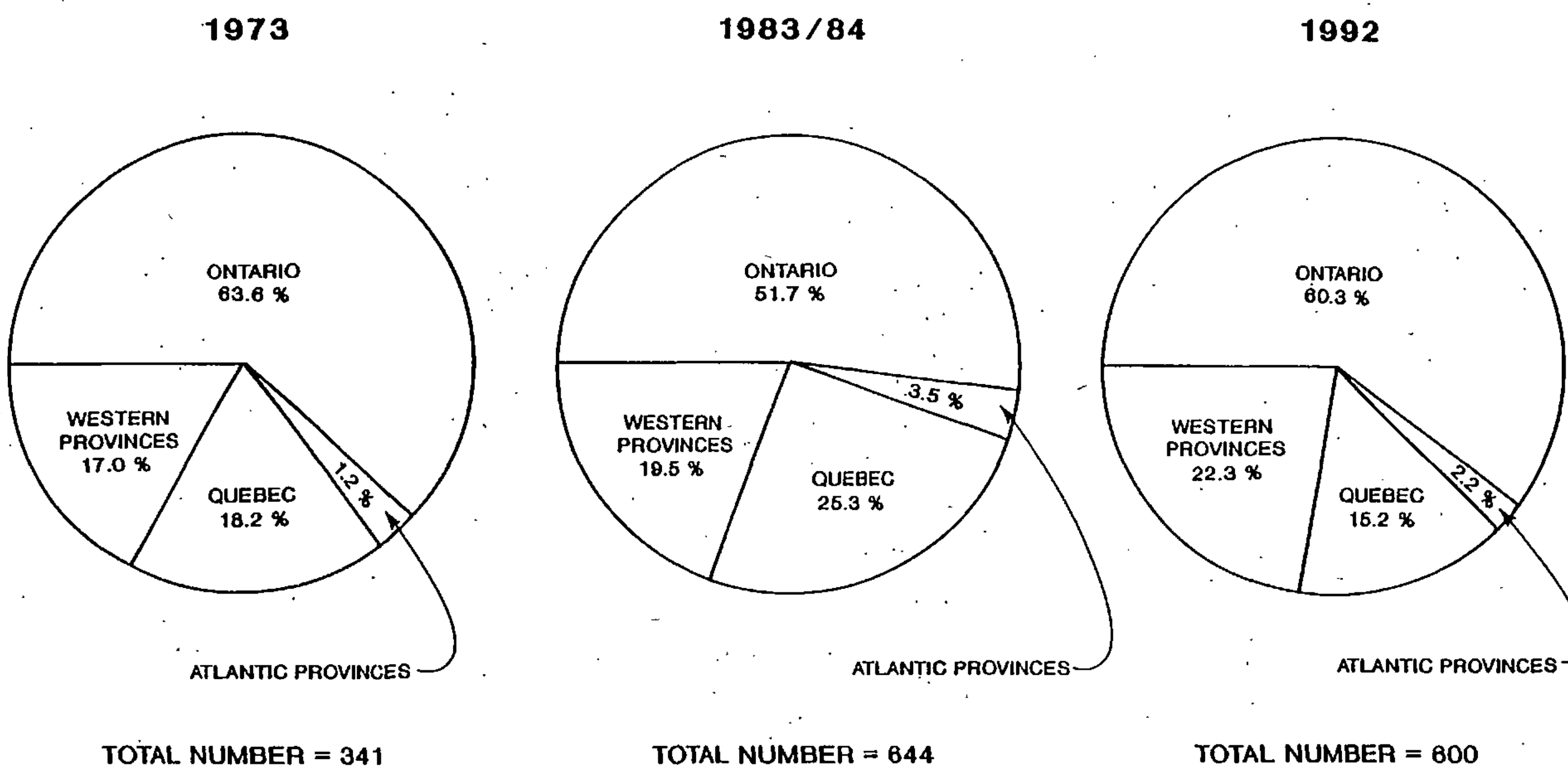


FIGURE 2–2:

DISTRIBUTION OF METAL FINISHING PLANTS IN CANADA

Table 2.2
Number of Companies Having Electrolytic Processes

Process	Nova Scotia	New Brunswick	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	British Columbia	Canada	
									Number	% of Companies
Brass	1	0	6	21	2	0	5	6	41	11
Cadmium	0	0	6	15	1	0	3	2	27	7
Chromium	1	0	19	56	8	2	10	14	110	28
Hard Chrome	2	1	12	36	0	1	16	11	79	20
Total Chrome	3	1	31	92	8	3	26	25	189	48
Copper	1	0	23	83	5	1	8	12	133	34
Gold	0	0	20	37	0	0	3	9	69	18
Lead	0	0	0	2	0	0	0	0	2	<1
Nickel	1	0	34	101	8	2	10	21	177	45
Rhodium	0	0	3	4	0	0	0	0	7	2
Silver	0	0	16	22	3	0	1	3	45	12
Tin	0	0	6	15	1	0	1	1	24	6
Tin-Lead	0	0	5	27	0	0	0	4	36	9
Zinc	0	0	14	57	0	0	3	4	78	20
Anodizing	0	1	6	20	1	0	7	3	38	10

Note: 1. This information was available from industry representatives for 72%, or 390, of the 541 companies identified in this study.

Table 2.3
Number of Companies Having Non-electrolytic Processes

Process	Nova Scotia	New Brunswick	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	British Columbia	Canada	
									Number	% of Companies
Copper	0	0	5	27	0	0	0	4	36	9
Nickel	0	0	5	18	0	0	2	2	27	7
Galvanizing	2	0	9	6	2	1	4	3	27	7

Note: 1. This information was available from industry representatives for 72%, or 390, of the 541 companies identified in this study.

Table 2.4
Number of Companies Having Chemical Treatment Processes

Process	Nova Scotia	New Brunswick	Quebec	Ontario	Manitoba	Saskatchewan	Alberta	British Columbia	Canada	
									Number	% of Companies
Alkaline Cleaning	3	1	65	188	12	3	23	34	329	84
Pickling	3	0	59	169	12	3	16	34	296	76
Chromating	0	0	16	61	1	0	3	5	86	22

Note: 1. This information was available from industry representatives for 72%, or 390, of the 541 companies identified in this study.

Other studies have also examined the breakdown of production processes in use in the metal finishing sector. However, none have attempted to define a primary activity (e.g. zinc plating, chromating, anodizing, etc.) for each facility. For analysis in subsequent sections, it was desirable to develop some form of demographic information regarding the likelihood of release of priority substances from various types of processes. This was achieved by examining available data on processes in use generated in this study, the previous Environment Canada study (1987), as well as recent studies in Ontario (MOE, 1991), and Alberta Environment (1992).

For the purposes of this study, the breakdown required involves identifying those facilities generating raw, untreated wastewater containing hexavalent chromium, complexed metals, or both. This breakdown also recognizes that all facilities also generate a so-called "common metals" raw waste stream. The breakdown developed is presented in Table 2.5.

The estimates presented in Table 2.5 rely on the following generalizations:

- The total percentage of electroless plating facilities ranges from 5 to 19 percent in the various studies. This breakdown assumes that 15 percent is a representative figure, that all PCB manufacturing is included in that total and that approximately one-third of that group may have hexavalent chromium-bearing wastewater based on data available from the U.S. (USEPA, 1983).

- The majority of the remaining processes such as electroplating, anodizing, chemical milling and etching, and chemical conversion coating, will be divided between those generating hexavalent chromium-bearing wastewater and those not. Chromium electroplating ranges from 25 to 55 percent of all facilities and anodizing from 8 to 15 percent. Reliable figures regarding chemical milling and etching and chemical conversion coating were not available from all studies. The percentage of facilities generating hexavalent chromium wastewater has been estimated at 45 percent based on this information.

- The remainder of facilities (40 percent) would generate only common metals wastewater.

GENERAL INDUSTRY TRENDS

PRODUCTION RATES AND CAPACITIES

As noted previously, sales by suppliers indicate that production in the metal finishing sector is approximately half of its late 1980's peak. This decline has been less severe in western provinces where the metal finishing industry is less dependent on the automo-

Table 2.5
Raw Wastewater Demographic Characterization of the Canadian Metal Finishing Sector

Wastewater Generation	Facilities Included	Approximate Percentage of Facilities[1]	Approximate Number of Facilities[2]
Common metals	• Non-chrome electroplating • Hot dip coating • Non-chrome anodizing • All other non-chrome activities	40%	240
Common metals, hexavalent chromium	• Chrome electroplating • Chromating • Chromic acid etching and anodizing	45%	270
Common metals, complexed metals	• Non-chrome electroless plating and PCB manufacturing	10%	60
Common metals, hexavalent chromium, complexed metals	• Chrome electroless plating and PCB manufacturing	5%	30

Notes: [1]Based on available data from various studies: Environment Canada (1987), MOE (1991), Alberta Environment (1992) and this study.
[2]Based on an estimate of 600 facilities in Canada in 1992.

tive industry (Coatings Magazine, 1991a).
Many of the larger metal finishing operations have improved productivity and hence increased their capacities. There have, however, been a number of large companies closing their operations. As a result the overall industry capacity is believed to be relatively stable.

The industry has been undergoing a major restructuring along with most other manufacturing sectors and this trend is expected to continue. In the future, it is expected that there will be a smaller number of specialized large companies or groups of companies supplying the majority of the metal finishing requirements in Canada. In addition to these companies, it is expected that there will continue to be a large number of small companies which will be difficult to locate, monitor and control with respect to environmental issues.

It is expected that the majority of metal finishing production will continue to be centred in Ontario and Quebec.

TURNOVER RATE

The failure rate of companies during the current recession is highest among the smaller and medium sized companies. Increased production efficiency has been one means for companies to fend off the effects of the economic downturn.

Future costs associated with environmental compliance are expected to continue to increase while at the same time it will likely become more difficult to raise capital for companies in the metal finishing industry. Banks are starting to scrutinize their relationship with companies who could expose them to an environmental liability and this trend is expected to become more prevalent in the future. Old established metal finishing companies are apparently finding it more difficult to leave the industry due to the costs of environmental requirements for sale or closure while new companies are finding it more difficult to get financing to get into the industry for these same reasons.

All of these factors are resulting in a rationalization of the industry and a slow down in the turnover rate. Companies are becoming more focused and specializing in certain sectors of the market for economic reasons but as a result are also thereby limiting the range of environmental management concerns associated with their operations. Medium-sized companies are expected to be absorbed by larger companies or forced out of business. Greater competition along with the increased cost of doing business in Canada will make it more difficult for them to survive.

The smallest companies, those with one or two employees, will probably continue to survive in their established niches, but again, firm data on these operations are difficult to develop.

TRENDS IN MARKETS/PRODUCTS

Increased demand has been realized in the areas of functional finishes such as zinc plate and electrogalvanized steel.

There has been a substantial growth in the use of printed circuit boards (PCB) by the automotive companies, from almost none in the early 1980s to approximately 25 percent of the total PCB market in 1992.

The use of decorative nickel-chrome has dropped in both the automotive and furniture markets.

More plated product from outside North America is being used in the automotive and hardware markets.

Cadmium for use as a protective coating has been banned in Japan and all Scandinavian and NATO countries due to health concerns. The major replacement product is a zinc-nickel alloy (Coatings Magazine, 1991b). It should be noted, however, that the military and aircraft industries continue to specify cadmium. The automotive industry has responded more quickly to the bans and some companies now specify zinc-nickel.

Other surface finishing methods have replaced some traditional metal finishing markets. For example, powder painting is now widely used and electrolytic painting has encroached on phosphating markets. However, where greater product durability is required, metal finishing may be the process of choice.

FINISHING PROCESSES

The unit processes in use today have changed little since the previous study (Environment Canada, 1987). There have been improvements in the reliability and performance of the systems but the actual chemistry used is essentially the same.

According to industry representatives, future growth is seen in the following areas:

- Decorative trivalent chrome plating, when this process is approved by the automotive companies.
- Electroless nickel plating in the automotive and aerospace industries.
- Use of electro-lacquers to replace brass plating.
- Nickel chrome plating on aluminium, especially for use on automobile wheels.
- Zinc alloy plating.
- Acid gold plating.

TRENDS IN INDIVIDUAL SECTORS

AUTOMOTIVE PARTS

The use of electroplated metals for decoration in the automobile industry has continued to fall. Paint and coloured plastic have replaced nickel-chrome plating in numerous applications such as bumpers and trim. There are signs that this trend may be abating as more nickel-chrome is being used on plastics, aluminium and zinc decorative strip. As further weight reduction requirements come into place for automobiles, a trend towards nickel-chrome plated aluminum wheels is expected. Nickel-chrome plating of stainless steel trim is expected to become more prevalent on cars at the upper end of the price scale.

The use of zinc plated components has increased with the need to provide better product life. There has been considerable growth in the use of electrogalvanized steel which is subsequently painted. Most electrogalvanized steel is produced outside of Canada.

There has been a significant increase in the amount of printed circuit boards used in automobiles. The automobile industry now accounts for approximately 25 percent of the printed circuit board production.

STEEL STRIP MILLS

There has been a major increase in the amount of zinc and aluminum coated steel strip. Most of this product is produced either in the United States or off-shore. The extremely high costs associated with setting up this kind of operation make it unlikely that any new facilities will be set up in Canada.

HARDWARE AND ARCHITECTURAL GOODS

There have been no significant changes in this industry other than the general effects of the recession on the housing and construction industry.

ELECTRICAL APPLIANCES

There has been a trend away from plated steel components towards coloured plastics for various items such as kettles, toasters, etc. Some plated plastics are now being used on stoves replacing parts previously made of metal.

WIRE GOODS

There has been a major trend in this area away from nickel-chrome plating. Zinc plating has replaced nickel-chrome on a major portion of the shopping cart industry.

Powder paint has replaced nickel-chrome to a large extent on display racks and shelving.

PLUMBING FIXTURES

There has been an increased use of coloured plastics and plated plastics in this market.

ELECTRICAL EQUIPMENT

There has been an increased demand for zinc plated conduit; otherwise there is little change.

FURNITURE

The trend has been away from nickel-chrome plated furniture to painted finishes. In addition, it is expected that the electro-lacquer finishes will replace brass plating.

POLE HARDWARE AND HEAVY STEEL

Whereas hot dip galvanizers in Ontario used to supply parts all over Canada, there has been a trend to form barriers between provinces by specifying content requirements on contracts. As a result, there are now more galvanizing plants in other provinces.

There has been some push to replace hot dip galvanizing with other finishes such as mechanical plating. This has been successful in certain markets (for example, nails) but in other areas requiring Canadian Standards Association approval, there has been little movement.

ELECTRONICS

There has been a trend to higher density, thicker multilayer circuit boards. As an indication of production in the sector, total sales by suppliers have increased approximately 50 percent over the last ten years. Job shops are much more prevalent in this sector, at about 90 percent of all facilities.

Military usage of boards is down whereas automobile usage has increased substantially. Future growth is expected in both the aerospace and automobile industry.

Greater use of tin and tin/lead plating for electronic components is also anticipated.

ENGINE AND WORN PARTS

There has been an increased demand for hard chrome plating due to the recession. Companies have been refurbishing parts rather than replacing them with new equipment.

Further growth is expected for hard chrome in the steel roll market as the automotive industry is requiring a better texture on steel panels that are subsequently painted.

HOLLOWWARE AND FLATWARE

No significant trends were identified in this relatively small and stable sector.

JEWELLERY

The major trend foreseen in this area is a requirement for nickel free costume jewellery.

MILITARY AND AIRCRAFT

These sectors, especially aerospace, have gained in importance in the Canadian metal finishing industry since the last Environment Canada review (1987), but have also experienced declines due to the recession since 1989. The financial difficulties of aircraft manufacturers in Ontario have been widely reported.

SUMMARY

Several recent economic pressures have influenced the metal finishing sector in Canada, including:

- The current recession.
- Restructuring and rationalization that is occurring in most major manufacturing sectors as global trading blocks develop.
- Loss of market share to other surface finishing methods.
- More stringent environmental requirements and stricter enforcement.

As a result, the number of metal finishing plants appears to be declining and those remaining are generally larger and more specialized. Overall capacity of the sector has not declined as quickly as the number of facilities since the surviving plants have been forced to become more efficient. Potential environmental liability has also made financing more difficult to obtain than in the past. This has slowed the turnover rate of companies. Industry representatives feel that all of these factors will affect the industry's ability to meet any new environmental requirements.

Section 3
SOURCES AND RELEASES OF PRIORITY SUBSTANCES IN THE METAL FINISHING SECTOR

WASTEWATER, SPENT PROCESS SOLUTIONS AND SLUDGES

INTRODUCTION

The purpose of this section is develop information regarding the sources and releases of priority substances in wastewater, spent process solutions and sludges from the metal finishing sector. The words *sources* and *releases*, and a number of others, have been given specific definitions for the purposes of this study (see Section 8, Glossary). The release estimates presented in this section do not necessarily imply direct release to the environment. Where possible, based on available information, estimates for releases from metal finishing facilities are broken down according to the fate of such releases. For example, releases from metal finishing facilities may be released to the municipal sanitary sewer and subsequent Water Pollution Control Plants (WPCPs), to sludge reclaimers such as smelters and foundries, and so forth.

As documented in Section 4, the metal finishing industry has developed and implemented a wide range of environmental control technologies. These efforts have focused on the reduction, reuse, recycling and recovery of wastes, as well as treatment. The purpose of developing estimates of sources and releases in the metal finishing industry is to provide information to the ongoing process of developing pollution prevention priorities and strategies.

Wastewater, spent process solutions and sludges have been grouped together in the effort to develop estimates of releases of priority substances because of the nature of information available and the estimate methodology which arose from it. In addition, the practice of treating some spent process solutions with wastewater and the fact that the majority of sludges arise from wastewater treatment provides a rationale for their joint consideration. Finally, these wastes have traditionally been the focus of waste minimization efforts in the metal finishing sector.

The major sources of priority substances are indicated conceptually in Figure 3-1. Liquid sources include rinsewater and spent process solutions. Other sources not identified on Figure 3-1 that are pertinent to this study, include spills, wastewater generated from cleanup/maintenance activities, and water used in other operations associated with metal finishing.

Most of the liquid waste generated in the metal finishing industry is treated (either onsite or offsite) before subsequent discharge to a surface water or a municipal sewer system; a portion of the liquid wastes generated from metal finishing activities is released to the environment without treatment. In addition, some spent process solu-

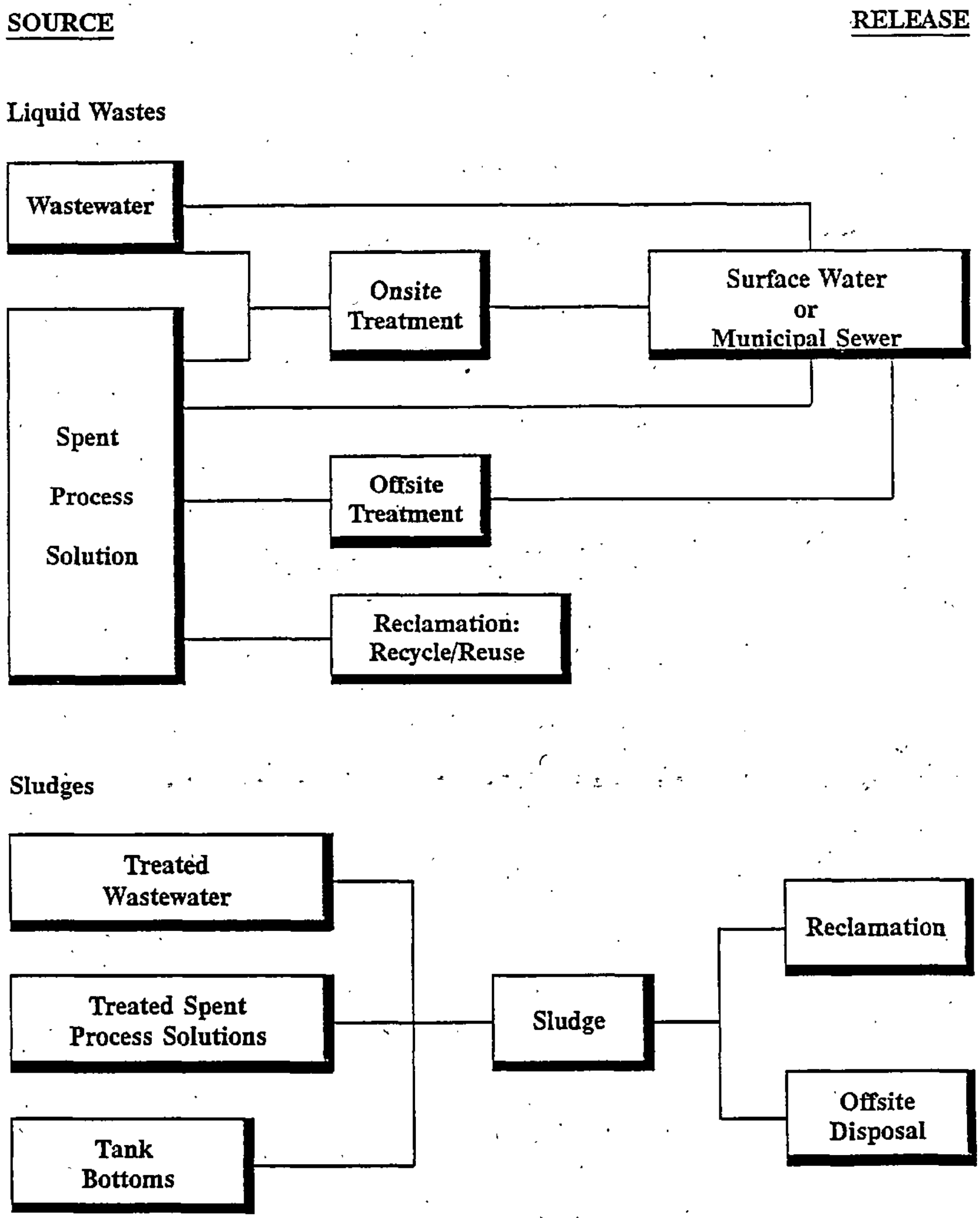


Figure 3–1
Major Sources and Releases in the Metal Finishing Sector

tions are reclaimed for recycle/reuse. Sources of sludges generated in metal finishing operations include tank bottom sludges in addition to those generated in the treatment of liquid wastes. Depending on the quantity and quality of the sludge, these materials may be reclaimed or disposed offsite, typically in secure landfills.

The development of release estimates from the metal finishing sector is a complex task owing to the diverse nature of the industry, apparent in the description provided in the previous section. The effort to develop release estimates has attempted to take this diversity into account while recognizing the limitations of the available data.

This section has been broken into a number of subsections to help clarify the methodology used to make release estimates. The first describes the information sources available to this study and focuses on those which were of greatest importance in developing the estimates. Subsequent sections describe the use of the various information sources in developing estimates of the release of priority substances.

INFORMATION SOURCES

This description of information sources focuses on those of greatest importance to developing release estimates for the metal finishing industry in Canada. Many other resources have been employed, as noted in Section 7, Bibliography.

Municipal/MISA Wastewater Database

A number of municipalities were approached regarding the possibility of providing sewer use monitoring data from metal finishers under their jurisdiction. It was hoped that this information would provide data for several segments of this study including:

- Development of liquid waste and sludge release estimates
- Assessment of existing liquid waste treatment and sludge management
- Review of municipal regulation and enforcement with respect to the Canadian metal finishing sector

The following municipalities were contacted during the course of the study:

- Montreal Urban Community (Québec)
- Region of Durham (Ontario)
- Metropolitan Toronto (Ontario)
- Region of Peel (Ontario)
- Region of Halton (Ontario)
- Region of Waterloo (Ontario)
- Region of Niagara (Ontario)
- City of Windsor (Ontario)
- City of Calgary (Alberta)
- City of Edmonton (Alberta)
- Greater Vancouver Regional District (British Columbia)

The selection of these municipalities was based on the fact that over 80 percent of the Canadian industry is located in Alberta, British Columbia, Ontario and Quebec and that it is concentrated in the larger urban sectors. Some of the smaller Ontario regions such as Durham, Halton and Niagara were included in order to provide data from smaller centres. It should be noted that while some limited number of metal finishers may be located in smaller centres, these centres are the least likely to have an active sewer use bylaw monitoring and enforcement program. This fact limited the availability of such data to this study.

The ability of municipalities to respond to information requests was influenced by the fact that in a large majority of cases no formal data summary had been undertaken as part of the sewer use monitoring program and internal resources were limited to provide the requested information. In some municipalities, the lack of resources has meant that no formal monitoring program exists and the provisions of the sewer use bylaws are not being actively enforced.

In addition, survey and monitoring data were available for five additional municipalities in Ontario through the MISA municipal pilot study program. These municipalities were:

- Region of Hamilton-Wentworth
- City of Thunder Bay
- Town of Cobourg
- Town of Gananoque
- Town of Ingersoll

A summary of the nature of the information provided by municipalities is provided in Table 3.1. The level of detail provided by these various information sources varies widely, making a consistent, overall summary of the information difficult. For the purposes of this study, this database represents the most comprehensive and recent (1991/92) Canadian data available.

Each of the municipal databases is limited to a consideration of liquid wastes discharged to the municipal sewer (i.e. wastewater). The information available for each facility typically consists of a single estimated/measured value of flow rate (usually derived from annual water use), and the results of analyses for heavy metals conducted on a limited number of wastewater grab samples collected periodically by the municipality (i.e. end-of-pipe release to municipal sewer).

The data provided by municipalities was especially useful in developing release estimates specific to liquid waste streams generated by metal finishing activities. Major contributions to these streams include rinsewater and spent process solutions.

MOE 1991 Survey of Ontario Metal Finishing Industry

Other important sources of information include studies published by various Canadian government agencies. In approximately 1989, a survey of the metal finishing industry in Ontario was conducted by Proctor & Redfern Limited for the Ontario MOE (MOE, 1991). In this survey, a questionnaire was sent to 1,343 active companies, 695 of whom

Table 3.1
Description of Data Available from Municipalities[1,2]

Municipality	Number of Facilities	Production Information	Pretreatment Information	Flow Rate Data	Monitoring Data[3]
Montreal Urban Community	71	- job or captive shop - list of processes - metals used	- list and description of pretreatment used	- 1 flow rate per industry (measured or estimated)	- 3+ data points per metal - may or may not include all priority metals
MISA Municipalities (dBase files)	16	- narrative description - point of discharge information - # of employees	- list of pretreatment used	- 1 measured flow rate per company	- 1-3 data points for each priority metal
Region of Peel	61	- process description for 11/61 companies from MOE survey	- pretreatment information for 11/61 companies from MOE survey	- no flow data	- 1-14 data points for each priority metal
Region of Halton	14	- narrative description	- narrative description	- 1 measured flow rate per company	- no Hg or As data - 12+ data points for other priority metals
Region of Durham	6	- narrative description	- narrative description	- 1 flow rate per company based on water consumption	- 2-12 data points available per company for priority metals
Metro Toronto (spreadsheet and hard copy)	93	- narrative description	- narrative description plus water reduction methods utilized	- 1 flow rate per company	- 1-30 data points available per company for priority metals
Region of Niagara	13	- minimal narrative description	- narrative description	- 1 flow rate per company	- a range for Cr,Ni,Cd concentrations per company
City of Windsor (dBase files)	11	- process description available for 5/11 companies from MOE survey	- pretreatment information available for 5/11 companies from MOE survey	- 1-2 measured flow rate per company	- 1-2 data points for each priority metal

Notes: [1]Information was requested from other municipalities. Information was not available from these other sources within the time frame of the study.
[2]Unless otherwise noted, all data are in hard copy format only.
[3]"Priority metals" include As, Cd, Cr, Pb, Hg and Ni. Data for the 1991/92 period collected.

responded. Of these, 282 were identified as conducting at least one, and most often more, of the following operations:

- Electroplating
- Anodizing
- Chemical conversion coating
- Electroless plating, including immersion plating
- Chemical etching and milling or bright dipping
- Printed circuit board manufacturing
- Hot dip coating, including galvanizing

These are the same operations of interest to this study. The survey collected information on production processes, wastewater management and management of spent process solutions and sludges. A sampling and analytical program was not part of this study. The results for each survey respondent, summarized in spreadsheet format, were made available by the MOE to this study.

The information available from this source was useful in identifying key features of waste generation and waste management in the metal finishing sector. Key characteristics include:

- Relative quantities of wastewater pretreated and not pretreated prior to release to the municipal sewer
- Relative quantities of spent process solutions treated onsite, treated offsite, reclaimed, or not treated/reclaimed (i.e. released to sewer)
- Demographic profile of the metal finishing processes in use in Ontario

Other Studies

Monenco Inc. recently reviewed waste management by the chemical and electrochemical plating industry in Alberta for Alberta Environment (Alberta Environment, 1992). The main objective of the study was to develop recommendations for the improvement of waste management in the metal finishing sector. The study involved identifying and profiling companies as well as conducting a field inspection and sampling program. In addition to the published report, Alberta Environment made characterization data on an industry-anonymous basis available to this study.

Survey results from previous Environment Canada studies (Environment Canada, 1987) have also provided some information on the breakdown of production processes, pretreatment technologies and waste management practices in the Canadian industry. It is recognized that this information is dated and its validity has been weighted accordingly.

In general, little data characterizing the priority substance content of sludges in the metal finishing sector have been identified. While management, storage and disposal of a number of these wastes are subject to special waste and dangerous goods regulations across the country, manifesting does not require characterization beyond, for example, leachate toxicity testing. The release estimate methodology has made an effort to circumvent this lack of characterization data by assuming that the majority of sludges result from wastewater and spent process solution treatment, as described further on.

USEPA Development Document for the Metal Finishing Sector

The information sources identified above were supplemented with the database summarized in the USEPA development document for effluent limitations in the metal finishing sector (USEPA, 1983). The document made use of flow rate and concentration data for heavy metals collected at 322 metal finishing facilities during the development of the federal categorized pretreatment regulations for the metal finishing sector in the United States.

The development document provided information on the quantity and quality of wastewater generated by metal finishing operations and is the only information source to characterize/quantify untreated wastewater.

The summary statistics provided for each metal finishing facility include: maximum, minimum, mean, and median wastewater stream mass concentrations, and flow-proportioned mean concentrations for a range of heavy metals. This information is provided for both segregated (i.e. hexavalent chromium-bearing, cyanide-bearing, complex metal-bearing, common metal-bearing, etc.) and combined/co-mingled wastewater streams prior to onsite pretreatment. Summary statistics on flow rate for both total plant flow and segregated wastewater streams are also included.

DESCRIPTION OF APPROACH

The basic approach involves developing estimates of the mass discharge of priority substances in each of the major source/release pathways indicated in Figure 3-1. For the liquid streams, this includes estimating flow rates and mass concentrations. The flow rate data of the individual municipal databases from the 1991/92 period were evaluated to determine the distribution (i.e. mean, variance, median) of wastewater quantities characteristic of the municipality. The major municipal databases were then pooled to determine the distribution of wastewater flow rates characteristic of the metal finishing industry in Canada.

The characteristics of the flow rate distributions for the Canadian metal finishing industry as a whole were used in conjunction with industry-specific databases to estimate the flow rates characteristic of wastewater streams typically segregated for separate treatment including:

- those containing hexavalent chromium
- those containing complexed metals

Release estimates of priority substances from the Canadian metal finishing industry were then developed from the following sources of information:

- Wastewater flow rate estimates described above
- MOE (1991) data on the management of rinsewater and spent process solutions
- Demographic information on wastewater streams described in Section 2 (Table 2.5)
- Wastewater characterization data

The following sections describe the estimate methodology in greater detail.

SOURCES OF PRIORITY SUBSTANCES

General Description

Certain wastewater streams are typically segregated from other metal finishing wastewater based on treatability considerations. As indicated in Figure 3-2, the six wastewater streams typically segregated for pretreatment prior to co-mingling include:

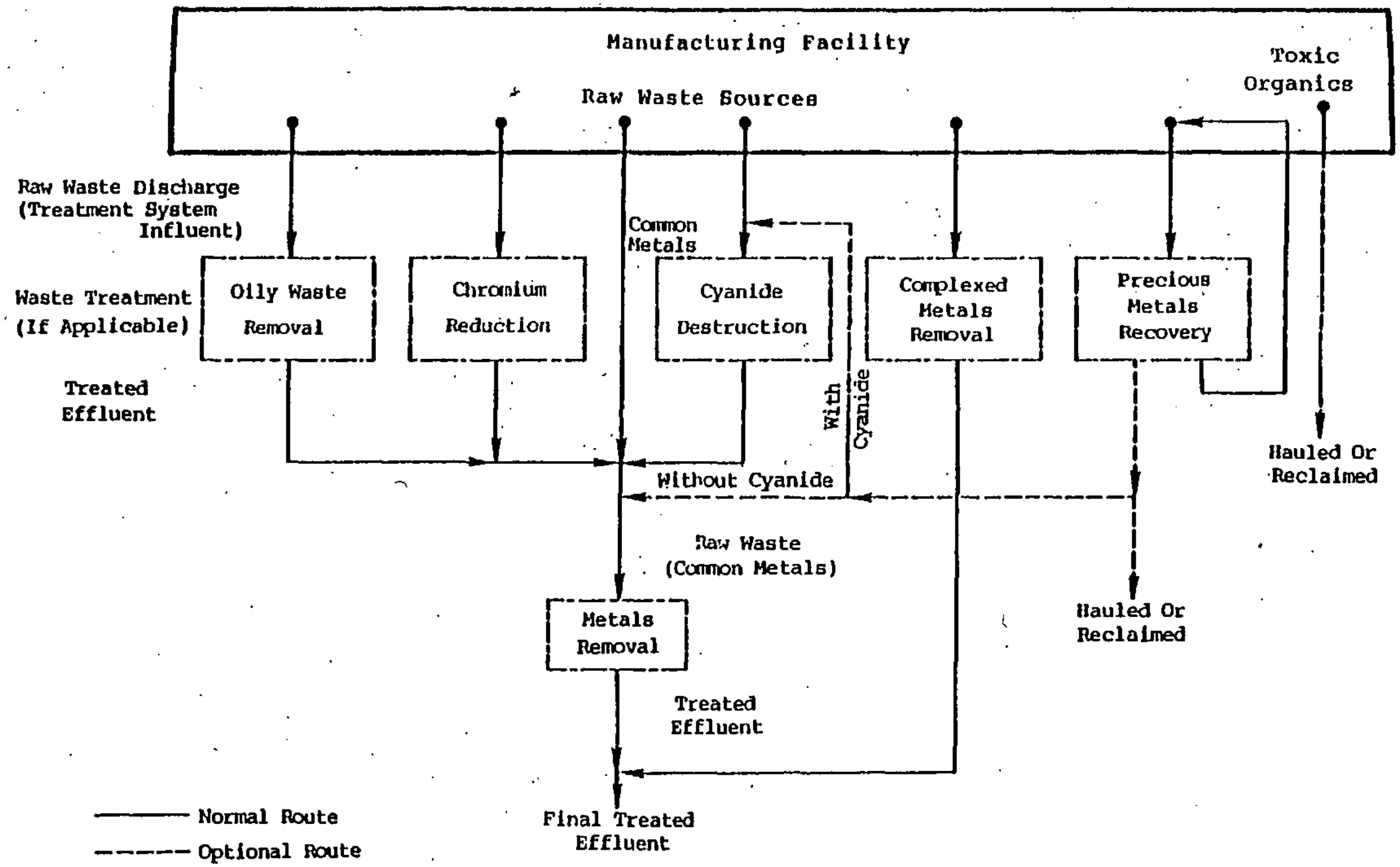
- Common metals
- Hexavalent chromium
- Complexed metals
- Precious metals
- Cyanide
- Oily waste

The first three of these streams are relevant to the release of toxic and priority metals such as arsenic, cadmium, chromium, lead, mercury and nickel, as well as a number of others. These waste streams define the nature of pretreatment required for any given plant. The pretreatment processes used for the various waste streams are discussed in more detail in Section 4.

The relationship of these untreated wastewater streams to production processes in use provides some degree of demographic breakdown of sources among the various types of metal finishing facilities. Table 3.2, presented previously as Table 2.5, provides a description of how these untreated wastewater streams relate to processes in use, as well as the best estimates available for how many Canadian plants fit into each of the defined categories, as discussed in Section 2.

Total Flow Distributions

Figure 3-3 depicts the distribution of total plant wastewater flows for metal finishing facilities in Canada and the total plant wastewater flow distribution for the U.S. metal finishing industry. Data for the Canadian plot represent all flow information available from the municipal databases for the 1991/92 period. More than 200 facilities, or one third of all Canadian plants, are represented. Distributions for individual municipalities are presented in Appendix C and are well represented by the pooled data presented in



Note: Discharge from precious metals recovery may be hauled in alternative ways, depending on the recovery method in use.

REFERENCE: USEPA, 1983

FIGURE 3-2: UNTREATED WASTEWATER SOURCES AND PRETREATMENT

Table 3.2
Raw Wastewater Demographic Characterization of the Canadian Metal Finishing Sector

Wastewater Generation	Facilities Included	Approximate Percentage of Facilities[1]	Approximate Number of Facilities[2]
Common metals	• Non-chrome electroplating • Hot dip coating • Non-chrome anodizing • All other non-chrome activities	40%	240
Common metals, hexavalent chromium	• Chrome electroplating • Chromating • Chromic acid etching and anodizing	45%	270
Common metals, complexed metals	• Non-chrome electroless plating and PCB manufacturing	10%	60
Common metals, hexavalent chromium, complexed metals	• Chrome electroless plating and PCB manufacturing	5%	30

Notes: [1]Based on available data from various studies: Environment Canada (1987), MOE (1991), Alberta Environment (1992) and this study.
[2]Based on an estimate of 600 facilities in Canada in 1992.

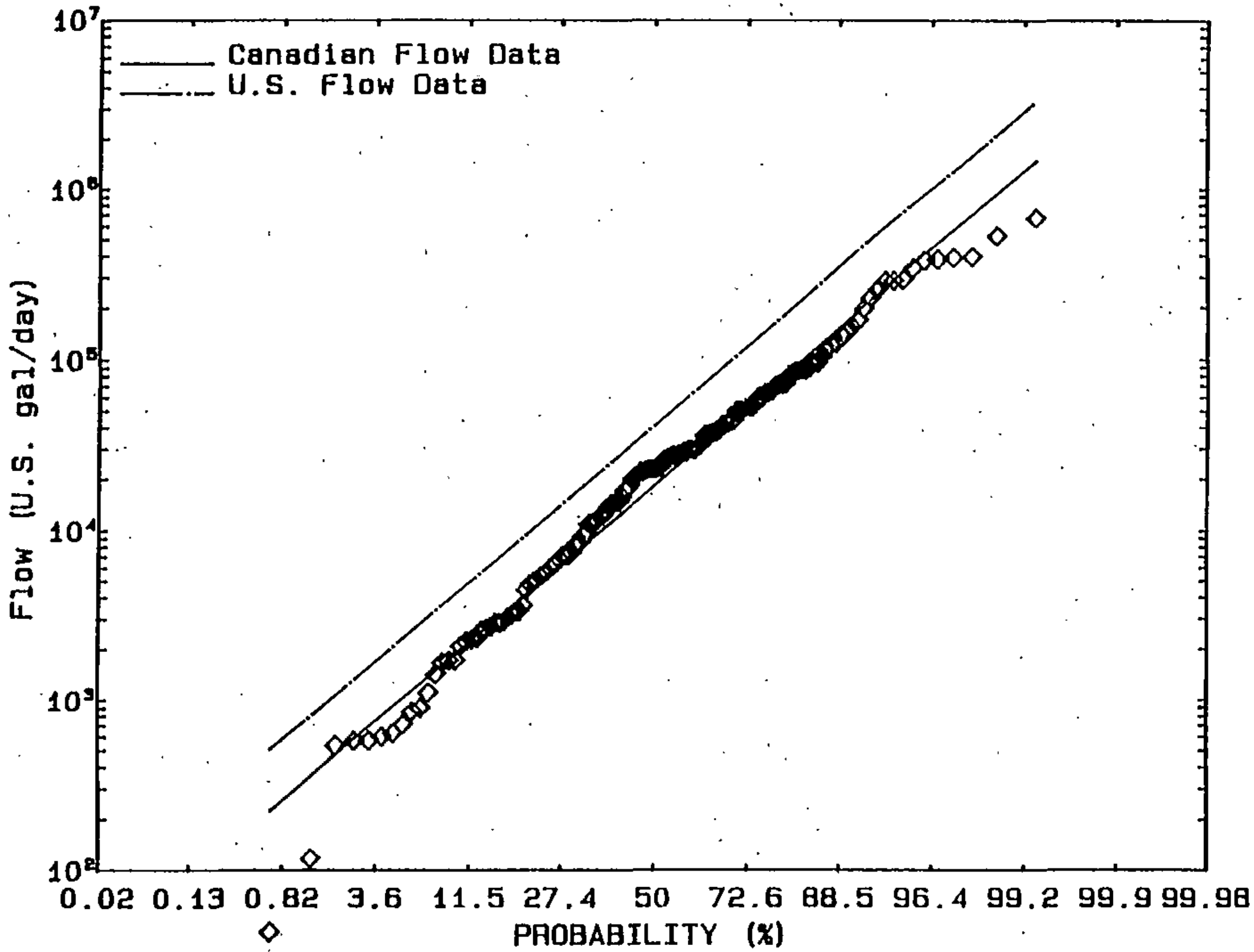


FIGURE 3-3:
DISTRIBUTION OF TOTAL PLANT FLOWS – U.S. AND CANADA

Figure 3-3. The U.S. plot is based on data for more than 320 plants presented in the development document.

Flows in Canada and the U.S. are both log-normally distributed, as evidenced by the linearity of the two plots. The variance of the two distributions is similar, as demonstrated by the parallel nature of the plots. The vertical separation between the two plots indicates that the means of the two distributions are different, the Canadian mean being approximately 30 to 40 percent of the U.S. value. Because the lines are parallel, this scaling factor is constant across the entire distribution. The lower flow rates characteristic of the metal finishing industry in Canada likely reflect the fact that the U.S. data are from the 1983 period and the Canadian data from the 1991/92 period, as well as the generally smaller scale of operations in Canada. Water use reduction techniques implemented across the industry in the intervening years has likely contributed to the lower relative Canadian flows.

Distributions for both Canada and the U.S. encompass a wide range of flows. This reflects the fact that the industry is made up of both large, integrated manufacturing facilities for large parts such as aircraft assemblies and smaller facilities which may operate a small plating line in a corner of the shop.

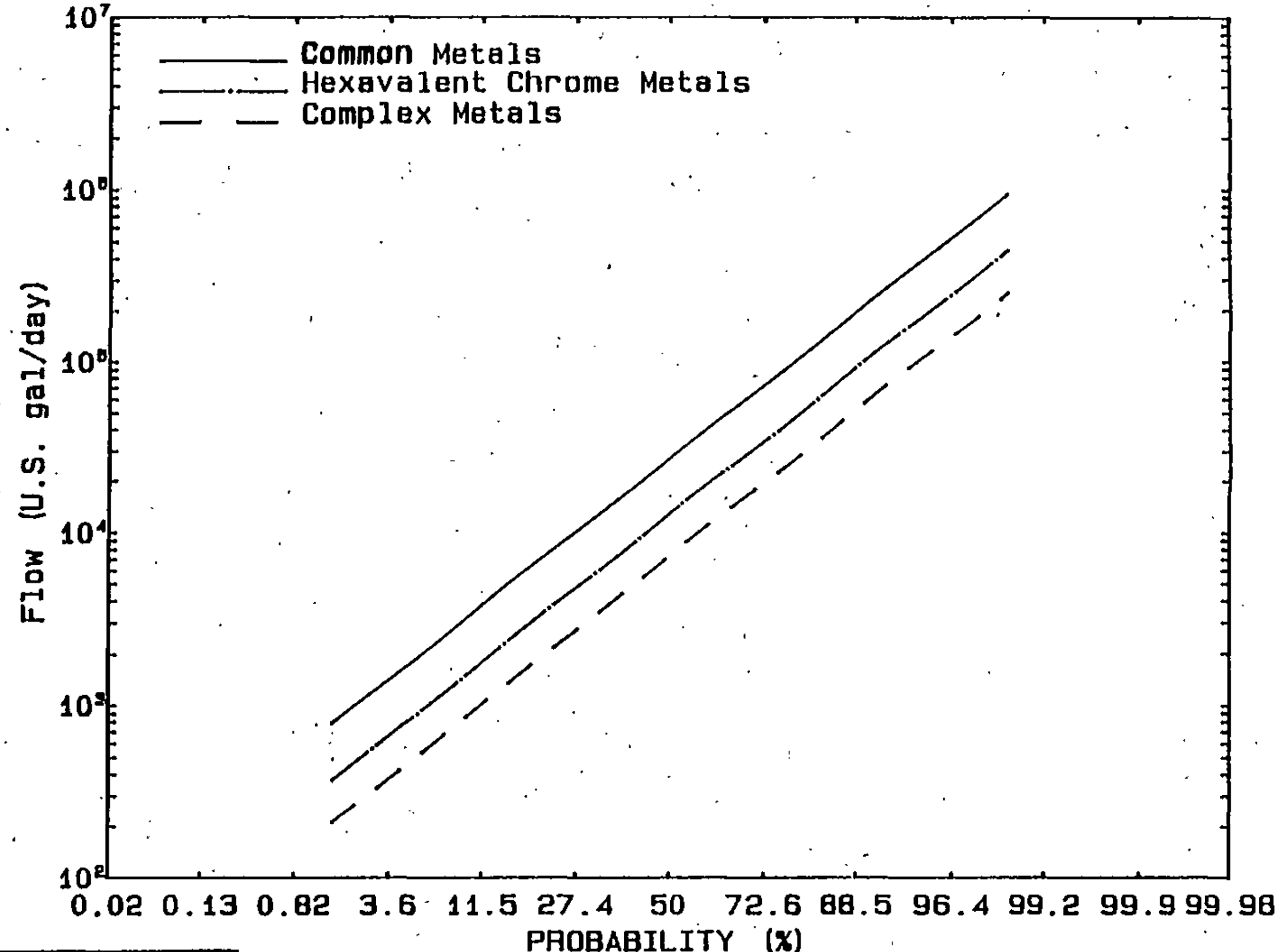
Segregated Wastewater Flow Distributions

Estimates of flow rates were developed for each of the key segregated wastewater streams from metal finishing operations:

- Common metals
- Hexavalent chromium
- Complexed metals

This approach recognized the need to distinguish among the various sources in the metal finishing sector.

Essentially, the estimates were made using the rationale that the ratio of total flow to segregated wastewater flow for Canadian metal finishing operations is approximately that for U.S. metal finishing operations. Specifically, this was achieved by first assuming that the distribution of flow rates of each of the segregated streams would have common characteristics (i.e. log-normal distribution, common variance) as the distribution of flow rates represented by a pooling of the three individual databases. This assumption was supported by the industry-specific flow distributions reported in the USEPA development document. The three databases were combined and the pooled slope was calculated. Once this slope was estimated, it was used to fit the individual data from each of the three segregated wastewater streams. These distributions were then adjusted by the scaling factor determined from Figure 3-2 to convert these flows from those characteristic of the metal finishing industry in 1983 to those characteristic of the Canadian metal finishing industry in 1991. The adjusted flow rates are indicated in Figure 3-4. This approach results in a set of three distributions, which have different



STREAM	FLOW (U.S. gal./day)	
	Median (50%)	Mean
Common Metals	31,300	79,900
Hexavalent Chrome	14,800	37,800
Complex Metals	8,410	21,500

FIGURE 3-4:
DISTRIBUTION OF UNTREATED WASTEWATER FLOWS–CANADA

means indicating the different flow rates typical of each of the segregated streams. The medians and means of these distributions are reported in Figure 3-4.

All plants generate the common metals wastewater stream (see Figure 3-2) and it is often the largest single process wastewater source, as demonstrated by the fact that it has the highest flows of the three sources depicted. The other two streams are more likely to be the focus of waste minimization efforts, since treatment costs are higher, resulting in significantly lower flows.

SEGREGATED WASTEWATER CHARACTERIZATION

The characteristics of untreated wastewater streams from metal finishing operations are summarized in Table 3.3 for three databases:

- **USEPA, 1983:** This database was established by the USEPA to support the development of categorical pretreatment requirements for metal finishing operations. Flow proportional mean concentrations of individual heavy metals were determined from the coincident measurement of flow rate and mass concentration of contaminants.

  The characteristics of those streams typically segregated for treatment were developed based on wastewater quantity and quality measurements made at over 100 facilities for the Common Metals Stream, at over 30 facilities for the Complexed Metals Stream and at over 40 facilities for the Hexavalent Chromium Stream.

  The usefulness of this database is limited somewhat by the following factors:

  - The scale/demographics of the metal finishing industry in the United States is different than that for Canada.
  - Industry-wide changes adopted since 1983 are not reflected in the database.

  This database is the most comprehensive available specific to the metal finishing sector, and is the only database to characterize segregated wastewater streams prior to treatment.

- **MOE, 1991:** This database summarizes the results of a survey of the metal finishing sector in Ontario undertaken by MOE in the period 1989-1990. The survey collected information on production processes, wastewater management and management of spent process solutions and sludges. A sampling and analysis program was not part of the MOE study.

  The range of values listed in Table 3.3 are the typical characteristics of raw wastewater streams from common metals plating reported in the MOE study.

Table 3.3
Reported Characteristics of Segregated Wastewater Streams

Segregated Wastewater Stream/ Parameter	USEPA, 1983			MOE, 1991		Patterson, 1985	
	Flow Proportioned Mean Value	Range of Values		Range of Values		Range of Average Values	
		Min	Max	Min	Max	Min	Max
Common Metals Stream							
Arsenic	0.015	ND	0.064	NA	NA	NA	NA
Cadmium	0.070	ND	21.5	0.007	21.6	2	60
Chromium	1.39	ND	35.4	0.088	525.9	1	700
Copper	1.84	ND	500	0.032	272.5	2	900
Lead	0.738	ND	42.3	0.663	25.39	ND	140
Nickel	4.16	ND	415	0.019	2954	ND	205
Zinc	41.6	ND	16,500	0.112	252.0	2.4	1050
Complexed Metals Stream							
Cadmium	0.173	ND	3.65	NA	NA	NA	NA
Copper	9.68	ND	62.6	NA	NA	NA	NA
Lead	0.240	ND	3.61	NA	NA	NA	NA
Nickel	18.8	ND	294	NA	NA	NA	NA
Zinc	2.52	ND	17.6	NA	NA	NA	NA
Hexavalent Chromium Stream							
Hexavalent Chromium	54.6	0.005	12,900	0.005	334.5	1	700

Notes:

1. All values listed are mg/l
2. USEPA, 1983: Development Document for Effluent Limitations Guidelines and Standards for the Metal Finishing Point Source Category U.S. Environmental Protection Agency, Washington, D.C. (1983).
3. MOE, 1991: Metal Finishing Survey for Ontario, Waste Management Branch, Ministry of the Environment, Province of Ontario, January 1991.
4. Patterson, 1985: Industrial Wastewater Treatment Technology, Second Edition, Butterworth (1985).
5. NA: Not Available.
6. ND: Not Detected.

- **Patterson, 1985:** The minimum and maximum value listed in Table 3.3 approximate the range of average mass concentration values provided in this database for wastewaters generated from metal finishing activities.

It is evident from Table 3.3 that there is a large range of values considered to be representative of the mass concentration of individual heavy metals in each of the segregated wastewater streams. Maximum values are typically orders of magnitude larger than minimum values. The high degree of uncertainty associated with the wastewater characteristics suggested by the large ranges is indicative of the broad diversity in the industry and reflects the influence of several factors, including:

- Different levels of housekeeping/spills management across the industry. Good housekeeping practices would tend to reduce the mass concentration of heavy metals in wastewaters; poor housekeeping practices would tend to increase these concentrations.

- Co-mingling of spent process solutions with rinsewater at some facilities. Such co-mingling would tend to significantly increase the mass concentration of heavy metals in wastewaters.

- Implementation of counter-current rinsing and other flow reduction techniques at some facilities. These practices would tend to increase the mass concentration of heavy metals in wastewaters while reducing the quantities of wastewater released.

Each of the above factors, and likely others, contributes to the broad range of wastewater characteristics reported for the metal finishing industry. The influence of these factors cannot reasonably be quantified based on the information available.

The USEPA, 1983 study is the only database identified that characterizes/quantifies segregated wastewater streams prior to treatment through the implementation of a systematic measurement of individual stream quantity and quality. In addition, this database was developed based on measurements at a large number of facilities. The statistical summaries indicated in Table 3.3 for the individual segregated streams are based on data collected from between 30 and 100 facilities. For these reasons, the flow proportioned mean concentrations developed from this database were considered to be the most reasonable representation of the quality of those wastewater streams typically segregated for pretreatment.

To account for the uncertainties identified above, a range of mass concentrations was estimated for each parameter as indicated in Table 3.4. The range for each parameter was established based on the following considerations:

- Each range should be estimated relative to the corresponding flow proportioned mean value, and ideally should bracket the value.

- Each range should reflect the estimated degree of uncertainty associated with the corresponding flow proportioned mean value as inferred from the range of values reported for the individual parameters listed in Table 3.3.

Table 3.4
Estimated Range of Mass Concentrations in Segregated Wastewater Streams

Segregated Stream	Parameter	Flow Proportioned Mean Concentration[1] (mg/L)	Estimated Range (mg/L)	
			Low	High
Common Metals	Arsenic	0.015	0.005	0.05
	Cadmium	0.070	0.01	0.1
	Chromium	1.39	0.5	5
	Copper	1.84	0.5	5
	Lead	0.738	0.25	2.5
	Nickel	4.16	1	10
	Zinc	41.6	1	50
Complexed Metals	Cadmium	0.173	0.05	0.5
	Copper	9.68	2.5	25
	Lead	0.240	0.05	0.5
	Nickel	18.8	5	50
	Zinc	2.52	1	10
Hexavalent Chromium	Hexavalent Chromium	54.6	1	55

Notes: [1]U.S. EPA, 1983.

- Account should be taken of the apparent higher-than-reasonably expected flow proportioned mean values reported for zinc (common metals stream), and chromium (hexavalent chromium stream).

For each of these values the maximum reported concentration (Table 3.3) is greater than the flow proportioned mean by at least two orders of magnitude. Each of these values appears to be strongly influenced by the maximum reported value in the database. Excluding this single measurement decreases the calculated mean value for zinc (Common Metals Stream) from 312 mg/L to 178 mg/L, a difference of 43 percent; and that for chromium (Hexavalent Chromium Stream) from 377 mg/L to 99 mg/L, a difference of 74 percent. The effect of eliminating the maximum values on the value for the flow proportioned mean cannot be quantified since the complete database, including coincident flow data, is not available.

- Account should be taken of the apparent difference in metal finishing industry demographics between the U.S. and Canada (i.e. specialized industry subsectors) as it relates to estimates for the release of lead. The available information indicates there are only two facilities in Canada using electrolytic processes for lead.

Rinsewater Mass Loadings

The range of mass concentration values listed in Table 3.4 for each parameter was assumed to provide reasonable low and high values of the rinsewater component for each of the segregated wastewater streams. That is, it was assumed for the purposes of this study that the influence of spent process solutions are not included in these mass concentration values. This assumption would tend toward resulting in higher-than-actual release estimates. Based on the unknown influence of spent process solutions on the flow proportioned mean concentration levels, it was considered prudent to adopt this conservative approach and reflect the underlying uncertainty in the data through the use of the estimated range of values.

The mass loading of heavy metals from rinsewater sources was estimated from the range of mass concentrations listed in Table 3.4 and the mean flow rates indicated in Figure 3-3. A range of loadings was calculated for each parameter in each of the segregated wastewater streams, as indicated in Table 3.5.

The loadings summarized in Table 3.5 represent Canada-wide estimates based on the segregated stream demographics listed in Table 3.2 (i.e. common metals, complex, hexavalent chromium, etc.) and include additive loadings to represent those plants that generate more than one of the wastewater streams.

Spent Process Solution Mass Loadings

In addition to rinsewater, spent process solutions make a significant contribution to liquid waste loadings of priority substances.

Periodically the concentrated process solutions are removed from service and replaced. The useful life of a concentrated production bath depends on many factors, including:

- the type/range of metal finishing operation(s) undertaken at the facility.
- the quality control requirements for the operation (actual and/or specification)
- the production practices/housekeeping specific to the facility
- the influences of market forces

Table 3.5
Rinsewater Loadings - All Facilities[1]

Element	Common Metal Only[2]		Common & Complex Metals[2] (kg/day)		Common & Chromium Metals[2] (kg/day)		Common, Chromium & Complex Metals[2] (kg/day)		Total Loadings[3] (kg/day)	
	Low	High	Low	High	Low	High	Low	High	Low	High
Arsenic	0.36	3.6	0.091	0.91	0.41	4.1	0.045	0.45	0.91	9.1
Cadmium	0.73	7.3	0.43	4.3	0.82	8.2	0.21	2.1	2.2	22
Chromium	36	360	9.1	91	79	2500	8.8	280	130	3300
Copper	36	360	21	210	41	410	11	110	110	1100
Lead	18	180	4.8	48	20	200	2.4	24	46	460
Nickel	73	730	43	430	82	820	21	210	220	2200
Zinc	73	3600	23	960	82	4100	12	480	190	9100

Notes: [1]Figures may not add due to rounding. Figures reported to two significant figures.
[2]Loadings are calculated based on the total number of plants in each category reported in Table 3.2.
[3]These figures are totals for the previous four columns.

Typical "useful life" can range from several weeks to several months. Spent process solutions typically are comprised of a range of priority substances at concentrations orders of magnitude larger than those typical of rinsewaters. Bath volumes range from tens of gallons to thousands of gallons. As a result, the release of spent process solutions typically represents a significant portion of the mass discharge of priority substances from production operations.

It is difficult to estimate the "typical" contributions from the periodic discharge of spent process solutions relative to that from the discharge of rinsewater. Data is not readily available to allow an estimate of this factor.

Based on evaluations reported by Altmayer (1990), it has been estimated that approximately 50 percent of the mass loadings of metals from production is associated with rinsewater and approximately 50 percent is associated with spent process solutions.

ESTIMATED RELEASES OF PRIORITY SUBSTANCES

In this section, releases of priority substances and other key metals are estimated for liquid wastes and sludges. The major release pathways are indicated in Figure 3-5.

Liquid Release Estimates

Liquid releases are comprised of two major components: rinsewaters and spent process solutions.

Rinsewater Release Estimates. Table 3.6 summarizes rinsewater releases. Based on data reported by the MOE (1991) and discussed in detail in Appendix D, 12 percent of wastewater loadings do not receive pretreatment, while the remaining 88 percent are pretreated prior to discharge.

The removal efficiency of treatment technologies is a function of several factors including the blend of heavy metals present in the raw rinsewater, the mass concentration of the individual heavy metal constituents, the variability in rinsewater flow volumes, the level of attention applied to the treatment system, and other facility specific factors. These are discussed in detail in Section 4.

A 90 percent treatment removal efficiency has been assumed for all the substances noted in Table 3.6. This removal efficiency adequately represents the range in rinsewater concentrations prior to pretreatment as well as both conventional and advanced technologies.

Spent Process Solution Release Estimates. Based on data reported by the MOE (1991) and discussed in detail in Appendix E, 89 percent by volume of spent process solutions are released to the sanitary sewer, 4 percent are treated offsite with resulting sludges disposed in secure landfill and 7 percent are reclaimed. For the purposes of these estimates, it has been assumed that for the 89 percent released to sanitary sewer,

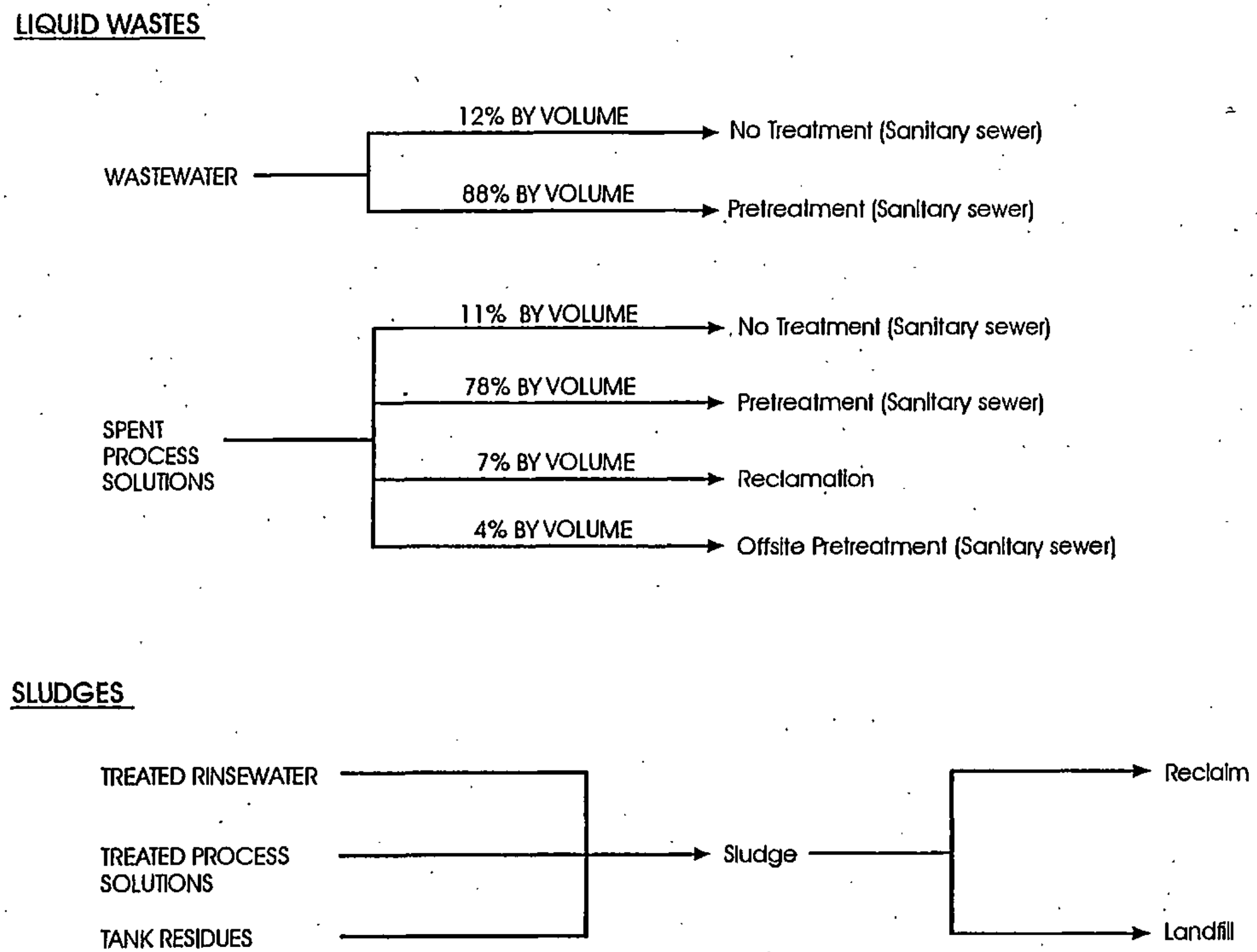


FIGURE 3-5:

MAJOR RELEASE PATHWAYS FROM THE METAL FINISHING SECTOR

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Table 3.6
Releases from Wastewater

Element	Total Loadings in Raw Wastewater[1] (kg/day)		Releases from Untreated Wastewater[2] (kg/day)		Releases from Treated Wastewater[3] (kg/day)		Total Releases from Wastewater[4] (kg/day)	
	Low	High	Low	High	Low	High	Low	High
Arsenic	0.91	9.1	0.11	1.1	0.080	0.8	0.19	1.9
Cadmium	2.2	22	0.26	2.6	0.19	1.9	0.45	4.5
Chromium	130	3300	16	390	12	290	28	680
Copper	110	1100	13	130	9.6	96	23	230
Lead	46	460	5.5	55	4.0	40	9.5	95
Nickel	220	2200	26	260	19	190	45	450
Zinc	190	9100	23	1100	17	800	39	1900

Notes: [1]*From Table 3.6.*
[2]12% of loadings are discharged untreated, based on MOE, 1991.
[3]88% of loadings are discharged to treatment, based on MOE, 1991; 90% treatment removal efficiency assumed.
[4]Total releases include treated and untreated wastewater.

12 percent are untreated, as is the case for rinsewater. Thus, the breakdown by volume of spent process solution disposal, depicted in Figure 3-5, is:

- 78 percent treated onsite and released to the sanitary sewer
- 11 percent untreated and released to the sanitary sewer
- 4 percent treated offsite and released to the sanitary sewer, with resulting sludges disposed in secure landfill
- 7 percent reclaimed and not released to the environment

For the 82 percent of total loadings receiving treatment (78 percent treated onsite, 4 percent treated offsite), treatment removal efficiencies are assumed to be comparable to those for rinsewater treatment. This is the case since volumes of spent process solutions are negligible compared to rinsewater flow rates and it is common to "bleed-in" spent process solutions to the rinsewater treatment system.

Based on these assumptions, spent process solution release estimates are summarized in Table 3.7.

Sludge Release Estimates

Sludge release estimates are summarized in Table 3.8. These estimates have been developed based on extent of treatment and removal efficiencies assumed for rinsewater and spent process solutions. Sludges containing metals are generated principally as residues from the treatment of rinsewaters and spent process solutions.

The fate of sludge releases is not readily quantified. The only available information is the 1991 MOE study, which solicited information regarding sludge management. Many facilities reported multiple methods, so the following percentages total greater than 100:

- Secure landfill - 57 percent of facilities
- Municipal landfill - 19 percent of facilities
- Reclamation by metal recycling companies - 17 percent of facilities
- Onsite storage - 4 percent of facilities
- Reclamation by smelters - 3 percent of facilities
- Reclamation by foundries - 1.5 percent of facilities
- Other unspecified offsite management - 14 percent of facilities.

Unfortunately, the survey did not gather information on the quantities of sludge managed by each of the noted methods. Although a significant percentage of facilities reported that sludge reclamation was practices, the portion of sludges from each facility amenable to this management option is not known. As a general rule, sludges resulting from the treatment of mixed wastewater streams will be less amenable to treatment. Waste segregation is generally required to produce sludges appropriate for reclamation technologies. For these reasons, it is believed that the actual amounts of sludge managed by reclamation are less than the percentages noted above may indicate.

Table 3.7
Releases from Spent Process Solutions

Element	Total Loadings in Spent Process Solutions[1] (kg/day)		Releases from Untreated Spent Process Solutions[2] (kg/day)		Releases from Treated Spent Process Solutions[3] (kg/day)		Total Releases from Spent Process Solutions[4] (kg/day)	
	Low	High	Low	High	Low	High	Low	High
Arsenic	0.91	9.1	0.10	1.0	0.074	0.74	0.17	1.7
Cadmium	2.2	22	0.24	2.4	0.18	1.8	0.42	4.2
Chromium	130	3300	15	360	11	270	26	630
Copper	110	1100	12	120	8.9	89	21	210
Lead	46	460	5.0	50	3.8	38	8.8	88
Nickel	220	2200	24	240	18	180	42	420
Zinc	190	9100	21	1000	15	750	36	1800

Notes: [1]Assumed equal to raw rinsewater loadings.
[2]11% of loadings are discharged untreated, based on MOE, 1991.
[3]82% of loadings are discharged to treatment, either onsite (78%) or prior to secure landfilling (4%), based on MOE, 1991; 90% treatment removal efficiency assumed.
[4]Total releases include treated and untreated spent process solutions.

Table 3.8
Releases from Sludges

Element	Wastewater						Spent Process Solutions						Total Releases from Sludges[5] (kg/day)	
	Total Loadings[1] (kg/day)		Loadings to Pretreatment[2] (kg/day)		Releases from Sludges (kg/day)		Total Loadings[3] (kg/day)		Loadings to Pretreatment[4] (kg/day)		Releases from Sludges (kg/day)			
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Arsenic	0.91	9.1	0.80	8.0	0.72	7.2	0.91	9.1	0.74	7.4	0.67	6.7	1.4	14
Cadmium	2.2	22	1.9	19	1.7	17	2.2	22	1.8	18	1.6	16	3.3	33
Chromium	130	3300	120	2900	110	2600	130	3300	110	2700	99	2400	200	5000
Copper	110	1100	96	960	86	860	110	1100	89	890	80	800	170	1700
Lead	46	460	40	400	36	360	46	460	38	380	34	340	70	700
Nickel	220	2200	190	1900	170	1700	220	2200	180	1800	160	1600	330	3300
Zinc	190	9100	170	8000	150	7200	190	9100	150	7500	140	6800	290	14000

Notes:
[1] From Table 3.5.
[2] 88% of rinsewater loadings are discharged to treatment, based on MOE, 1991; 90% treatment removal efficiency assumed, with all metals transferred to the solid phase.
[3] Assumed equal to raw rinsewater loadings.
[4] 82% of spent process solution loadings are discharged to treatment, based on MOE, 1991.
[5] Total releases include sludges from treatment of rinsewater and spent process solutions.

The recycling of nickel and nickel-copper based sludges at primary metallurgical facilities has been in place for several years. The Canadian Association of Metal Finishers (CAMF) estimates that about 100 tonnes of nickel metal are recovered annually. Assuming an average metal content of 10 to 12 percent, CAMF estimates this recycles about 1,000 to 1,200 tonnes of sludge per year. These sludges also contain lesser amounts of copper and chromium and CAMF estimates their percentages at 2 percent and 3 percent respectively in the same total tonnage of sludge.

Summary

Release estimates from rinsewater, spent process solutions and sludges are summarized in Table 3.9.

MUNICIPAL RELEASE ESTIMATES

Introduction

The preceding sections presented release estimates for the Canadian metal finishing sector as a whole. It is important to note that larger urban centres, where a significant portion of the industry is located, may be actively enforcing a sewer use bylaw and that this may have a significant impact on release estimates. The purpose of this section is to apply the estimate methodology using demographic information more typical of these larger urban centres.

As an example of how characteristics of the industry may differ in a larger urban centre, consider information available for Metropolitan Toronto. In Toronto, 93 metal finishing facilities are monitored under the sewer use program. Of these, 91 facilities (98 percent), representing 98.7 percent of the total flow, have some form of pretreatment system in place. This compares to the Ontario averages of 78 percent of facilities with pretreatment in place, representing approximately 88 percent of total flows, used in the Canada-wide release estimates presented previously.

Mean concentrations for each facility for each of four metals have been calculated. Table 3.10 summarizes information regarding mean concentrations as an indication of the degree of pretreatment achieved.

Table 3.9
Summary of Releases

Element	Releases from Liquid Effluent[1] (kg/day)		Total Releases from Sludges[2] (kg/day)		Total Releases (kg/day)	
	Low	High	Low	High	Low	High
Arsenic	0.36	3.6	1.4	14	1.8	18
Cadmium	0.87	8.7	3.3	33	4.2	42
Chromium	53	1300	200	5000	260	6300
Copper	44	440	170	1700	210	2100
Lead	18	180	70	700	88	880
Nickel	87	870	330	3300	420	4200
Zinc	76	3700	290	14000	360	18000

Notes: [1]Liquid effluents include treated and untreated rinsewater and spent process solutions (Tables 3.6 and 3.7).
[2]From Table 3.8.

Table 3.10 Summary of Metropolitan Toronto Mean Concentrations Discharged to Sanitary Sewer from Metal Finishing Operations			
Element	**Percentage of Facilities Monitored for Element**	**Percentage of Facilities Monitored with Mean Concentration Less than 1 mg/L**	**Maximum Mean Concentration (mg/L)**
Chromium	63	76	3.25
Copper	69	48	17.00
Nickel	67	79	3.32
Zinc	57	66	31.93

The large percentage of facilities, generally greater than 50 percent, achieving mean concentrations less than 1 mg/L indicates that the levels of pretreatment are high in the majority of cases.

It is not appropriate to make direct comparisons between data for Metro Toronto, for example, and the Canada-wide estimates presented previously. In order to allow comparison, the demographic information used in the estimate methodology has been adjusted to better reflect the situation in larger urban centres. The following assumptions have been used:

- 95 percent of total onsite loadings receive treatment, compared to 88 percent of rinsewater loadings and 78 percent of spent process solution loadings assumed to be typical for "Canada-wide"
- 95 percent removal efficiencies are achieved, compared to 90 percent assumed earlier
- 89 percent of spent process solutions by volume are managed onsite, as assumed to be typical for "Canada-wide", but 95 percent of these loadings receive treatment
- Loadings from spent process solutions treated offsite, estimated at 4 percent by volume in the Canadian release estimates are not included, since these loadings are not reflected in the municipal database.

In Figure 3-6, low and high estimates generated by the estimate methodology for chromium, copper, nickel and zinc are presented in units of kg/day/facility. For this calculation, the total loadings estimated have been divided by a total of 600 Canadian facilities. These estimates are also compared to loadings calculated from the municipal database for Metro Toronto, Montreal, Halton and Windsor in Figure 3-6. The raw data for Figure 3-6 is summarized in Table 3.11.

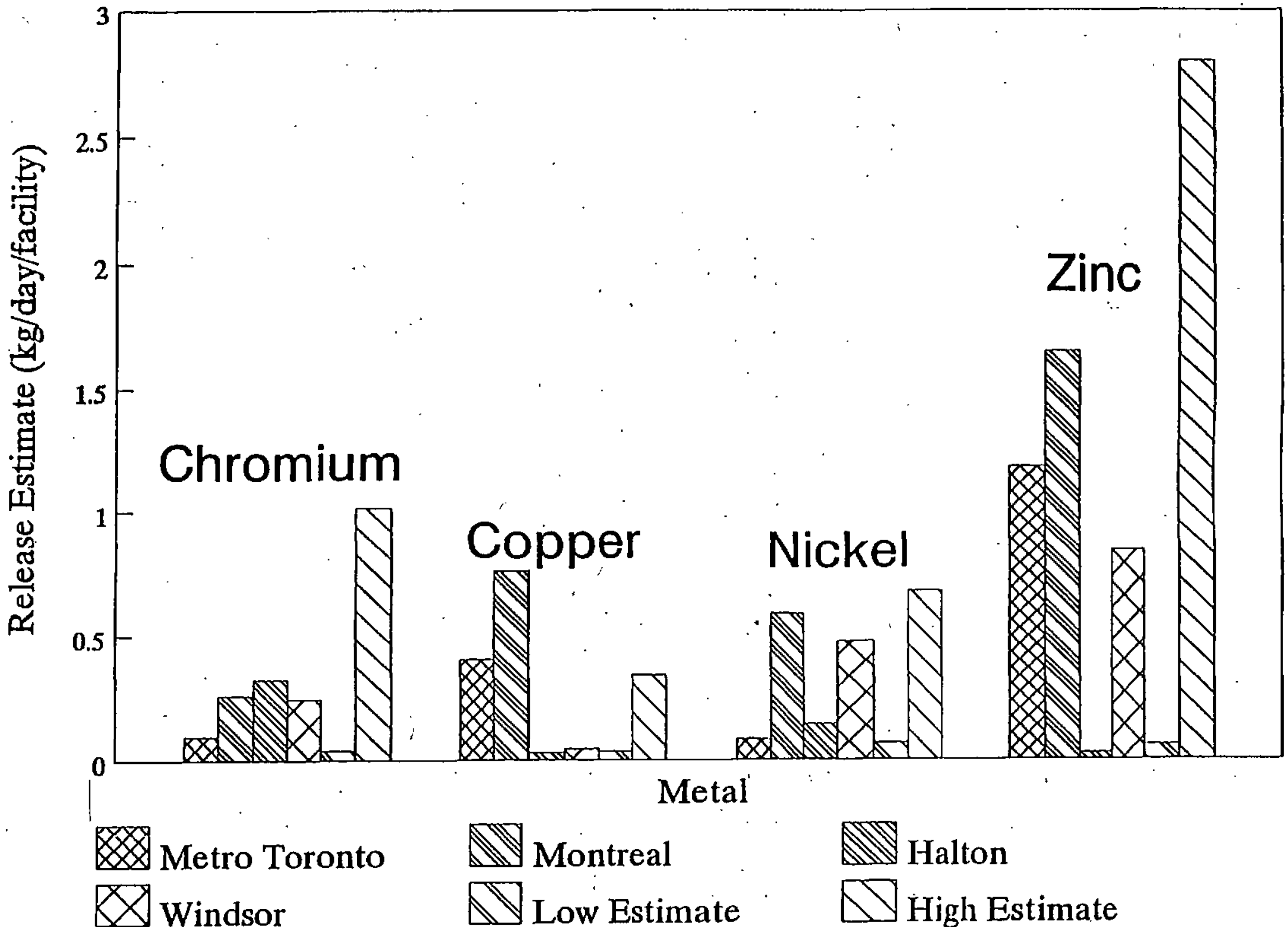


FIGURE 3-6:

SUMMARY OF RELEASE ESTIMATES TO SANITARY SEWER

Table 3.11
Summary of Release Estimates to Sanitary Sewer

Source of Estimate	Number of Facilities	Percentage of Facilities	Daily Release per Facility for Each Metal (kg/day/facility)			
			Chromium	Copper	Nickel	Zinc
Metro Toronto	93	16%	0.10	0.40	0.08	1.18
Montreal Urban Community	72	12%	0.26	0.76	0.59	1.65
Halton	14	2%	0.32	0.03	0.14	0.03
Windsor	16	3%	0.24	0.04	0.48	0.84
Canadian Release Estimate - Low*	600	100%	0.04	0.03	0.07	0.06
Canadian Release Estimate - High*	600	100%	1.01	0.34	0.68	2.79

Note: *These values reflect areas where sewer use bylaws are enforced: 89% of spent process solutions by volume are managed onsite, 95% of loadings by volume are treated and all facilities achieve 95% removal efficiencies.

The estimates for larger urban centres developed using the methodology reasonably reflect the data available from municipalities, especially given the considerable variability among loadings estimates based on municipal data. In addition, the methodology has provided Canada-wide release estimates, and information regarding sources and releases to both liquid wastes and sludges.

AIR EMISSIONS

SOURCES OF PRIORITY SUBSTANCES

There are two major sources of air emissions in the metal finishing sector. The first of these, solvent degreasing, involves the use of chlorinated and, increasingly, non-chlorinated organic solvents. Air emissions and inappropriate management of spent solvents are the major release pathways for these compounds in the metal finishing sector. Only trace amounts have been detected in effluent and wastewater treatment sludges, as noted earlier. Solvent degreasing operations were not included in the scope of this study, since, as noted in the Introduction, other federal initiatives are examining it in greater detail (Chen, 1992). No further discussion is provided here.

The second air emission source results from the ventilation of metal finishing unit operations including baths and rinses. Mists generated during normal operations may be collected and exhausted by the general ventilation system. These could include fumes from heated baths as well as mists generated during spray rinsing. Such emissions may be corrosive in nature and materials of construction for the ventilation system are selected for corrosive service when required. No significant amounts of metals are believed to be entrained in these mists, with the one most likely exception being chromium.

In electrolytic processes using chromic acid, such as decorative and hard chromium plating and chromic acid anodizing, chromium, unlike any other metal used in metal finishing, is present as an anion and is considered electrically "weak". Most of the current supplied to these baths is consumed in producing hydrogen gas at the cathode and on the tank walls. Oxygen gas is also formed at the anode. The generation and subsequent release of this gas results in mist formation. Aqueous chromium may become entrained in this mist. Other contributing factors to mist generation may include elevated temperatures in the bath and air sparging provided for mixing. Since the mists generated from electrolytic chromic acid tanks present an occupational health hazard, these tanks are generally fitted with fume hoods or dedicated exhaust ducts.

Air pollution control devices for both general ventilation and chromic acid tank ventilation include mist eliminators, condensers, wet scrubbers, packed bed scrubbers and others. These are described in greater detail in Section 4. Waste streams from these devices are commonly treated and/or discharged with other wastewater from the facility. In this sense, they are considered liquid effluent sources and have already been considered in the estimates developed for wastewater and sludges presented in the previous section.

ESTIMATED RELEASES

As noted earlier, air emissions of metals from metal finishing facilities are not believed to be significant. An analysis of the limited available data on chromium emissions was undertaken to assess their significance, since chromium is the most likely of any of the metals to be emitted. This analysis uses the following data to develop a worst-case scenario for the release of chromium from metal finishing facilities:

- Data on airflow rate to scrubbers used for the removal of chromium bearing mists at two large U.S. aircraft metal finishing facilities.
- Data on chromium concentrations released from one tank at one of these facilities.
- Likely future requirements under the U.S. Clean Air Act, as summarized in Table 3.12.

Table 3.12
Possible Future Maximum Achievable Control Technology (MACT) Standards for Air Emissions from Chromium Plating in the U.S.[1]

Type of Chrome Plater	Technology	Possible MACT Standard (mg Cr/m³ of air)
Existing decorative chrome	Use of wetting agents to reduce surface tension to 40 dynes/cm	0.01
Existing hard chrome	Packed bed scrubber	AP-42 ≈ 0.048 0.03
New decorative chrome	Must use trivalent plating	-
New hard chrome	Packed bed scrubber	0.01

Notes: 1. Altmayer, 1992b.

Airflow rates to chromium scrubbers at these two large facilities are 45,000 and 180,000 cfm, respectively. Under test conditions, chromium concentrations in uncontrolled air emissions from one tank at one of these facilities ranged from 20 to 1,500 ug/m^3 (Pegnam and Pilat, 1992). Maximum concentrations were correlated with the plating cycle; that is, concentrations peaked at approximately the same time as electrical current flowing to the process. Based on the assumption that the maximum concentration of 1,500 ug/m^3 (1.5 mg/m^3) applies at all times, the maximum estimates of uncontrolled chromium emissions from each facility are both in the 1 to 10 kg/d range (see Table 3.13; based on 16 hour days). Under the least stringent possible control requirements reported in Table 3.13 (0.03 mg/m^3), these uncontrolled emissions would be reduced to significantly less than 1 kg/d (see Table 3.4).

Table 3.13
Estimated Releases of Chromium to Air for Two Large Metal Finishing Facilities

Air Flow Rate (cfm)[1]	Uncontrolled Air Emissions[2]		Controlled Air Emissions[3]	
	Chromium Concentrations in Air (mg/m^3)[2]	Air Emissions (kg Cr/d)	Chromium Concentrations in Air (mg/m^3)[3]	Air Emissions (kg Cr/d)
45,000	1.5	1.8	0.03	0.037
180,000	1.5	7.3	0.03	0.15

[1]Two large metal finishing facilities are represented by their respective air flow rates.
[2]Based on Pegnam and Pilat, 1992
[3]Based on Altmayer 1992b.

In order to assess the relative significance of these emissions, it is useful to make a comparison to the estimates for releases to liquids and sludges summarized in Table 3.9. Three important factors must be taken into account:

- The releases for two large facilities presented in Table 3.13 are not representative of smaller facilities. More representative values for the average facility would be 1 kg Cr/d for uncontrolled emissions and 0.02 kg Cr/d for controlled emissions (these values are approximately equivalent to an air flow rate of 25,000 cfm).
- Approximately 40 percent of facilities in Canada (or 240 out of 600) use electrified chromium processes likely to generate air emissions. This value is an estimate based on the industry demographics presented in Table 3.2.
- The emission estimates presented in Table 3.13 represent worst case scenarios for chromium concentrations and therefore total estimates should be compared to the "high" estimate of releases to liquids and sludges presented in Table 3.9.

If it is assumed that none of the 240 plants with chromium air emissions have controls, total air emissions represent less than 4 percent of estimated releases to liquid and sludges. If all 240 plants achieve 0.03 mg/m^3 (or 98 percent removal) through the use of controls, total air emissions represent less than 0.1 percent of estimated releases to liquid and sludges. Although these totals for air emissions are significantly less than the release estimates for liquids and sludges, it may be important to recognize the potential impacts of air emissions of chromium when considering only a single facility. Similarly, it is believed that emissions of other metals are less than those for chromium since they are less likely to become entrained in mists released from the process tanks.

Section 4
ENVIRONMENTAL CONTROL TECHNOLOGIES

INTRODUCTION

This section addresses a range of environmental control technologies/strategies used in the metal finishing sector. Those described first are so-called "4-R's" technologies/ strategies: waste reduction, reuse, recycling and recovery. The final sections deal with treatment of wastewater and spent process solutions, sludge management and air emissions control in the metal finishing sector. The information presented for each technology includes a description of the technology and its advantages and disadvantages, and factors affecting its choice for a particular application. The section closes with discussions regarding the extent of use and costs of wastewater and spent process solution treatment/recovery technologies.

WASTE REDUCTION

INTRODUCTION

Often the most cost-effective method to reduce releases of priority and other substances is to reduce waste generation at its source. Additional benefits to implementing a waste reduction program can include reduced operating costs due to recovery of metals, improved product quality and occupational safety as well as increased production rates.

The feasibility of implementing waste reduction measures is typically highly dependent on case- and site-specific factors such as: available space, customer imposed specifications, etc.

Several methods which have been implemented in the metal finishing sector are described below. Except where noted, this information has been developed largely from Higgins (1989).

DRAG-OUT MINIMIZATION

Drag-out is that portion of the plating solution which remains on the part once it is removed from the plating bath. Obviously, the need for rinsewater can be minimized if the amount of drag-out on the parts is also minimized. In addition, metal or other chemical losses from the process tank can be minimized and bath life extended. Several strategies exist for drag-out minimization as described below, but their effectiveness in a given situation is dependent on the extent of existing drag-out. In general, barrel plating tanks are more prone to drag-out difficulties than rack plating tanks, as are those parts whose shape and design may result in excessive drag-out.

Processes, such as cadmium, zinc and decorative chrome, whose plating times are relatively short, are also characterized by relatively large quantities of drag-out due to frequent withdrawal of parts from the tank.

Longer withdrawal/drainage times may be used to allow more of the plating solution to drain back to the process tanks. In addition, slowing the velocity of withdrawal will minimize the amount of drag-out adhering to parts. The impacts of this method on production schedules must be considered in consideration for implementation.

Improved racking orientations and part design can reduce the amount of drag-out carried out of the tank by parts.

Reduced bath viscosity or surface tension both allow drag-out to drain more quickly from parts. Viscosity may be reduced by reducing the chemical concentration of the bath or by increasing its temperature. Surface tension may be decreased through the use of wetting agents or by increasing bath temperature.

Air knives may be used to blow or evaporate drag-out off workpieces (Cushnie, 1985).

Drag-out recovery devices, such as drip bars, drain boards and drip tanks, allow drag-out to be recovered and returned to the plating bath prior to rinsing steps.

RINSING TECHNIQUES

Rinsing is used to remove residual drag-out from parts and racks. Traditional methods of rinsing have usually entailed the use of a single, continuous-flow tank for this purpose. There are several methods available to decrease the volume of rinsewater used. In general, these methods reduce the volume of wastewater requiring treatment. This may reduce the costs of treatment, unless the wastewater becomes concentrated to a point where treatability, using conventional physical or chemical technologies, is impaired, due to the presence of interfering compounds, suspended or dissolved solids or due to excessive chemical requirements. Conversely, highly concentrated rinsewater may be suitable for recycle to the plating tanks as makeup for evaporative losses, thereby substantially reducing the need for treatment and providing for metal recovery. The performance and cost of implementing these modifications in rinsing techniques, however, is highly case- and site-specific. Several methods for modifying rinsing techniques are described in the following paragraphs.

Counterflow rinsing involves the sequential immersion of parts in a series of rinse tanks. Rinsewater in these tanks flows in a direction opposite to the movement of parts. The optimal number of tanks used is usually three and the concentration of contaminants in each successive tank can decrease by a factor of ten. This method can reduce rinse-water flows by as much as 95 percent as compared to traditional methods. Disadvantages to this method include the space requirement for additional tanks and increased production time since the parts must be rinsed in more than one tank.

The costs associated with additional tanks and space should be evaluated relative to the reduced cost of treatment typically realized. The cost-effectiveness potential is usually higher for new metal finishing installations than for retrofitting existing facilities.

Spray rinsing, also referred to as fog rinsing, conducted over the plating tanks, can increase the efficiency of rinsewater use by allowing rinsewater to drain directly back to the plating tanks to make up for evaporative losses. This can result in recovery of 75 percent of the metals contained in the drag-out. This method is best suited to flat parts such as Printed Circuit Boards (PCBs) which drain efficiently. It is also well-suited in cases where there is insufficient space for additional rinsing tanks. This method is applicable to plating baths which are operated at elevated temperatures so that evaporation rates are sufficiently high to allow the addition of rinsewater makeup to the tank. Spray rinsing is also commonly used within the confines of empty rinse tanks. This allows collection of a relatively small volume of rinsewater for reuse, treatment and/or recycle, but does not require that parts be delayed over the plating tanks for drainage. For this reason, this application of spray rinsing does not necessarily require parts which drain as efficiently as those rinsed over the plating tank.

Still or "dead" rinsing involves the use of a tank of rinsewater which is not continuously overflowing and being replenished. Such dead rinsewaters can be returned to the plating tank to make up for evaporative losses. In some cases increasing the temperature of the bath to increase evaporative losses may be justified in order to recycle the dead rinsewater.

Cascade rinsing is the use of rinsewater effluent from one operation as rinsewater supply for a compatible operation. Its application is limited by the fact that it can complicate operations by tying them together, possibly resulting in changes to production schedules, and also by the fact that operations must be compatible. For example, the use of acid dip tank rinsewater as rinsewater for an alkaline cleaning operation is a potentially compatible operation since the acidic nature of the rinsewater increases its utility in rinsing alkaline drag-out.

Improved mixing in rinse tanks means that a lower rinsewater flowrate can be tolerated since the full volume of water in the tank is being utilized and recesses in parts are being fully rinsed. One common method to help achieve improved mixing is to ensure that the influent water line is submerged and as close to the base of the tank as possible. This evenly distributes influent water throughout the tank and creates a rolling action. A second alternative involves the use of aeration, achieved using low-pressure blowers and perforated piping installed in the base of the tank.

Flow control can be achieved using water supply control valves to keep influent flowrates to the rinsing tanks at their minimum acceptable values despite variations in line pressure. Flow restrictors are sometimes used to limit the maximum flowrate in rinsewater supply lines. This technique has limited effectiveness where high flowrates are required to provide adequate mixing in the tanks.

Conductivity control can be used to operate rinse tank flow control valves on the premise that clean water has a lower conductivity than that contaminated with drag-out. Although widely used in the plating industry because they are relatively inexpensive, conductivity controllers do not perform well if they are not regularly maintained and their use has often been abandoned due to this factor. Disadvantages to their use include frequent cleaning and recalibration required and difficulty in establishing appropriate setpoints.

Timers can be used to reduce the daily rinsewater flow by providing influent water only when rinsing is taking place. These also help to ensure adequate flow and mixing at the appropriate times.

MATERIALS/PROCESSES SUBSTITUTION

Material substitutions may be used to eliminate undesirable constituents from the metal finishing process, thereby reducing waste management costs and, in some cases, toxicity of residuals. The feasibility of implementation of waste reduction methods is highly case- and site-specific.

Alternative metal finishing processes are finding increased use for those cases in which waste management costs are high and/or residuals from traditional processes have unacceptably high levels of toxicity. A number of these are described below. Implementation of these alternatives could entail a complete refurbishing or replacement of the metal finishing process line and could have a significant impact on the overall economics of the metal finishing operations. These factors should be weighed against potential benefits from reduced costs associated with wastewater treatment/waste management.

Non-cyanide baths are increasingly being used in favour of the alkaline cyanide baths traditionally used in the plating of zinc, cadmium, brass and precious metals. This eliminates the need for additional treatment technologies typically required when metal cyanide complexes are present in plating bath dumps and rinsewater. Most of the research and development in this area has been devoted to zinc plating due to the high volume production of parts finished using zinc. Many alternative bath solutions have been developed: the most frequently used are the acid sulphate, chloride and fluoborate baths. Neutral chloride baths using ammonium or potassium ions as well as chelating agents are less popular due to the added complexity of treating chelated compounds. Similar acid baths have been developed for cadmium plating. Depending on materials of construction, conversion to these acid baths may be expensive, but the savings in eliminating cyanide treatment can be greater in some cases. In the case of zinc acid baths, product quality is comparable to that obtained using cyanide baths. In the case of cadmium acid baths, more parts cleaning prior to treatment is required and bath throwing power and cathode efficiency may be reduced. Non-cyanide baths are more expensive than cyanide baths, but these costs must be weighed along with a number of other factors including:

- Cost of corrosion-resistant equipment
- Differences in labour and chemical costs
- Changes in production rate
- Avoided cost of cyanide treatment.

Non-chelated chemicals can typically be removed from wastewaters by less costly technologies than can chelated compounds. Depending on the case-specific circumstances and product specifications, it may be possible to substitute non-chelated chemicals and derive economic benefits on treatment technologies.

Deionized or distilled water used as rinsewater and as evaporative makeup can improve plating quality and avoid complications in subsequent waste treatment (Kushner and Kushner, 1981). The cost-effectiveness of this practice should be evaluated incorporating the potential for reduced waste treatment costs.

Trivalent chromium plating used in place of traditional hexavalent chromium plating results in lower chromium drag-out and lower sludge volumes since baths are less concentrated. The need for a reducing agent such as sodium bisulphite in wastewater treatment is also eliminated. It should be noted, however, that neither military nor automotive specifications currently recognize trivalent chromium plating as a suitable substitute. A further disadvantage is that trivalent plating solutions can be as much as two to three times as expensive as hexavalent baths.

Vacuum deposition of cadmium can be used as an alternative to electroplating which often involves the use of cyanide baths. This method eliminates the need for traditional wastewater treatment, but is accompanied by a number of other concerns. Operationally, it is difficult to achieve a uniform deposit on an irregularly shaped part and adhesion of the deposit to the base metal is not as strong as is achieved using electroplating. From an environmental standpoint, management of cadmium vapours and condensed aerosols requires careful control to avoid air emissions.

Ion vapour deposition (IVD) of aluminum may be used in place of cadmium plating for corrosion protection and has been developed in response to environmental concerns specific to the use of cadmium. Its advantages include the fact that aluminum has equivalent or better properties than cadmium for corrosion protection. However, IVD has had only limited success in replacing cadmium plating due to the fact that it requires a relatively clean working environment to prevent contamination of the vacuum chamber used by ambient gases. In addition, the operation is more complex and requires substantially more labour and skill to produce the equivalent product.

Electroless nickel plating can replace conventional nickel electroplating where greater protection of the substrate is required since electroless deposits are less porous than conventional deposits. Nickel concentrations in electroless baths are less than 10 percent of those for Watts nickel baths resulting in lower drag-out quantities and sludge production. However, in cases where conventional electroplating can be used, it is almost always more cost-effective. This is due to the use of chemical reducing agents in electroless plating, and the increased costs of treating wastewaters containing chelated compounds.

EXTENDING BATH LIFE

Periodically, metal finishing process solutions may become degraded and/or contaminated to the point where they must be replaced. The resulting waste is either treated onsite or hauled offsite for treatment and/or disposal. The cost of these waste management practices has increased significantly over recent years and methods for extending bath life have become an important means of reducing the number of bath dumps necessary. Some of the more important of these methods are described in the following paragraphs. This information is based on Cushnie (1985).

Filtration, commonly using cartridge filters, continuously removes suspended solids which may result in roughness or other plating defects on the workpieces. This applies to chromium, nickel, copper, cadmium, zinc and electroless nickel baths.

Activated carbon is used to remove degraded organic constituents of the bath such as brighteners prior to replenishment and is commonly used for nickel baths.

Chemical treatment such as peroxide or permanganate oxidation of organics in a bath may be carried out prior to replenishment in order to ensure that the correct concentrations are achieved using replenishment. Other chemical treatment methods include the precipitation of undesirable potassium carbonate from cyanide baths using calcium or barium hydroxide, barium cyanide or calcium sulphate.

Replenishment of bath additives such as brighteners can also extend bath life.

Dummying is an electrolytic purification method which may be used in nickel and copper plating baths to remove trace metals, such as divalent iron, that affect plate quality. It may also be used in chromic acid baths (used for electroplating, anodizing, etching, chromating and sealing) to oxidize trivalent chromium buildup to the hexavalent form.

Ion exchange, discussed in detail under Waste Recovery, may also be considered as a means to extend bath life.

HOUSEKEEPING PRACTICES

Simple, readily implemented housekeeping practices can reduce waste generation at metal finishing facilities. These practices can decrease operating costs, improve product quality, and increase production rates. These practices include but are not limited to:

- Repair of leaking tanks, pumps, valves, etc.

- Periodic inspection of tanks and tank liners to avoid failures that may result in accidental tank dumps
- Periodic inspection of steam coils and other heat exchanger equipment to prevent contamination of the plating bath with steam condensate or cooling water
- Installation of high-level alarms on process tanks to avoid accidental bath overflows.
- Maintenance of plating racks and anodes to minimize contamination of the plating bath, including removal of racks and anodes when the bath is not in use
- Minimization of the amount of water used in cleanup operations. The use of spring-loaded hose nozzles and the installation of water meters on wash-water supply lines sometimes help.
- Training of production personnel regarding the importance of minimizing bath contamination and wastewater discharge
- Thorough cleaning and rinsing of parts prior to plating to prevent bath contamination
- Removal of parts from baths when not being plated to prevent bath contamination.

WASTE REUSE

In some cases, it may be possible to reuse cooling water or contaminated rinsewater directly in process operations. For example, cooling water may be suitable as rinsewater and, as described under Rinsing Techniques, cascade rinsing may be possible if compatible operations are in place.

Waste reuse may be an important facet of a zero-discharge strategy. These practices are limited by site-specific factors such as the sensitivity of operations to contamination and increased complexity of the process flow, as well as the availability of space to implement the retrofitting required.

WASTE RECYCLING

Depending on the degree of wastewater treatment practiced, it may be possible for treated effluent to be recycled for use as rinsewater, cooling water or for other purposes. Waste recycling may be an important facet of a zero-discharge strategy. This practice is limited by economics as well as by technical factors since in many cases it typically remains cost effective to discharge treated effluent and use fresh intake water rather than to treat the effluent to the level required for recycling applications. In addition, space constraints may exist for the retrofitting required to install advanced treatment or to direct treated effluent to process uses.

WASTE RECOVERY (FROM RINSEWATER)

WASTE SEGREGATION

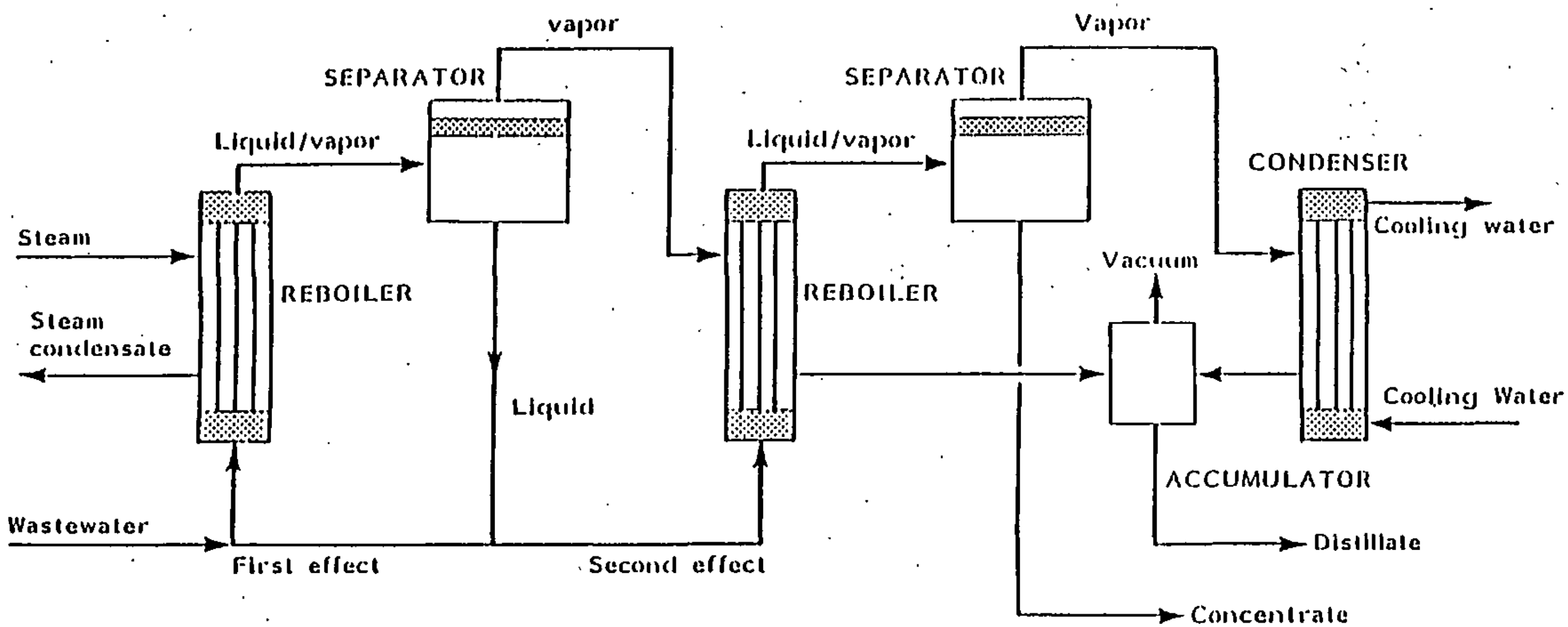
The following paragraphs describe technologies for the recovery of metal values from rinsewater. The feasibility of implementing these technologies is dependent on site- and case-specific factors, the most important being the extent to which waste segregation is practised. As a general rule, waste recovery will be most effective where waste segregation is maximized. The costs of waste segregation (e.g. retrofitting of inplant process sewers) must be weighed against the savings to be realized from metal recovery and from lower costs for rinsewater treatment.

EVAPORATION

Evaporation is achieved by boiling rinsewater to concentrate it for return to the plating bath. One typical configuration for evaporation is depicted in Figure 4-1. Steam condensate from the process can be reused as rinsewater. If operated under vacuum, evaporators consume less energy due to the lower boiling point and thermal degradation of plating additives may be avoided. If the evaporation rate from the plating baths is increased, the degree of concentration required from the evaporators is reduced. One means to achieve this in an energy efficient manner is aeration of the plating baths. Evaporation is most cost-effective for high temperature baths such as those used in chromium plating, but it has also been effectively used for ambient temperature baths such as nickel and metal cyanide.

ION EXCHANGE

Ion exchange (IX) involves the exchange of ions from a solid matrix (resin) with ions from solution. Cations or anions may be selectively removed from solution using this technology. Once exchange sites on the resin are saturated, the resin is regenerated by passing an acid or base through it. In the metal finishing sector, rinsewater may be purified for recycling using ion exchange. Metals may also be recovered in the concentrated regenerant and returned to the plating bath. An IX system typically consists of a wastewater storage tank for flow equalization, prefilters to prevent fouling of the exchange resins, cation or anion exchange vessels and caustic or acid regeneration equipment.



REFERENCE: CUSHNIE, 1985

FIGURE 4-1:

TYPICAL DOUBLE-EFFECT EVAPORATION

Anionic exchange resins have been used to recover chromic acid (as depicted in Figure 4-2), cyanide and metal cyanide complexes, while cationic resins have been used to recover cationic metals. IX has also been used to recover spent acid cleaning solutions and to purify plating baths for extended service life.

In general, IX applications are most successful where the rinsewater treated is relatively dilute and a relatively low degree of concentration is required for recycle of regenerant to the plating bath. For this reason, it may sometimes be necessary to use it in conjunction with evaporation. Successful commercial applications include acid-copper, acid-zinc, nickel, tin, cobalt and chromium plating baths. IX is most cost-effective when drag-out rates are relatively high and the cost of wastewater treatment and sludge disposal is prohibitive.

When ion exchanged water is recycled as rinsewater, fresh water consumption can be reduced by as much as 90 percent. In some cases, however, regenerants are not suitable for returning to the plating bath and may be difficult and expensive to treat. The environmental and economic benefits of reduced water consumption are sometimes offset by treatment costs.

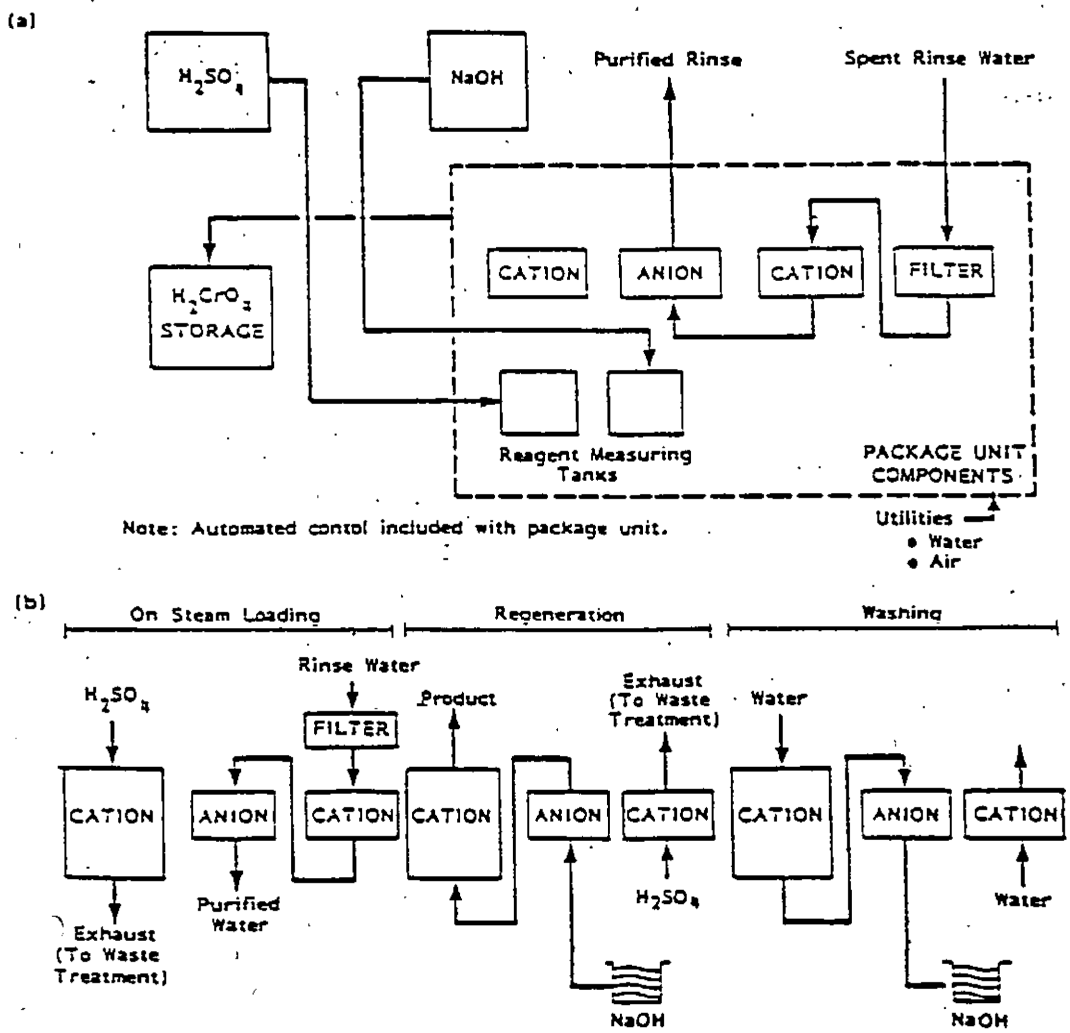
ELECTROLYTIC RECOVERY

Metal can be recovered from relatively concentrated rinsewater, as well as from spent etchants containing copper, through the use of electrolytic recovery. In the traditional application of this process, stainless steel electrodes are used to recover elemental metal at the cathode, while oxygen is evolved at the anode. A number of advanced methods have also been developed but the basic operating principle is the same. Metal recovery rates of 90 to 98 percent have been reported, depending on the system in use (MOE, 1991), and 80 percent or more of the recovered solution may be recycled as rinsewater (Kushner and Kushner, 1981). An additional benefit of this process for cyanide-bearing rinsewater is that cyanide is simultaneously destroyed through oxidation (MOE, 1991). The cost-effectiveness of electrolytic recovery will depend on metal values as well as the savings realized in wastewater treatment. This process has been applied at a demonstration level to recover copper, tin, and silver. Its use as a wastewater treatment technique, however, is limited because the cathode reactions are not complete at reasonable times and voltages.

MEMBRANE TECHNOLOGIES

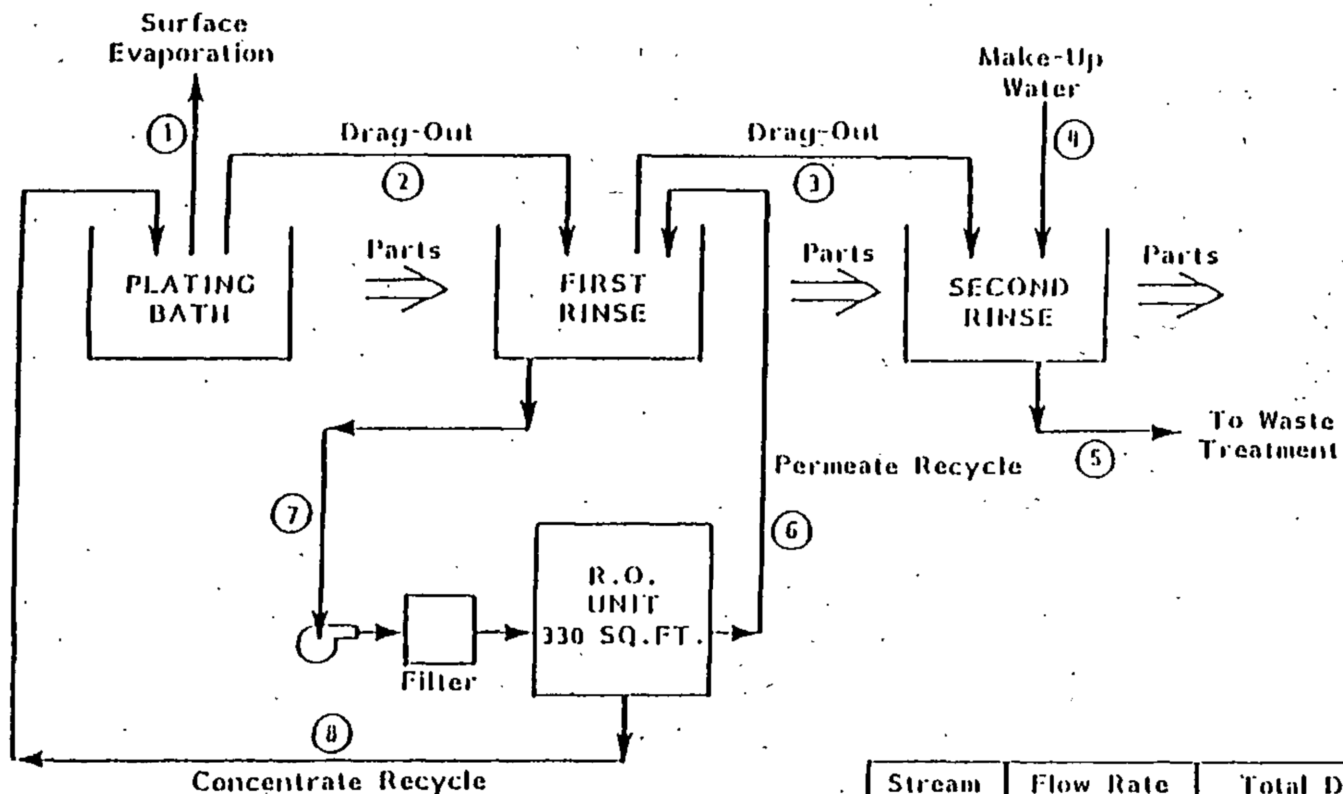
A number of membrane technologies have been applied for recovery purposes in the metal finishing sector, the most important of which are described below.

Reverse osmosis (RO), depicted in Figure 4-3, is a process in which dissolved constituents are separated from water through the use of a semipermeable membrane and the application of high pressure (400 to 800 psig). The membrane permeate is suitable for recycling as rinsewater, while the concentrate remaining may be returned to the plating bath. RO is typically used for the concentration of divalent ions such as nickel, copper,



REFERENCE: CUSHNIE, 1985

FIGURE 4-2:
CHROMIC ACID RECOVERY RECIPROCATING FLOW ION EXCHANGE
(a) Hardware Components,
(b) Operating Cycle



Stream No.	Flow Rate gph	Total Dissolved Solids--Mg/l
1	3.0	--
2	1.0	252,500
3	1.0	4,300
4	15.0	30
5	15.0	300
6	57.0	86
7	60.0	4,300
8	3.0	84,000

Note: Reverse Osmosis Unit Performance Based on 98% Solids Rejection and 95% Product Recovery
Flux Rate = 0.18 Gal/h/Ft^2
Drag-Out Recovery = 99%

REFERENCE: CUSHNIE, 1985

FIGURE 4-3:

PLATING DRAGOUT RECOVERY USING REVERSE OSMOSIS

cadmium and zinc and can produce 10 to 20 percent solutions for recycle. An RO system typically consists of a membrane, a membrane support structure, a containing vessel, a high-pressure pump, a pre-filter to prevent membrane fouling and an activated carbon filter for the removal of organic constituents from the concentrate.

The most common application of RO has been for concentrating rinsewater from slightly acidic nickel plating baths using cellulose acetate membranes. Nickel recovery efficiencies of 90 to 95 percent can be achieved. Membranes typically require replacement every one to three years. Membranes are less robust in solutions with high oxidation potential, such as chromic acid, or at extremes of pH (less than 2.5 or greater than 11.0). For this reason, other applications in the metal finishing sector have been limited, but the anticipated development of better membranes should increase the use of RO for non-nickel baths.

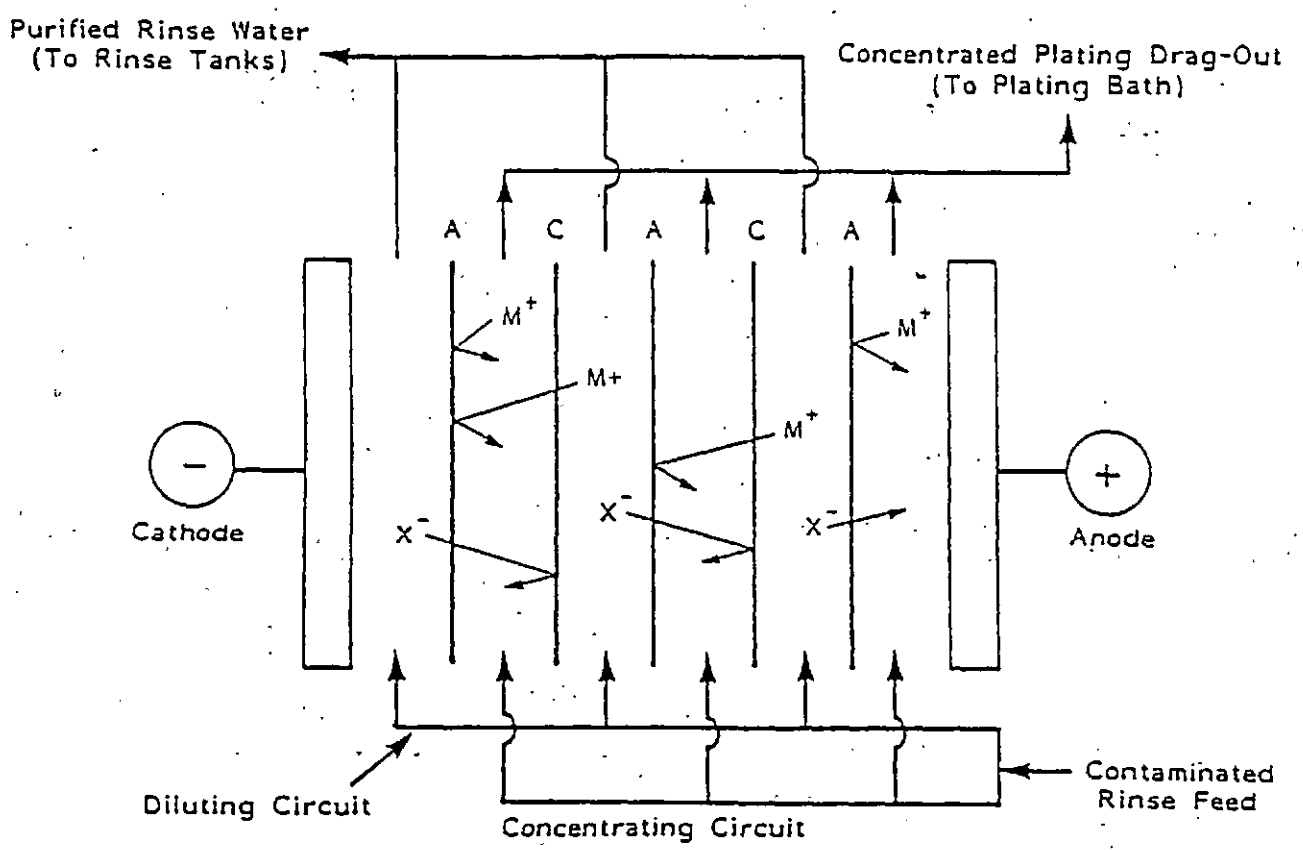
For ambient temperature plating baths, RO must often be supplemented by evaporators. Other factors affecting the cost-effectiveness of RO include cost of fresh water supply and wastewater disposal and the expected useful life of the membrane.

Electrodialysis (ED) separates ionic species in a water solution, usually rinsewater, through application of an electric potential across the solution and the use of semipermeable ion-selective membranes as depicted in Figure 4-4. Cationic species migrate toward the negative electrode and anionic species migrate toward the positive electrode and the selective membranes are used to control this flow. Cation membranes pass only cations such as metals while anion membranes pass only species such as sulphates, chlorides or cyanides. Alternating cells of concentrated and dilute solutions are formed between the cation and anion membranes. Typically, dilute solutions are recycled as rinsewater, while concentrated solutions are returned to the plating bath.

In general, ED is capable of producing more concentrated solutions than IX or RO since it is limited only by the solubility of the species being separated. For this reason, it does not often require the accompanying use of an evaporator when used with ambient temperature baths. One disadvantage ED shares with RO is that it is a non-selective method of concentration. This results in the recycle of impurities such as brighteners and wetting agents to the plating bath unless some other form of treatment such as activated carbon filtration is used as an intermediate step. In addition, careful control of the applied voltage must be maintained in order to avoid the formation of hydroxide ions, since this may result in the precipitation of metals and resultant fouling of the membranes.

LIQUID/LIQUID EXTRACTION (LLE)

Liquid/liquid extraction (LLE) is another potential process for recovery from metal finishing wastes. It takes advantage of the increased solubility of metals such as hexavalent chromium in certain organic phases as well as on the easy separation of the



Legend: C = Cation Selective Membrane
A = Anion Selective Membrane
M^+ = Cations
X^- = Anions

REFERENCE: CUSHNIE, 1985

FIGURE 4-4:
TYPICAL ELECTRODIALYSIS UNIT

organic phase from the aqueous because of specific gravity differences. LLE has only been investigated on a laboratory-scale (Sittig, 1978).

WASTEWATER TREATMENT

INTRODUCTION

A wide variety of wastewaters that require treatment are generated by metal finishing operations. The contaminants requiring removal to the levels dictated by the applicable effluent standards typically include cyanides, chromium, cadmium, lead, nickel, silver, zinc, and organic pollutants. A variety of processes may be used to effect these removals. In addition to the variety of wastewaters and process baths that require treatment, the presence of organic chelating agents resulting from electroless plating operations and alkaline cleaning solutions has the potential to complicate and interfere with some traditional metals removal wastewater treatment practices.

Wastewaters from metal finishing operations are typically segregated at source by characteristics into: hexavalent chromium-bearing, cyanide-bearing, and others. Depending on the case-specific circumstances, wastewaters containing chelated compounds are typically segregated from those containing non-chelated compounds.

The purpose of segregation is to minimize the volume of wastewater requiring specialized treatment such as cyanide destruction and chromium removal. In the description of treatment technologies that follows, technologies appropriate for segregated streams are described first followed by those required for heavy metals removal, as depicted in the generalized pretreatment schematic presented in Figure 4-5. This organization and presentation of the information provides a summary of which technologies are applicable to the removal of specific contaminants.

Depending on site- and case-specific factors, treatment facilities may be installed at satellite locations, close to the individual sources, or larger centralized facilities may be installed. Factors such as space, system complexity, and capital relative to operations and maintenance costs are important in these considerations.

There is an array of treatment alternatives available to the metal finishing industry. The purpose of this section is to highlight those that are most commonly used for typical waste streams. Technologies for wastewater treatment, in many instances, are similar to those for spent process solutions. Spent process solutions are sometimes co-mingled at an acceptable rate (i.e. "bled-in") with the other wastewaters, while in other cases, they are treated on a batch basis using methods similar to those in place for continuous wastewater treatment, as discussed in subsequent sections.

A typical wastewater treatment process might consist of cyanide destruction, hexavalent chromium reduction, neutralization, precipitation and solids removal. This treatment scenario is the one selected for consideration in the U.S. development document for metal finishing (USEPA, 1983) and is depicted as Figure 4-5. The unit processes making up this scenario are described in the following paragraphs, along with other treatment technologies. Where appropriate, information regarding the use of these unit processes for treatment of spent process solutions is also included.

CYANIDE DESTRUCTION

Chlorination is the most common means of cyanide destruction for wastewater and spent plating baths. Cyanide wastes are most common in the electroplating of cadmium, copper, precious metals and zinc. Oxidation of cyanide to the less toxic cyanate is achieved through direct addition of hypochlorite to the waste stream or by addition of chlorine gas and sodium hydroxide. Greater amounts of hypochlorite are required for complete oxidation to carbon dioxide and nitrogen.

Complete oxidation is usually achieved using a two-stage process as depicted in Figure 4-6. The first stage is operated at a pH of 10.0 for the oxidation of cyanide to cyanate and the second at 8.5 for oxidation of cyanate to carbon dioxide and nitrogen. Addition of sodium hydroxide is controlled by pH and addition of hypochlorite is controlled by the oxidation reduction potential (ORP). Each stage is designed to provide approximately one hour retention volume.

Advantages and disadvantages of oxidation of cyanide using chlorination are summarized in Table 4.1.

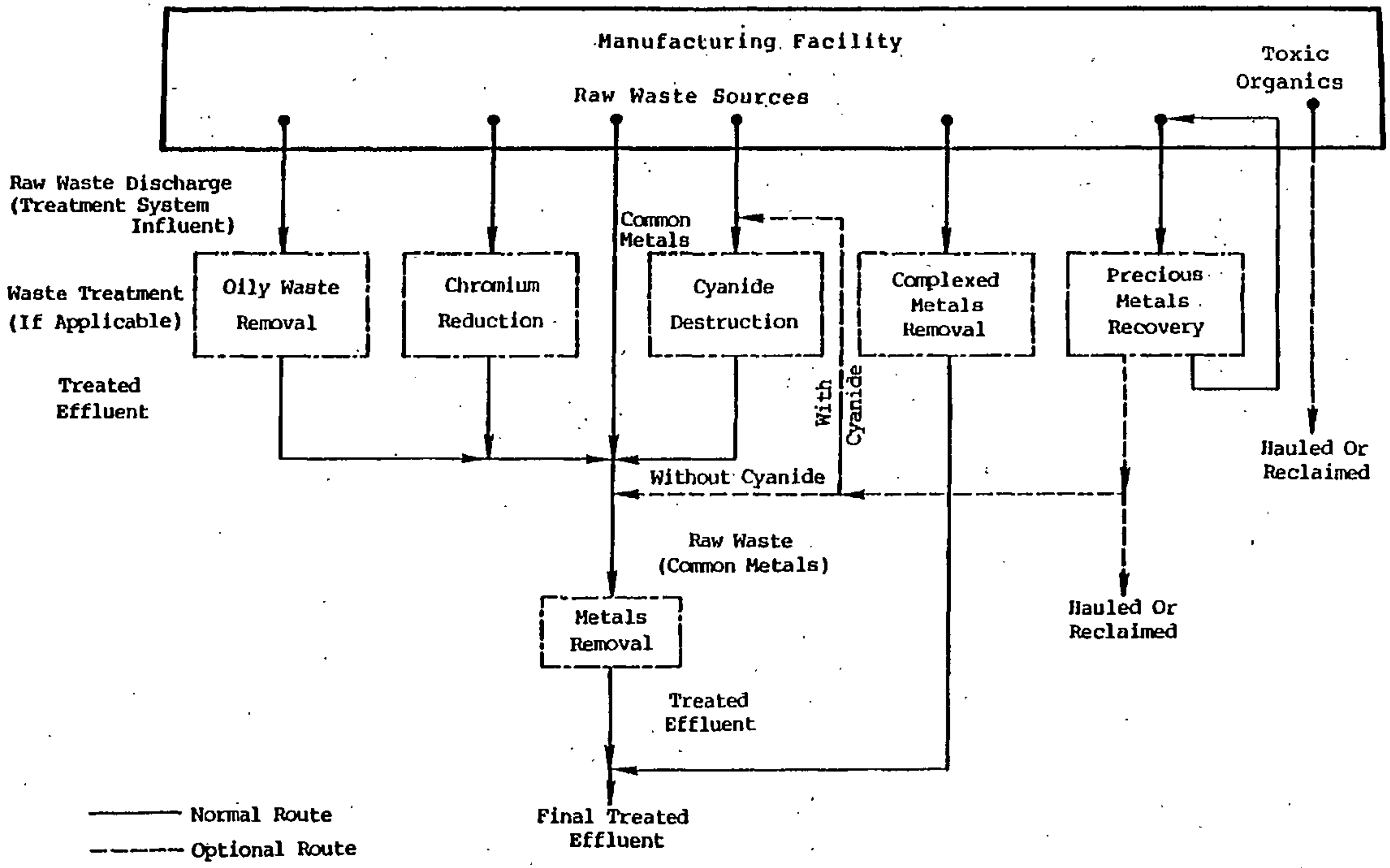
Table 4.1
Advantages and Disadvantages of Cyanide Destruction Using Chlorination

Advantages	Disadvantages
• Widespread, proven application in the sector for over 30 years • Effluent concentrations of cyanide generally less than 1 mg/L • Relatively simple operation and maintenance • No solid wastes or sludges generated	• Safety concerns if chlorine gas used • Potential release of cyanogen chloride (toxic gas) if cyanide oxidized below a pH of 10.0 • Not effective on stable cyanide complexes such as those formed with iron and nickel • Adds to the dissolved solids content of the effluent

A well operated and maintained system can consistently achieve effluent concentrations of 1 mg/L total cyanide.

Other methods of cyanide destruction include:

- ozone oxidation (sometimes supplemented by UV radiation)
- thermal oxidation
- electrolytic destruction
- oxidation by hydrogen peroxide

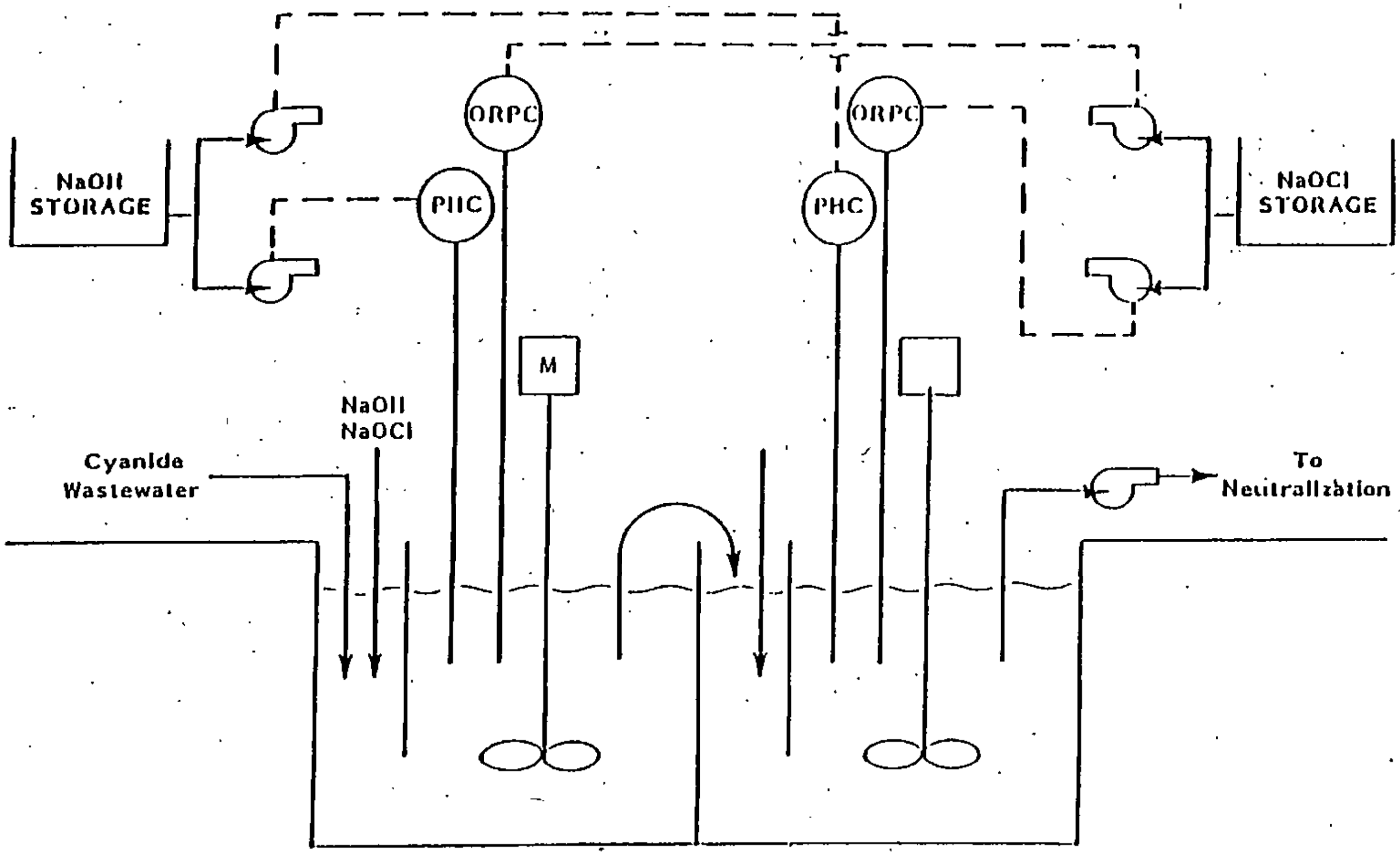


Note: Discharge from precious metals recovery may be hauled in alternative ways, depending on the recovery method in use.

REFERENCE: USEPA, 1983

FIGURE 4–5:

UNTREATED WASTE WATER SOURCES AND PRETREATMENT



REFERENCE: CUSHNIE, 1985

FIGURE 4-6:
TYPICAL CYANIDE DESTRUCTION BY CHLORINATION

- ferrous sulphate precipitation
- the Inco SO_2/air process developed in the mining sector

None of these methods is used as widely as chlorination due either to cost or lack of proven commercial application.

HEXAVALENT CHROMIUM REDUCTION

Chemical reduction is the most common means used to reduce hexavalent chromium found in rinsewater and process solutions from decorative and hard chromium plating to the trivalent form. The trivalent form is more desirable for two reasons, the first being that it is more readily precipitated from wastewater, the second being that it is less toxic than the hexavalent form. The conventional practice is to segregate chromium-bearing waste streams for chemical reduction. A typical process unit is depicted in Figure 4-7. Wastewater is maintained at a pH of 2.5 through the pH-controlled addition of sulphuric acid to maximize the reaction rate. The chemical reducing reagent is added based on oxidation reduction potential (ORP) control.

After this step, the segregated wastewater may be mixed with the remaining metal finishing wastewater for pH adjustment and precipitation of the trivalent chromium as a hydroxide.

Several chemicals are suitable to achieve chromium reduction:

- Sulphur dioxide (SO_2)
- Sodium bisulphite ($NaHSO_3$)
- Sodium metabisulphite ($Na_2S_2O_5$)
- Ferrous sulphate ($FeSO_4$, a by-product of sulphuric acid pickling of steel)

Advantages and disadvantages of chemical reduction of hexavalent chromium are summarized in Table 4.2.

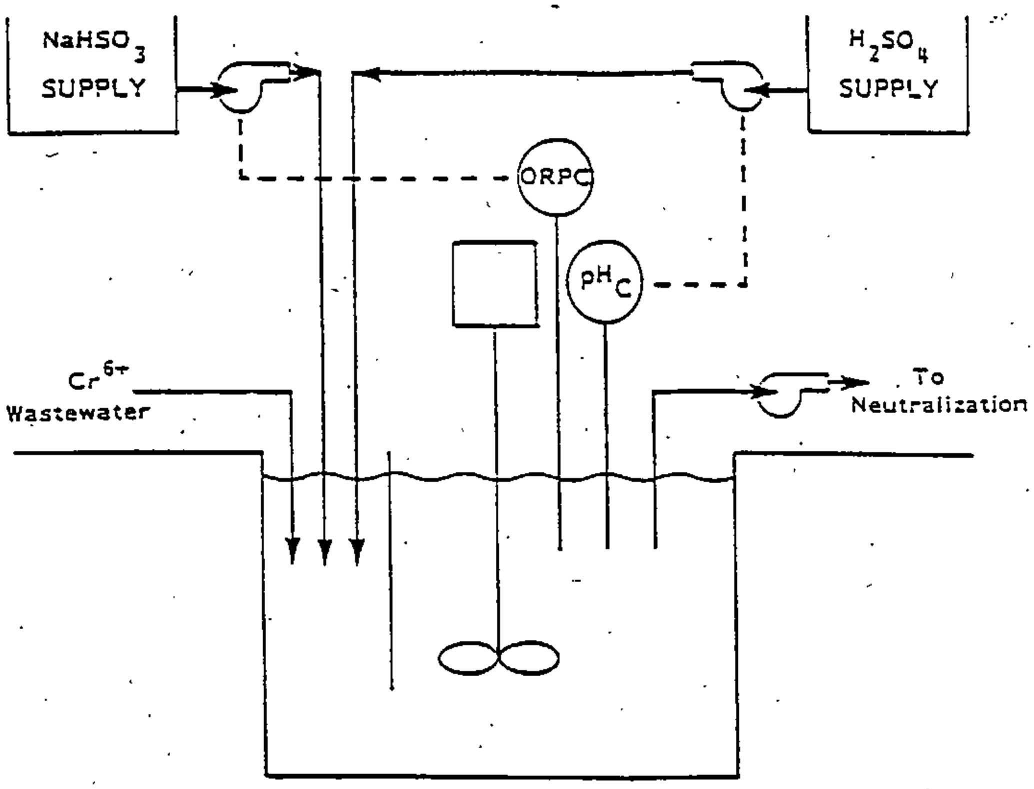
Effluent dissolved hexavalent chromium levels less than 1.0 mg/L are achievable. The level realized is a function of the specific water chemistry, the level of chromium in the wastewater and other factors.

Two much less common methods used for hexavalent chromium removal are:

- Electrolytic reduction using sacrificial iron anodes
- Direct precipitation of hexavalent chromium salts.

AMMONIA REMOVAL

Ammonia removal is sometimes necessary since the presence of ammonia in metal bearing waters can result in the formation of ammonia-metal complexes which increase the solubility of the metal (Stumm and Morgan, 1970). As a result, the presence of



REFERENCE: CUSHNIE, 1985

FIGURE 4–7:

TYPICAL CHROMIUM REDUCTION TREATMENT

ammonia can prevent the precipitation of metals to acceptable levels during subsequent hydroxide precipitation (Curry, 1972; USEPA 1978). Under conditions of elevated pH, generally higher than that used for hydroxide precipitation, the ammonia/ammonium equilibrium is dominated by the presence of free ammonia which can be readily removed from solution by air or steam-stripping (Metcalf and Eddy, 1979; Curry, 1972). One system for the removal of ammonia from metal-finishing wastewater would consist of a tank aerated with a suitable blower and diffuser system and with a chemical feed and control system for the maintenance of pH in the range of 11 to 12. Alternatively, an air stripping tower could be employed for ammonia removal. A necessary requirement for any building-enclosed ammonia stripping system is the use of a vacuum-evacuated exhaust system.

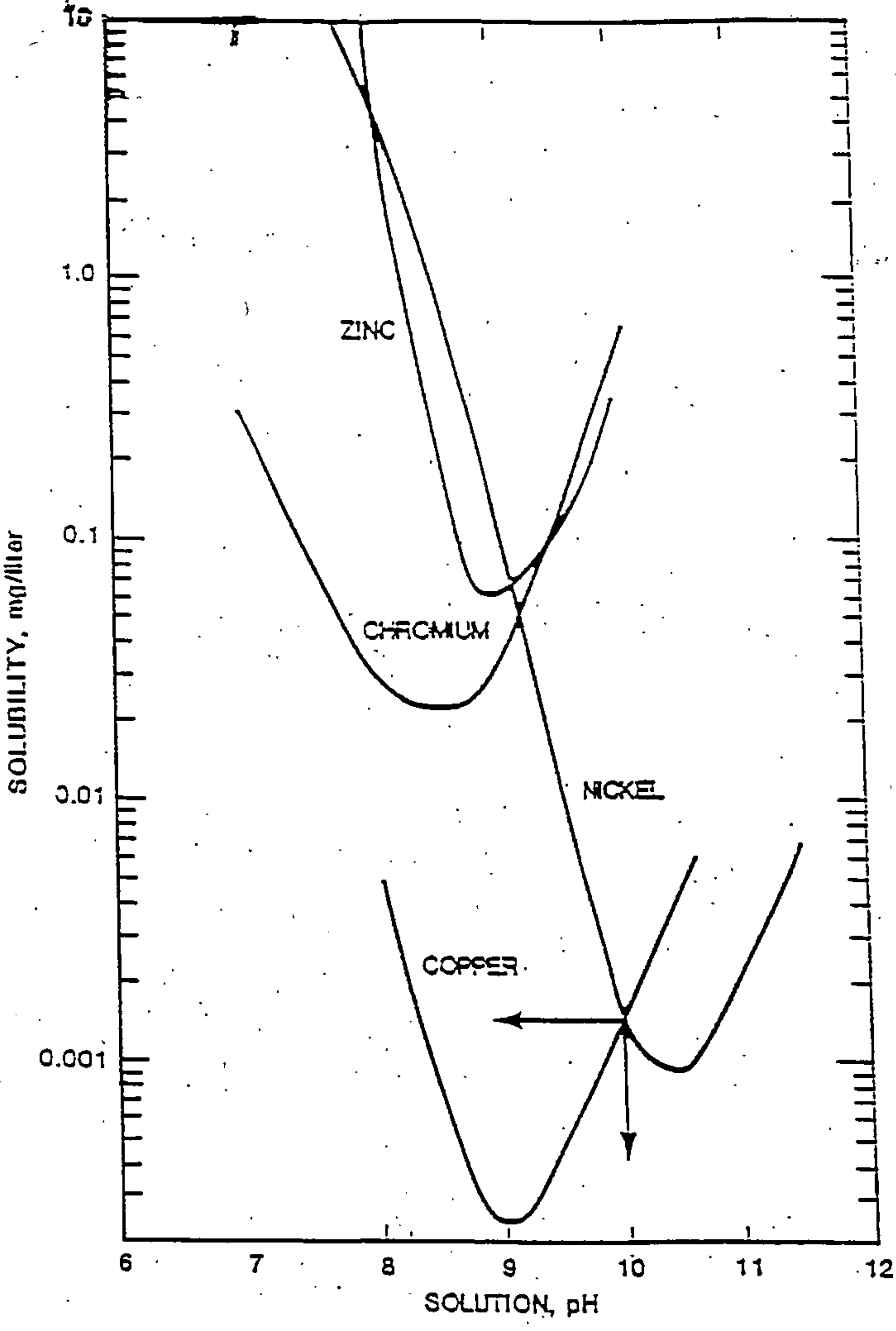
Table 4.2
Advantages and Disadvantages of Chemical Reduction of Hexavalent Chromium

Advantages	Disadvantages
• Widespread, proven application in the metal finishing sector • Effluent levels of less than 1.0 mg/L are achievable • Relatively simple operation and maintenance	• High acid consumption to lower pH to 2.5, depending on the alkalinity of the rinsewater • Possible release of gases with noxious odour • Large sludge volumes generated in subsequent neutralization and/or precipitation of trivalent chromium, especially when ferrous sulphate used

PRECIPITATION

Hydroxide precipitation can be used to remove trivalent chromium, nickel, copper and other metals as their insoluble hydroxides using sodium hydroxide or lime. This process is the most common method employed for the treatment of metal bearing wastewaters (USEPA, 1978). Although the use of lime has in the past been the preferred method, it is subject to two major disadvantages when compared to the use of caustic soda. First, the use of lime requires provisions for handling and slaking the dry chemical prior to use, whereas caustic soda is available in liquid form which can be readily metered into the treatment process. Second, lime-induced-precipitation sludge volumes can be significantly greater than those generated using caustic soda because large excesses of lime (which remain undissolved) are often required to achieve acceptable effluent metal concentrations. Sludges resulting from the addition of sodium hydroxide are typically more difficult to dewater than are those resulting from the addition of lime.

The effluent metal levels obtainable by hydroxide precipitation depends upon the insolubility of the metal hydroxides formed in the treated water and upon their settling and filtering characteristics. The solubilities of the metals are dependent upon many factors, the most influential of which is pH. The solubilities of various metals as a function of pH are illustrated by Figure 4-8. Since the optimum pH for metal removal is also a function of the metal itself, the precipitation of a combined waste stream may not produce the best possible water quality. For example, the optimum pH range for chromium precipitation is around 8.5 while nickel precipitates best at a pH of 10 to 11



REFERENCE: USEPA, 1983

FIGURE 4-8:

SOLUBILITY-OF HEAVY METALS AS A FUNCTION OF pH

and copper at a pH of 9.0. However, there are many cases of successful co-precipitation to achieve metal levels below 1 mg/L each for combinations of Cu, Ni, Cr, plus other metals (e.g. Cushnie, 1985). For such systems, there is an optimum pH that results in a minimum overall metal solubility. In some instances, it may be necessary to use more than one pH adjustment step to achieve acceptable effluent quality with this technology.

After pH adjustment to the desired range, the precipitated hydroxides are flocculated and removed by clarification. A filtration step using granular media filtration may also be included as a polishing step for the removal of non-settleable, but precipitated metals. Inorganic coagulants or polyelectrolytic flocculants are typically added to the waste stream before clarification or filtration to enhance the settling or filtering characteristics of the particles. A properly operating clarification system is capable of efficient removal of precipitated metal hydroxides. The performance is a function of the extent of flow equalization, the hydraulic retention time and surface loading rate/overflow rate of the clarifier in addition to the settling characteristics of the suspension. When coagulants and flocculants are used, the optimum pH for metal removal is that which optimizes the solids removal process.

Prior to hydroxide precipitation, certain wastewaters must receive pretreatment which will render the metals precipitable. Hexavelant chromium must be reduced to the trivalent form. Cyanide pretreatment is required to meet discharge standards, and to prevent the formation of metal complexes (most notably nickel/cyanide) of relatively high solubility. Ammonia, present in copper pickling and other wastewaters, similarly forms complexes with copper which inhibits hydroxide precipitation. Chromium reduction, cyanide destruction, and ammonia removal, discussed previously, are most economically practiced on segregated waste streams.

Advantages and disadvantages of hydroxide precipitation are summarized in Table 4.3.

Table 4.3
Advantages and Disadvantages of Hydroxide Precipitation

Advantages	Disadvantages
• Widespread application in metal finishing sector with documented performance. • Relatively straightforward operation and maintenance. • Typically cost-effective relative to other technologies.	• Requires significant space. • Limited applications for treatment of chelated compounds (i.e. electroless operations). • Generates solid residues/sludges requiring costly disposal/management, resulting in possible longterm liability. • May be difficult to achieve effluent criteria for wastewaters containing a range of metals. • Susceptible to flow/hydraulic variations.

Effluent dissolved heavy metal concentrations in the 1 mg/L range are achievable. The level realized is a function of the specific wastewater characteristics, including the range of heavy metal constituents present.

Sulphide precipitation has the potential to produce a superior quality effluent (with respect to heavy metals) than that obtainable by hydroxide precipitation since the sulphides of metals are much less soluble than their corresponding hydroxides (Peters, et al., 1984; USEPA, 1980 a,b: Cherry, 1982). Reported achievable effluent levels of Ni, Cu, and Cr are in the range of 0.05-0.10 mg/L. In recent years, the interest in sulphide precipitation of metals has increased. In part this is because hexavelant chromium can be reduced and precipitated in the sulphide process under the proper conditions without separate pretreatment operations and, there is evidence of improved performance using sulphide for the precipitation of chelated metals over that obtained using hydroxide precipitation.

Sulphide precipitation is conducted by the addition of gaseous, soluble, or insoluble sulphide at a pH of about 8. The use of gaseous hydrogen sulphide has the disadvantage that it is toxic and requires special control. Accurate control using sulphide probe instrumentation loops has sometimes been difficult to achieve in practice. The addition of soluble salts such as sodium sulphide and sodium hydrosulphide must be carefully controlled to prevent an excess of soluble sulphide in the process effluent. Sulphide is toxic above threshold levels, can be corrosive in sewers and is subject to effluent quality limitations. The pH must be carefully controlled and maintained in the alkaline range to prevent the dissolution of toxic hydrogen sulphide gas. A final aeration or oxidation step can be used to lower the soluble sulphide concentration of the process effluent.

These process disadvantages can be eliminated/minimized by the use of essentially insoluble sulphide compounds which are added to the process as solids and are maintained in suspension. These materials provide sulphide by dissolving as the metals precipitate from solution. The primary disadvantages of the insoluble sulphide process are the need for more materials handling equipment and the generation of significantly more sulphide sludge.

The use of insoluble sulphide requires the addition of excesses of ferrous sulphate to ensure sufficient metal sulphide precipitation. Sulphide compounds are reactive and capable of decomposition upon exposure to air thereby releasing the previously precipitated metals to the environment. Consequently, the long term ultimate disposal of sulphide sludges is uncertain. It is possible that in the future only a limited number of landfills will accept sulphide sludge.

Sulphide precipitation can be used as the sole metal precipitation process using sodium hydroxide or lime for pH adjustment. Alternately, sulphide precipitation may be used as an effluent polishing step following hydroxide precipitation. Both applications of sulphide precipitation are currently in use at full-scale installations. To minimize sulphide sludge production, it is preferable to use sulphide precipitation as a polishing step. Whether used alone or as a polishing step, clarification and/or filtration are necessary for solids removal. Also, as with hydroxide precipitation, cyanide pretreatment is necessary. Chromium reduction may or may not be necessary depending upon a number of unknown factors of which the presence of iron appears to be critical (USEPA, 1980a).

Because of the recent and relatively limited interest in sulphide precipitation, guidelines and criteria for process selection and design are not as well established as those for the hydroxide precipitation process. Reaction or detention times are typically on the order of those employed for hydroxide precipitation. Loading rates for solids removal unit operations are also consistent with those typically used in hydroxide precipitation. A difference between the hydroxide and sulphide precipitation processes exists in the types and dosages of coagulants or flocculants that result in optimum performance. Also the dewatering and handling characteristics of sulphide sludges are similar to those of hydroxide sludges.

Advantages and disadvantages of sulphide precipitation are summarized in Table 4.4.

Table 4.4
Advantages and Disadvantages of Sulphide Precipitation

Advantages	Disadvantages
• Effective at reducing heavy metals concentrations to low levels. • Effective for wastewater containing a range of heavy metals. • Unit operations are relatively straight forward to operate and maintain. • Compatible with most equipment used for hydroxide precipitation. • Effective for removal of chelated compounds. • Effective at removing hexavelant chromium eliminating need for chemical reduction step.	• Limited commercial application. • Difficult to control sulphide dosages. • Effluent polishing of sulphide required. • Reactive sludge produced. Costly to manage/dispose of. Potential long-term liability. • Requires significant space. • Corrosion potential must be addressed.

Effluent dissolved heavy metal concentrations in the 0.05 to 0.1 mg/L range are achievable with this technology.

Borohydride precipitation chemically reduces metals and results in the precipitation of the metals in their elemental form. Sodium borohydride reduction/precipitation has the ability to remove metals in the presence of chelating agents. Additionally, separate chromium reduction pretreatment is typically not required. This process does not appear to be common on a large-scale basis for the treatment of metal containing wastewaters due, primarily to the high cost of the sodium borohydride reagent. It is, however, used for the recovery of metals from process solutions or for the treatment of concentrated solutions prior to disposal (Shipley Company, Inc., 1982).

CHELATED METAL REMOVAL

The presence of organics and inorganic chelating or complexing materials in metal containing wastes can interfere with hydroxide precipitation of the metals because of an increase in the metal solubilities. The formation of ammonia/copper and cyanide/nickel complexes are examples. In these cases, hydroxide metal precipitation is usually successful only after the removal of ammonia and oxidation of the cyanide, respectively.

Effect of Organic Chelating Agents

The presence of organic chelating agents in metal finishing wastewaters arises from the use of EDTA, citrate, tartrate, and other such agents in electroless plating operations and from the use of some cleaners. The presence of the chelating agents can increase the solubilities of metal hydroxides to the point that precipitation at elevated pH may not result in sufficiently low residual metal concentrations in the process effluent. Additionally, during such precipitation, the chelating agents may not be removed and may therefore cause problems if they were to be combined with other untreated, metal-containing wastewaters.

The effect of chelating agents on metal solubility is a function of the type and concentration of the chelating agent and of the metal as well as the solution composition, eg. pH. The design and operation of a precipitative metal removal process is therefore sensitive to changes in the processes from which the wastewaters are derived. A change in plating solutions which would involve a change of chelating agent could result in improved or degraded metals removal.

There are several alternative treatment processes that can be effective in the removal of metals in the presence of chelating agents. Included are high pH precipitation, sulphide precipitation, borohydride precipitation, ion exchange, and ozone oxidation.

High pH Precipitation

High pH precipitation is a modification of hydroxide precipitation in which metal hydroxides are precipitated at a pH of around 12 rather than 8 to 10 as with conventional hydroxide precipitation. Little practical information is available in the engineering literature regarding this process, however good laboratory results have been reported. The use of lime, rather than sodium hydroxide for pH adjustment may improve the effectiveness of high pH precipitation because of the presence of additional divalent cation (Marino, 1984; USEPA, 1978).

Sulphide Precipitation

The sulphide precipitation process previously described has the ability to achieve excellent metals removal in the presence of chelating agents. As with metal hydroxides, the metal sulphide solubilities are increased by the presence of chelating agents. However, because of the very low "non-chelated" solubilities of the sulphides, the increased solubilities due to chelation can remain relatively low (Peters, et at., 1984). It should be noted that again, the performance of sulphide precipitation is dependent upon the types of metal complexes which are present. Also, the chelating agents may remain in solution and care must be exercised when such waters are combined with other metal bearing wastewaters.

Borohydride Precipitation

Borohydride precipitation, as described earlier in this section, is capable of removing metals in the presence of chelating agents.

Ion Exchange

Ion exchange is capable of removing copper and nickel from the complexed wastewater that is typically produced from electroless plating operations. Subject to the same limitations that were presented in the previous discussion of ion exchange, this technology may be a viable alternative for the treatment of segregated, complexed-metal wastes.

Ozone Oxidation

The ozone oxidation of organic chelating agents, thereby reducing or eliminating their interference on metal precipitation, has been proposed as a technology for the treatment of complexed-metal wastewaters. This technology is not, however, well established. Additionally, capital costs of ozone oxidation systems can be high.

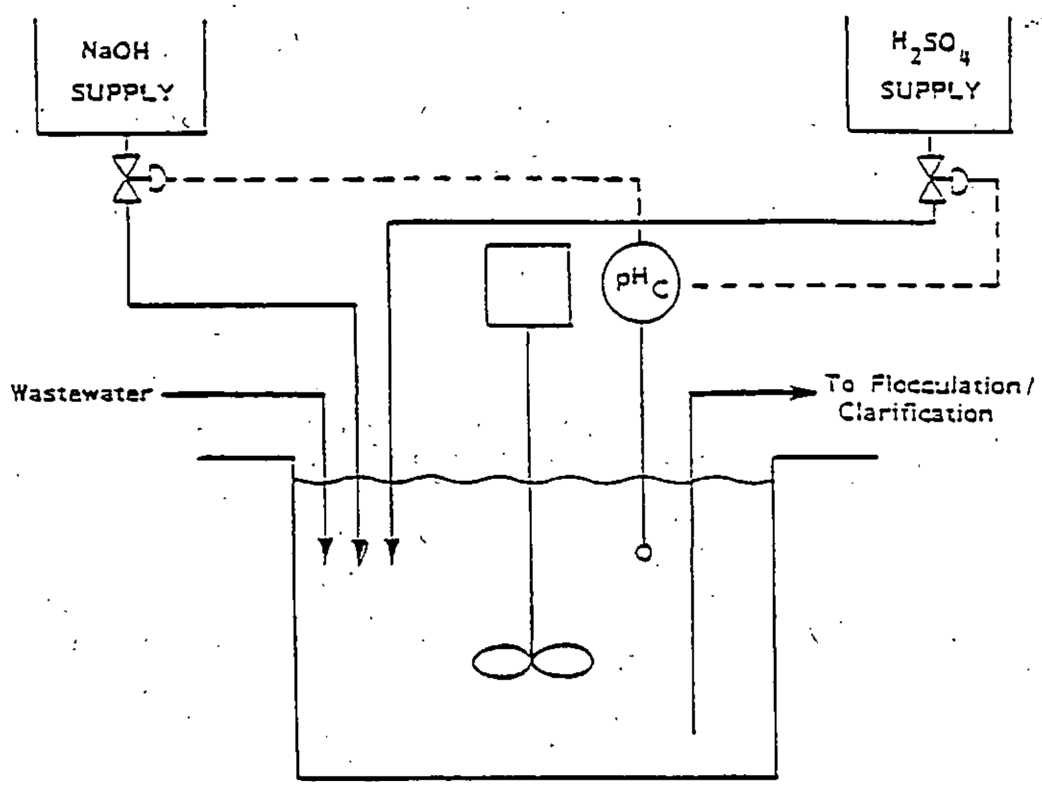
NEUTRALIZATION/pH ADJUSTMENT

Spent acid and caustic process solutions not containing heavy metals can be discharged after pH adjustment/neutralization. Those wastewaters containing heavy metals may be treated by chemical precipitation which typically involves a pH adjustment unit operation and possibly a final pH adjustment (neutralization) after removal of the precipitated metals and before discharge. A single-stage unit is depicted in Figure 4-9.

Wastewaters containing cyanide, hexavelant chromium or chelated compounds are typically pretreated and then blended with metal-bearing wastewater streams for metal precipitation (i.e. pH adjustment) and/or neutralization prior to discharge.

The pH adjustment/neutralization unit operation can be accomplished in a single step or multi-step (usually two-step) arrangement. The number of steps required is based on overall process stability considerations and is influenced by the chemical matrix of the wastewater and the magnitude of the pH adjustment required.

Spent acids and caustics from production activities can sometimes be used to effect the required pH adjustment. Typical chemicals employed for pH adjustment include lime and sodium hydroxide (alkaline reagents) and sulphuric acid (acidic reagent). Reagent



REFERENCE: CUSHNIE, 1985

FIGURE 4-9:
SINGLE-STAGE pH ADJUSTMENT

addition is usually affected by a pH-based control loop. Usual design considerations require that the pH adjustment/neutralization tank be completely mixed and provide an adequate residence time to effect the desired change (i.e. process stability).

The choice of reagent to effect the pH change is typically based on cost, site specific factors (space, etc.), handling equipment required, and sludge generation potential.

FLOCCULATION

The purpose of the flocculation unit operation is to provide an environment for agglomeration and growth of metal precipitates. This is typically accomplished by providing a slowly stirred, low fluid-shear environment where the floc particulates are given the opportunity to collide and form larger particles. The formation of these larger particles in the flocculation step is critical to the efficient operation of the subsequent gravity clarification process. To allow the growth of large easily settleable floc particles, an adequate amount of "reaction" time must be provided.

The essence of the flocculation process is the slow stirring activity which must take place for floc formation to occur. Tall cylindrical tanks with mechanical flocculators are typically used. To further promote the required shear action, stationary baffles are sometimes installed on the tank walls. Polymers are sometimes employed to enhance floc formation.

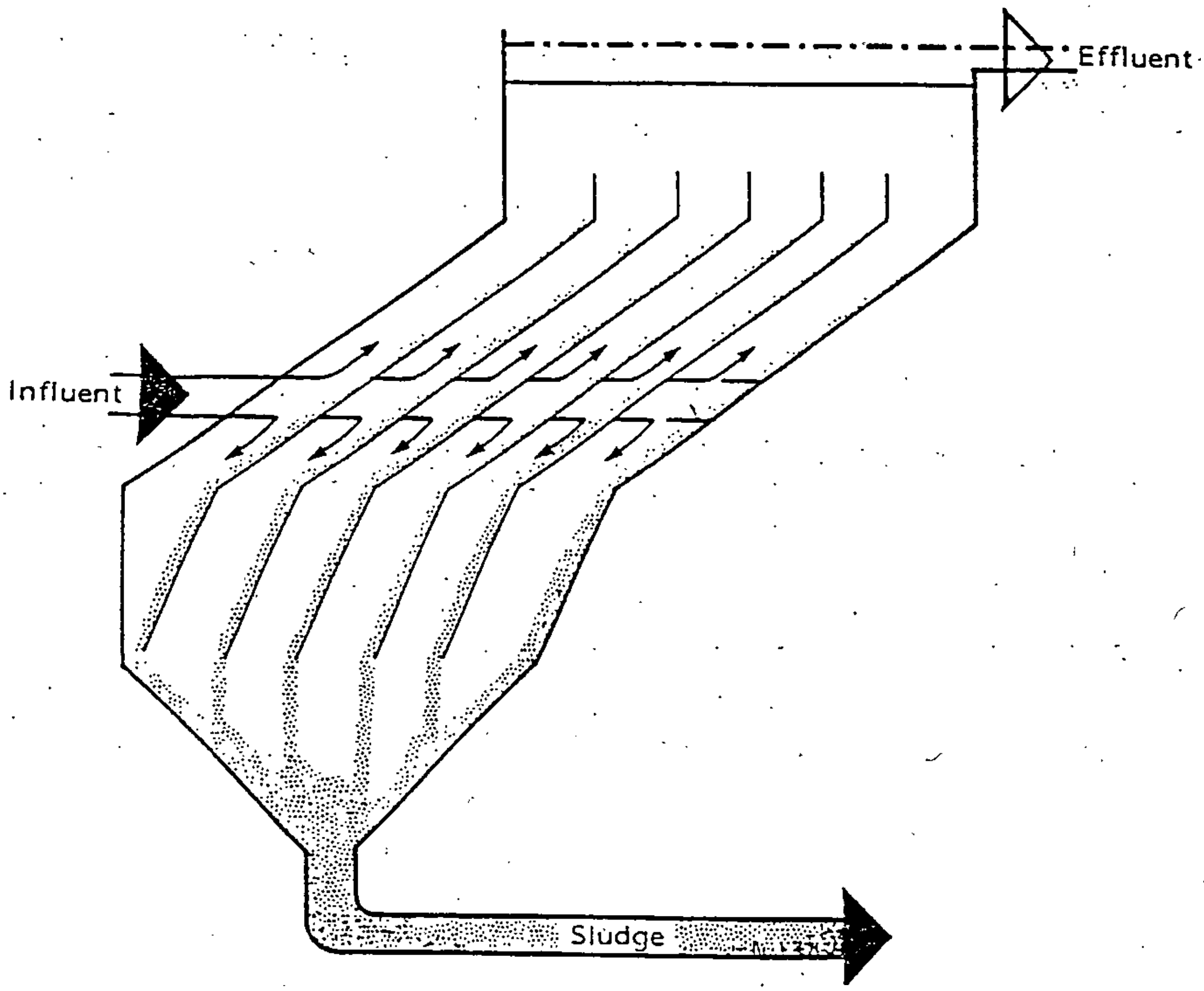
If inadequate mixing energy is imparted to the fluids, floc formation rates will be impeded, resulting in formation of small, poorly-settling particulates. If the energy input is too great, the floc particles will be broken-up by the shearing activity and will not grow to large mature settleable floc. Variable speed flocculators are sometimes used to allow field optimization.

GRAVITY SETTLING

Following the pH adjustment and flocculation steps, the flocculator effluent typically flows to a clarifier. Special care is usually exercised in the design of piping connecting the two unit processes to eliminate undue fluid shear that may damage the floc as it travels from one unit to another.

Typically "off-the-shelf" tube or lamella (inclined plate) settlers are used in metal finishing applications. These units are efficient since they reduce short circuiting, produce laminar flow and reduce the settling distance required to effect solids capture. Some units are available with integral flocculation chambers.

The clarifier provides for the collection and storage of settled solids in a hopper at the bottom, and the discharge of clarified effluent over the weirs at the top of the unit, as depicted in Figure 4-10.



REFERENCE: CUSHNIE, 1985

FIGURE 4–10:
TYPICAL INCLINED PLATE SETTLER

The quality of the liquid effluent is a function of the hydraulic loading applied to the unit, the amount of flow equalization practiced, the effectiveness of polymer addition, the heavy metal content of the new wastewaters and the operation of upstream unit operations/unit processes. Typically, small quantities (less than 10 mg TSS/L) of precipitated metal and other solids (pin floc) are discharged in the effluent.

The sludge collected in the hopper can be evacuated on a batch basis (once per shift, once per week, etc.) or on a continuous basis, depending on the amount of sludge generated.

FILTRATION

To remove the pin floc discharged from the clarifier, package-type gravity filters are typically used in the metal finishing industry. Without filtration, effluents may not achieve the levels of heavy metals required by sewer use ordinances.

Filters are available in a continuous backwash or a sequential backwash mode. The backwash water is typically recycled to the front end of the treatment train. Effluents containing less than one mg/L of suspended solids are achievable with this well established technology.

SLUDGE DEWATERING

The sludge collected in the hopper of the clarifier is typically transferred to a sludge holding tank for additional thickening. The clarified supernatant is usually decanted and recycled to the head-end of the treatment system. The thickened sludge is typically dewatered in plate and frame filters (i.e. filter presses) as depicted in Figure 4-11. These units typically operate at pressures up to 100 psi, and result in filter cakes with solids content ranging from 30 percent to over 50 percent. The moisture content depends on the water "matrix", the reagent used to adjust the pH, the heavy metals present and other factors.

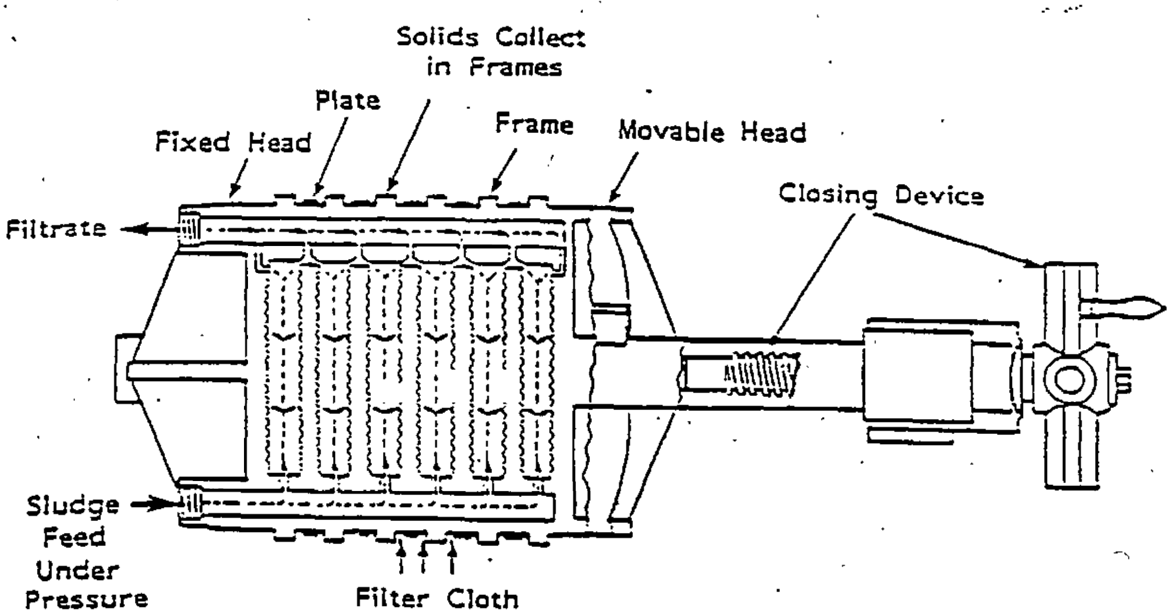
To reduce the moisture content to desired levels, thermal drying of the filter cake is sometimes practical. Package-type units are available for metal finishing applications.

Filter cake is typically hauled to a landfill for disposal, or to a reclaimer for metal extraction depending on the range and amount of metals.

Filtrate from the press operation is typically recycled to the treatment plant for processing. Spent acid used to clean the filter clothes is also typically bled-in to the wastewater flow.

MEMBRANE TECHNOLOGIES

Reverse osmosis and electrodialysis are generally used as recovery technologies, as described earlier in this section.



REFERENCE: CUSHNIE, 1985

FIGURE 4-11:

SLUDGE DEWATERING USING PLATE-AND-FRAME FILTER PRESS

Membrane filtration may be used as a tertiary level of solids removal to remove colloidal particles that escape gravity settling and conventional filtration. In this process, wastewater is passed through a tubular or flat channel with porous walls. Depending upon the application, pore diameter may range from 0.001 to 5 μm. Three types of membrane filtration are defined in Table 4.5.

Table 4.5
Membrane Filtration Technologies

Type of Membrane Filtration	Membrane Pore Diameter Range (μm)	Applications and Comments
Ultrafiltration	0.001 - 0.01	• Removal of colloidal particles • Expensive for removal of any larger particles
Microporous	0.1	• Used with specialized precipitation systems • High sludge solids produced (15 to 20 percent)
Microfiltration	1 - 5	• Limited application to metal-bearing wastewater

The main advantages of these systems are the small particle sizes which can be effectively treated and the relatively high solids content of the resulting sludge (10 to 20 percent). Their cost is usually only justified in situations where effluent limitations are extremely stringent. Disadvantages include:

- Specialized training and monitoring of pressure drop and pH required for stable operation
- Occasional chemical or physical cleaning or replacement required to prevent membrane fouling
- Organic constituents of metal finishing baths, such as brighteners, antifoamers and surfactants, may foul membranes
- Limited application in the metal finishing sector for the removal of metal-bearing solids.

MISCELLANEOUS TECHNOLOGIES

Activated carbon adsorption has been considered for the adsorption of hexavelant chromium from solution. Activated carbon has been shown to be effective in adsorbing chromium from rinse water in laboratory scale testing. Some data also exists which indicates that the chromium is also reduced when in contact with the activated carbon. Little information exists regarding the use of activated carbon to remove copper or nickel. In addition, carbon requires regeneration (with an NaOH/chelating agent solution) producing a concentrated chromium solution that is not reusable in the plating baths. There are no known metal finishers using this treatment. Note that this technology may also be applicable in extending bath life as noted under "Waste Reduction".

Other miscellaneous systems have been proposed for treating or recovering metal finishing wastes in general, or copper, nickel or chromium containing wastes specifically. Some of these methods are outlined below. All are in the preliminary developmental stage and/or demonstration stage or are not competitive with other technologies for cost reasons. These technologies include:

- Ion flotation - similar to LLE but metals are complexed and concentrated in a phase which foams when the aqueous phase is aerated. The froth containing the metals is removed from the system by a skimmer (Sittig, 1978).
- Chromium precipitation by barium - hexavelant chromium can be directly precipitated by the addition of $BaCl_2$
- Chromium precipitation by lead - hexavelant chromium can be directly precipitated by the addition of $PbNO_3$
- Chromium reduction and precipitation by iron - uses flue gas and ferrous sulphate to reduce and precipitate chromium
- Adsorption of metals and/or cyanides using activated carbon, synthetic polymeric resins, clay, peat and other materials (MOE, 1991)
- Crystallization of metal salts from supersaturated rinsewater (MOE, 1991)
- Starch xanthate used to replace heavy metal ions in solution (similar to ion exchange)(MOE, 1991)
- Oxalation using oxalic acid, ammonia and sodium hydroxide to recover metals from sludges (Sittig, 1978)
- Soluble sorbent clarification for simultaneous precipitation of mixed metal wastes at pH 8.5 to 9.0 (Sittig, 1978)
- Freezing for the removal and recovery of concentrated metal waste from rinsewater (Sittig, 1978)
- Coupled transport membranes to recover metals from rinsewater (Cushnie, 1985)
- Donnan dialysis, an ion exchange membrane technology, to remove metals and metal cyanide complexes from wastewater (Cushnie, 1985)

- Ion transfer membranes for the recovery of chromate ions from rinsewater and the extraction of cation impurities from chromic acid solutions (Cushnie, 1985)

CONTINUOUS VERSUS BATCH TREATMENT

Any of the above described treatment technologies can be conducted on either a batch treatment basis or as a continuous flow process. Generally, the governing factor which controls the choice of treatment methodology is the volume of wastewater flow. Batch treatment processes are applicable for small flows and are frequently operated on a manual, as-needed basis. Typically, lower flows amenable to batch treatment techniques are encountered in upstream, decentralized segregated waste streams such as cyanide or hexavelant chromium-bearing streams. For large flows, such as those typical of a centralized wastewater treatment facility, continuous, automated treatment systems are appropriate. Whether batch or continuous systems are employed, sufficient wastewater storage volumes must be provided for the accumulation of wastewater between and during periods of batch treatment system operation and to equalize the rate of flow to a continuous treatment process.

SPENT PROCESS SOLUTIONS TREATMENT/DISPOSAL ALTERNATIVES

The optimum handling of spent process baths requires evaluation of several options. The baths can be disposed of directly, treated onsite, or recycled or treated offsite. This section sets forth the advantages and limitations of each.

DIRECT DISPOSAL

The direct disposal of untreated spent process solutions or spills from baths to plant drains was once common practice for metal finishing facilities. The extent of this practice has been reduced in recent years owing to the establishment and enforcement of sewer use bylaws and controls on direct discharges as well as to economic incentives for waste minimization.

However, contact with municipal representatives during this study indicates that, especially in those municipalities where sewer use bylaw enforcement is less stringent, this practice still occurs. This can result in pH swings at the influent to WPCPs and can jeopardize secondary treatment. Data from a recent survey in Ontario (MOE, 1991) indicates that as many as 13 percent of all facilities may employ direct disposal. Municipal sewer use bylaw enforcement is comparatively stringent in the larger municipalities in Ontario, indicating that the practice may be more common outside the larger centres.

Data from a recent Alberta Environment study (1992) indicated that, in at least two instances, overflows from floor sumps, discharging directly to sanitary sewers, were identified as hazardous waste requiring appropriate regulated management based on metal concentrations.

ONSITE PURIFICATION

Onsite purification of spent plating solutions falls into two categories: recovery and reconcentration of solutions lost as dragout to rinsewater and the removal of contaminants from spent plating baths. The first of these alternatives has been discussed in the "Waste Reduction" and "Waste Recovery" sections of this chapter.

Ion exchange is potentially applicable to the onsite purification of spent plating baths. However, as a practical matter only baths with a relatively simple makeup are potential candidates for this approach.

The direct regeneration of spent plating baths onsite is the subject of a great deal of research, centred on the ion exchange and electrolytic processes and on chromium containing baths. Requirements for in-plant recycling processes are in some respects more stringent than those for a simple metal recovery process from rinse water. Reagent additions are limited since reagent removal would then be necessary. Any volume increase or chromium concentration decrease would require an evaporative type system. In addition, the severe environment of the baths poses major problems for any proposed systems. Although there is a great deal of research currently underway there are few operating process bath regenerant systems online at metal finishing operations.

ONSITE TREATMENT

Onsite treatment of spent plating baths can be accomplished in two ways: segregated from rinse waters and treated in a separate (usually batch) treatment system or commingled with rinse waters by slowly bleeding the spent bath into the rinsewater (usually continuous) treatment system. Segregated treatment can be accomplished by many of the wastewater treatment techniques discussed in this chapter. The key to a successful onsite treatment system is flexibility because of the widely varying character of spent process solutions.

OFFSITE RECYCLE/TREATMENT

In lieu of treating spent plating baths on site they can be transported to offsite facilities which accept similar wastes from other generators. Based on the relative frequency of disposal of the various baths, the volume of baths to be treated, and other case-specific factors, offsite treatment may or may not be a cost-effective alternative.

WASTEWATER TREATMENT SLUDGE MANAGEMENT

Apart from sludge dewatering and sometimes drying, discussed earlier, very little onsite management of wastewater treatment sludge is practised. Offsite management alternatives are generally limited to final disposal methods, which vary according to regulatory requirements.

Data from the recent survey in Ontario (MOE, 1991) indicate the following percentage of facilities using the noted sludge receivers (wastewater treatment accounts for the vast majority of sludge volumes generated in Ontario):

- 57 percent—secure landfill
- 19 percent—municipal/sanitary landfill
- 17 percent—metal recycling companies
- 14—unspecified offsite management
- 3 percent—offsite metals reclamation by primary metallurgical smelters and refineries
- 1.5 percent—offsite metals reclamation by foundries

(Some facilities use more than one management method, so figures total more than 100 percent.)

The importance of waste segregation in maximizing waste recovery opportunities must once again be emphasized. Wastewater treatment residuals from segregated wastewater streams may be amenable to management options such as the metals recovery by primary metallurgical smelters and refineries noted above. Sludges from mixed wastewater streams may be more problematic in metals recovery.

AIR EMISSIONS CONTROLS

GENERAL DESCRIPTION

In general, implementation of air emission control in the metal finishing sector has been driven largely by occupational health and safety (OH&S) concerns rather than by requirements for emissions. Tanks containing solutions which present an OH&S risk are typically directly vented, while the general ventilation system is used to capture any fugitive fumes which may be present in the facility.

Due to the nature of the emissions from metal finishing baths, the primary task of emission control is phase separation: removing entrained liquid particles from the gas flow. This may be achieved through use of several technologies. Those most commonly used in the metal finishing sector include mist eliminators, wet scrubbers and cyclones. It should be noted that emissions from other operations including those generating organic vapours (such as solvent degreasing) and dust (such as machining and grinding) may be controlled using other devices but these operations are not within the scope of this study.

Ductwork for directly vented tanks is often fitted with mist eliminators which are used to prevent the majority of the fumes from reaching the central exhaust system. This is especially true in cases where recovery of metal values from segregated streams may be economically desirable (Sittig, 1978). Mist eliminators operate on the principle of impingement capture and typically use wire mesh pads usually 10 to 15 cm deep with a void volume of 97 to 99 percent to achieve emission control (Perry and Chilton, 1973). Liquid may also be entrained by the gas flow exiting a wet scrubber and mist eliminators are often installed at the gas outlet.

Wet scrubbers employ liquid, usually water, to assist in the removal of entrained liquid particles from the gas stream. The venturi scrubber is common and entails introduction of the liquid spray in concurrent flow with the gas at the venturi throat. These are sometimes used in conjunction with cyclone separators for recovery of the scrubber effluent and commonly operate at efficiencies of higher than 95 percent for the particle size range of concern (greater than 10 microns).

FACTORS FOR CONSIDERATION

Two important factors are typically considered with respect to air exhaust and emission control systems. These are the chemical nature of the liquids being entrained and the particle size range of the entrained liquid (Sittig, 1978).

The following general items are usually considered when the chemical nature of the liquids being entrained is a consideration:

- As noted in Section 3, the most common source of priority substance air emissions in the metal finishing sector is chromium electroplating. The generation of hydrogen and oxygen gases in an electrified tank containing chromic acid results in increased turbulence in the tank and increased entrainment of liquid droplets in the off-gases. For this reason, these tanks are often equipped with dedicated exhaust systems fitted with mist eliminators to reduce the amount of chromic acid corrosion in the ductwork and to enhance the recovery of chromium. The amount of liquid entrained from non-electrified chromic acid tanks, such as those used in chromating, is typically lower. These tanks are typically vented/exhausted with other acidic emissions. In this latter case, any liquid wastewater generated will likely have to be treated for chromium removal.
- Exhaust systems for cyanide bearing solutions should be segregated from those for acidic solutions to preclude the formation of toxic hydrogen cyanide.
- Non-cyanide bearing solutions of an alkaline nature may be exhausted with acidic exhaust in order to effect some limited amount of neutraliza-

tion ahead of the scrubber. This practice is precluded in systems where recovery of acidic constituents from scrubber effluent is conducted.

- Exhausts from tanks holding ammonium-based alkalis, used in some metal finishing operations such as brass plating and copper pyrophosphate baths, should be segregated from exhausts from tanks containing hydrochloric acid to preclude the formation of ammonium chloride. Once formed, ammonium chloride can form a dense white cloud of submicron particles which are not removed by the conventional air emission control technologies.

- Ductwork and all components of the exhaust system should be constructed of materials suitable to the service required. In acid service, fibreglass reinforced plastic (FRP), polyvinyl chloride coated steel (PVS), or other plastic material (i.e. PVC, CPVC, etc) may be specified. Drains in the ductwork are also used for the collection of condensed vapours to prevent their accumulation.

Generally, entrained liquid particles are defined as those 10 microns in size and larger. These are released from metal finishing tanks as a result of air agitation, drippings, mechanical agitation and other factors. As a general rule, the size of liquid particles entrained from baths operating at room temperature will be relatively large, at approximately 100 microns and larger. Smaller particles in the 10 micron range may be generated if the tank is heated or agitated. In the case of electrified chromic acid tanks, liquid entrainment is enhanced by the generation of gas in the tank, as discussed earlier, and particles in the 3 to 5 micron range may be generated. Exhaust velocities must be carefully selected to ensure adequate capture, without resulting in smaller particle sizes which are generally more difficult to remove.

EXTENT OF USE

Data on the current extent of use of environmental control technologies were limited to information on wastewater treatment and recovery technologies. Data were available from the 1989 survey of the Ontario sector by the MOE (MOE, 1991) and from the Montreal Urban Community (MUC), who provided data on those facilities involved in their sewer use control program. These data are summarized in Table 4.6. The total number of facilities for which data were available in Ontario was 236, and in MUC, 72. This sample represents approximately half of the Canadian metal finishing sector.

Examination of Table 4.6 indicates that the technologies most commonly employed are those considered to be conventional:

- Neutralization
- Precipitation
- Gravity settling.

Table 4.6 Summary of Environmental Control Technologies in Use[1]						
Technology	Ontario Facilities		Montreal Urban Community Facilities		Combined Ontario/MUC	
	Number	Percentage	Number	Percentage	Number	Percentage
Any	184	78	67	93	251	81
Neutralization	141	60	65	90	206	67
Cyanide Destruction[2]	45	19	21	29	66	21
Precipitation	88	37	42	58	130	42
Gravity Settling	105	44	54	75	159	52
Filtration	91	39	14	19	105	34
Chlorination[2]	29	12	0	0	29	9
Hexavelant Chromium Reduction	75	32	22	31	97	31
Evaporation	24	10	4	6	28	9
Ion Exchange	10	4	6	8	16	5
Electrolytic Recovery or Destruction	18	8	1	1	19	6
Ultrafiltration	2	1	0	0	2	1

1 Data for Ontario taken from MOE, 1991. Data for MUC obtained through contact with MUC.
2 Survey results are reported as collected. It is unknown whether the figures for cyanide destruction include those facilities using chlorination for this purpose, although it is unlikely that chlorination would be used for other purposes in the metal finishing sector.

In addition, although percentages for conventional technologies such as cyanide destruction and hexavelant chromium reduction are lower, not all plants require these technologies. Evaporation, ion exchange and other more advanced technologies which focus on waste recovery are far less common.

In the release estimates presented in Section 3, the percentage of facilities having pretreatment facilities was assumed to be the same as it is for Ontario, 78 percent. Comparison to the data for Montreal reveals that an active sewer use monitoring and enforcement program can increase this level to greater than 90 percent. It should also be noted that most metal finishing facilities are located in the larger municipalities with active programs. This suggests that the extent of pretreatment outside of municipalities with active programs is significantly lower in order to achieve an average of 78 percent of facilities having pretreatment.

RELATIVE TREATMENT COST ESTIMATES

Costs associated with the treatment of metal finishing wastewaters include capital costs and operating and maintenance (O & M) costs. Capital costs are a direct function of the size of the required treatment facilities and are predominantly influenced by rinsewater flowrates.

O & M costs are a direct function of the rate of chemical consumption, the volume of sludge residues which must be managed, level of operator attention/manpower and other factors. These costs tend to be heavily influenced by the mass discharge of heavy metals from production activities, and thus by the manner in which spent process solutions are managed.

Several site-specific factors are typically evaluated in developing a cost-effective approach to wastewater treatment, including:

- the merits of satellite treatment systems close to source relative to a single central treatment facility,
- the merits of batch treatment relative to continuous treatment,
- the benefits of retrofitting in-plant process sewer piping to achieve segregated waste streams,
- the benefits of investing in waste minimization to reduce the size (and therefore the costs) of required treatment facilities.

The size and complexity of the facility and the availability of space influence the importance of these considerations and have a significant effect on the relative importance of capital cost levels to O & M cost levels.

It is difficult to quantify costs due to several site-specific factors which cannot reasonably be estimated, including:

- the required degree of interface of construction activities with production activities and associated impacts on production,
- the extent of site preparation required including foundations, containment structures, buildings, etc.,
- the quantities of spent process solutions requiring management/treatment,
- the characteristics of the water matrix comprising the wastewater which influences the type and quantity of chemical addition required and the volume of sludge generated,
- the extent of waste minimization modifications that are warranted,
- the time value of capital and the period of return for estimating present worth of O & M costs,
- the extent of instrumentation/automation desired.

Table 4.7 summarizes relative capital cost factors for the indicated treatment technologies. For purposes of this summary, a conventional treatment system has been arbitrarily assigned a cost factor of one.

Table 4.7
Relative Capital Costs Of Wastewater Treatment Technologies

Item		Relative Cost
Standard Technologies		
• Heavy Metals Removal	• Hydroxide Precipitation (Conventional)	1.0
	• Sulphide Precipitation	1.2
	• Borohydride Precipitation	1.2
Segregated Stream Technologies		
• Cyanide Destruction	• Alkaline Chlorination	0.3
• Chromium Reduction	• Chemical Reduction	0.3
• Ammonia Removal	• Air-Stripping	0.2
Metal Recovery Technologies		
• Ion Exchange		0.4
• Electrolytic Recovery		0.4
• Membrane Technologies	• Reverse Osmosis	0.6
	• Electrodialysis	0.6
Miscellaneous Technologies		
• Activated Carbon Adsorption		0.2
• Air Stripping		0.2
• Sludge Dryer		0.1

NOTES: Basis for cost estimate is continuous flow of 40 gpm unless otherwise noted.

Several treatment technologies/combinations of technologies are available in "package" form from equipment suppliers. The relative costs indicated do not reflect the cost savings potentially typically available for use of the "package" approach.

Cost estimates assume a continuous flowrate of 40 USgpm (approximately 60,000 USgpd) except as noted below:

- Cost for reverse osmosis based on 600 ft^2 of membrane area.
- Cost for electrolytic recovery based on 100 ft^2 of plating area.

Costs for metal recovery technologies assume "standard" volume and bath life characteristics for spent process baths.

This system is assumed to consist of the following unit operations/unit processes:

- Liquid Stream: flow equalization, pH adjustments, flocculation, gravity clarification
- Sludge/Solids Handling: sludge holding/gravity thickening, dewatering by filter press

Estimated costs assume slab-on-grade construction. Costs associated with structures to house the system and those associated with interfacing to existing utilities/production operations are not included.

The costs of alternate treatment options and various "segregated stream treatment technologies", metal recovery technologies, and miscellaneous technologies have been assigned cost factors relative to the conventional treatment system. These cost factors were developed based on information reported by Cushnie (1985), information reported by EPA (1981), and available project specific information.

The cost factors listed in Table 4.7 were estimated for an assumed average flowrate of 40 usgpm (57,600 gpd). Figure 4-12 indicates the estimated variation of treatment cost as a function of flow rate.

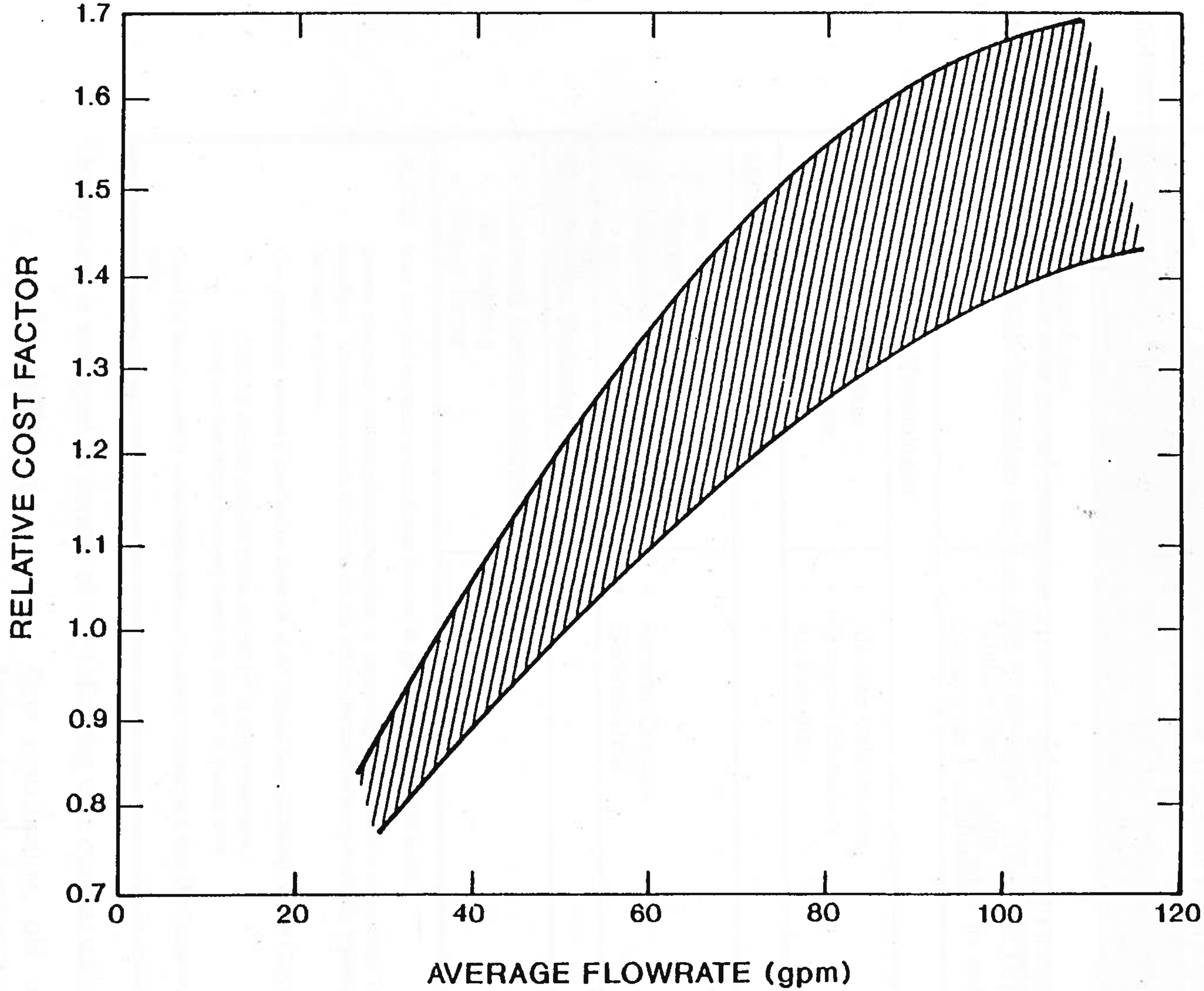


FIGURE 4-12:

ESTIMATED RELATIVE COST FACTORS

Section 5
REGULATIONS AFFECTING THE METAL FINISHING INDUSTRY

INTRODUCTION

This section provides a brief overview of the legislative framework under which metal finishing facilities operate in several different jurisdictions. The purpose of this review is to compare Canadian legislation and enforcement related to the release of Priority Substances to that in other countries. Since more than 90 percent of all metal finishing operations in Canada are centred in Alberta, British Columbia, Ontario and Quebec, summaries of Canadian information focus on these four provinces. In addition, since this study primarily examined the release of Priority Substances, summaries of any pertinent objectives, guidelines and limits highlight these compounds. In this sense, this section does not constitute an exhaustive regulatory review, which was not within the scope of this study.

The section is divided by legal jurisdiction, and further by subsections pertaining to air emissions, wastewater discharges and waste management. Pertinent regulations are described in general terms including any compliance and reporting requirements. In addition, information on enforcement actions is provided where available. A brief summary is also included.

CANADA

FEDERAL

Air Emissions

The *Canadian Environmental Protection Act* (CEPA) contains provisions to control toxic substances throughout their life cycle. These provisions include the power to control industrial sources where a violation of international agreement would otherwise result. The federal government may also develop ambient air quality objectives and encourage their adoption as binding provincial standards, however these powers are not likely to directly affect metal finishing operations.

A Priority Substances List has been established under CEPA. Substances appearing on this list will be investigated regarding their potential toxicity. Under the federal Green Plan, reports summarizing options for the control of potentially toxic releases from a number of industrial sectors are being prepared. Control option reports will then be used as supporting documentation to regulations or other controls in each industrial sector.

In addition, a National Pollutant Release Inventory (NPRI) is being developed under the Green Plan. The purpose of the NPRI is to provide comprehensive and national data on the release of specified substances into the air, water, and land. The NPRI will require mandatory reporting of releases by any facility meeting defined criteria. The data reported will be summarized into a publicly accessible computer database. The first annual report will be available in 1994.

The federal government is also currently involved in the implementation of a *Management Plan for Nitrogen Oxides (NO_x) and Volatile Organic Compounds (VOCs)*. This Plan was developed by the Canadian Council of Ministers of the Environment (CCME) to address the problem of urban smog. Under this Plan, initiatives for industrial source control may be included.

Wastewater

Under the *Fisheries Act*, the federal government issued the *Metal Finishing Liquid Effluent Guidelines* in 1977. These guidelines are not binding but are intended to provide a national baseline for direct discharges to receiving waters. As noted in the section pertaining to releases from the metal finishing sector, a small minority of metal finishing operations discharge wastewater directly to receiving waters. The guidelines as they pertain to Priority Substances and lead are summarized in Table 5.1.

Table 5.1
Federal Metal Finishing Liquid Effluent Guidelines for Priority Substances and Lead

Priority Substance	Maximum Total Concentration (mg/L)
Cadmium	1.5
Chromium (total)	1.0
Lead	1.5
Nickel	2.0

As noted under the Air Emissions section, CEPA has given the federal government powers to regulate toxic substances throughout their life cycle. No specific wastewater regulations affecting the metal finishing sector have yet been developed under the Act.

Waste

The major piece of federal legislation affecting waste management by metal finishing facilities is the *Transportation of Dangerous Goods Act (and Regulations)*. A number of metal finishing wastes are specifically identified in these regulations, as summarized in Table 5.2. These wastes may contain Priority Substances as discussed in Section 3.

Other wastes generated in this sector may also fall under these requirements depending on their physical and/or chemical characteristics.

The federal regulations apply for the transportation and management of dangerous goods within provinces (except when transported by road) as well as inter-provincial and international transportation by any means. The regulations require manifesting of wastes, along with appropriate distribution of completed manifests. Small quantity exemptions from the regulations may apply depending on the nature of the waste.

CEPA gives the federal government the power to create guidelines and codes for waste management practices and to issue permits for the control of dumping at sea. These provisions are likely to have little direct impact on the metal finishing sector. However, the power to develop regulations to control the management of toxic substances may affect some metal finishers in the future, especially in those provinces where comprehensive provincial hazardous or special waste regulations are not yet in place.

Table 5.2
Metal Finishing Wastes Listed Under Federal Transportation of Dangerous Goods Regulations

Waste Type	Description
6 (NA9306)	Wastewater treatment sludges from electroplating operations except for the following processes: (1) sulphuric acid anodizing of aluminum; (2) tin plating on carbon steel; (3) zinc plating (on a segregated basis) on carbon steel; (4) aluminum or aluminum-zinc plating on carbon steel; (5) cleaning/stripping associated with tin, zinc, and aluminum plating on carbon steel; and (6) chemical etching and milling of aluminum.
7 (NA9307)	Wastewater treatment sludges from the chemical conversion coating of aluminum.
8 (NA9308)	Spent cyanide plating bath solutions from electroplating operations (except for precious metals electroplating spent cyanide plating bath solutions).
9 (NA9309)	Plating bath sludges from the bottom of plating baths from electroplating operations where cyanides are used in the process (except for precious metals electroplating plating bath sludges).
10 (NA9310)	Spent stripping and cleaning bath solutions from electroplating operations where cyanides are used in the process (except for precious metals electroplating spent stripping and cleaning bath solutions).

PROVINCIAL

Air Emissions

Provincial requirements related to air emissions vary widely across the country. Some provinces such as Ontario and British Columbia may require permitting of point sources of air emissions depending upon certain factors such as the age and size of the facility and the potential impact of the emissions. In all provinces, however, there have been relatively few requirements for the monitoring of emissions of Priority Substances.

In Ontario, the Clean Air Program (CAP) was proposed to address concerns surrounding emissions of toxic and/or persistent substances. Increasingly, monitoring and/or point-of-impingement modelling are being required to obtain point source Certificates of Approval. In addition, the Ministry of the Environment is conducting a voluntary industry survey of emissions, the results of which will be available some time in 1993. No new regulations have arisen out of the CAP initiative.

Wastewater

Provincial jurisdiction in the area of industrial wastewater discharges has traditionally focused on direct discharges to receiving waters. In this sense, these regulations have very little impact on the metal finishing sector, since as noted throughout this report, the vast majority of metal finishers are indirect dischargers. In these cases, control of discharges may be regulated by municipal bylaws, as discussed in subsequent sections. Municipal jurisdiction in this area is granted by the provincial Municipal Act, or its equivalent, in each province.

In Ontario, a small number of metal finishers are direct dischargers and these facilities are required to make monitoring data available to the Industrial Monitoring Information System (IMIS) under the provisions of their Certificates of Approval (C of As). There are only five metal finishers included under the Metal, Plastic Fabricating and Finishing category in the *Report on the 1989 Industrial Direct Discharges in Ontario* (MOE, 1991). This category has not been a part of the initial effluent monitoring and limits regulations development undertaken by the MISA program in a number of other industrial sectors in Ontario.

An ongoing initiative of the Ontario Ministry of the Environment will indirectly affect metal finishers discharging to municipal sanitary sewers. The Municipal Industrial Strategy for Abatement (MISA) program will eventually regulate discharges of persistent toxics from Water Pollution Control Plants (WPCPs) with the ultimate objective of virtual elimination of discharges of toxic and persistent substances. In turn, it has been proposed that many municipalities in Ontario will be required to develop more stringent bylaws controlling industrial discharges to the sanitary sewers feeding WPCPs in order to meet WPCP discharge requirements.

Waste

Almost without exception, the federal *Transportation of Dangerous Goods Act* has been adopted as a minimum set of requirements for the transport and manifesting of hazardous wastes within the provinces. As noted earlier, some metal finishing wastes are specifically identified in these regulations and others may be included based on their physical and/or chemical properties.

In addition to these regulations, most of the larger provinces, including Alberta, British Columbia, Ontario and Quebec where more than 90 percent of all metal finishing facilities are located, have adopted some form of hazardous or special waste regulations. In addition to governing the transport and manifesting of waste meeting regulation criteria, these regulations may specify requirements in the following areas:

- Generator registration
- Waste storage
- Waste recycling, reuse, recovery and disposal

In the four provinces mentioned previously, the five metal finishing wastes listed in Table 5.2 are covered by hazardous or special waste regulations. Other metal finishing wastes may also be covered depending upon their physical and/or chemical characteristics such as:

- Leachability
- Ignitability
- Corrosiveness
- Reactivity
- etc.

Small quantity exemptions from the regulations may also apply.

MUNICIPAL

Air Emissions

The control of air pollution sources in Canada is largely a provincial jurisdiction and, as such, municipalities generally have no authority over metal finishing facilities in this regard. Notable exceptions exist, however, such as the powers granted to the Greater Vancouver Regional District (GVRD) and the Montreal Urban Community (MUC) by their respective provincial governments. The GVRD and MUC have the authority to control air emissions within their jurisdictions in a manner similar to and essentially replacing the provincial authority. Another possible exception would be the enforcement of odour or general nuisance bylaws, but these do not pertain specifically to releases of Priority Substances.

Wastewater

Through the various provincial municipal acts, municipalities may have the power to enact bylaws to control the use of sanitary and storm sewers. Traditionally, this power has been used to enter into surcharge agreements with industrial dischargers. Under such agreements, parameters such as biological oxygen demand (BOD), total suspended solids (TSS) and oil and grease may be monitored and a surcharge for the treatment of these wastes at the Water Pollution Control Plant (WPCP) assessed. Priority Substances have not traditionally been monitored or been allowed as surchargeable parameters.

Within the last few years, effluent bylaw limits have become more stringent, now include more Priority Substances and have been more actively enforced. These trends have developed in response to several concerns, including the reduction of potentially toxic discharges from WPCPs and the protection of programs involving the application of residual sewage sludge to agricultural lands.

As an example of these developments, the Ontario Ministry of the Environment has developed the Model Sewer Use Bylaw and has encouraged its adoption by municipalities across the province while the MISA program is still under development. Effluent limits for discharges of Priority Substances under the Model Bylaw are summarized in Table 5.3.

Table 5.3
MOE Model Sewer Use By-Law Limits for Priority Substances, Lead and Mercury

Priority Substance	Discharges to Sanitary or Combined Sewers	Discharges to Storm Sewers
Arsenic	1 mg/L	-
Cadmium	1 mg/L	1 µg/L
Chromium (total)	5 mg/L	200 µg/L
Fluorides	10 mg/L	-
Lead	5 mg/L	50 µg/L
Mercury	0.1 mg/L	1 µg/L
Nickel	3 mg/L	50 µg/L

As an example of how regulations are becoming more stringent, it should be noted that the more recent MOE Model Bylaw has more stringent requirements for discharges to storm sewers than the comparable federal liquid effluent guidelines for direct discharges summarized in Table 5.1. The Model Bylaw also covers a broader range of parameters.

Since the release of the Model Bylaw in 1988, numerous Canadian municipalities have begun to impose more stringent discharge limits and to enforce these limits with increased monitoring and compliance programs. A recent Canadian Association of Metal Finishers (CAMF) newsletter (1992) presented a tabular comparison of effluent limits for one city in each province, which is reproduced with corrections as appropriate in Table 5.4. Limits for additional municipalities contacted during this study are included in Table 5.5.

Monitoring and compliance programs in a number of municipalities were also investigated as part of this study through telephone and personal interviews with municipal staff. Brief descriptions of the various programs, which outline the type of monitoring and enforcement activities conducted, have been developed based on available information as follows.

Greater Vancouver Regional District (GVRD). Since 1988, metal finishing facilities have been required by GVRD to obtain a permit for sanitary sewer discharge. Requirements of the permit include self-monitoring by the facilities for contaminants of concern for each particular facility and processes in use. This approach reduces GVRD's monitoring needs, but audit sampling is conducted on a regular basis to confirm results reported by the facility. It was reported that many metal finishing facilities have installed pretreatment facilities since 1988.

City of Calgary. Indirect dischargers may pay surcharges for the treatment of BOD, TSS, and oil and grease at the municipal treatment facility. The majority of metal finishers have entered into compliance programs with the City to address parameters other than those noted. This gives the facilities the time required to address discharge problems and avoid further action such as fines. A history of unacceptable swings in pH at one of the municipal treatment facilities lead to an investigation of upstream sources, which identified metal finishing facilities as the cause of the problem. One such facility has now initiated pretreatment but monitoring at other facilities is hampered by lack of manholes. Calgary has fewer than ten known indirect discharging metal finishers.

City of Edmonton. The City of Edmonton has recently passed a new sewer use bylaw. Monitoring is conducted on a random basis by the City. The bylaw requires that the owner provide a manhole for sampling access.

City of Windsor. The City of Windsor initiated an Industrial Waste Control program in the early 1970s when its sewer use bylaw first came into force. Metal finishing facilities were one of the first sectors targeted since acidic and heavy metal discharges were of greatest concern at that time. As dischargers were identified, a short intensive sampling effort was conducted. Based on the results of sampling, facilities were required to develop an abatement plan, generally including a schedule for the design, construction and commissioning of a pretreatment system. Once operational, the City conducts random monitoring of the pretreatment system effluent to ensure compliance with the sewer use bylaw. Enforcement actions consist of verbal and written

Table 5.4
CAMF Comparison of Canadian Sanitary Sewer Use Effluent Limits[1]

Province/By-law / Element (Symbol)	B.C. Greater Vancouver Regional District	Alta. Edmonton[2]	Sask. Regina	Man. Winnipeg	Ont. Toronto	Ont. Model Sewer Use Bylaw	Que. Montreal Urban Community	P.E.I.	N.B. Fredericton	N.S. Halifax	Nfld. St. John's
Aluminum (Al)	50.0			50.0	50.0	50.0			50.0	50.0	
Antimony (Sn)		1.0			5.0	5.0				5.0	
Arsenic (As)	1.0	1.0			1.0	1.0	1.0		1.0	1.0	
Barium (Ba)		3.0							5.0	5.0	
Bismuth (Bi)					5.0	5.0				5.0	
Boron (B)	50.0	1.0									5.0
Cadmium (Cd)	0.2	0.05	4.0	2.0	1.0	1.0	2.0		2.0	1.0	0.05
Chromium (Cr)	4.0	1.0	5.0	5.0	5.0	5.0	5.0	3.0	5.0	5.0	0.05
Cobalt (Co)	5.0				5.0	5.0				5.0	
Copper (Cu)	2.0	0.5	4.0	5.0	3.0	3.0	5.0	1.0	5.0	2.0	0.3
Cyanide (CN)	1.0	1.0	3.0	2.0	2.0[4]	2.0	2.0[5]	2.0	2.0	2.0	2.0
Iron (Fe)	10.0				50.0	50.0			50.0	10.0	15.0
Lead (Pb)	1.0	1.0	5.0	2.0	5.0	5.0	2.0		5.0	2.0	0.2
Manganese (Mn)	5.0	1.0			5.0	5.0				5.0	
Mercury (Hg)	0.05	0.1		0.1	0.1	0.1	0.05		0.1	0.1	0.005
Molybdenum (Mo)	1.0				5.0	5.0				5.0	
Nickel (Ni)	2.0	0.5	5.0	5.0	3.0	3.0	5.0		5.0	2.0	
Selenium (Se)		1.0			5.0	5.0				5.0	
Silver (Ag)	1.0	1.0			5.0	5.0				1.0	
Tin (Sn)					5.0	5.0	5.0		5.0	5.0	
Titanium (Ti)					5.0	5.0				5.0	
Vanadium (V)					5.0	5.0				5.0	
Zinc (Zn)	3.0	1.0	5.0	5.0	3.0	3.0	10.0		5.0	2.0	0.5

Table 5.4
CAMF Comparison of Canadian Sanitary Sewer Use Effluent Limits[1]

Province/By-law / Element (Symbol)	B.C. Greater Vancouver Regional District	Alta. Edmonton[2]	Sask. Regina	Man. Winnipeg	Ont. Toronto	Ont. Model Sewer Use Bylaw	Que. Montreal Urban Community	P.E.I.	N.B. Fredericton	N.S. Halifax	Nfld. St. John's
Chloride (Cl)					1500.0	1500.0			1500.0	1500.0	
Fluoride (F)				10.0		10.0			10.0	10.0	
pH (lower)	5.0	6.0	5.5	5.5	6.0	5.5	6.0	5.5	6.0	5.5	5.5
pH (upper)	11.0	10.0	9.5	9.0	10.5	9.5	10.5	9.5	10.5	10.5	9.0
Phenols	1.0	0.1	0.1		1.0	1.0	1.0	50.0	1.0		0.5
Phosphorus (P)					10.0	10.0			100.0	10.0	0.0005
Phosphates (P_2O_5)		100(30[3])									10.0
Solvent Extractables (Inorganic)					15.0	15.0					
Solvent Extractables (Organic)					150.0	150.0					
Sulphate (SO_4)	1500.0				1500.0	1500.0			1500.0	1500.0	
Sulphides (H_2S)	1.0	1.0	3.0	10.0				5.0			
Threshold Water Limits (litres/day)					50000	50000					

Notes: [1]For discharges to sanitary sewers (unless otherwise noted, units are mg/L, undiluted).
Blank cells = Not specified
[2]City of Edmonton Bylaw No. 7118, as amended to December 13, 1989. More recent bylaw has been passed but was not available.
[3]Surcharge strength (limit at which a surcharge is assessed).
[4]Reported as HCN.
[5]Cyanides amenable to chlorination (expressed as CN).

Table 5.5
Sewer Use Effluent Limits for Additional Municipalities Contacted

Province/By-law Element (Symbol)	Alta. Calgary (mg/L)	Ont. Durham (mg/L)	Ont. Halton (mg/L)	Ont. Niagara (mg/L)	Ont. Peel (mg/L)	Ont. Waterloo (mg/L)	Ont. Windsor (mg/L)
Aluminum (Al)		50	50	50	50	50	50
Antimony (Sb)		5	5		5	5	
Arsenic (As)		1	1	1	1	1	1
Barium (Ba)				5			5
Bismuth (Bi)			5		5	5	
Boron (B)							
Cadmium (Cd)	1	1	1	2	1	0.5	2
Chromium (Cr)	3	5	3	5	5	5	5
Cobalt (Co)		5			5	5	5
Copper (Cu)	3	3	3	5	3	3	5
Cyanide (CN)	3	2[1]	2[1]	1[1]	2[1]	2[1]	2[1]
Iron (Fe)		50	50	50	50	50	50
Lead (Pb)	1	5	3	5	5	5	5
Manganese (Mn)		5	5		5	5	
Mercury (Hg)	0.01	0.1	0.1	0.1	0.1	0.1	0.1
Molybdenum (Mo)			5		5	5	5
Nickel (Ni)	3	3	3	5	3	3	5
Selenium (Se)		5	5		5	5	3
Silver (Ag)			5		5	5	2
Tin (Sn)		5	5	5	5	5	5
Titanium (Ti)		5	5		5	5	
Vanadium (V)		5	5		5	5	
Zinc (Zn)	3	3	3	5	3	3	5
Chloride (Cl)		1500	1500	1500	1500	1500	1500
Fluoride (F)		10	10	10	10	10	10
pH (lower)	5.5	5.5	6	6	5.5	5.5	6
pH (upper)	10	9.5	10	10.5	9.5	9.5	10.5
Phenols	0.1	1	1	1	1	1	1
Phosphorus		10	10	100	10	10	100
Phosphates (P2O5)							
Solvent Extractables (inorganic)		15	15	15	15	15	
Solvent Extractables (organic)		150	150	100	150	100	
Sulphate (SO4)		1500	1500	1500	1500	1500	1500
Sulphides (H2S)	3						2
Threshold Water Limits (litres/day)							

NOTES: [1]Reported as HCN

communication at the management level, followed by legal action (one or two court cases per year) when these are not effective. Windsor employs a Chemist-Pollution Control Officer and two technologists for sampling and analyzing, as well as follow-up with industries, as required.

Region of Niagara. Sewer use bylaw enforcement in the Region of Niagara is carried out by Industrial Waste staff consisting of four inspectors and one technician. Sampling by the Region is conducted using automatic time base samplers. In addition, industries are required to conduct their own monitoring program and report results regularly to the Region. Analytical work on samples taken by the Region is conducted in their own lab, staffed by two technicians, one assistant and one clerk. Enforcement actions consist of issuing violation notices and action requests based on the results of sampling by the Region. Further legal action is considered for those cases where notices and requests are repeatedly ignored.

Municipality of Metropolitan Toronto. The Metro Toronto sewer use bylaw is closely modelled after the MISA model bylaw and efforts have been made to survey all indirect dischargers in order to categorize them according to their potential impact on municipal treatment facilities. Most metal finishers are in the "High Potential" (HP) category and, as such, are sampled 12 times per year and inspected once a year. Over-strength discharges from HP facilities are not amenable to treatment at municipal treatment facilities and, as such, parameter violations will result in charges or in the issue of a violation notice or warning. Industries may also enter into compliance programs that allow violations over a short duration to allow the company the time required to correct the problem. Sampling, plant inspections and prosecutions are performed by twelve crews, each responsible for a specific geographic area, and each consisting of a District Enforcement Officer (DEO) and Quality Control Investigator (QCI).

Region of Durham. Sewer use bylaw enforcement in the Region of Durham is carried out by Works Division staff. Monitoring is conducted on a regular basis, both for surchargeable and non-surchargeable parameters, the latter being those common in metal finishing. Violations may result in establishment of a compliance agreement program. Six metal finishing operations are currently monitored in the Region.

Montreal Urban Community. The MUC's program of industrial waste control began in 1977 with efforts to gain industry's cooperation in protecting the sewer infrastructure and primary treatment facilities from damage due to wastes discharged by industry. In 1986, a sewer use bylaw was passed which requires that industrial discharges meet both qualitative and quantitative objectives. Industrial waste control focuses on two types of measures: internal source control and pretreatment of effluents which do not conform with the bylaw. Internal controls focus on water use reduction, prevention of water contamination, spill prevention and appropriate management of hazardous wastes. MUC staff work in cooperation with industry to first implement appropriate internal controls and then to oversee implementation of pretreatment in only those cases where it is required to meet bylaw limits. These activities take place during the permit issue process. Monitoring conducted by MUC may result in notices of violation, which, if they occur repeatedly, may lead to court action. MUC staff involved in these activities include:

- A superintendent
- Four engineers
- Two inspectors to respond to complaints
- Five technicians involved in permitting, approvals and site surveys
- A supervisor, three technicians and two assistants involved in monitoring
- Lab staff involved in analytical work

Corresponding staff are responsible for industrial air emissions control.

Waste

As is the case for air emissions, municipalities generally have no jurisdiction in matters pertaining to waste management for metal finishing facilities. In some cases, the municipality may provide collection of solid, non-hazardous waste and may allow the use of a voluntary household hazardous waste collection program to dispose of small quantities of special wastes, however these programs are not regulated.

Bans on certain materials at municipal landfills or escalating tipping fees may affect metal finishers, as is presently the case in Ontario, where considerable amounts of industrial non-hazardous waste, generally collected by contractors, are being transported to the U.S. for disposal. Although material bans may include scrap metal, these measures do not include the regulation of Priority Substances, per se.

UNITED STATES

GENERAL DESCRIPTION

The metal finishing industry in the United States (US) is a very broad group of manufacturing operations which are difficult to uniformly categorize. Metal finishing products range from large equipment such as construction machinery and automobiles to smaller items such as fasteners, ornamental jewelry, and writing instruments. Many and varied unit operations are also used to manufacture these products, including cleaning processes such as solvent degreasing and paint stripping, surface preparatory processes such as machining and etching, plating or coating operations such as electroplating and electrostatic painting, and other surface finishing processes such as tumbling and burnishing.

Demographic information such as the number, size or type of metal finishing facilities, products, production rate, or method of production has not been developed by any governmental agency, professional or trade organizations, or industry representatives

(Crane, 1993). Two professional organizations, the American Electroplaters and Surface Finishers Society (AESF) and the National Association of Metal Finishers (NAMF) are currently initiating a study to produce this data. Estimates from individuals active within the industry and professional organizations are that 9,000 to 14,000 metal finishers are currently operating in the US, depending upon the definition used to categorize facilities (Crane, 1993). The main difficulty in categorizing the industry is that no uniform standard for measuring product or production, such as basis metal surface area finished or volume of raw material used, can be uniformly applied to the industry (Crane, 1993, U.S. EPA, 1982).

In general, Federal, State and local municipal regulations govern emissions from metal finishing facilities. Historically, the US Environmental Protection Agency (EPA) has developed regulations at the federal level for air, water, and waste emissions. The EPA normally delegates authority to implement and enforce the regulations to state agencies. With respect to air and waste emissions, the state is normally the lead agency in implementing regulations; however, municipalities are often the lead agency for governing water emissions because most metal finishing facilities discharge to publicly owned treatment works (POTW), for which the municipality is responsible.

At about the time that discharge regulations were implemented, the metal finishing industry experienced a 20 percent to 30 percent reduction in manufacturing facilities (Crane, 1993). Although there are many factors which may have contributed to the industry decline, discharge regulations were a factor due to the cost to comply with regulations requiring installation and use of wastewater treatment equipment. Some metal finishers with marginal financial performance elected to close facilities. Other metal finishers relocated operations outside of the US, mainly to Asia, due in part to the fact that many host countries did not require environmental controls (Crane, 1993).

Several important articles of US legislation which impact the metal finishing industry, including the Clean Water Act (CWA) and the Resource Conservation and Recovery Act (RCRA), are due for reauthorization in the next few years, and are likely to contain new provisions placing further discharge restrictions on the industry. The reauthorized Clean Air Act (CAA) of 1990 affects metal finishers to a much greater extent than did earlier versions. The schedule to promulgate new air emission regulations on the metal finishing industry is incremental and will affect some facilities before others, depending upon air emission sources. Ultimately, all metal finishers will need to comply with air emissions regulations by the year 2000.

FEDERAL

The federal agency responsible for developing environmental regulations is the US Environmental Protection Agency (EPA). The EPA develops regulations for consideration and approval by the US congress. These regulations, when enacted into law, limit discharge or disposal of certain materials which may adversely affect human health and the environment. Historically, the EPA has developed procedures by which state agencies may assume responsibility for adopting, executing, and enforcing the regulations. The intent of the EPA is to delegate this authority, and it does so by requiring states to submit plans, for EPA review and approval, indicating the state's proposed regulations and method of implementation. The EPA clearly establishes that states may adopt regulations more stringent than those of the EPA, and that the provisions in the federal regulations represent the minimum standards which must be achieved.

Air Emissions

The CAA was first enacted into law in 1963. The original act granted authority for federal air pollution control activities (including federal grants to establish and improve state and local programs), provided for federal action to abate interstate air pollution, and provided for research on motor vehicle pollution and sulphur dioxide emissions from coal and oil combustion. The CAA amendments of 1970 provided for national ambient air quality standards (NAAQS) and required EPA to develop them by 1971, with implementation by 1975. The CAA was reauthorized in 1977, but not again until 1990, although public laws were incorporated in the years between all reauthorizations.

Prior to the CAA amendments of 1990, air emissions regulations did not significantly affect metal finishers. However, the 1990 CAA does affect the metal finishing industry because it brings under regulation 189 air toxics (Altmayer, 1992a) (in comparison to the eight substances originally regulated) some of which are emitted by metal finishing operations. Additionally, the EPA will promulgate emissions standards for a number of major sources (possibly 175) of air contaminants, including electroplating and anodizing operations. The 1990 CAA includes a schedule for promulgating rules and compliance requirements. It is anticipated that most sources applicable to the metal finishing industry will not be promulgated until around 1997, except that chromium sources will be handled on an accelerated basis.

The EPA also included steps in the 1990 CAA to encourage early reduction of emissions. If substantial reductions in emissions are implemented at a facility before the regulations are proposed, an extension of up to six years can be granted before the new laws apply to that facility. For example, for a metal finisher with emissions of hexavelant chromium, if a 95 percent reduction in chromic acid mist emissions can be demonstrated, compared to 1987 or later levels, that metal finisher can delay in implementing maximum achievable control technology (MACT), which may be a packed bed scrubber, by up to six years (Altmayer, 1992a).

The 1990 CAA increased the authority of the EPA to enforce air emissions regulations. The EPA has authority to request fines of up to $25,000 per day for each violation by seeking judicial imposition. The 1990 CAA further provides EPA with the authority to issue administrative penalties of up to $25,000 per day of violation, and citations for minor violations (e.g. record-keeping errors) of up to $5,000 per day.

Wastewater

Although not the first federal statute on water quality, the Federal Water Pollution Control Act Amendments of 1972, as the original Clean Water Act (CWA) of 1972 is officially entitled, contained a far-reaching set of national programs to address almost every type of water pollution control problem (Federal Register, 1987). Its four major precepts are:

- Discharge of pollutants to a navigable stream requires a permit
- The permit shall limit discharge of pollutants
- Certain pollution control measures are required, regardless of the quality of the receiving stream
- Any variance from federal guidelines must be based on receiving stream water quality

The CWA has been amended 12 times since its inception, but the major amendments were in 1977, 1981, and 1987. The 1987 CWA extended authorization until 1994, and bills to amend the CWA have already been introduced in 1992 (but held over). Reauthorization will be coming up in the next few years.

The 1972 CWA established a comprehensive program to restore and maintain the integrity of the nation's waters, and required that by 1977 existing industrial dischargers achieve effluent limitations requiring the application of the best practicable control technology currently available (BPT). By 1983 these dischargers were required to achieve effluent limitations requiring application of the best available technology economically achievable (BAT) to effect further progress toward the stated national goal to eliminate discharge of pollutants. New industries discharging directly to a receiving stream were required to comply with new source performance standards (NSPS) based on best available demonstrated technology, and new and existing industrial dischargers to publicly owned treatment works (POTW) were subject to pretreatment standards. The 1977 CWA incorporated the requirement to achieve, by 1984 effluent limitations requiring application of BAT for toxic pollutants. The 1977 CWA further required that best conventional pollutant control technology (BCT) be implemented for conventional pollutants such as suspended solids. The factors considered in assessing BCT included costs of attaining a reduction in effluents and the benefits derived compared to the costs of reduction (U.S. EPA, 1982).

The EPA has instituted a program to establish effluent quality criteria for indirect industrial discharges on an industrial sector basis. These sets of criteria are collectively known as the Categorical Pretreatment Standards and include a set of standards for the metal finishing sector.

The standards for each industrial sector were developed based on the results of a study of each sector (the Development Document) incorporating public/industry comment.

The Categorical Pretreatment Standards establish minimum requirements which must be adopted and enforced by the local agency with responsibility/authority for the operation of the POTW. Under certain circumstances it is possible for local agencies to adopt less stringent criteria than those established in the Categorical Pretreatment Standards. Such a variance requires the approval of the EPA based on a demonstration by the local agency that the quality of effluent and solid residues from the POTW will not be adversely impacted if less stringent criteria are adopted.

The Categorical Pretreatment Standards specific to metal finishing operations are defined in 40 CFR 433 and are summarized in Table 5.6.

Table 5.6
United States Categorical Pretreatment Standards for the Metal Finishing Sector

Parameter	Unit	Existing Sources		New Sources	
		Daily Maximum	30-Day Average	Daily Maximum	30 Day Average
Cyanide (Total)	mg/l as CN	1.20	0.65	1.20	0.65
Cyanide (Free)	mg/l as CN	0.86	0.32	0.86	0.32
Cadmium	mg/l as Cd	0.69	0.26	0.11	0.07
Chromium, Total	mg/l as Cr	2.77	1.71	2.77	1.71
Copper	mg/l as Cu	3.38	2.07	3.38	2.07
Lead	mg/l as Pb	0.69	0.43	0.69	0.43
Nickel	mg/l as Ni	3.98	2.38	3.98	2.38
Silver	mg/l as Ag	0.43	0.24	0.43	0.24
Zinc	mg/l as Zn	2.61	1.48	2.61	1.48
TTOs[4]	mg/l	2.13	—	2.13	—

[1]Categorical Pretreatment Standards (40 CFR 433)

In establishing applicable effluent limitations and standards, the EPA considered raw waste characteristics, manufacturing processes, raw materials, product type and production volume, size and age of plants, number of employees, water usage characteristics, and other characteristics. Based on this information, the EPA determined that a single metal finishing category could be established, not due to the similarity of facilities, but rather due to the fact that all wastewaters produced from industries within the category were amenable to treatment by a single system. The effluent limitations and standards were based on concentration of pollutants rather than limitations based on production units because correlation to productions factors could not be determined (U.S. EPA, 1982).

The metal finishing category is a process defined category. The industries covered by the metal finishing category are included in the Standard Industrial Classification (SIC) Major Groups 34 through 39 and are those that perform some combination of 45 manufacturing unit operations. Those unit operations are:

- Electroplating
- Electroless plating
- Anodizing
- Conversion Coating
- Etching (chemical milling)
- Cleaning
- Machining
- Grinding
- Polishing
- Tumbling (barrel finishing)
- Burnishing
- Impact deformation
- Pressure deformation
- Shearing
- Heat Treating
- Thermal cutting
- Welding
- Brazing
- Soldering
- Flame spraying
- Sand blasting
- Other abrasive jet machining
- Electric discharge machining
- Electrochemical machining
- Electron beam machining
- Laser beam machining
- Plasma arc machining
- Ultrasonic Machining
- Sintering
- Laminating
- Hot dip coating
- Sputtering
- Vapor plating
- Thermal infusion
- Salt bath descaling
- Solvent degreasing
- Paint stripping
- Painting
- Electrostatic painting
- Electropainting
- Vacuum metalizing
- Assembly
- Calibration
- Testing
- Mechanical plating

When amended, the new CWA will likely contain some provisions of bills introduced prior to reauthorization (Altmayer, 1992b, Dhonau, 1992). One provision likely to be included is the requirement that EPA establish new effluent standards based on best available technology. This may require metal finishers to install and use the technology which EPA determines can reduce pollutants to the maximum extent possible (Altmayer, 1992b). This may affect metal finishers by requiring implementation of a technology regardless of cost or applicability to specific plants.

The new CWA may also require EPA to issue guidelines to reduce, to the maximum extent practicable, the use of toxic chemicals and the generation of waste (Altmayer, 1992b). Authority may be vested in EPA to require changes in production, products, or raw materials to meet this goal.

The new CWA may also require EPA to place a ban on discharge of certain toxics (Altmayer, 1992b). Eight toxics, including mercury, may be banned immediately. Any other toxic pollutant presently regulated under the CWA and determined by EPA to be as toxic as the eight banned substances, or any other pollutant with a high bioaccumulation (based on a bioaccumulation factor) would also be banned from discharge.

Industry has responded to the potential provisions of the new CWA by forming an ad-hoc group, called The Clean Water Industry Coalition, consisting of associations representing many of the major manufacturing and service industries, including the automobile, chemical, food processing, pulp and paper, surface finishing, electric utility, and other associated industries (Altmayer, 1992b). The coalition is trying to provide congress with information on the impact of these potential provisions on industry. Their position is that the present CWA is working well and was sufficiently strengthened by the 1987 amendments to continue to address water quality issues, especially for toxic pollutants. Many of the programs adopted in 1987 are now only beginning to be implemented, and the coalition's position is that altering them at this point would be unwise. The resulting disruption of current programs would result in the implementation of new programs without the benefit of knowledge gained from the 1987 amendments. The coalition also feels that the regulators would be overwhelmed administering new provisions proposed in 1992 (Federal Register, 1987).

Waste

The Resource Conservation and Recovery Act (RCRA) was enacted in 1976 and is the regulatory statute designed to provide control of solid and hazardous waste to protect human health and the environment from the effects of improper management of waste (Wagner, 1989). RCRA imposes management requirements upon generators and transporters of hazardous waste, along with owners and operators of treatment, storage, and disposal facilities. The management requirements placed upon a generator, for example, are the length of time waste may be stored at the facility, labelling requirements for containers of hazardous waste, personnel training for those who handle the waste, regular inspections of the areas where hazardous wastes are stored, and development and implementation of contingency plans in the event of spills or releases of toxic or hazardous substances.

RCRA is administered through a notification and permitting process (Wagner, 1989). Any generator, transporter, or owner of a treatment, storage, and disposal facility must notify the EPA of the regulated activity. This notification requires the facility's location, description of the regulated activity, and identification of the types and quantities of hazardous wastes. This information is retained by EPA in its Hazardous Waste Data Management System.

The EPA has listed hazardous wastes based on certain criteria, and if the waste meets the listing definition it is presumed to be hazardous regardless of concentration of hazardous constituents (Wagner, 1989). The criteria for listing of hazardous wastes are based on toxicity, reactivity, corrosivity, and ignitability. The listed hazardous wastes consist of wastes from nonspecific sources (F codes), wastes from specific sources (K codes) and commercial chemical products (U and P codes). For example, a listed hazardous waste from a nonspecific source is electroplating wastes, including anodizing and chemical etching, etc. Wastes from specific sources are those generated from a specific industrial process such as API separator sludge from the petroleum industry.

The EPA also promulgated criteria for identifying characteristics of hazardous waste that are separate from listed wastes (Wagner, 1989). The primary responsibility for determining whether a waste exhibits a characteristic rests with the generator. Characteristics were selected that were measurable by standard available testing protocols (Dhonau, 1992). The EPA established ignitability, corrosiveness, reactivity, and extraction procedure toxicity as the characteristics of hazardous waste.

One of the intents of RCRA was to encourage recycling. Therefore, the EPA set forth rules regarding recycling of secondary materials. The recycling regulations refer to spent materials, sludges, byproducts, scrap metal, and commercial chemical products recycled in ways that differ from their normal use. The actual recycling process is unregulated, but generation, transportation, and storage prior to recycling is regulated unless the specific waste is excluded. For example, a facility that distils solvents from off-site sources must have a permit for storage of the waste. However, a generator may recycle and/or store wastes prior to recycling without a permit, providing that the waste was generated onsite and that accumulation is done within the guidelines (Wagner, 1989).

The intent of RCRA was to establish a viable state-federal partnership to carry out the provisions of RCRA (Wagner, 1989). For a state to operate the program, its program must be equivalent to the federal program, be consistent with the federal and other state programs, and provide for adequate enforcement. The purpose of RCRA's enforcement program is to compel compliance with its regulations. The primary method of monitoring compliance is the facility inspection. The facility inspection is a formal visit to review records, obtain samples, and observe facility activities. The EPA and authorized states have authority to enter and inspect any facility that has handled hazardous waste. The three enforcement options available under RCRA are: administrative actions, civil actions, and criminal actions. An administrative action is a nonjudicial enforcement action taken by the EPA or state under its own authority. A civil action is a formal lawsuit, filed in court against an individual or facility that has failed to comply with requirements. Criminal actions are for more serious, knowing violations, and carry more severe penalties.

RCRA is also up for reauthorization in the next few years (Dhonau, 1993). As with the CWA, the congress adjourned with several draft bills being delayed. Draft bills focused on increased requirements for waste reduction, recycling and enforcement, with a broader scope of solid waste management, as opposed to the hazardous waste focus of the 1984 reauthorization (Altmayer, 1992b).

STATE LEVEL

Air Emissions

The primary authority for implementing and enforcing air emissions regulations is at the state level. As stated previously, the state must implement regulations at least as stringent as the federal regulations, but are able to adopt more stringent regulations. Several states, including California and Wisconsin, are proactive in the development of air emissions regulations. Wisconsin adopted NR 445 in 1988, which restricts the emission of toxic substances to air, prior to reauthorization of the CAA.

The method by which air emission regulations are implemented varies somewhat by state. For example, Wisconsin requires that each facility conduct an air emissions inventory and supply the state with the report. Cumulative totals of each toxic compound are compared to allowable levels as determined by the state. If a facility exceeds allowable levels for any toxic substance, a compliance plan must be developed and submitted. The compliance plan must detail steps to reduce emissions of each compound exceeding allowable levels, starting at the largest source. The state regulations require that compliance be achieved by using best available control technology economically achievable, and data on the economic feasibility of the control technologies must be submitted, with concurrence by the state, before any control technology can be eliminated from consideration. Installation of MACT emission control equipment as outlined in the 1990 CAA is required on the date the 1990 CAA rules are effective or five years from the date of installation of best available control technology under NR 445, whichever is greater.

Emissions are further scrutinized based on location. If a new source is planned in an area which is in attainment of certain air quality goals (namely those for sulphur dioxide, nitrous oxides, carbon monoxide, ozone precursors, lead, and particulate matter), information must be provided showing that the new source will not cause the area to fail its attainment status. Should an emissions source be proposed for an area which is not in attainment with the air quality goals, air emissions credits of 150 percent of the estimated emissions must be obtained, most likely by purchase from other industries in the area with emissions less than permitted.

Wastewater

The state is responsible for regulating discharges directly to receiving waters; however, because most metal finishers discharge to municipalities, most of the responsibility for implementing and enforcing water emissions falls at the municipal level. In instances where direct discharge is practiced, the EPA developed regulations based on BPT and BAT. These regulations are implemented by issuance of a National Pollutant Discharge Elimination System (NPDES) permit containing appropriate provisions to which dischargers must comply. Dischargers are generally required to practice self-monitoring of discharges, with compliance determined based on comparison of average daily and maximum daily discharges to permitted limits.

Indirect dischargers (those who discharge to a POTW) must comply with pretreatment programs generally applied by the local authority.

Waste

Although the regulations governing handling of waste were developed by the federal agency, monitoring of compliance and enforcement of the waste disposal rules is the responsibility of each authorized state (Wagner, 1989). The state program elements involve developing a state hazardous waste program and approval by EPA. Because the EPA's hazardous waste regulations were developed in stages, the states were given the opportunity to implement a phased approach, as well. A state with final authorization may be more stringent or broader in scope than EPA. If the program is broader in scope, that part of the program is not federally approved and generally is not eligible to receive support from EPA enforcement.

The program description that each state seeking authorization must submit to the EPA must contain:

- The scope, structure, coverage, and process for the state program
- The state agencies responsible for running the program
- The staff who will carry out the program
- The state's compliance tracking and enforcement program
- The state's manifest system
- The estimated costs to administer the program and available funding

Although a state with an authorized program assumes primary responsibility for administering RCRA, the EPA still retains some responsibilities and oversight powers in relation to the state's execution of its program. In addition, the EPA will support the state, if requested, or take enforcement actions in authorized states, if it deems necessary to take timely and appropriate action (Dhonau, 1992).

MUNICIPAL

Air Emissions

Air emission regulatory programs are administered at the state level, with minor input from municipalities. Municipalities generally only get involved if a local ordinance is violated, such as that for odour.

Wastewater

Municipalities govern industrial wastewater discharged to their POTWs. In addition to administering a pretreatment program as required by the federal and state agencies, municipalities may further restrict discharge of substances which may harm the operation of the POTW, threaten the health of workers, or pass through the POTW without undergoing substantial treatment. In order to ensure that the POTW meets its own permitted discharge limits, the municipality may also restrict discharges of substances which may cause it to exceed permitted discharge levels or which may render byproducts such as biosolids unfit for beneficial reuse.

The pretreatment program is administered through a permit process. Industries must apply for a discharge permit, or some other form of agreement, on the order of every three to five years. Municipalities generally write permits containing average daily and maximum daily discharge limits, including any local requirements, with provisions for self-monitoring by the industry, and requirements for notification and reapplication in the event of significant alteration of discharge characteristics (e.g. flow increases by 20 percent).

Waste

Municipalities have little responsibility for hazardous waste handling and disposal. The primary responsibility rests with the authorized state or federal agency.

EUROPE

GENERAL

A review of Western European regulations affecting metal finishing operations was undertaken because it was believed that these would be at least as progressive as Canadian regulations. Once again, the purpose was not to provide an exhaustive review but rather to describe initiatives directed toward reduction of toxic discharges. This is achieved through an explanation of the European Economic Community's (EC's) role in setting and achieving common environmental objectives, as well as through a number of examples of regulations from the EC's member states.

The EC produces the following five types of legislation:

- Regulations
- Directives
- Decisions
- Recommendations
- Opinions

Regulations are directly applicable as law in member states and are used to control specific matters such as finance and the Common Agricultural Policy. The majority of EC legislation takes the form of Directives which are binding in terms of the results to be achieved but leave the onus of implementation and enforcement on the member states. Decisions may be addressed to specific members or their agencies and are binding in their entirety. Recommendations and opinions are suggestions for the direction of policy development by member states and cannot be regarded as legally binding.

Metal finishing facilities are expected to comply with the major Directives listed in Table 5.7. In some cases, laws of the member states may be more stringent than the corresponding EC Directive. In these cases, the more stringent member state law applies.

Table 5.7
List of Applicable EC Directives

Directive	Subject
76/464	Dangerous substances in water
78/319	Transport and disposal of dangerous toxic waste
83/513	Limit values and quality objectives for cadmium discharges
80/68	The protection of groundwater from contamination
86/280	The protection of the aquatic environment
84/360	Air pollution from industrial plants

Two other important concepts help to shape EC legislation:

- Environmental Quality Standards

  In setting EQS, the EC tacitly recognizes the variety of environmental conditions within the EC and that this environment may be able to absorb some pollutants without permanent and/or extensive degradation.

- BATNEEC (Best Available Technique Not Entailing Excessive Cost)

  The identification and implementation of BATNEEC is most often required for releases of higher risk compounds and usually implies a system of application, permitting and inspection to ensure that emissions of these substances are reduced to a minimum.

EC legislation is not necessarily specific to various industrial sectors. The rules tend either to define an environmental quality standard or emission limit for a certain substance regardless of what industry it is being used in and at what process stage it is used.

Air Emissions

As noted in Table 5.7, Directive 84/360 provides the framework for air pollution control in EC member states. This Directive makes the following provisions:

- Prior authorization by the member state involved for the operation and substantial alteration of industrial plants which can cause air pollution. Facilities subject to the Directive include metal melting and production installations, which would appear to include metal finishing facilities.

- Identification and implementation of BATNEEC.
- Assurance that operation of the plant will not cause significant air pollution, especially from emissions of specific substances, including the following Canadian Priority Substances:
  - Organic compounds, in particular hydrocarbons (except methane).
  - Heavy metals and their compounds.
  - Fluorine and its compounds.
- None of the applicable emission limit values established at the national level will be exceeded.
- All of the applicable air quality limit values established at the national level will be taken into account.

The federal German air pollution control legislation, referred to as TA Luft, provides a good example of how a member state has established standards exceeding those of the EC by incorporating extensive industry specific information including details on sampling, measurement, ventilation, stack height, etc. TA Luft requires permitting of facilities and that permits set standards for approved mass concentrations, mass ratios, emission ratios, mass flows, odour reduction and other precautionary measures. To obtain a permit, the facility operator must prove that:

- No harmful effects on the environment can be generated for the general public and the neighbourhood due to the air pollutants emanating from the facility.
- Precautionary measures were taken against harmful effects arising from the facility.

Emission standards are also defined for a number of carcinogens, some of which are included in the Canadian Priority Substance List, as summarized in Table 5.8.

Table 5.8
German Air Emission Standards for Carcinogenic Substances

Substance Class	Emission Standard	Toxic and Priority Substances Included
1	0.1 mg/m^3 for mass flow rates of 0.5 g/h or more	• Benzo(a)pyrene • Dibenzo(a,h)anthracene
2	1.0 mg/m^3 for mass flow rates of 5.0 g/h or more	• Arsenic trioxide and arsenic pentoxide, arsenious acid and its salts, arsenic acids and its salts (in respirable form) • Chromium(6) compounds (in respirable form), as far as calcium chromate, chromium(3)chromate, strontium chromate and zinc chromate • Nickel (in the form of respirable dust/aerosols of nickel metal, nickel sulphide and pyritiferous ores, nickel oxide and nickel carbonate, nickel tetracarbonyl)
3	5.0 mg/m^3 for mass flow rates of 25 g/h or more	• Benzene

Other German regulations exist which specify procedures for metal finishing facilities, including the use of waste gas purification facilities and limits for other parameters which are not included on the Canadian Priority Substance List.

The French regulatory system also provides for permitting and inspection of so-called "classified installations" and for specific emission standards for metal finishing facilities. These are summarized in Table 5.9 for Canadian Priority Substances.

Table 5.9
French Air Emission Standards for Priority Substances from Metal Finishing Facilities

Priority Substance	Emission Standard (mg/m^3 at STP)
Cr (total)	1.0
Cr (VI)	0.1
HF, expressed as F	5.0

Wastewater

Wastewater discharges are also governed by an EC Directive (76/464). This Directive identifies two lists of substances and outlines procedures to be followed by member states in authorizing discharges of wastewater containing these substances. Canadian Priority Substances on these two lists are summarized in Table 5.10.

Table 5.10
Canadian Priority Substances on EC Directive 76/464 Lists

EC Directive List Number	Toxic or Priority Substance
1	• Organohalogen compounds and precursors • Organotin compounds • Mercury and its compounds • Cadmium and its compounds • Persistent mineral oils and hydrocarbons of petroleum origin
2	• Arsenic and its compounds • Chromium and its compounds • Fluorides • Lead and its compounds • Nickel and its compounds • Non-persistent mineral oils and hydrocarbons of petroleum origin

The member state permit must lay down effluent standards and forbid discharges to the groundwater of any List 1 substance.

A second EC Directive (80/68) governs indirect discharges of List 1 and 2 substances to the groundwater and requires that member states grant authorization for such discharges provided that the place and method of discharge and precautionary measures are defined by the permit.

An extensive review of sewer use control practices in Europe (United Kingdom, France and Germany) was conducted under the MISA program (MOE, 1989). Such a review was beyond the scope of this study, so some of its results are included as noted below.

Specific effluent standards have been developed by the French government for metal finishing facilities and are summarized in Table 5.11 for Canadian Toxic and Priority Substances. These regulations also govern monitoring methods and record keeping.

Table 5.11
French Effluent Standards for Metal Finishing Facilities for Canadian Toxic and Priority Substances

Priority Substance	Effluent Standard (mg/L)
Cr (III)	3.0
Cr (VI)	0.1
Cd	0.2
Ni	5.0
Pb	1.0
F	15.0

In the U.K., metal finishing facilities are defined as "prescribed processes" by Her Majesty's Inspectorate of Pollution (HMIP) and as such, permits for operation are required under the Environmental Protection Act (1989). HMIP inspects the plant to ensure that BATNEEC is being employed and that the facility is capable of meeting legislative requirements before issuing a permit. Electroplating facilities are required to meet a monthly flow-weighted average concentration of total cadmium in the discharge of 0.2 mg/L.

Maximum allowable concentrations of many compounds in receiving waters have also been established by the National Rivers Authority. Where HMIP BATNEEC requirements are not adequate to meet these standards, a more stringent effluent limit may be imposed.

At the time of the MISA review (MOE, 1989), typical limits applied to discharges to sewers were those noted in Table 5.12. These limits were not specifically developed for metal finishing facilities and are derived for individual facilities based on the following case-specific factors:

- Dilution available due to additional sewage flows from other sources
- Removal efficiency and capacity of the sewage treatment works
- Receiving water flow rate
- Receiving water quality objectives
- Sludge disposal route

Table 5.12
Typical Limits Applied to Discharges to Sewers in the United Kingdom[1]

Substance	Concentration[2] (mg/L)
Heavy metals	2-10 total in solution 5-30 total in solution and suspension
Cadmium Arsenic Mercury Selenium Silver	<1
Lead Chromium Nickel Tin Copper	2-5
Zinc	5-10
Sulphide	1-10
Cyanide	1-10
Phenols	5-20
Ammonia-N	<250
Chlorinated hydrocarbons	0-1
Sulphate	300-1000 as SO_3
Oil	Shall not contain physically separable, dispersed or emulsified oil.

Notes: [1]Reference: MOE, 1989
[2]Ranges indicate limits applied depending on significance of discharge to size of sewage works and receiving water quality.

At the time of the MISA review (MOE, 1989), states in Germany, such as Bavaria, were deriving sewer discharge limits for various industrial sectors. Those proposed at that time for the metal fabrication industry are summarized in Table 5.13.

Table 5.13
Proposed Bavaria Sewer Effluent Limits Based on Best Available Technology for the Metal Fabrication Industry[1]

Parameter	Minimum Requirements (Generally Achievable Technology) (Values Depend on Type of Activity) (mg/L)	Proposed Bavarian Sewer Effluent Limits (Best Available Technology) (mg/L)
Arsenic, total	-	0.1 (only for ladder manufacturing)
Lead, total	0.3 - 2	0.5
Cadmium, total	0.1 - 0.5	0.2 (0.1 for garages and heat zinc treatment)
Chromium, total	0.5 - 2	0.5
Copper, total	0.3 - 2	0.5
Nickel, total	0.3 - 2	0.5
Mercury, total	0.005-0.05	0.05 (only permissible for battery manufacturing)
Total chlorine	0.5 (active chlorine)	0.5
Adsorbable organically halogens (AOX)	-	1.0
1,1,1-Trichloroethane Trichloroethylene Tetrachloroethylene Trichloromethane		1.0 (sum of compounds calculated as Cl)

Notes: [1]Reference: MOE, 1989

Waste

EC Directive 78/319 establishes the concept of "Duty of Care" in the management of waste and delegates responsibilities as follows:

- Waste shall be disposed without risk to the environment and without creating a nuisance or other adverse effects.

- Records of the quantity and nature (physical and chemical) of the waste shall be kept and made available for inspection by the competent authority.

- Waste in transit shall be accompanied by a form outlining:
  - the nature, composition and volume or mass of the waste
  - the name and address of the producer or of the previous holder
  - the name and address of the next holder or of the final disposer
  - the location of the final disposal site (where known).

- Facilities storing, treating or disposing of the waste must have a permit issued by the competent authority.

- The cost of disposing of toxic and dangerous waste shall be borne by the waste holder or an installation, establishment or undertaking and/or the previous holders or the producers of the product from which the waste came.

More stringent requirements are being considered for adoption by the EC which address sustainable waste management.

Section 6
SUMMARY FINDINGS

SCOPE OF THE METAL FINISHING INDUSTRY IN CANADA

- The number of metal finishing facilities in Canada in 1992 is estimated to be 600, based on information collected as part of this study.
- The geographic distribution of facilities appears to have changed little over the last decade, although there appears to have been small shifts in favour of the western provinces.
- The number of facilities peaked in the late 1980s and has been declining since that time.
- Sales by metal finishing suppliers in the first quarter of 1992 were approximately half of their 1989 first quarter peak, indicating the extent of the impact of the economic recession on the metal finishing sector.
- It is expected that there will be a smaller number of specialized large companies or groups of companies supplying the majority of metal finishing requirements in Canada in the future. A larger share of the production will likely come from job shops.
- The following economic pressures have affected the Canadian metal finishing sector:
  - The current (1992) recession.
  - Restructuring and rationalization that is occurring in most major manufacturing sectors as global trading blocks develop.
  - Loss of market share to other surface finishing methods.
  - More stringent environmental requirements and stricter enforcement.
- The turnover rate of companies has been slowed in part by the potential environmental liability associated with real estate transfers.

SOURCES AND RELEASES OF PRIORITY SUBSTANCES IN THE METAL FINISHING SECTOR

- Wastewater flowrate data were compiled through contact with Canadian municipalities who have active sewer use programs and from data published by the U.S. EPA during the development of effluent limits for the metal finishing sector. These data indicate that flows in the Canadian metal finishing sector have the same log-normal distribution as flows from U.S. facilities.

- The mean flowrate for Canadian facilities, appears to be approximately 40 percent of the U.S. value. No definitive reason for this difference was found, but likely factors for this occurrence include the following. The first is that the Canadian market for metal finished goods will not support the same economies of scale as the American market due to factors such as the sparse nature of the Canadian population base. The second factor is that the available U.S. data are at least ten years older than the corresponding Canadian data. Water conservation strategies that have been implemented over the last ten years in both Canada and the U.S. will be reflected in the Canadian data but not the American.

- Three major sources of priority substance releases to wastewater were identified:

  - Common metals waste stream (generated by all facilities)
  - Hexavalent chromium waste stream (generated by facilities using chromium)
  - Complexed metals waste stream (generated by facilities using electroless processes, including PCB manufacturing).

- Data on the composition of these streams were available for the U.S. metal finishing industry. Raw wastewater characteristics for Canadian plants were inferred from information on the number of facilities at which these streams are present and total wastewater flow data.

- Estimates of releases of priority substances and other metals to wastewater and residuals made as a part of this study are summarized in Table 6.1. The assumptions and limitations of these estimates are discussed in Section 3.

- Releases of heavy metals to wastewater may be significantly reduced under a suitably enforced municipal sewer use program, as demonstrated through analysis of data available from Metropolitan Toronto, and the Montreal Urban Community, among others. The use of pretreatment facilities in such large municipalities is higher than the national average. Higher implementation of waste reduction technologies may also be a contributing factor.

- The quantities of priority inorganic substances, released as air emissions, are not likely significant in comparison with releases in wastewater and solid residues. This interpretation may not apply to solvent degreasing operations, consideration of which was not within the scope of this study.

Table 6.1 Summary of Releases						
Element	Releases from Liquid Effluent[1] (kg/day)		Total Releases from Sludges[2] (kg/day)		Total Releases (kg/day)	
	Low	High	Low	High	Low	High
Arsenic	0.36	3.6	1.4	14	1.8	18
Cadmium	0.87	8.7	3.3	33	4.2	42
Chromium	53	1300	200	5000	260	6300
Copper	44	440	170	1700	210	2100
Lead	18	180	70	700	88	880
Nickel	87	870	330	3300	420	4200
Zinc	76	3700	290	14000	360	18000

Notes: [1]Liquid effluents include treated and untreated rinsewater and spent process solutions (Tables 3.6 and 3.7).
[2]From Table 3.8.

ENVIRONMENTAL CONTROL TECHNOLOGIES

- This study reviewed environmental control technologies/management strategies available to the metal finishing sector under the following major headings:

  - Waste reduction
  - Waste recovery (from rinsewater)
  - Wastewater treatment (including sludge dewatering)
  - Spent process solutions treatment/disposal alternatives
  - Wastewater treatment residuals management
  - Air emission controls

- The feasibility of implementing many environmental control technologies management strategies is typically dependent on site-specific/facility-specific factors.

- The economic feasibility of waste reduction and recovery technologies is strongly influenced by the value of the recovery of lost metal values and other process materials relative to the cost of treatment residuals management.

- Conventional wastewater treatment technologies such as neutralization, precipitation and gravity settling are the most common technologies in use. Cyanide destruction and chromium reduction are also common in plants requiring such treatment, while waste recovery technologies such as evaporation and ion exchange are significantly less common.

- Municipalities with active sewer use monitoring and enforcement programs have a significantly higher percentage of facilities using pretreatment. More than 90 percent of facilities in municipalities such as the Montreal Urban Community and Metropolitan Toronto (where the majority of facilities are located) have pretreatment in place, while the national average appears to be closer to 78 percent.

- The costs associated with implementation of environmental control technologies/management strategies depend on many site-specific factors and are difficult to quantify. Relative cost factors have been estimated for control technologies.

REGULATIONS AFFECTING THE METAL FINISHING SECTOR

- Regulations in most jurisdictions address specific metal finishing sources or metals commonly used in the metal finishing sector.

- It is difficult to make direct comparisons among regulations for different jurisdictions for the following reasons:
  - Regulations may be specific to a much narrower or broader industrial sector than the metal finishing operations considered in this study.
  - Limits may be established based on different criteria. For example, in some cases, limits are based on receiving environment impacts on a case-by-case basis, and in others they are based on what is technologically achievable.
  - Limits may be based on different base units. For example, limits may be production rate-based, concentration-based or loadings-based.
  - Regulations are administered at different levels in the various jurisdictions.
- Enforcement of regulations specific to metals finishing operations in certain jurisdictions in the United States has resulted in a decrease in the number of metal finishing facilities. Some facilities have been unable to support the costs associated with environmental compliance and have closed. Some facilities have relocated to other jurisdictions where environmental requirements are less costly to address.

Section 7
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Section 8
GLOSSARY

Captive shop. A metal finishing facility which is part of and supplies dedicated services to a larger, integrated manufacturing facility. In general, information on these facilities is more difficult to obtain, since these facilities may not use a Standard Industrial Classification (SIC) code typical for metal finishing, and may not necessarily belong to metal finishing industry associations. Wastes from captive shops are often combined with those from the remainder of the operation.

Job shop. A metal finishing facility which provides services to outside interests on a contract basis. Wastes from job shops may vary significantly over time since the processes in use may vary depending on the contract.

Liquid wastes. Treated or untreated wastewater and spent process solutions.

Loadings. The product of: the mass concentration of a wastewater constituent (expressed in units of mass per unit volume, usually mg/L); and, the wastewater flow rate (expressed in units of volume per unit time, sometimes L/day). Loadings may be calculated for each wastewater constituent and are expressed in units of mass per unit time (e.g. kg/day).

Metal finishing processes. This study addresses the following metal finishing processes specifically:

- Electroplating
- Electroless plating (including immersion plating)
- Anodizing
- Hot dip coating (including galvanizing)
- Printed circuit board manufacturing
- Chemical conversion coating (including phosphating, chromating and colouring)
- Chemical milling and etching and bright dipping.

In addition to these specific processes, ancillary cleaning and postplating operations are included, with the exception of solvent degreasing. Typically, alkaline cleaners are used for the removal of oil and grease, while acidic cleaners are used for the removal of scales and oxides. In addition, most metal finishing facilities also conduct some form of stripping operations for the recovery of improperly finished parts. Both acidic and electrolytic stripping are common.

Pretreatment. Treatment of wastewater and/or spent process solutions at the metal finishing facility, prior to release to the sanitary sewer.

Releases. For the purposes of this report, releases refer to the amounts of priority substances leaving a metal finishing facility in the form of liquid waste, sludge or air emissions. It is important to recognize that these amounts are not released directly to the environment. For example, most wastewater at most metal finishing facilities is released to the sanitary sewer, and not directly to a receiving waterbody.

Rinsewater. Untreated wastewater resulting from rinsing processes used at metal finishing facilities.

Sludges. Moist, particulate material resulting from the physical and chemical treatment of rinsewater and spent process solutions in the metal finishing sector.

Sources. Those metal finishing processes resulting in subsequent releases.

Spent process solutions. Process solutions of no further direct use in metal finishing processes. For the purposes of this study, this includes the following spent process solutions:

- Metal finishing/plating baths
- Alkaline and acidic cleaners
- Stripping baths.

Waste. Material no longer of direct use in metal finishing processes. Includes, in most cases, treated or untreated wastewater, sludges and air emissions. Depending on how it is managed, waste is not necessarily released from the facility or to the environment.

Wastewater. Water resulting from rinsing processes used at metal finishing facilities. May be untreated (i.e. rinsewater) or treated.

Appendix A

LIST OF INDUSTRIAL REPRESENTATIVES CONTACTED

Appendix A
LIST OF INDUSTRIAL REPRESENTATIVES CONTACTED

NAME	AFFILIATION	COMMENTS
Serge Archambault	Vice President and General Manager, Enthone - OMI	Major chemical supplier
Nick Castellani	MacDermid	Major chemical supplier with emphasis on the PCB market
Ray Field	Parfield Enterprises	Major chemical supplier
Jim Hall	Sales Manager, Chemical Equipment Fabricators	Wastewater and emissions control systems, automated finishing systems
A.M. MacDonald	Torcad Ltd.	Large barrel zinc plating company
William T. Spratt	General Manager, Court Galvanizing Ltd.	Large galvanizer

Note: 1. Contacts made by Mr. Jim Sutherland, subconsultant to the study, and executive member of CAMF.

Appendix B

LIST OF METAL FINISHING COMPANIES

Province : Alta

Company name
Acadian Metal Finishers (1984)
Advanced Plating.
Alan Co.
Alberta Chrome & Grinding Ltd.
Alberta Plating.
All Brite Metal Finishing Ltd
Alpine Chrome Industries
Barber Industries
Calgary Bumper Repair
Centennial Zinc Plating Ltd
Chinook Industrial Ltd.
Classic Bumper Repair
Columbia Chrome Industries (1980)
DAAM
Daymond Aluminium
Dominion Chrome Industries
Edmonton Hydra Matic Ltd
Fairmont Electroplating (1990)
G & G Custom Works Ltd
Gifts Unique.
Gir Del Hydraulic Services
Indalex Division of Indal Ltd.
Industrial Galvanizing Co. Ltd
Industrial Plating (1985)
Inventronics Ltd.
Juniper Emblems Ltd.
Kawneer
L.A. Mint.
Len's Custom Plating (1987) Ltd
Marking Systems of Alberta Ltd.
Merit Design Mfg. Ltd.
Moores Engine Professionals Ltd.
Mr. Crankshaft Div of Reliable Engine
Olson Silver
P R Galvanizing Co. Ltd
Quality Hard Chroem Plating Inc
Reliable Engine Services Ltd.
Supreme Plating (1983) Ltd
Surf - Tech Industries
Valley Metal Fabricators Ltd
Wespen Industries Ltd.
Western Hard Chrome Plating
Western Industrial Product
Western Propellor Co. Ltd.
Western Rockbit Co. Ltd.

Province : B.C.

Company name
A.W.Engineering Inc.
Acme Plating & Silver Shop
Action Plating Ltd
Ahoy Industrial Corp Ltd.
Altech Anodizing Ltd.
Antique Memories
Brahmnes Electroplating
Briggs Industries Ltd.
British Chrome
C.D.M. Machine Shop & Plating
Canadian Airlines International
Canadian Decorative Plating
Canadian Forces Base Esquimalt
Canron
Cariboo Chrome
Catalans Enterprises Inc.
Celero Galvanic Surface Protection Inc
Chilco Inc.
Circuit Graphics Ltd.
Coast Hydraulic Ltd
Coast Valve Industries
Columbia Chrome Inds
Comet Plating
Delta Industrial Coatings
Dependable Plating Ltd.
Dynamic Chrome
Ebco Metal Finsining
Enameltec.
Fintec Surface Finishing Tec Ltd.
Fireplace Decor
Fraser Valley Electroplating
Gibbs Nortac
Hudson Plating Co.
Indalex
Jefferies & Co. Silversmith
Kelowna Electroplating
Mayfair Industries
Modern Auto Plating
Modern Hardchrome (1986)
Molectro Polishing & Hard Chroming
Nanaimo Chrome Plating
Okanagan Electroplating Ltd.
Pacific Design Engineering Ltd.
Pacific Plating
Pressed Metal Products Ltd.
Shield Electroplating
Specialized Industrial Rebuilders Ltd
Specialty Plating
Spilsbury & Reid

Province : B.C.

Company name
Sterling Circuits Inc
Sun Hard Chrome.
Superior Electro-plating & Anodizing
Thorcast Inc.
United Industrial Plating
Victoria Plating
Weiser Inc.
West Coast Chrome
Western Wire Products
Zinco Inc.

Province : N.B.

Company name
C.B.C.
Enterprise Faucett
Hansa Sealand (Moncton N.B.)
Maritime Hydraulics
Maritime Plating

Province : Man

Company name
Cadorath Plating Co Ltd
Chrome Pit, The (Winnipeg)
Commercial Plating Co Ltd
Dominion Bridge
Fairmont Plating (Manitoba)
Falcon Machinery (1965)
House of Silver
Inductec Alchemist (1987)
North Star Plating
Riverview Plating
Winnipeg Silver Plate Co.
Zol-Mark Inds.

Province : N.S.

Company name
Atlantic Hard Chrome
Dalton Industries
Eagle Beach Contractors
Galvatech Inc.
Hydrachrome Services Inc.
IMP Aerospace
Zenith Chrome & Brassworks

Province : Ont

Company name
A & D Bumper Repair
A.G.Simpson (Cambridge)
A.G.Simpson (Oshawa)
A.M.L. Div of 724572 Ont. Inc 1040
AAMAX Precision Engineering
Acadian Barrel Finishing
Acadian Platers Company Ltd.,
Accuplate Technologies Inc
Acme Chrome Windsor
Active Metal Finishing
AEL Microtel Ltd., Switching Gear
Alcan Can (Kingston)
Alfred Ward
Allen Bradly
Alpha Metal Finishing
Alumabrite Anodizing Ltd.
Alzar Industries Inc
Ampere Metal Finishing
Ancaster Tool Company
Anchor Machine & Manuf
Androck Hardware
Anti Friction Ent
Antique Metal Finishing & Plating
Aram Polishing
Ardaven Platers
Arts Metal Finish
Atom Electroplating
Auto Chrome Ltd., Precision Platers
Automotive Industries
Autotek Electroplating
B & H Plating
B.A. Machine
Bacham Aerospace Corp
Barrie Hard Chrome
Baycoat
Bedford Refinishing
Boeing of Canada Ltd.
Braconi Plating Specialists
Brimac Anodizing
Bristol Plating Inc
British America Bank Note
Brown Boveri Canada
BTL Div. of Jannock Ltd.
Burns and Wilson Silver Plating
Butcher Engineering
C.G.F. Metal Fabricating
Cambridge Custom Chrome
Cametoid Ltd
Camptech Circuits Inc.

Province : Ont

Company name
Can Plate Ltd
Can-Am Electroforms Ltd
Canada Lamp Corp.
Canadian Bank Note
Canadian Chrome Plating
Canadian Electroplating Enterprises
Canadian Industrial Hard Chro
Canadian Metal Ad Corp
Canadian Trueline Roller
Canvil
CBS Records
Chamelion Coating
Chayne Enterprises
Circtronics 1976 Ltd
Classic Coatings
Coatings 85
Color Tech Finishers
Com Dev Ltd.
Commercial Metal Finishing
Concord Hard Chrome & Crankshaft
Continuous Color Coat
Cooper Plating
Court Galvanizing
Court Industries
Crane Canada
Crest Circuit Co.
Crimp Circuits Inc.
Crouse Hinds Co.
Crown Silverplating
D Lite Custom Metal
D.C.Chrome
D.T.I Precision Products
Dalcan Services
Data Circuits Div of Computer Logics Ltd
Davar Bronzing
Daymond Aluminium
De Havilland Aircraft of Canada
Decor Metal Products
Dependable Anodizing
Deshevy Industrial Coatings
Desna Metal Finishing
Diamonite Treating
Digital Equipment of Canada
Divacco
Diversified Plating Ltd.
Dofasco
Domestic Plating Company
Dominion Electroplating
Dovercourt Electro plating

Province : Ont

Company name
Dynamic Circuits Corp
E.T.F. Manufacturing
Eastend Plating
Eaton Yale
Electro Coating
Electro Kleen Alloy Polishing
Elite Metal Finishing
Emco Ltd Waltec Faucets
F.R. Custom Metal Fabricating
Fantom Manufacturing
Feher Machine
Fike Canada
Filtran Microcircuits Inc
Fine Line Circuits Ltd.
Four Star Plating
Fraser George M Ltd.
Fredrick Hardchrome Corp of Canada
Fused Metals
G & A Bumper Services
Galvcast MfgInc
Garys Custom Cycle
Gaya Industry
General Magnaplate
Gennum Technology Inc
Globe Stamping
Graphico Electronics Group
Graves Engineering
H & E Plating
H & M Metal Finsihing
H.Sullivan Bumper Services
Hager Hinge Canada
Hamilton Engraving Co. Ltd.
Harjohn Industries
Hawker Siddeley
Hendriks Precision Grinding Ltd
Herb Metal Finishing Co (Ottawa)
Holly's Anodizing Service
Holody Electroplating
Honeywell
Hudson Bay Diecast
Hy Power Coatings
Hyda Industries
Imperial Eastman
Indal Ltd (Indalex)
Industrial Chrome & Machining
Industrial Processing
Ingersoll Fasteners
Integrated Technology
International Cooling Systems Inc

Province : Ont

Company name
Interoptics Div of Lumonics
ITL Circuits
J D S Accu-finish
J.E. Thomas Specialties
J.E.Climax Plating
Jac-Mor Mfg
Jay's Metal Polishing
Jetco Manufacturing
Jewellers Workshop
Jim's Polishing & Buffing
Johnson Metal Finishing
Joyce & Smith
Kaiser Aluminium
Knape & Vogt
Konar Corporation
Koolrad Design & Manufacturing
Krebsz Electro Plating
Kuntz Electroplating
L & J Plating
Larsen & Shaw
Latem Industries
Leader Plating On Plastics
Leak Metal Finishing
Leaside Plating
Linread Canada
London Nuclear Ltd.
Lorlea Architectural Systems
Lumiray Corp
M & M Plating
M.A.Electronics Canada
M.P.S. Micro Finish
MacDonald Douglas Aircraft
MacFarlane Nameplate & Anodiz
Mallory Industries
Masterchrome
Material Processing
Material Processing
MBF Industries
McKee Specialty
Meta Metal Finsihing
Metal Koting
Metal Spray On
Metal Surface Finishers
Metalon Technology
Metaplast Circuits
Microchrome Crankshaft
Midway Plating
Milvan Plating
Mississauga Anodizing

Province : Ont

Company name
Mobile Mold Finishing
Monroe Auto Equipment of Canada
Moorewood & Williams Engineer
MPC Circuits Inc.
Multichair
Myrand Electronic Systems Ltd.
Nelander Artistic & Handbench
Nelson Industrial Fabricating
Nelson Steel
New Toro Plating Co Ltd.
Norcoat Powder Systems
North American Fabricators
North American Hard Chrome
North American Plastics
North Star Plating
North Star Polishing
On Site Plating Services
Ontario Chromium Plating
Ottawa Printed Circuits
Pacific Plating
Paintplas Ltd.
PAK Electroplating
Pannell Gravure Services
Papazian Machine & Tool
PC World Div of Helix Circuits Inc.
Peel Finishing Ltd.
Pen K Electroplating
Perm Metal Protection
Permashell Corp
Planar Circuits
Plate Way
Plating House of Canada
Plus 1, Div of DY-4 Systems Inc
Porous Metals
Precious Plate
Precision Plate
Precision Platers
Prestige Circuits
Prism Printed Circuits Inc.
Pritchard Plating Ltd.
Pro plating
Progressive Anodizers
Prokote
Protec Finishing
Prototype Circuits Inc.
Psionic Systems (Windsor)
Pure Metal Galvanizing
Pure Metal Galvanizing
Pure Metal Galvanizing

Province : Ont

Company name
Quadraplex Design & Graphics
Quality Anodizing
Quality Circuits Manufacturing
Quality Hydraulic Services
Quality Plating
Queen City Plating
Quest Tech Precision
R.G.P. Electroplating
R.P.L. Mould Finsihings
Rauscher Plating
Redman Machine & Metallizing
Reliable Plating & Surface Finishing
Rexcan Circuits Inc.
Rexdale Custom Metal Finishing
Rideau Electroplating
Robert Pope & Co
Rockwell Int'l (Guelph)
Rockwell Int. (Toronto)
Romet
Rustshield Plating Ltd.
S.M.S. Metal Polishing
Saifee Neon Signs
Samuel Manu Tech
Scandia Metal Finishing
Seeburn Metal Products
Senti Metal of Canada
Shield Plating
Sidbec Dosco
Sigco Industries
Silver by Cachia
Space Electroplating
Spar Aerospace
Spectra Anodizing
Spectronics Plating
St. Catherines Machine Products
St.Croix Memorials
Standard Plating
Stanley Manufacturing
Stanton M. Electroplating
Steelbrite Ltd
Strip Tinning of Canada
Sugrims Metal Polishing
Sun Polishing
Superfinish
Superfinishing Co.Ltd.
Superior Anodizing
Superior Metal Finishing
Surfmet Canada
T.N.T. Polishing

Province : Ont

Company name
Technical Hard-Chrome
Teckote
Tektron Equipment Corp.
Thermoburr Canada
Tichbourne
Tmis Precision Machine Shop
Toolchrome Ltd
Torcad
Tork Electroplating
Toronto Chromium Plating
Toronto Crankshaft
TPS Industries
Tri Krete Coatings
Trican Industrial Services
Trimplas
Tumbling Metal Services
Ultra Chrome
Universal Fasteners
W.R.E. of Canada
Waterloo Furniture Components
Wellington's Silversmiths
Wellmaster
West Custom Finishing
Western Metal Finishing
Westinghouse Canada
Williams E.S.G. Inc
Wilson Silversmiths
Winters Hydraulic Service
X-Pert Mould Polishing
York Electroplating
Young's Polishing
Zincon Metal Finishing

Province : Que

Company name
Anopec Inc
Argentech Polissage & Placage Eng
Auto-Chrome Du Parc
Baum S Tooling Co
Beaugrand Gilles
Belleville J Arsene
C.M.R. Circuits Ltd.
Canadian Marconi Co. Components Div.
Canadian Plastics Inc
Cari-all
Century Products
Circo Craft Company Inc
Corbec Corp
DDS Inc
Electro Finition Inc
Electropac Canada Inc.
Entreprise Galvanoplastie Electro Loh
Equipment Pomerleau
Etamage De Quebec Enrg
Filochrome Inc
Flexo Les Equipments Industriels Inc.
Forestube Inc
Furneco Industrial Supplies
G V Polissage
Galvacor
Galvacor Inc
Galvan Metal
Galvano Div Ivacco Inc
Galvanoplastie Canadienne Inc.
GRM Circuits Inc.
H O P Division Columbia International
Heroux Inc.
Indalex Div of Indal Ltd
Industries Locweld Inc.
Industries Tri-Steel Inc
Industries U S P Inc
Jelco Unican
Khrome Tech
Lalonde & Brosseau
Lasalle Plating Inc.
Les Industries de Placage Lego Ltee
Lesmon Enr
Lunn G J Inc
Maynard Gilles Inc
Montreal Chromium Plating
Other - name not released
Other - name not released
Other - name not released
Pieces De Carrosserie Murray Ltee

Province : Que

Company name
Placage Alto Ltee
Placage Astro Chrome Inc
Placage au Chrome de Montreal
Placage Au Chrome De Ste-Foy Inc
Placage Chromex Inc
Placage Empire Ltee
Placage Express P A T Inc
Placage F & S Inc
Placage J G Ltee
Placage Manco T G V Inc
Placage Omnispec
Placage Regina Ltee
Placage Royal Quebec Inc
Placage Solma Ltee
Placage St Michel Inc
Placages C L Lesmon Inc
Placages Mirro Flash Inc.
Placages Techno-Spec Inc.
Polissage et Placage G G Inc
Polissage Rapide Inc
Prevost A & D
Prevost A&D Inc
R T Plating
Savard Jean Enr
Standard Orfevres
Super Chrome
Trait Met
Ultraspec Inc
Vacuum Platers Inc.
Verdun Anodizing Inc.
Vilebrequins Du Quebec Ltee
Zimmcor Co
Zorayan Inc

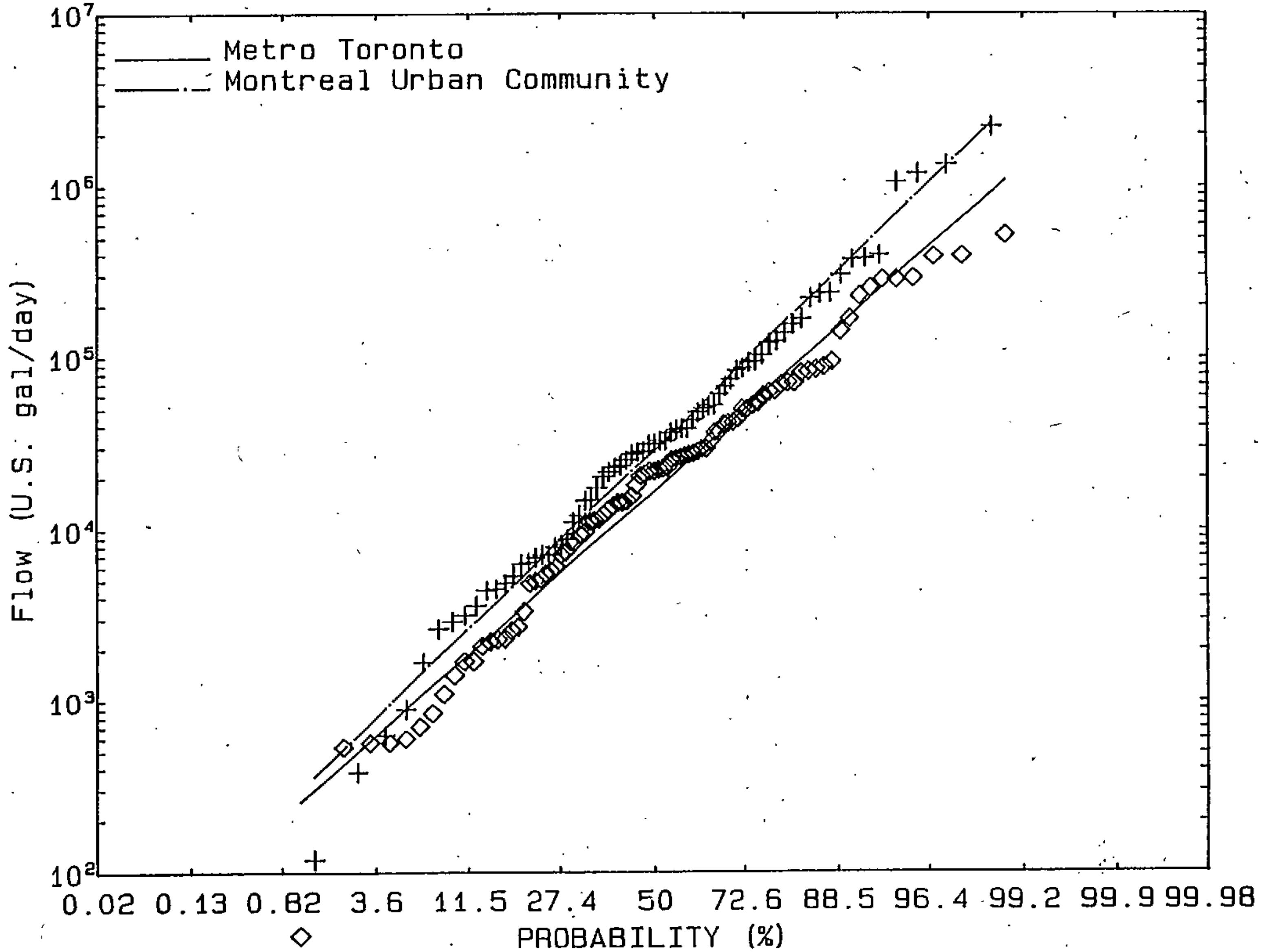
Province : Sask

Company name
North Star Plating (Sask)
Northern Industrial Plating
Provincial Galvanizing (Sask)
Provincial Plating
Superior Hard Chrome

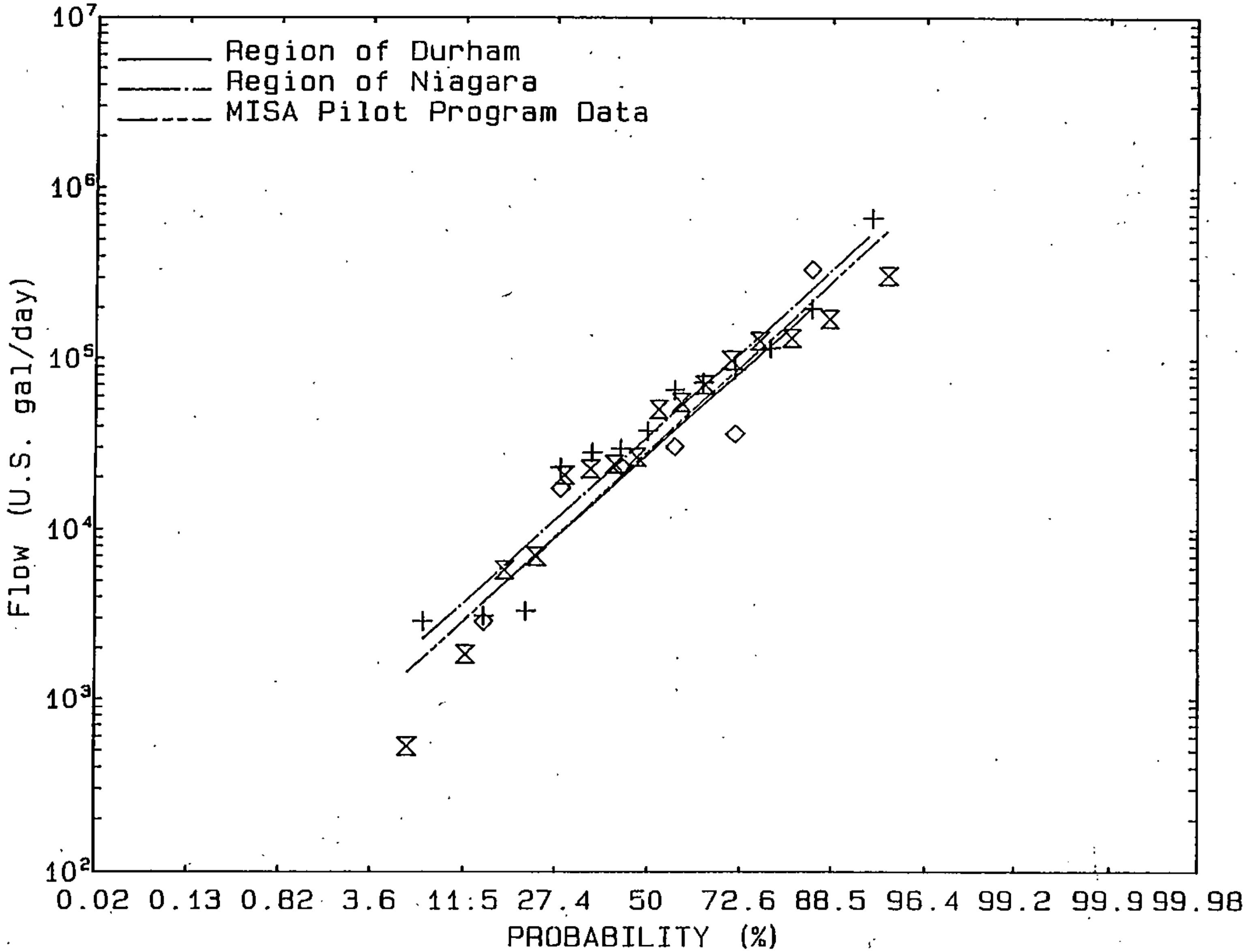
Appendix C

PROBABILITY DISTRIBUTIONS FOR FLOWS IN INDIVIDUAL MUNICIPALITIES AND FOR RAW RINSEWATER LOADINGS

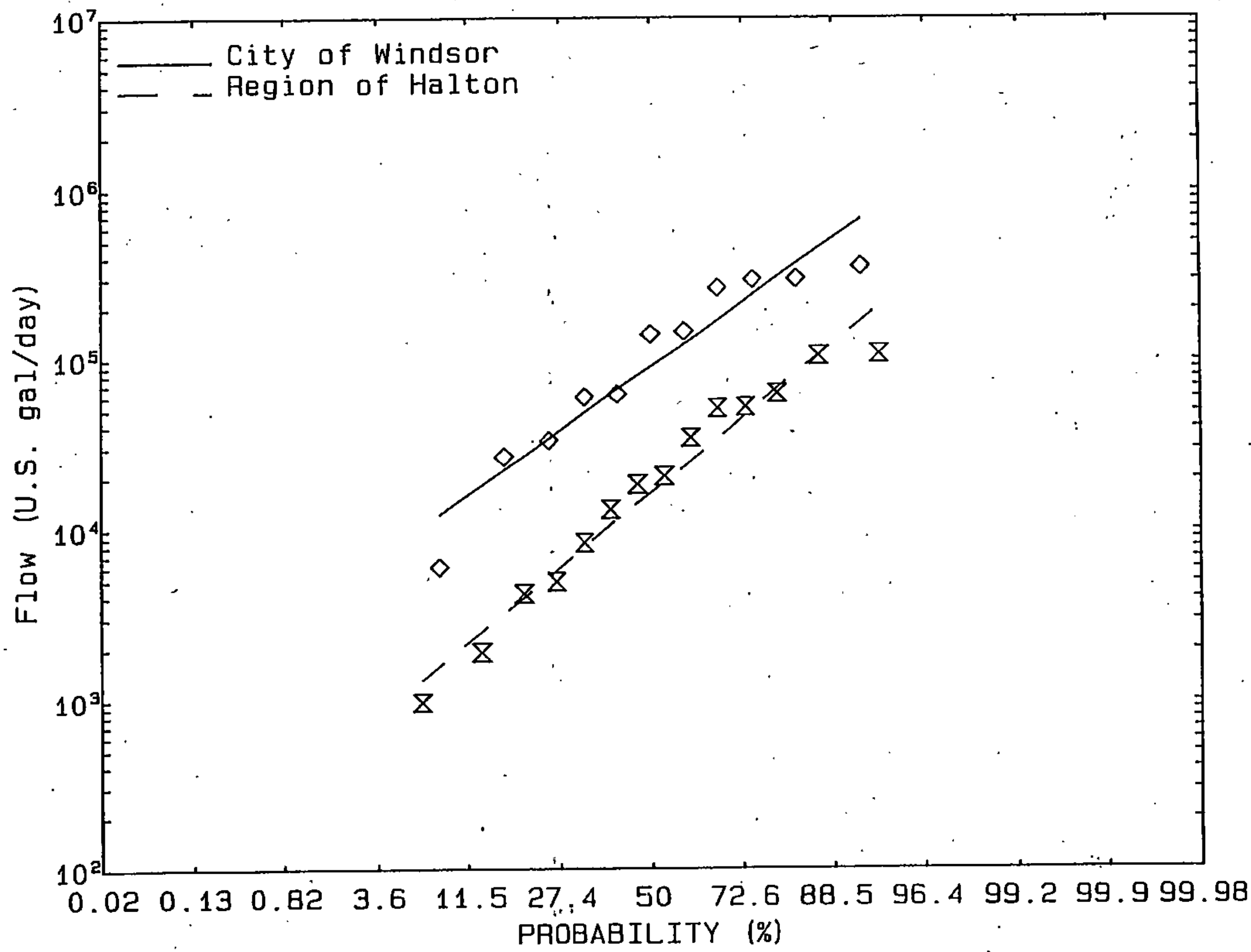
Canadian Metal Finishing Sector Flow Data

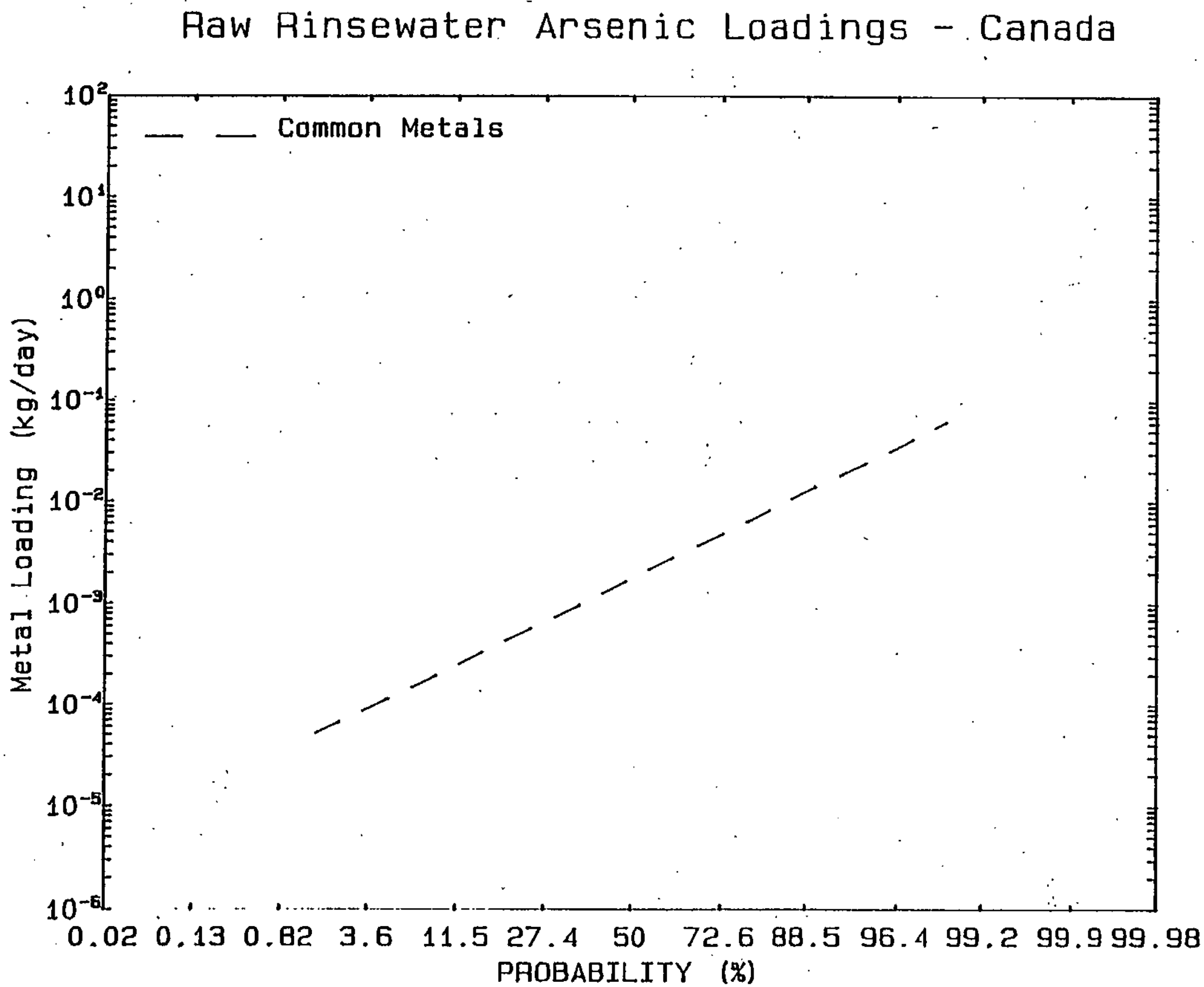


Canadian Metal Finishing Sector Flow Data

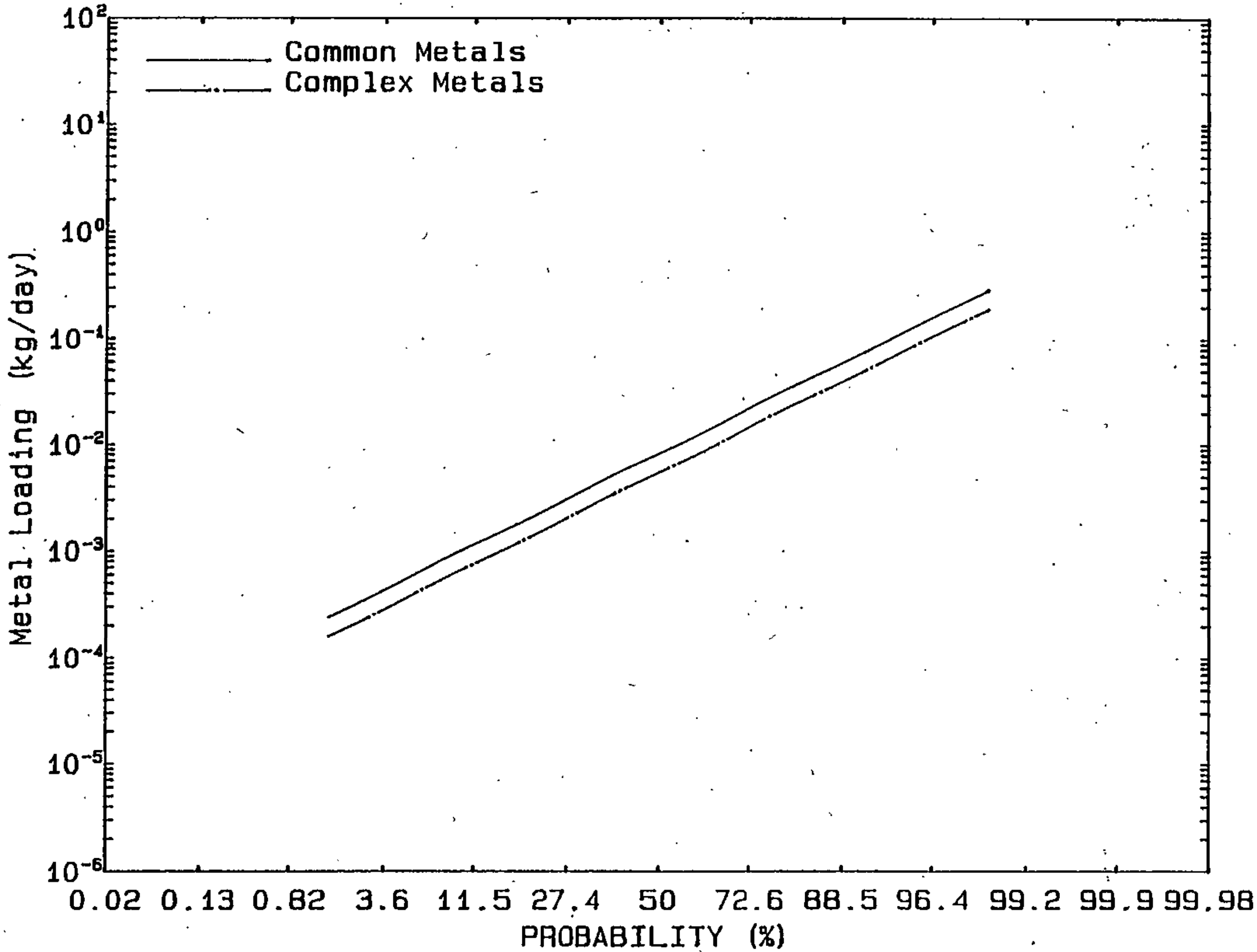


Canadian Metal Finishing Sector Flow Data

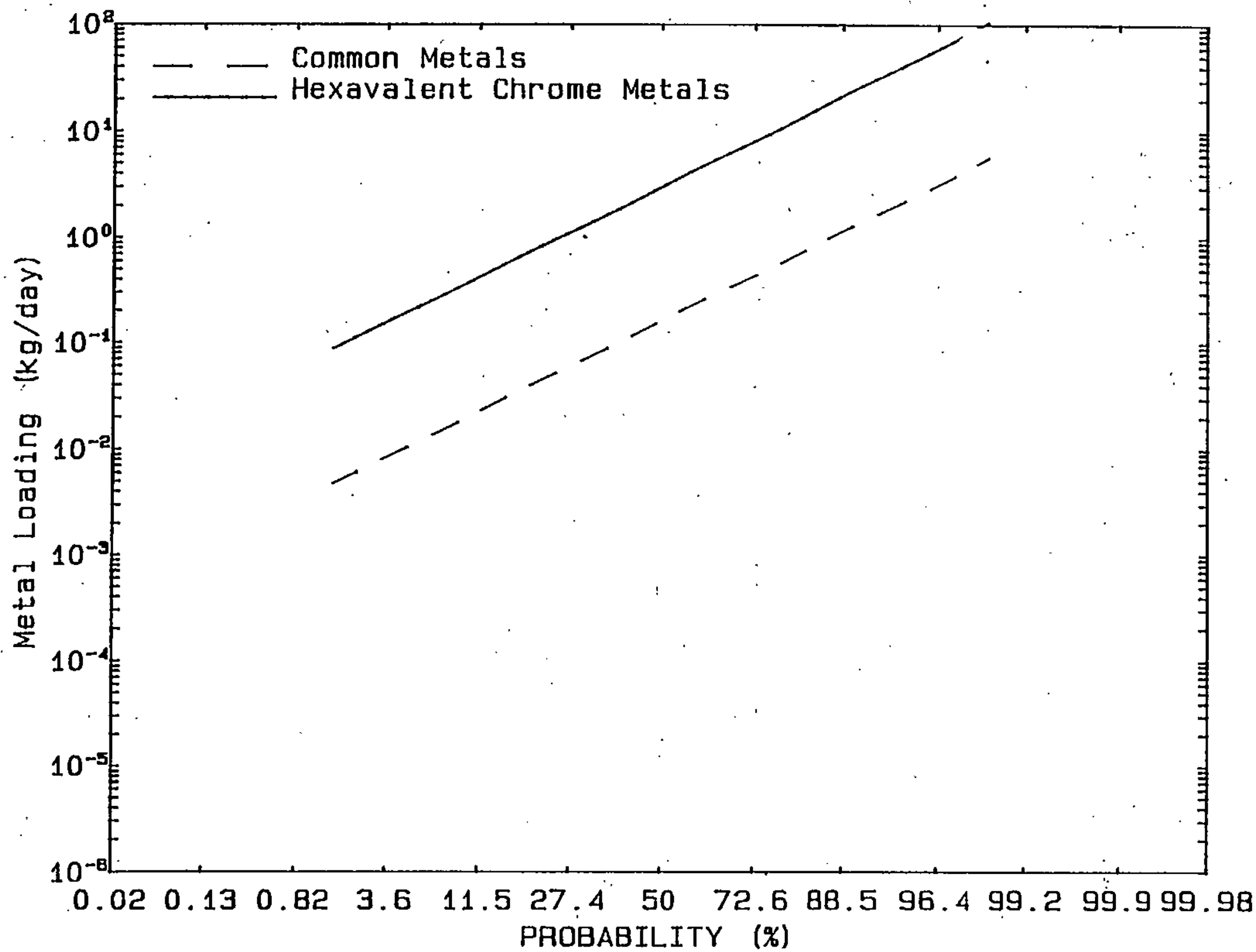


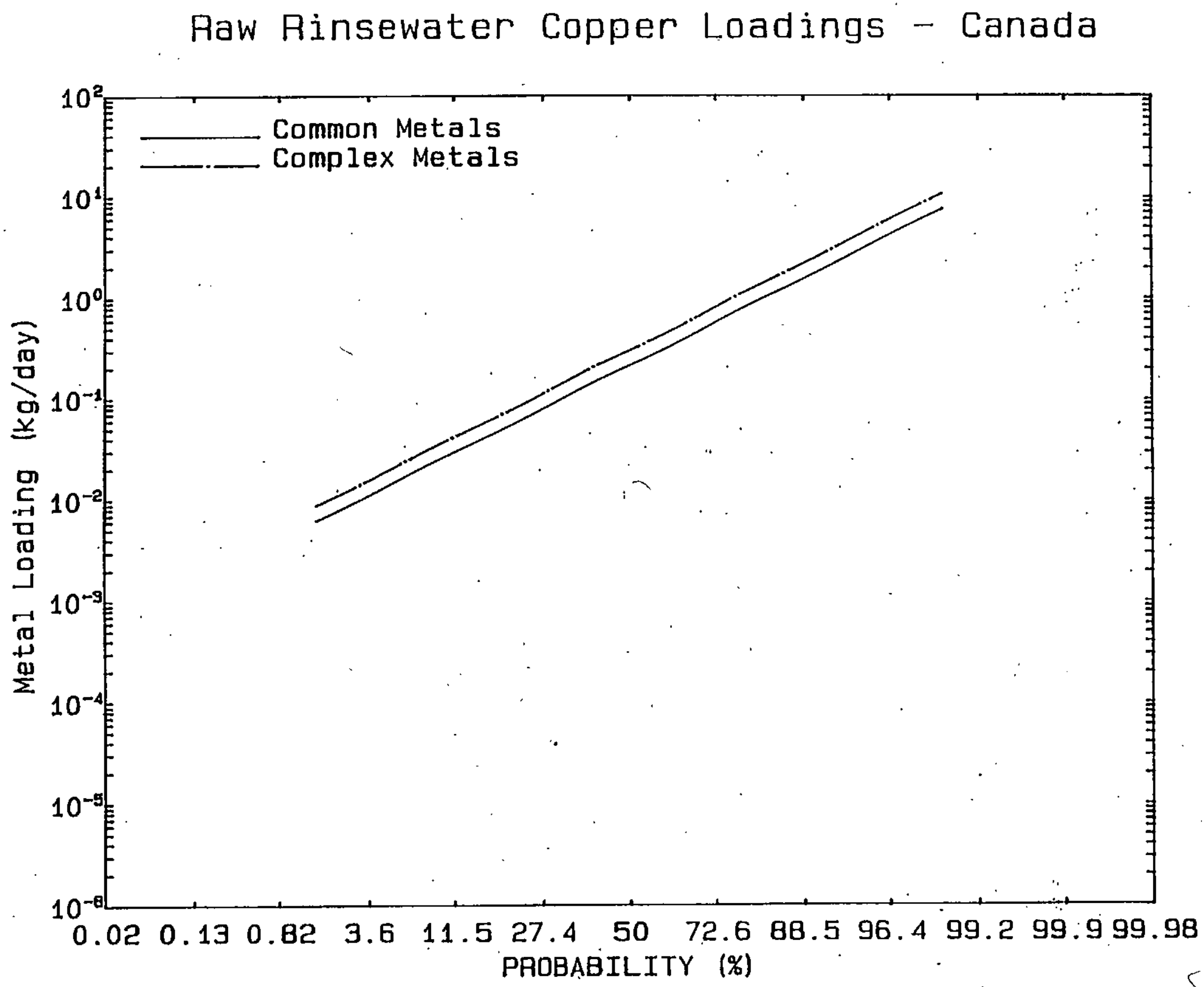

Raw Rinsewater Arsenic Loadings - Canada
Common Metals
Metal Loading (kg/day)
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.02 0.13 0.82 3.6 11.5 27.4 50 72.6 88.5 96.4 99.2 99.9 99.98
PROBABILITY (%)

Raw Rinsewater Cadmium Loadings - Canada

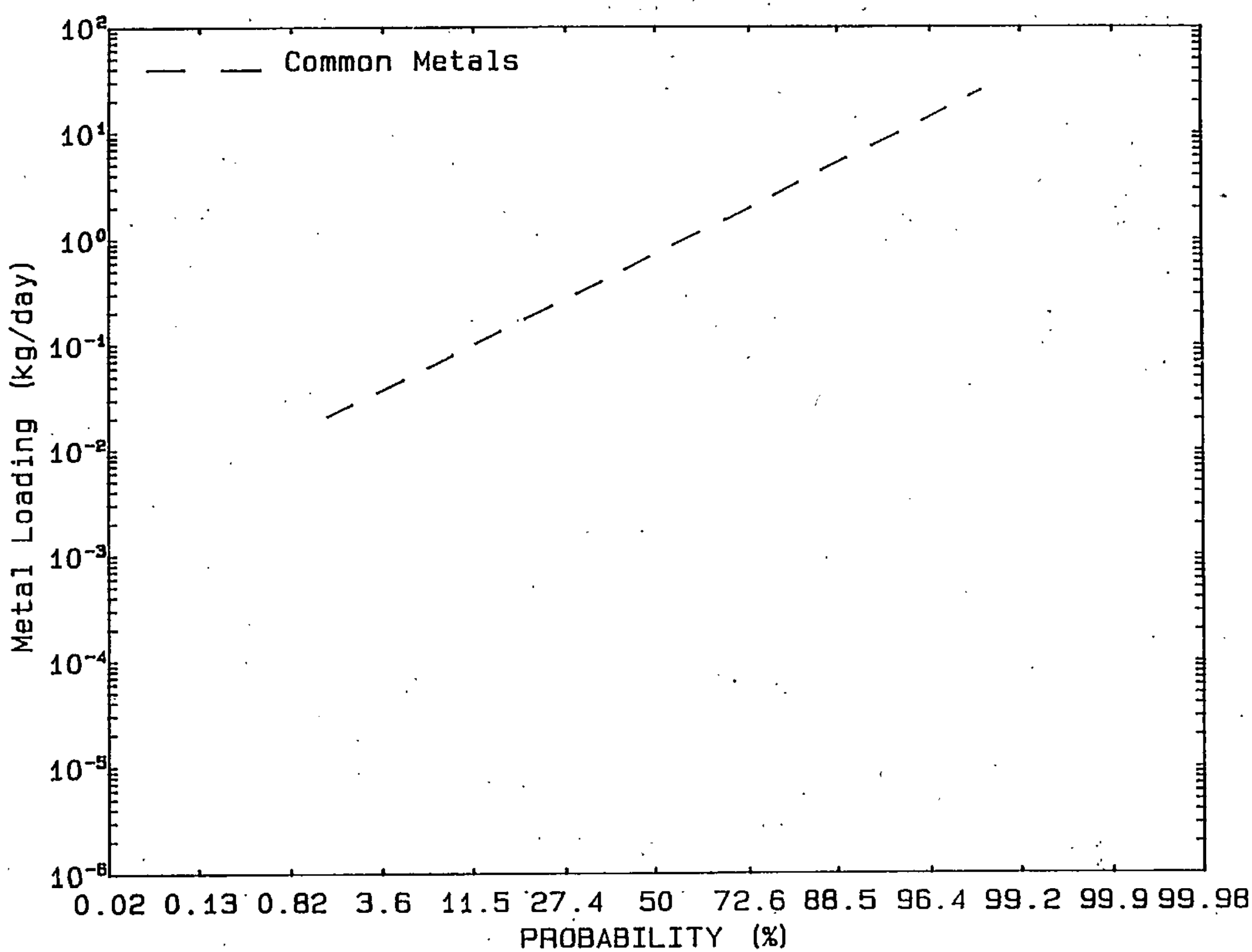


Raw Rinsewater Chrome Loadings - Canada

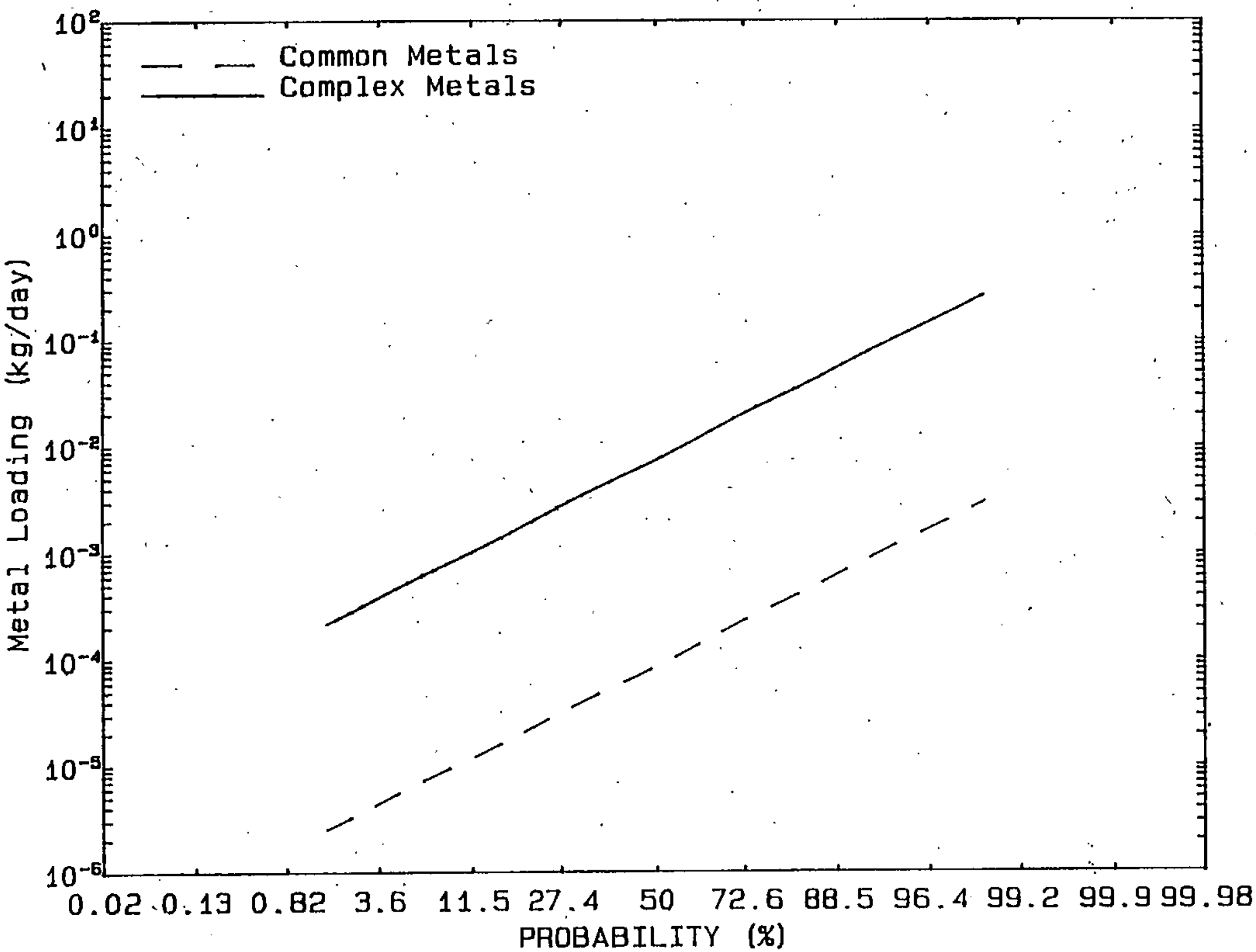



Raw Rinsewater Copper Loadings - Canada
Common Metals
Complex Metals
Metal Loading (kg/day)
10^{2}
10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
0.02 0.13 0.82 3.6 11.5 27.4 50 72.6 88.5 96.4 99.2 99.9 99.98
PROBABILITY (%)

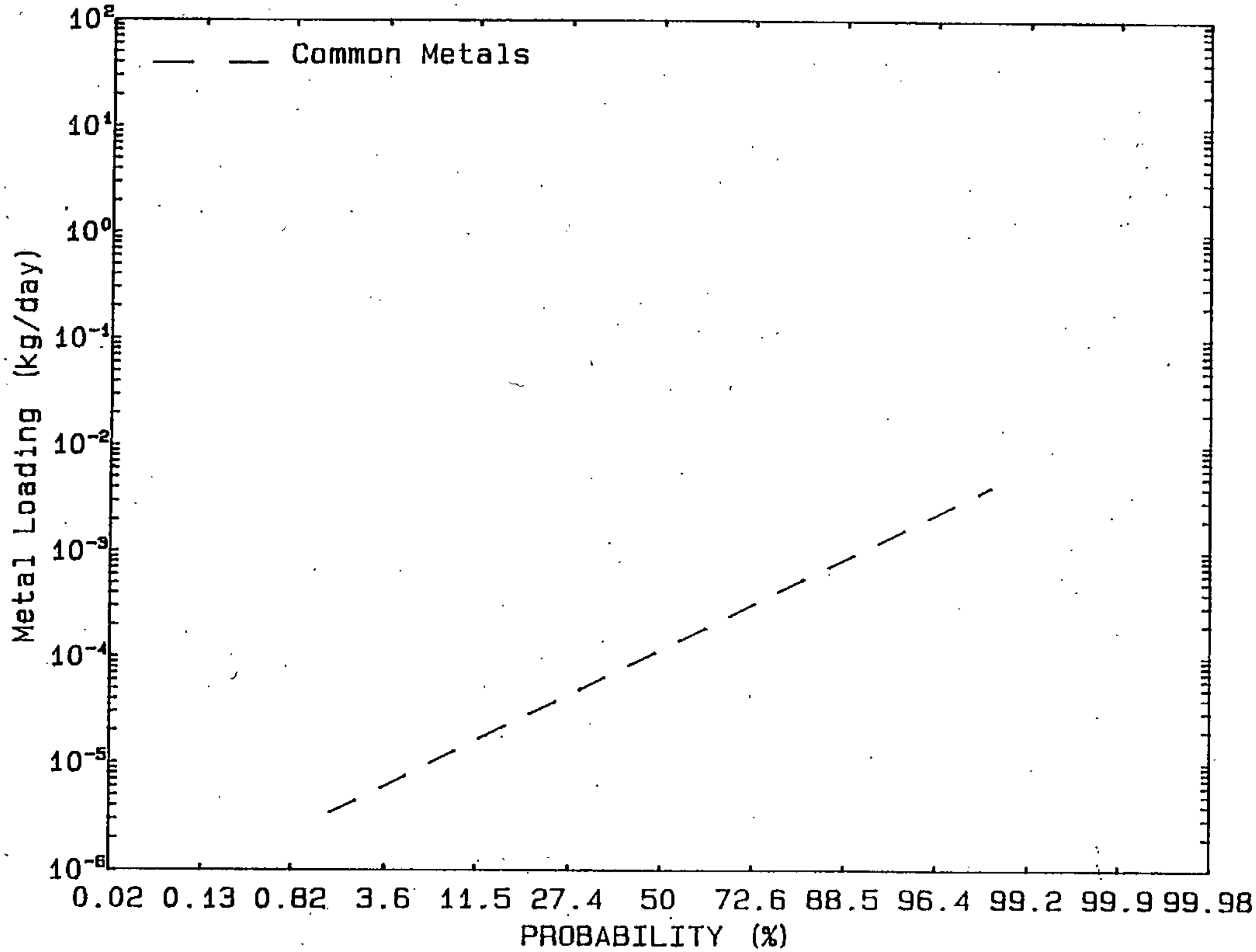
Raw Rinsewater Fluoride Loadings - Canada



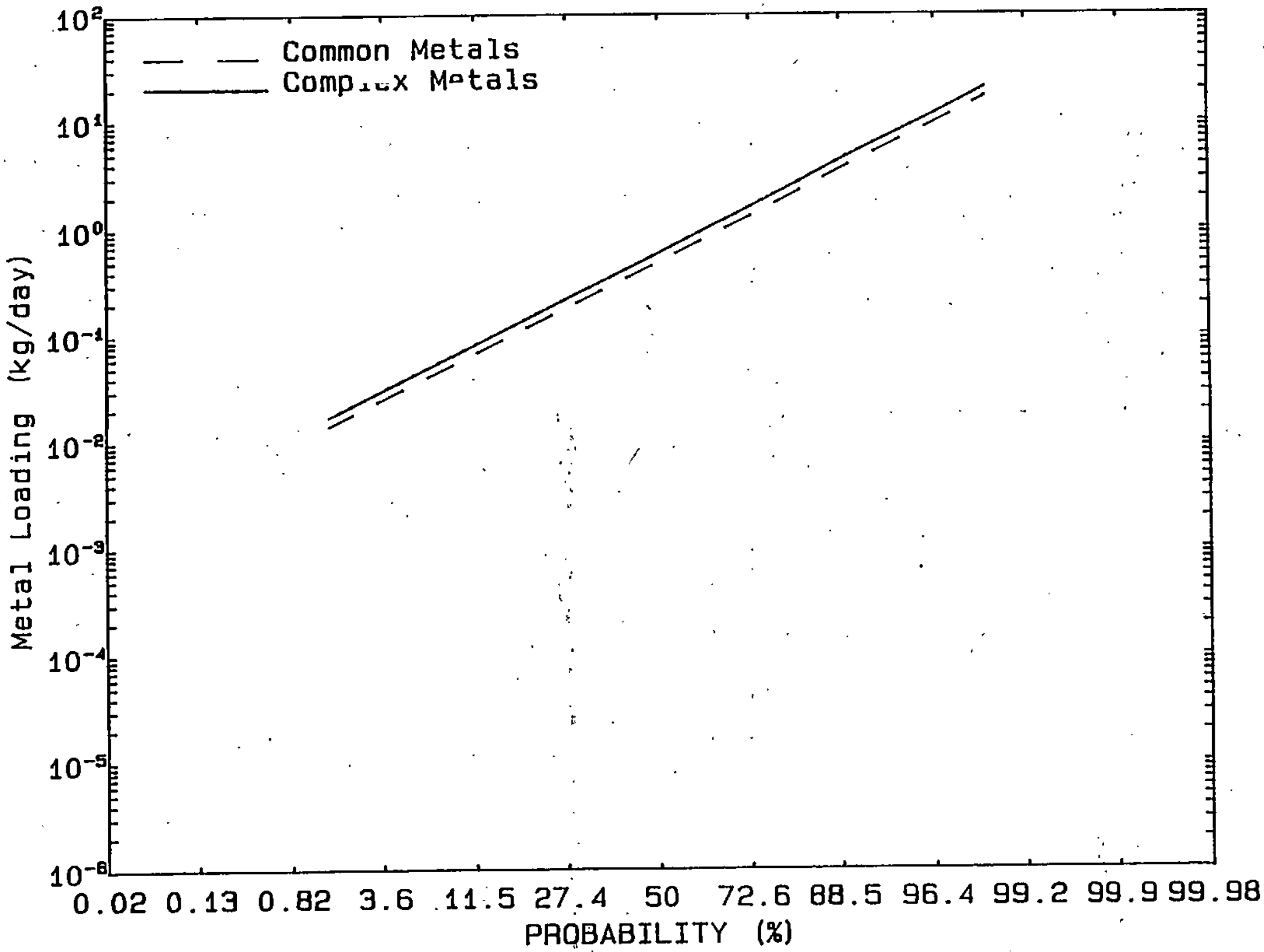
Raw Rinsewater Lead Loadings - Canada



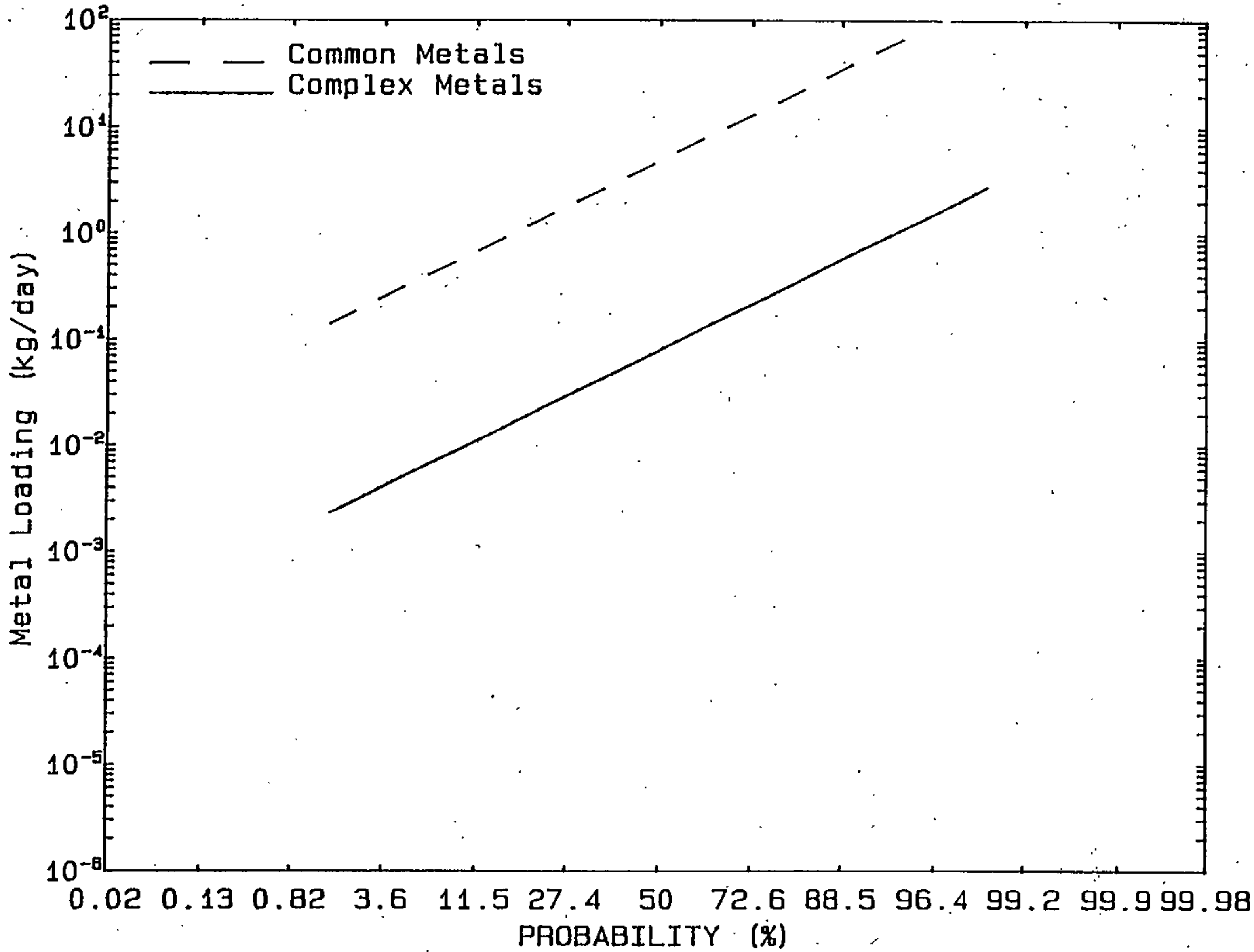
Raw Rinsewater Mercury Loadings - Canada



Raw Rinsewater Nickel Loadings - Canada



Raw Rinsewater Zinc Loadings - Canada



Appendix D

EXTENT OF PRETREATMENT BY VOLUME

Appendix D
EXTENT OF PRETREATMENT BY VOLUME

The survey data available from the MOE (1991) have been used to develop an estimate of the extent of pretreatment by volume of loadings from rinsewater (and spent process solutions). This analysis was undertaken since it was believed that smaller facilities in general were less likely to have pretreatment in place and that the percentage of loadings receiving pretreatment was likely to be higher than the percentage of facilities having pretreatment in place. The survey results indicated that 78 percent of facilities have pretreatment in place.

The results of this analysis are presented in Table D.1. The MOE survey did not gather specific flow rate data, but did ask respondents to estimate their flow rate by indicating the appropriate range of flows as noted in the table. The percentage of facilities in each flow range is shown in the table. As expected, the largest percentage of facilities (43 percent) are in the low flow range (less than 1,000 USgal/day). The raw survey data made available by the MOE was then analyzed to determine the extent of pretreatment in place for each of the flow ranges. The belief that smaller facilities are less likely to have pretreatment in place are confirmed by these data (only 56 percent of small facilities have pretreatment in place).

The following exercise was undertaken to estimate the extent of pretreatment by volume. A reasonable median volume for each flow rate range was selected and a total volume, based on the percentage of facilities and a total of 600 Canadian facilities, was calculated. This total volume for each flow range was then divided between treated and untreated volumes based on the percentage of facilities in each flow range that have pretreatment in place. The overall extent of pretreatment for all flow ranges is 88 percent as noted in the table. This estimate has been carried through the calculations in Section 3. As expected, this value is somewhat higher than the overall percentage of facilities with pretreatment in place (78 percent).

Table D.1 Percentage of Wastewater Treated by Volume					
Volume Discharged (USgal/day/facility)	**Median Volume (USgal/day/facility)**	**Percentage of Total Facilities**	**Percentage of Facilities Treating**	**Volume Treated (USgal/day)**	**Volume Untreated (USgal/day)**
0 - 1,000	500	43%	56%	72,074	55,636
1,000 - 10,000	5,500	22%	84%	622,892	119,277
10,000 - 100,000	55,000	28%	87%	7,951,807	1,192,771
>100,000	200,000	7%	89%	7,710,843	963,855
Percentage of Total Wastewater				**88%**	**12%**

Appendix E

DISPOSITION BY VOLUME OF SPENT PROCESS SOLUTIONS

Appendix E

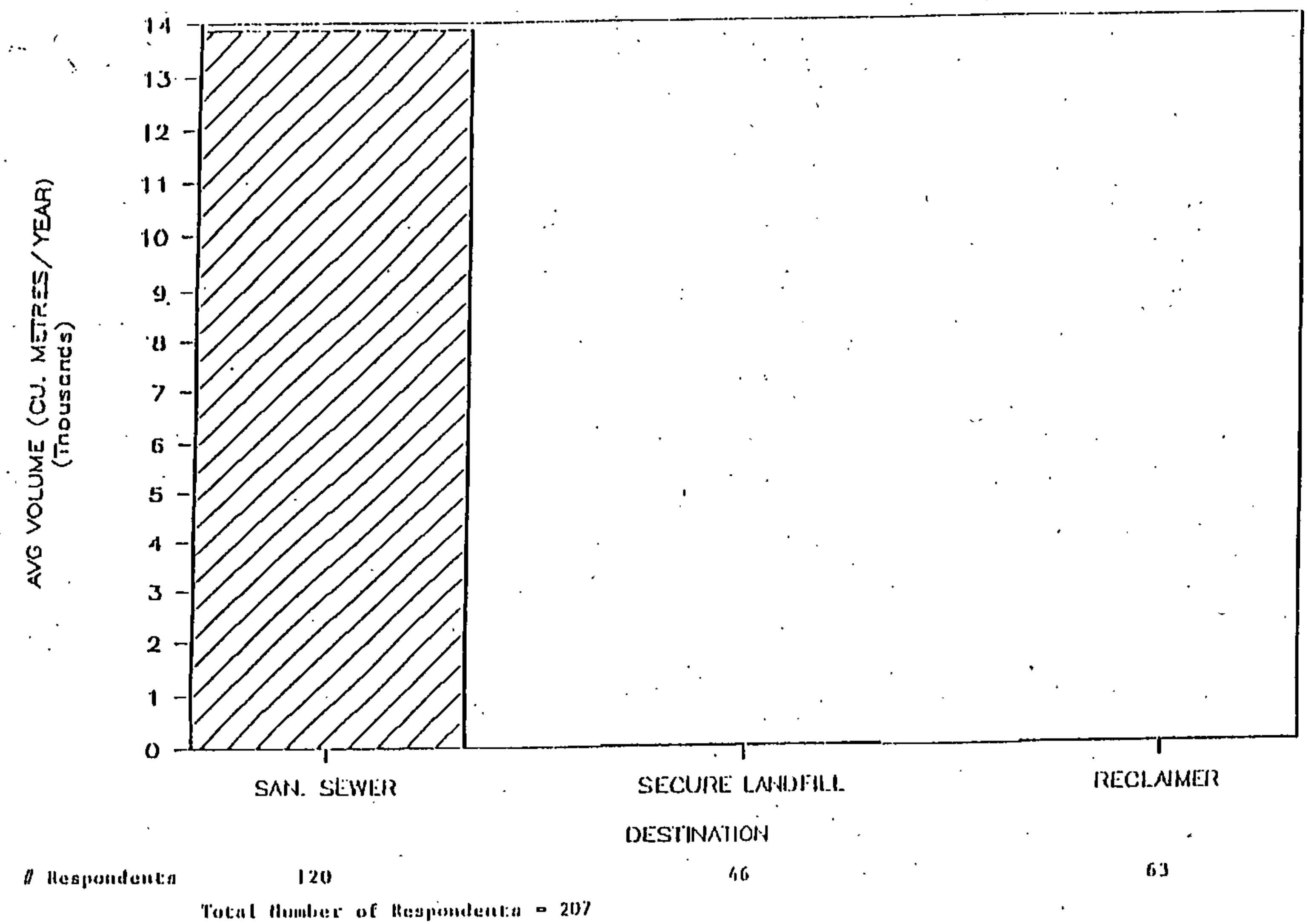
DISPOSITION BY VOLUME OF SPENT PROCESS SOLUTIONS

Figure E-1 is a summary of the data reported by MOE in 1991 on the disposition of spent process solutions. Included in this figure are data indicating those metal finishing facilities in Ontario which dispose of spent solutions to a municipal sanitary sewer (either directly or after pretreatment), those Ontario facilities which dispose of spent process liquids at a secure landfill, and those Ontario facilities for which spent process solutions are subjected to reclamation. Note that the volumes reported in Figure E-1 are arithmetic means and likely represent conservative (i.e. high) estimates of volumes disposed to sanitary sewer.

The cumulative probability plots of the MOE data in Figure E-2 indicate that the annual volumes of spent process solutions removed from service are log-normally distributed for each of the three disposal/management approaches.

Based on this database, approximately 58 percent (120 out of 207) of the metal finishing operations dispose of spent process solutions to the sanitary sewer. The median volume managed in this manner is approximately 13,500 U.S. gallons/year. Approximately 22 percent (46 of 207) facilities dispose of a portion (annual median of 1,750 U.S. gallons) at a secure landfill; and approximately 30 percent (63 of 207) facilities dispose of spent process solutions (annual median of 2,000 U.S. gallons) at reclaiming facilities.

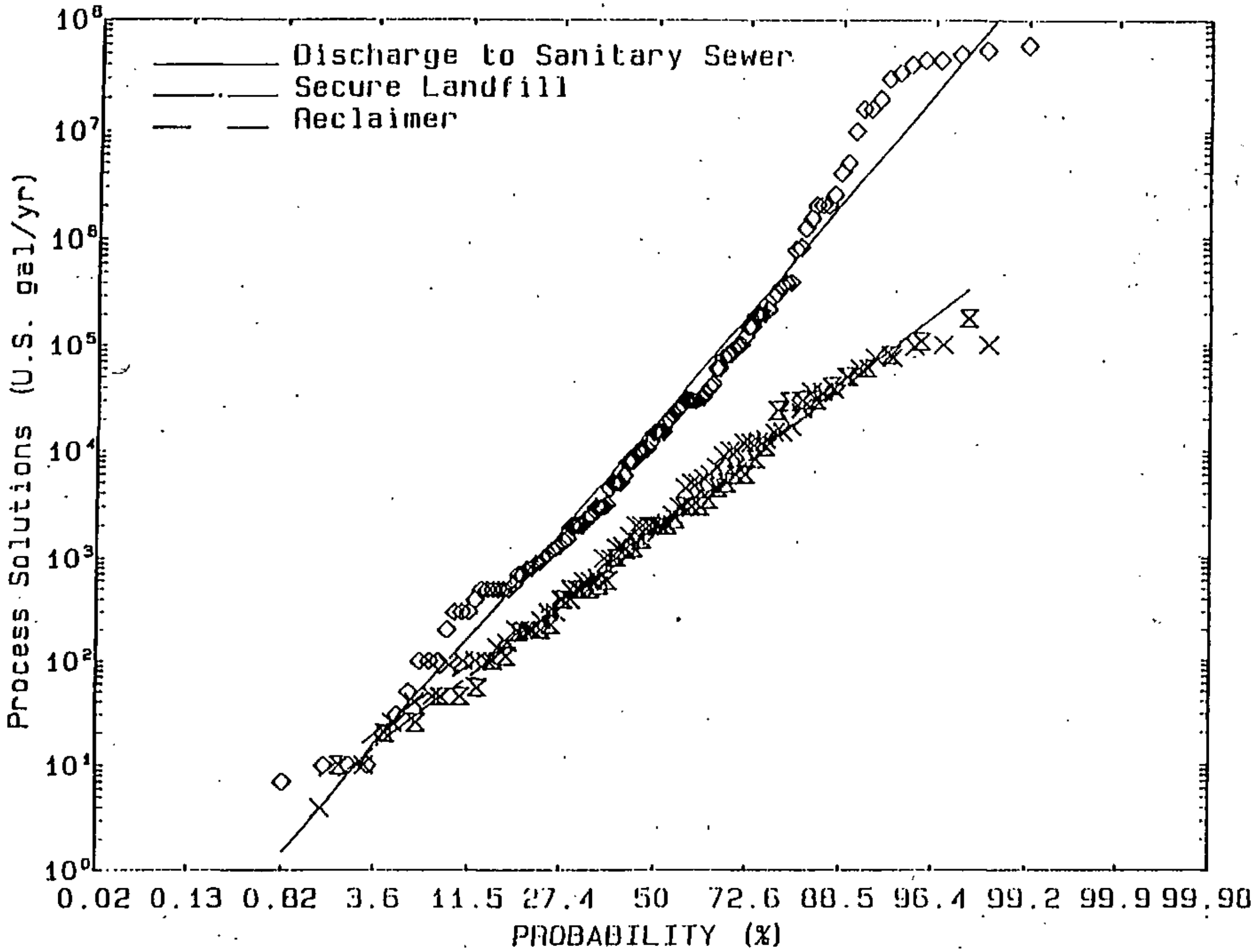
Assuming the Ontario population of metal finishing operations is representative of the Canadian industry as a whole, approximately five million gallons of spent process solutions are generated annually. This estimate is based on a Canadian industry comprised of 600 facilities. As indicated in Table E.1, most of this material (approximately 89 percent) is disposed of to the sanitary sewer. Approximately four percent is disposed of in secure landfills and seven percent is reclaimed.



CH2M HILL ENGINEERING LTD.
WATERLOO ONTARIO
PROJECT No. ONT29631.A0

FIGURE E1:

DISPOSITION OF SPENT PROCESS SOLUTIONS



CH2M HILL ENGINEERING LTD.

WATERLOO ONTARIO

PROJECT No. ONT29631.AO

FIGURE E2:

DISTRIBUTION OF ANNUAL VOLUMES OF SPENT PROCESS SOLUTIONS

Table E.1 **Estimated Spent Process Solution Volumes[1]**				
Management Approach	**Percent of Facilities**	**Median Annual Volume (U.S. Gallons)**		
		Per Facility	**For Industry[2]**	**Percentage by Volume**
Dispose to Sanitary Sewer	58%	13,500	4.7×10^6	89
Secure Landfill	22%	1,750	2.3×10^5	4
Reclamation	30%	2,000	3.6×10^5	7
Notes: [1]MOE, 1991 [2]Based on 600 facilities				