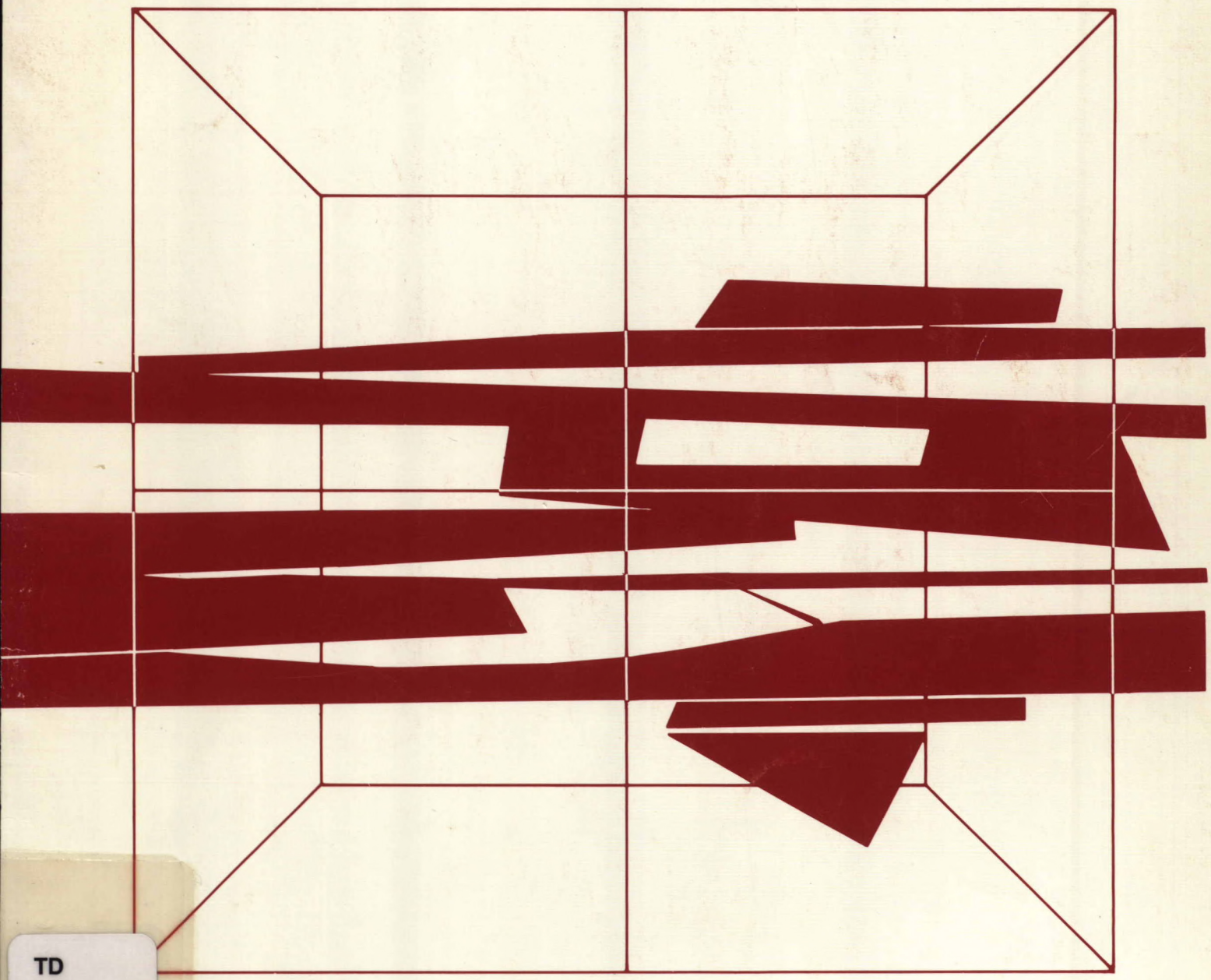
E. Porter

Status Report on Water Pollution Control in the Canadian Metal Mining Industry (1986)

Report EPS 1/MM/3
May 1988



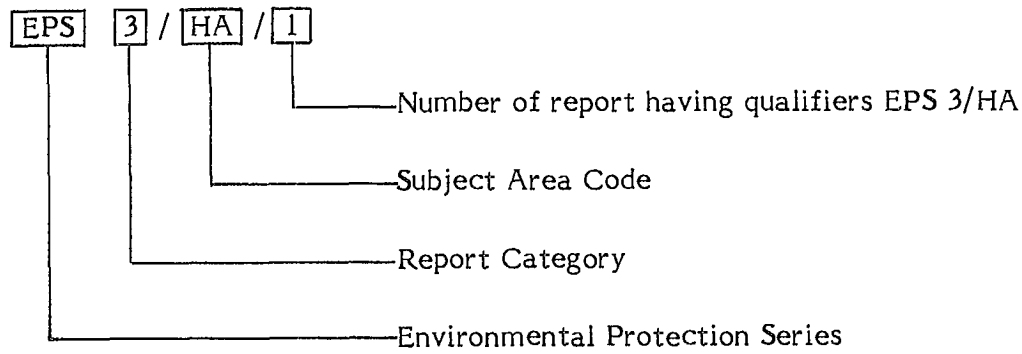
TD
182
R46
No.1/
MM/3

Environment Canada
Environnement Canada

Canada

ENVIRONMENTAL PROTECTION SERIES REPORTS

Sample Number:



Categories

1 Regulations/Guidelines/Codes of Practice
2 Public Consultation: Problem Assessment, Control Options
3 Research and Technology Development
4 Literature Reviews
5 Surveys
6 Social, Economic and Environmental Impact Assessments
7 Surveillance
8 Policy Proposals & Statements
9 Manuals

Subject Areas

AG Agriculture
AP Airborne Pollutants
AT Aquatic Toxicity
CC Commercial Chemicals
CE Consumers and the Environment
CI Chemical Industries
FA Federal Activities
FP Food Processing
HA Hazardous Wastes
IC Inorganic Chemicals
MA Marine Pollution
MM Mining & Ore Processing
NR Northern & Rural Regions
PF Paper and Fibres
PG Power Generation
PN Petroleum and Natural Gas
SF Surface Finishing
SP Oil & Chemical Spills
SRM Standard Reference Methods
TS Transportation Systems
UP Urban Pollution
WP Wood Protection/Preservation

New subject areas and codes are introduced as they become necessary. A list of EPS reports may be obtained from Environmental Protection Publications, Conservation and Protection, Environment Canada, Ottawa, Ontario, Canada, K1A 0H3.

Printed in Canada

ENVIRONMENT CANADA
LIBRARY, NOVA COAST PLAZA
PO BOX 2310 5019-52 ST.
YELLOWKNIFE, NT X1A 2P7

STATUS REPORT ON WATER POLLUTION CONTROL IN THE CANADIAN METAL MINING INDUSTRY (1986)

Library

Mining, Mineral, and Metallurgical Processes Division
Industrial Programs Branch
Conservation and Protection
Environment Canada

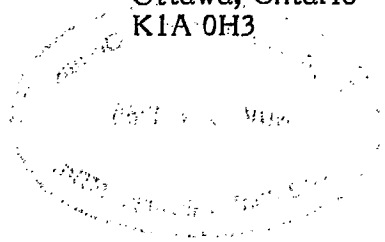
Report EPS 1/MM/3
May 1988

LIBRARY
Environmental Protection Service
Western & Northern Region

NOTICE

Any comments regarding this report should be addressed to:

Chief
Mining, Mineral and Metallurgical Processes Division
Industrial Programs Branch
Conservation and Protection
Environment Canada
Ottawa, Ontario
K1A 0H3



© Minister of Supply and Services Canada 1988
Cat. No. En 49-7/1-3E
ISBN 0-662-55761-1
BEAUREGARD PRESS LIMITED

TABLE OF CONTENTS

		Page
1	INTRODUCTION	1
2	METAL MINING LIQUID EFFLUENT REGULATIONS AND GUIDELINES	2
2.1	Regulations	2
2.2	Guidelines	4
2.3	Code of Practice	4
2.4	Technology Basis for Regulations	4
2.5	Implementation	5
2.6	Monitoring and Reporting Requirements	5
2.7	Designation of Tailings Impoundment Areas	6
2.8	Unconfined Disposal of Tailings	6
3	COMPLIANCE DATA	7
3.1	Data Collection	7
3.2	National Summary	7
3.2.1	Compliance with Regulations	8
3.2.2	Compliance with Guidelines	10
3.3	Data for Individual Mines	10
3.4	Summary of Compliance by Region	19
3.4.1	Pacific and Yukon Region	19
3.4.2	Western and Northern Region	19
3.4.3	Ontario Region	20
3.4.4	Quebec Region	20
3.4.5	Atlantic Region	20
4	WATER POLLUTION CONTROL TECHNOLOGY AT MINING AND MILLING OPERATIONS	21
4.1	Removal of Solids	21
4.2	Neutralization and Removal of Metals	22
4.3	Removal of Radium-226	23
4.4	Removal of Cyanide	23
4.5	Effluent Treatment Plants	24
REFERENCES		26
APPENDIX	MINING COMPANIES ASSESSED FOR COMPLIANCE	29

LIST OF TABLES

Table		Page
1	AUTHORIZED LEVELS OF DELETERIOUS SUBSTANCES PRESCRIBED IN THE METAL MINING LIQUID EFFLUENT REGULATIONS	3
2	SUMMARY OF COMPLIANCE FOR MINES SUBJECT TO REGULATIONS	9
3	TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN BRITISH COLUMBIA IN 1986	12
4	TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN THE YUKON IN 1986	13
5	TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN THE NORTHWEST TERRITORIES IN 1986	13
6	TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN SASKATCHEWAN IN 1986	13
7	TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN MANITOBA IN 1986	14
8	TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN ONTARIO IN 1986	15
9	TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN QUEBEC IN 1986	17
10	TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN NEW BRUNSWICK IN 1986	18
11	TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN NOVA SCOTIA IN 1986	18
12	TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN NEWFOUNDLAND IN 1986	18

LIST OF FIGURES

Figure		Page
1	MINE-MILL EFFLUENT TREATMENT FLOWSHEET	22
2	MECHANICAL EFFLUENT TREATMENT PLANT FLOWSHEET	25

1 INTRODUCTION

This report assesses the compliance by Canadian metal mines with the Federal Metal Mining Liquid Effluent Regulations and Guidelines during 1986. It also describes briefly the water pollution abatement technologies used by the mining industry. This is the second report of this type. The first such report described the status of compliance for metal mines during 1982 (1).

Section 2 describes Environment Canada's legislative efforts to reduce water pollution from the metal mining industry. The *Fisheries Act* is the primary legislative authority for federal water pollution control programs. Subsection 33(2) of the *Fisheries Act* prohibits the deposit of deleterious substances into waters frequented by fish. The Metal Mining Liquid Effluent Regulations (MMLER) were passed in February, 1977, under the *Fisheries Act*. The regulations apply to new, expanded, and reopened metal mines, but not to gold mines using the cyanidation process. Guidelines were published at the same time for existing metal mines.

Environment Canada administers and monitors compliance with the regulations and guidelines. The regulatory requirements are implemented through licences or permits issued by the provinces or other federal agencies. Cooperative arrangements with these other government agencies are important elements in Environment Canada's pollution control programs.

Section 3 reviews the status of individual mines in meeting the requirements of the regulations and guidelines in 1986.

In addition to its regulatory role, Environment Canada promotes the advancement of technology to control pollution. Section 4 briefly outlines some of the technology used to control water pollution from metal mines.

2 METAL MINING LIQUID EFFLUENT REGULATIONS AND GUIDELINES

The Metal Mining Liquid Effluent Regulations and Guidelines, an Environmental Code of Practice, and Explanatory Notes were published as a single document in 1977 by Environment Canada (2). The regulations are found in the *Consolidated Regulations of Canada*, chapter 819 (3).

2.1 Regulations

The Metal Mining Liquid Effluent Regulations limit the concentrations of

1) arsenic (As)
2) copper (Cu)
3) lead (Pb)
4) nickel (Ni)
5) zinc (Zn)
6) total suspended matter (TSM)
7) radium-226 (Ra-226)

that may be discharged in effluents from new, expanded, and reopened metal mines. The regulations do not apply to gold mines that use the cyanidation process. The regulations also provide a lower limit for pH. Table 1 shows the authorized levels of the deleterious substances and pH prescribed by the regulations.

In these regulations a mine is defined as all metal mining and milling facilities, and associated smelters, pelletizing plants, sinter plants, refineries, acid plants and any similar operations where the effluent from such operations is combined with effluents from mining and milling. A new mine is a mine that commenced commercial production after February 25, 1977. An expanded mine is a mine that increased its production rate by more than 30% after February 25, 1977. A reopened mine is a mine that resumed production after February 25, 1977, and that was not in production for more than two months in the 12-month period before this date.

The release of pollutants in effluents from metal mines is often related, among other factors, to (i) the natural characteristics of the ore, and (ii) uncontrollable water flows into the mine, waste rock dumps, or tailings pond. Consequently, there is no direct relationship between the production rate of mines and the amount of deleterious substances that may be released. Tailings or waste rock at an abandoned mine may also continue to release substantial amounts of deleterious substances after mining and milling operations have ceased. Therefore, the limits in the Metal Mining Liquid Effluent Regulations and Guidelines are based on the concentrations of deleterious substances in the effluent rather than on the production rate of the mine.

TABLE 1 AUTHORIZED LEVELS OF DELETERIOUS SUBSTANCES PRESCRIBED IN THE METAL MINING LIQUID EFFLUENT REGULATIONS

Part 1 Authorized Levels of Substances

Item	Substance	Column I Maximum Authorized Monthly Arithmetic Mean Concentration	Column II Maximum Authorized Concentration in a Composite Sample	Column III Maximum Authorized Concentration in a Grab Sample
1	Arsenic	0.5 mg/L	0.75 mg/L	1.0 mg/L
2	Copper	0.3 mg/L	0.45 mg/L	0.6 mg/L
3	Lead	0.2 mg/L	0.3 mg/L	0.4 mg/L
4	Nickel	0.5 mg/L	0.75 mg/L	1.0 mg/L
5	Zinc	0.5 mg/L	0.75 mg/L	1.0 mg/L
6	Total Suspended Matter (TSM)	25.0 mg/L	37.5 mg/L	50.0 mg/L
7	Radium-226	10.0 pCi/L (0.37 Bq/L)	20.0 pCi/L (0.74 Bq/L)	30.0 pCi/L (1.1 Bq/L)

Note: The concentrations are given as total values with the exception of radium-226 which is a dissolved value after filtration of the sample through a 3 micron filter.

Part 2 Authorized Levels of pH

Parameter	Column I Minimum Authorized Monthly Arithmetic mean pH	Column II Minimum Authorized pH in a Composite Sample	Column III Minimum Authorized in pH a Grab Sample
pH	6.0	5.5	5.0

Note: The acceptable levels of substances in the Metal Mining Liquid Effluent Guidelines have the same numerical values as the authorized levels of deleterious substances prescribed in the Metal Mining Liquid Effluent Regulations.

2.2 Guidelines

The Guidelines for Liquid Effluents from Existing Metal Mines apply to all metal mines in operation before 1977 except gold mines using cyanidation. They contain the same numerical limits for deleterious substances as the regulations. While the guidelines are not a specific law, they indicate the levels of contaminants in effluents which are considered by Environment Canada as meeting the spirit of the law. A mine may also be legally obligated to meet the guidelines if a government agency imposes these limits in a permit or licence issued under other legislation.

Environment Canada also developed Guidelines for the Measurement of Acute Lethality in Liquid Effluents from Metal Mines which specify a bioassay test procedure in which fish (rainbow trout) are exposed to undiluted effluent for 96 hours. If 50% of the fish survive, then the effluent is considered to pass the test. The toxicity test measures the short-term cumulative effect on fish of all deleterious substances that may be contained in an effluent.

2.3 Code of Practice

An Environmental Code of Practice for Mines was also developed and published with the regulations and guidelines. This code is a technical document that makes recommendations on the design and operation of mining and milling facilities which are related to water pollution control. The document identifies what Environment Canada considers to be good water pollution control practices.

2.4 Technology Basis for Regulations

The numerical limits prescribed by the regulations and guidelines are based on the application of "best practical technology". "Best practical technology" means the control of pollution at the source through the application of technology that is in commercial use and is both technically and economically viable. Effluent treated through the application of "best practical technology" should be able to meet the Guidelines for the Measurement of Acute Lethality in Liquid Effluents from Metal Mines in most circumstances.

Provincial agencies may impose their own effluent requirements, if they choose, in which case the company must meet the more stringent of the federal or provincial requirements.

2.5 Implementation

Environment Canada and Fisheries and Oceans Canada cooperate with provincial and territorial environmental agencies in the implementation of the Metal Mining Liquid Effluent Regulations and Guidelines. The federal government attempts to implement the requirements of the regulations and guidelines by having the provincial agencies include the federal effluent limits in the provincial licences or permits that they issue to a mining company. The inclusion of the federal requirements in the provincial permit or licencing process results in a "one window" approach to industry by the regulatory agencies.

In the coastal regions where the federal government administers the fisheries, Environment Canada and Fisheries and Oceans Canada are more directly involved in the review of provincial licence and permit applications to ensure that the federal requirements are met. Where federally managed fishery resources could be significantly affected by a mining operation, the federal agencies may deal directly with the operation to address the specific fisheries concerns.

Uranium mines are licenced under the *Atomic Energy Control Act*, and Environment Canada works closely with the Atomic Energy Control Board to implement the regulations and guidelines for uranium mines. The effluent standards of the regulations are included in the Mining Facility Operating Licences issued by the AECB to the uranium mining companies. In the Yukon and the Northwest Territories, Environment Canada works closely with the water boards and the Department of Indian Affairs and Northern Development in the licencing of mines under the *Northern Inland Waters Act*.

2.6 Monitoring and Reporting Requirements

The Metal Mining Liquid Effluent Regulations and Guidelines contain monitoring and reporting requirements in sections 6 to 10. Section 11 provides for modifications to the monitoring and reporting scheme. The monitoring and reporting provisions ordinarily permit a single monitoring and reporting scheme to be used to fulfill both the provincial and the federal requirements. The 1977 amendments to the *Fisheries Act* included subsection 33(14) which provides additional flexibility in specifying monitoring and reporting requirements.

Schedule 2 of the Metal Mining Liquid Effluent Regulations and Guidelines defines the frequency with which the prescribed parameters in effluents are to be sampled and analysed. Mining operations are required to sample and monitor their effluents and

report the results on a regular basis to government agencies. This information is available to Environment Canada, although the particular arrangements vary with each province. Similar arrangements exist between Environment Canada and other federal agencies.

2.7 Designation of Tailings Impoundment Areas

A proposed tailings impoundment area may include within its boundaries a small pond or lake that may be frequented by some species of fish. If these fish are not a significant stock, then the Minister of Fisheries and Oceans may designate this area a tailings impoundment area under subsection 5(2) of the Metal Mining Liquid Effluent Regulations. Since the regulations came into effect in 1977, three such tailings impoundment areas have been designated.

2.8 Unconfined Disposal of Tailings

Environment Canada's policy regarding the unconfined disposal of tailings is described as follows in the Environmental Code of Practice for Mines:

> "**6.1** Tailings should not be discharged to an unconfined disposal area unless confined disposal is shown to be impractical or unless the unconfined disposal alternative is environmentally preferable.
>
> "**6.2** For new, expanded and reopened mines unconfined disposal is not permitted under the federal Metal Mining Liquid Effluent Regulations. When it can be shown that the unconfined disposal alternative is the most practical method, and that it is environmentally preferable to confined disposal, a separate regulation for each specific site must be obtained to allow its use."

The three mines that discharged tailings into large lakes or marine waters in 1986 are identified in Tables 3 and 11. All of these mines commenced operations prior to 1977 and are subject to the Metal Mining Liquid Effluent Guidelines rather than to the Regulations. However, unconfined discharge at these mines was approved by regulatory agencies before the guidelines were issued.

Since 1977 unconfined disposal of tailings has been approved in only one case. The Alice Arm Tailings Deposit Regulations under the *Fisheries Act* (P.C. 1979-1112, April 4, 1979; SOR/79-345) authorize AMAX of Canada Ltd. to deposit tailings from the Kitsault Mine into Alice Arm, British Columbia under prescribed conditions. AMAX reopened the Kitsault Mine in April 1981, but the mine closed in November 1982.

3 COMPLIANCE DATA

3.1 Data Collection

The data used in the generation of this report were acquired principally through cooperative arrangements between the federal and provincial agencies. The data were consolidated from several sources. Samples collected and analysed by the mining companies and reported to provincial and federal agencies were the primary source. The frequency with which these analyses were performed and reported depends on the requirements of the regulating agency. Closed mines still discharging mine water and inactive tailings impoundment sites where the effluent is still being treated are also included in this report.

3.2 National Summary

The list below summarizes the number of mines that exceeded authorized monthly amounts of the various substances limited by the regulations and guidelines in 1986. A single mine may have exceeded more than one parameter and be included more than once in the list.

	Number of Mines Exceeding Monthly Authorized Levels in 1986	
Parameter Exceeded	Mines under Regulations	Mines under Guidelines
Arsenic	0	2
Copper	3	5
Lead	2	2
Nickel	0	6
Zinc	9	12
Total Suspended Matter	7	11
pH	2	3
Radium-226	0	1
Toxicity		16 out of 58 tests failed

These statistics are based on monitoring data that vary widely in frequency from mine to mine. A mine that exceeds the monthly average limit for one or more of the authorized parameters during any one month in 1986 is considered not to have met the

requirements. Some mines may only occasionally exceed the monthly limit, but still meet the requirements for most of the year.

3.2.1 Compliance with Regulations. Table 2 summarizes the status and frequency of compliance in 1986 for the 30 mining operations subject to the Metal Mining Liquid Effluent Regulations. Of these, 18 mines were in total compliance throughout 1986 and 11 mines were not in compliance with at least one of the seven effluent standards for one month or more during the year. Only one grab sample was reported for one mine which discharged a low flow of mine water; this was considered insufficient information to conclude whether the mine was in compliance or not. Of the mines that were not in compliance, one mine was not in compliance for two months, six mines for four months or less and one mine for 12 months. Excluding the one mine with insufficient information, the number of operational months under consideration for 1986 was 348 (29 mines x 12 months). Of these 348 months the mines were in compliance with the limits for 292 months, and exceeded the limits in 56 months, or 16.1% of the year. This percentage represents an upper limit as it presumes that, when a mine is not in compliance for a particular month, it has exceeded the limits on every day of that month and this is not always the case.

In 1982, 17 mines out of a total of 20 operations complied with regulated limits at all times. This represents a compliance rate of 85%. The comparable figure for 1986 was 62%.

During 1986 all mines complied with the monthly effluent requirements for arsenic, nickel and radium-226 100% of the time. Two mines were not in compliance for both lead and pH; three mines for copper; and seven for total suspended matter. Zinc proved the most difficult metal to maintain within the control limit, with nine mines failing to meet the standard for zinc, at least for part of the year.

The severity and duration of an incident of non-compliance at a mine can vary greatly, as can the magnitude of its effects on the receiving water. Serious effects were reported in only one case as a result of the incidents of non-compliance in 1986. Concern was expressed regarding possible damage to a fish habitat due to excessive suspended solids in the effluent from the East Kemptville Tin Corporation mine in Nova Scotia. The company has since modified its effluent treatment system to correct the problem. The cause of each incident of non-compliance is provided in column 4 of Table 2, along with any corrective actions subsequently taken at each mine.

TABLE 2 SUMMARY OF COMPLIANCE FOR MINES SUBJECT TO REGULATIONS

Name (Company), Province	Status	Frequency of Compliance in 1986	Comments
1. Afton (Teck Corporation), B.C.	Opened, 1978	100%	No surface effluent.
2. Blackdome, B.C.	Opened, 1986	Not in compliance for TSM during the 3 months when there was a discharge.	Company trying to solve problem by adding flocculant.
3. Equity Silver (Placer Development), B.C.	Opened, 1980	Not in compliance for copper (1 month), zinc (1 month) and TSM (3 months).	Noncompliance in spring due to spills and spring flood.
4. Erickson Gold, B.C.	Opened, 1980	100%	No surface effluent.
5. Highland Valley Copper (Lornex), B.C.	Expanded mine, 1986	100%	No surface effluent.
6. Kindrat (Bishop Resources Development), B.C.	Opened, 1983	100%	No surface effluent.
7. Westmin Resources, B.C.	Expanded mine, 1985	Not in compliance for copper (1 month), zinc (4 months), TSM (1 month). Discharge from pipeline road not in compliance for pH and zinc.	Collection system and treatment plant in place; situation improving. Uncontrolled acid mine drainage occurs from pipeline road; the company is removing the road.
8. Faro Mine (Curragh Resources), Yukon	Expanded, 1986	Not in compliance for lead (1 months) and zinc (3 months).	Reopened and expanded after 4-year shutdown. Noncompliance attributed to start up difficulties and high metal concentration in pit water discharged in large volume during dewatering.
9. Trout Lake Mine (Hudson Bay Mining and Smelting), Manitoba	Opened, 1982	Not in compliance for copper (4 months), lead (2 months), zinc and TSM (12 months).	New settling pond installed in 1985 does not meet performance expectation.
10. Spruce Point Mine (Hudson Bay Mining and Smelting), Manitoba	Opened, 1982	Not in compliance for zinc (5 months).	Treatment plant installed in 1985 requires closer control to remove zinc.
11. Snow Lake Mill (Hudson Bay Mining and Smelting), Manitoba	Opened, 1979	100%	
12. Rod Mine (Hudson Bay Mining and Smelting), Manitoba	Opened, 1984	100%	Mine water to Snow Lake mill tailings pond.
13. Polaris (Cominco), NWT	Opened, 1982	100%	
14. Bullmoose (Terra Mines), NWT	Opened, 1986	100%	
15. Cluff Lake Mine (Amok), Saskatchewan	Opened, 1980	100%	
16. Key Lake Mine, Saskatchewan	Opened, 1983	Not in compliance for pH (2 months).	Intermittent problem; pH is closely controlled, around minimum value, to reduce the toxic form of ammonia.
17. Collins Bay - Rabbit Lake (Eldorado), Saskatchewan	Opened, 1986	100%	Effluent from mine water settling pond is subject to regulation.
18. Denison Mines, Ontario	Expanded, 1982	100%	
19. Quirke Mine (Rio Algom), Ontario	Expanded, 1978	100%	
20. Panel Mine (Rio Algom), Ontario	Reopened, 1979	100%	
21. Stanleigh (Rio Algom), Ontario	Reopened, 1983	100%	
22. Lyon Lake Division (Noranda), Ontario	Opened, 1980	Not in compliance for zinc (11 months)	A second pond has been installed to provide additional treatment time.
23. Opemiska Division (Minnova)*, Quebec	Opened, 1977	Not in compliance for TSM.	Low flow; intermittent effluent.
24. Lake Dufault Division (Minnova)*, Quebec	Opened, 1981	Data insufficient to assess compliance (1 grab sample above limit for zinc)	Mine is closed but kept dewatered. Low effluent volume.
25. Selbaie (BP Canada), Quebec	Opened, 1981	In compliance during monitored period.	Data for 4 months only.
26. Remnor Mine (Noranda), Quebec	Reopened, 1985	100%	
27. Abcourt Mine, Quebec	Opened, 1985	Not in compliance for zinc (9 months) and TSM (2 months).	
28. Gallen (Noranda), Quebec	Opened, 1981	100%	Mine closed, October 1985; surface drainage is treated.
29. Mobrun Mine (Audrey Resources), Quebec	Opened, 1986	100%	
30. East Kemptville (East Kemptville, Tin Corp.), Nova Scotia	Opened, 1985	Not in compliance for zinc (4 months), pH (3 months) and TSM (4 months).	Problems of early part of the year solved by modifying treatment system.

* Name changed in April 1987 from Corporation Falconbridge Copper.

3.2.2 Compliance with Guidelines. Of the 81 operations that were subject to the Metal Mining Liquid Effluent Guidelines in 1986, 53 mines (65%) were in compliance throughout the year, while 28 mines (35%) were not. The mines subject to guidelines met the requirements 81.4% of the time in 1986.

Of the mines that did not comply with the guidelines, three practiced unconfined tailings disposal, a method which was approved for these three mines by regulatory agencies before the promulgation of the guidelines. Excluding these three operations, the mines subject to the guidelines met the requirements 84.3% of the time during the year.

Only five mines were not in compliance for the whole year. Zinc and total suspended matter limits were the most frequently exceeded requirements. In 1982, 63% of the mines (71 of 113) met the guidelines at all times. In 1986, this percentage rose to 65%, indicating a slight improvement in compliance with the guidelines.

3.3 Data for Individual Mines

Tables 3 to 12 list by province and territory all the mines subject to the Metal Mining Liquid Effluent Regulations and Guidelines in 1986. During 1986 no metal mines were operating in Alberta or Prince Edward Island.

Column 1 of the tables lists the names of the mines, the name of the company and the approximate location. Company names have been abbreviated by omitting such words as "Mines", "Corporation", "Limited", etc. Parent or managing company names are also given. The full names of all mining companies are provided as an appendix.

Column 2 lists:

(a) the metals produced (by-products in brackets),

(b) the rated capacity of the mill in metric tonnes of ore per day (tpd), or in the case of mines that ship ore to a mill at another location, the average amount of ore produced by the mine, and

(c) the method of mining (underground or open pit).

Column 3 describes the treatment facilities that the mine uses for water pollution control. Column 4 gives data for annual average quality of liquid effluents (or typical data where limited data are available). Column 5 indicates whether or not a mine generally meets the requirements of the regulations or guidelines, and the results of any toxicity tests conducted.

The effluent from any one mining operation does not necessarily contain measurable concentrations of all the metal parameters prescribed in the regulations and guidelines. Metals commonly occur in ore as insoluble minerals. In the absence of acid mine water, only low concentrations of metals would be expected to occur in the effluent.

To simplify the presentation of data in this report, metal concentrations less than 0.01 milligrams per litre (mg/L) are not reported in the tables. The letter "L" indicates that the analysis has been done, but that the concentration is less than 0.01 mg/L for that particular parameter, or in a few cases, less than the detectable limit of the particular analytical procedure. Such concentrations are far below the allowable limits of the regulations and guidelines. Total suspended matter (TSM) concentrations less than 5 mg/L are simply shown as "L". In some cases there are no 1986 data for a particular substance. The regulatory agency may not have required the company to provide 1986 data on some substances because historical data have shown the parameter was not of concern (i.e., the effluent was consistently well within the limits for that parameter). This accounts for blank spaces in the data for some of the mines.

As the frequency of monitoring varies considerably from mine to mine, the data summary in Column 4 of the tables provides only a general view of the effluent quality. In some cases the figures in Column 4 represent the average of extensive data, while in other cases they represent the average of a small number of samples.

The comments in Column 5 of Tables 3 to 12 are general observations based on an examination of the effluent data and other information available to Environment Canada. Column 5 indicates whether the mine is subject to the regulations or to the guidelines and whether the mine has complied with the legislation.

Column 4, in most cases, provides annual averages of effluent quality. However, the regulations and the guidelines specify limits in terms of (i) monthly averages, (ii) daily composites, and (iii) grab samples. Environment Canada regards the monthly average as the most important target when reviewing a mine's effluent records. The comment in Column 5 is based on an examination of all the data available to Environment Canada and not on the average of data shown in Column 4. For example, the annual average of zinc in a particular effluent might be 0.4 mg/L which is below the allowable 0.5 mg/L monthly average for zinc. The effluent may have exceeded the 0.5 mg/L during a few months, but still maintained an annual average below 0.5 mg/L. Column 5 therefore indicates the number of months the mine was out of compliance for a particular substance.

TABLE 3 TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN BRITISH COLUMBIA IN 1986

Mine (Company), Location	Products (By-products), Rated Milling Capacity, Mining Method	Treatment Facilities	1986 Average Quality of Liquid Effluent Metals and TSM in mg/L As	Cu	Ni	Pb	Zn	TSM	pH	Comments on Regulations or Guidelines
1. Afton (Teck Corporation), Kamloops	Copper 7600 tpd Open pit	Tailings pond with recycle.	No surface effluent							Complied with regulations.
2. Beaverdell (Teck Corporation), Kelowna	Silver (lead, zinc, gold) 110 tpd Underground	Tailings pond, decant exfiltration pond.	No surface effluent							Met guidelines.
3. Bell Copper (Noranda), Babine Lake	Copper 15 500 tpd Open pit	Tailings pond with recycle; seepage pond with recycle.	No discharge in 1986							Met guidelines.
4. Blackdome, Clinton	Gold (silver) 180 tpd (no cyanidation) Underground	Tailings pond with partial recycle, flocculant addition, settling ponds.	Mine started in May 1986. No discharge until August.							Above regulation for TSM. Passed 4/4 guideline toxicity tests.
			Seepage pond discharge:							
			0.02	0.02		L	0.03	110	7.0	
			Tailings pond effluent:							
			0.02	0.02		L	0.03	227	6.8	
5. Brenda (Noranda), Peachland	Copper, molybdenum 27 500 tpd Open pit	Tailings pond with recycle.	No surface effluent							Met guidelines.
6. Endako (Placer Development), Endako	Molybdenum 25 000 tpd Open pit	Tailings ponds with partial recycle; seepage collection ponds.	Seepage from No. 1 tailings pond North Dam:							Met guidelines.
			L	L	L	0.02	0.04	10	7.2	
			Seepage from No. 1 tailings pond South Dam:							
			L	L	L	L	L	7	7.1	
			Seepage from No. 2 tailings pond South Dam:							
			L	L	L	L	L	7	7.5	
			Seepage from No. 2 tailings pond East Dam:							
			L	L	L	L	0.04	8	7.3	
			Seepage from No. 2 tailings pond Saddle Dam:							
			L	L	L	L	L	13	7.5	
			Mine water discharge:							
			L	0.01	L	0.02	L	5	7.7	
7. Equity Silver (Placer Development), Houston	Silver, copper (gold) 8 000 tpd Open pit	Tailings pond with recycle; SO_2-air treatment for cyanide removal; acid mine drainage treatment.	Bessemer Creek silt check dam:							Bessemer Creek discharge occasionally above regulations for zinc, copper and TSM; failed 2/10 toxicity tests. Treated discharge met regulations and passed 1/1 toxicity test.
			L	0.07	0.08	L	0.11	22.8	6.6	
			Treated discharge to Foxy Creek:							
				0.03			0.05	7.0	7.4	
8. Erickson, Cassiar	Gold (no cyanidation) 270 tpd Underground	Tailings pond with recycle.	No surface effluent							Complied with regulations.
9. Gibraltar (Placer Development), Quesnel	Copper (molybdenum) 37 000 tpd Open pit	Tailings pond with recycle.	No surface effluent							Met guidelines.
10. Highland Valley (Lornex), Ashcroft	Copper, molybdenum 108 000 tpd Open pit	Tailings pond with recycle.	No surface discharge							Complied with regulations.
11. Island Copper (Utah Mines), Port Hardy	Copper (molybdenum) 48 000 tpd Open pit	Tailings are thickened before marine disposal.	Tailings deposited directly into Ruppert Inlet							Above guidelines. Marine discharge approved before guidelines promulgated.
12. Kindrat (Bishop Resources Development), Smithers	Silver (gold, lead, zinc, copper) 25 tpd	Tailings are dewatered and placed in old tailings pond; complete recycle.	No surface effluent							Complied with regulations.
13. Silvana (Dickenson), New Denver	Silver, lead, zinc 120 tpd Underground	Tailings pond.	Dissolved metals:							Above guideline for zinc (12 months).
				0.11		0.02	1.26	7.9	7.6	
14. Similkameen Division (Newmont), Princeton	Copper 20 000 tpd Open pit	Tailings pond with recycle. Partial recycle of tailings pond seepage.	West dam seepage (dissolved metals)							Met guidelines.
				L				L	7.8	
			East dam seepage (dissolved metals)							
				L				L	7.7	
15. Sullivan (Cominco), Kimberley	Lead, zinc (silver, cadmium, tin, antimony) 7 000 tpd Underground	Tailings pond, settling ponds, acid mine drainage treatment plant.	L	0.07		0.09	0.16	18	9.1	Met guidelines.
16. Westmin Resources, Campbell River	Copper, lead, zinc (silver, gold) 3 000 tpd Underground	Tailings pond with groundwater collection; acid mine drainage treatment plant.	Lynx pond discharge:							Lynx pond occasionally above regulations for copper and zinc; passed 3/3 toxicity tests. Myra pond occasionally above regulations for zinc and TSM; passed 5/5 toxicity tests. Price mine passed 4/4 toxicity tests. Tailings pond supernatant discharged only 3 weeks; passed 2/2 toxicity tests.
				0.12		0.01	0.47	8.2	8.9	
			Myra pond discharge:							
				0.02		L	0.30	14.8	8.8	
			Price mine water discharge:							
				0.01			0.31	L	7.3	
			Special tailings pond supernatant discharge:							
				0.02			0.08	L	8.9	

TABLE 4 TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN YUKON IN 1986

Mine (Company), Location	Products (By-products), Rated Milling Capacity, Mining Method	Treatment Facilities	1986 Average Quality of Liquid Effluent Metals and TSM in mg/L As	Cu	Ni	Pb	Zn	TSM	pH	Comments on Regulations or Guidelines
1. Faro Mine (Curragh Resources), Faro	Lead, zinc 12 000 tpd Open pit	Tailings pond.	Tailings pond decant: 0.02	0.03		0.07	0.54	L	7.8	Tailings pond decant occasionally above regulations for zinc and lead. Passed 1/1 guideline toxicity test.
			Tailings pond seepage discharge:	L		0.05	0.03	L	7.5	
2. United Keno Hill, Elso	Silver, lead, zinc 400 tpd Open pit and Underground	Tailings pond.	Tailings pond decant:	0.02		0.04	0.28	5	7.6	Above guideline for zinc (2 months).
			Drainage from old adits (1 grab sample for each adit):							
			Beliekeno adit 1.48	0.40	0.08	5.68	7.71	341	8.1	Above guidelines for arsenic, lead, copper, zinc and TSM.
			Silver King adit 0.14	0.07	0.06	0.03	0.93	17	7.2	
			Galkeno adit 0.4	L	0.49	0.06	29.8	L	6.9	
			Keno 700 adit 0.07	L	0.02	L	1.91	L	8.1	Above guideline for zinc.
			Bermingham adit L	L	L	L	7.85	L	7.6	
			Ruby 400 adit L	L	0.07	L	3.48	L	8.0	
			No Cash 500 adit 0.22	0.19	0.13	1.36	22.6	177	7.6	Above guidelines for lead, zinc and TSM.

TABLE 5 TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN NORTHWEST TERRITORIES IN 1986

Mine (Company), Location	Products (By-products), Rated Milling Capacity, Mining Method	Treatment Facilities	1986 Average Quality of Liquid Effluent Metals and TSM in mg/L As	Cu	Ni	Pb	Zn	TSM	pH	Comments on Regulations or Guidelines
1. Canada Tungsten, Tungsten	Tungsten 910 tpd Underground	Tailings pond with exfiltration to groundwater.	No surface effluent							Met guidelines.
2. Nanisivik Mine, Nanisivik	Lead, zinc 1800 tpd Underground	Tailings pond with partial recycle and lime addition.				0.11	0.03	L	10.8	Met guidelines.
3. Pine Point (Cominco), Pine Point	Lead, zinc 9900 tpd Open pit	Tailings pond with lime addition, polishing pond.		0.06		L	0.32	L	10.4	Met guidelines.
4. Polaris (Cominco), Little Cornwallis Island	Lead, zinc 2275 tpd Underground	Tailings thickened before discharge to a meromictic lake.		L		L	0.07			Complied with regulations.
5. Bullmoose (Terra Mines), Bullmoose Lake	Gold (no cyanidation) 75 tpd Underground	Tailings pond with complete retention.	No surface effluent							Complied with regulations.

TABLE 6 TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN SASKATCHEWAN IN 1986

Mine (Company), Location	Products (By-products), Rated Milling Capacity, Mining Method	Treatment Facilities	1986 Average Quality of Liquid Effluent Metals and TSM In mg/L As	Cu	Ni	Pb	Zn	TSM	pH	Comments on Regulations or Guidelines
1. Amok, Cluff Lake	Uranium 800 tpd Open pit	Tailings pond, $BaCl_2$ treatment, settling pond and filtration for radium removal.	0.01	0.01	0.01	L	0.03	6.1	7.0	Complied with regulations. Passed 2/2 toxicity tests.
			Total Ra-226: 1.8 pCi/L (0.07 Bq/L)							
2. Collins Bay - Rabbit Lake (Eldorado Resources), Rabbit Lake	Uranium 1800 tpd Open pit	Tailings pond, $BaCl_2$ treatment, settling and filtration for radium removal.	Settling pond effluent: 0.05	0.01	0.07	0.03	0.09	L	7.5	Complied with regulations. Passed 1/1 toxicity test. Airport road drainage occasionally above guidelines for TSM (2 months) and Ra-226 (3 months).
			Dissolved Ra-226: 0.5 pCi/L (0.02 Bq/L)							
			Airport road drainage: L	0.02	0.02	0.03	0.15	25.3	7.1	
			Dissolved Ra-226: 6.9 pCi/L (0.26 Bq/L)							
3. Key Lake Mine, Key Lake	Uranium 720 tpd Open pit	Tailings pond, neutralization, ammonia removal, $BaCl_2$ treatment and ion-exchange for radium removal.	0.12	L	0.27	0.03	0.05	L	6.1	Occasionally below pH regulations. Failed 1/3 guideline toxicity tests.
			Total Ra-226: 3.3 pCi/L (0.12 Bq/L)							

TABLE 7 TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN MANITOBA IN 1986

Mine (Company), Location	Products (By-products), Rated Milling Capacity, Mining Method	Treatment Facilities	1986 Average Quality of Liquid Effluent — Metals and TSM in mg/L As	Cu	Ni	Pb	Zn	TSM	pH	Comments on Regulations or Guidelines
1. Flin Flon Mine and Mill (Hudson Bay Mining and Smelting), Flin Flon	Copper, zinc (gold, silver) 6800 tpd Underground	Tailings pond with lime addition.	L	L	L	L	0.21	L	10.9	Met guidelines.
	Other HBMS mines providing ore for the Flin Flon mill, all underground:									
a) Trout Lake	2200 tpd	Surface settling pond.	0.01	0.30	L	0.15	2.0	132	7.7	Above regulations for lead zinc, copper and TSM.
b) Centennial	680 tpd	Surface settling ponds.	L	0.14	L	L	0.77	L	7.6	Above guideline for zinc (9 months).
c) Spruce Point	630 tpd	Treatment plant for mine water.	L	L	L	L	0.75	L	10.9	Above regulation for zinc (5 months).
d) Westarm	590 tpd	Settling pond for mine water.	L	L	0.1	L	0.21	9.1	7.6	Met guidelines.
2. Snow Lake Mill (HBMS), Snow Lake	Copper, zinc, lead (gold, silver) 3500 tpd	Tailings pond with partial recycle.	Discharge from July to November L	L	L	L	0.14	L	6.8	Complied with regulations.
	HBMS mines providing ore to Snow Lake mill, all underground:									
a) Chisel/Ghost Lake mines	Zinc, lead 865 tpd	Treatment plant for mine water.	L	L	L	L	0.36	L	10.5	Above guideline for zinc (2 months).
b) Stall Lake	1100 tpd	Effluent to Snow Lake tailings pond.								Met guidelines.
c) Anderson	775 tpd	Effluent to Snow Lake tailings pond.								Met guidelines.
d) Rod	450 tpd	Effluent to Snow Lake tailings pond.								Complied with regulations.
3. Thompson Complex (INCO), Thompson	Nickel, copper (gold, silver, cobalt) 18 000 tpd	Tailings pond.	L	0.02	0.43	0.02	0.02	7.3	7.4	Above nickel guideline (3 months).
	INCO Mines providing ore to Thompson mill:									
a) Thompson Mine	5900 tpd Underground	Tailings pond.	0.02	0.02	0.56	0.02	0.02	6.8	7.5	Above nickel guideline (7 months).
b) Pipe Mine	Mine closed but kept dewatered	Settling pond.	L	0.04	0.09	0.02	0.04	15.6	7.5	Met guidelines.
4. Ruttan (Sherritt Gordon), Leaf Rapids	Copper, zinc 9000 tpd Underground	Tailings pond with lime addition; partial recycle.	Discharged for only 6 months:	0.03	0.02	0.05	0.32	5.0	4.9	Below pH guideline (4 months).
5. Fox Mine (Sherritt Gordon), Lynn Lake	Mine is closed, but there is still a surface effluent.	Lime addition to tailings pond.	L	0.06	0.28	0.06	0.31	L	7.9	Above zinc guideline (3 months).
6. Tantalum Mining, Bernic Lake	Tantalum 630 tpd Underground	Tailings pond with lime and flocculant addition.	L	L	L	L	0.04	15	7.2	Above TSM guideline (2 months).

TABLE 8 TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN ONTARIO IN 1986

Mine (Company), Location	Products (By-products), Rated Milling Capacity, Mining Method	Treatment Facilities	1986 Average Quality of Liquid Effluent — Metals and TSM in mg/L							Comments on Regulations or Guidelines
			As	Cu	Ni	Pb	Zn	TSM	pH	
1. INCO Complex, Sudbury	Nickel, copper (cobalt, silver, gold, platinum) All underground.	Copper Cliff Creek Treatment Plant: lime addition, solids removal.		0.09	0.29		0.14		10.2	Met metal guidelines. Failed 1/1 toxicity test.
This facility treats the effluents from the various operations listed below; 90% of the effluent is recycled.										All met guidelines.
a) Frood-Stobie Mill	16 400 tpd	Tailings pond.								
Frood Mine	8 000 tpd									
Stobie Mine	6 300 tpd									
Little Stobie	4 200 tpd									
b) Clarabelle Mill	27 300 tpd	Tailings pond.								
Copper Cliff South	5 700 tpd									
Creighton	6 200 tpd									
Levack	3 800 tpd									
Garson	3 600 tpd									
McCreedy West	2 500 tpd									
Copper Cliff North	2 900 tpd									
c) Copper Cliff Mill	Treats concentrate from Frood-Stobie and Clarabelle mills.	Tailings pond.								
		Nolin Creek Treatment Plant; lime addition for pH adjustment and metal removal.		0.09	0.23		0.10		11.4	Above guideline for nickel (5 months). Failed 1/1 toxicity test.
Levack and McCreedy West Mines	Nickel, copper (cobalt, silver, gold, platinum) ore shipped to Clarabelle mill. 5400 tpd	Old tailings area used for mine water treatment by lime addition.		0.6	0.45		0.08		10.8	Met metal guidelines. Failed 1/1 toxicity test.
Garson Mine	Ore shipped to Clarabelle mill. 3600 tpd	Lime addition for metal removal from mine water.		0.02	0.29		0.07		10.6	Met guidelines. Passed 1/1 toxicity test.
Crean Hill Mine	Standby	Mine water treated by lime addition.		0.03	0.08				9.9	Met guidelines.
Coleman Mine	Standby	Mine water recycled to Falconbridge's Strathcona mill.	No surface effluent							Met guidelines.
2. Falconbridge Complex, Sudbury	Nickel, copper (cobalt, silver, gold, platinum)									
Falconbridge Mill and Falconbridge East Mine	2700 tpd Underground	Tailings pond; aeration, lime addition and settling pond for metal removal.		0.03	0.72				7.2	Above guideline for nickel (7 months).
Strathcona Mill	8200 tpd	Tailings pond; Moose Lake treatment system: limestone slurry addition for metal removal.		0.04	1.98				6.8	Above guideline for nickel (12 months).
The following mines provide ore for the Strathcona Mill:										
Strathcona	Underground									
Fraser	Underground									
North Mine	Underground									
Falco	Open pit									
Onaping	Underground	Mine water treated by lime addition for metal removal.		0.03	0.88				8.7	Above guideline for nickel (7 months).
Lockerby	Underground	Mine water treated by lime addition for metal removal.		0.08	0.22				8.3	Met guidelines.
3. Adams Mine (Dofasco), Kirkland Lake	Iron ore pellets 3500 tpd (as pellets) Open pit	Tailings pond with partial recycle.						38	7.4	Above guideline for TSM (4 months).
4. Algoma Ore Division (Algoma Steel), Wawa	Iron ore sinter 9000 tpd Underground	Tailings pond; neutralization of mine water; recycle.		0.01	0.02	0.05	0.02	L	7.9	Met guidelines.
5. Griffith Mine (Stelco), Red Lake	Iron ore pellets 3900 tpd Open pit	Tailings pond with partial recycle.	Mine closed in April 1986. L		0.01	0.01	0.01	8	7.7	Met guidelines.

TABLE 8 TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN ONTARIO IN 1986 (Cont'd)

Mine (Company), Location	Products (By-products), Rated Milling Capacity, Mining Method	Treatment Facilities	1986 Average Quality of Liquid Effluent Metals and TSM in mg/L As	Cu	Ni	Pb	Zn	TSM	pH	Comments on Regulations or Guidelines
6. Sherman Mine (Dofasco), Temagami	Iron ore pellets 3500 tpd Open pit	Tailings pond with partial recycle.	Based on one grab sample	0.03	0.1			8	7.5	Met guidelines. No flow for most of the year.
7. Denison, Elliot Lake	Uranium 13 650 tpd Underground	Tailings pond; $BaCl_2$ addition for radium removal, settling pond.		L			0.03		7.6	Complied with regulations.
			Dissolved Ra-226: 1.8 pCi/L (0.07 Bq/L)							
Stanrock Mine	Closed, with treatment system for inactive tailings area	$BaCl_2$ addition for radium removal.		0.02	0.02	0.01	0.02	L	8.9	Met guidelines.
			Total Ra-226: 4.4 pCi/L (0.16 Bq/L)							
		Williams Lake treatment system for inactive tailings area.		L				L	7.8	Met guidelines.
			Dissolved Ra-226: 2.5 pCi/L (0.09 Bq/L)							
8. Rio Algom, Elliot Lake	Uranium All underground									
a) Quirke Mine and Mill	6400 tpd	Tailings pond; $BaCl_2$ addition for radium removal, settling pond.		0.02	0.04	0.03	0.03	7	8.3	Complied with regulations.
			Dissolved Ra-226: 2.9 pCi/L (0.11 Bq/L)							
b) Panel Mine and Mill	3000 tpd	Tailings pond; $BaCl_2$ treatment for radium removal, settling pond.		0.01	0.03	0.03	0.04	L	8.1	Complied with regulations.
			Dissolved Ra-226: 4.6 pCi/L (0.17 Bq/L)							
c) Stanleigh Mine and Mill	4500 tpd	Tailings pond; effluent treatment plant with $BaCl_2$ addition followed by sand filtration for radium removal.		0.01	0.02	0.02	0.07	L	7.4	Complied with regulations.
			Dissolved Ra-226: 3.8 pCi/L (0.14 Bq/L)							
d) Nordic and Lacnor	Mine closed. Inactive uranium tailings	Effluent from tailings area is treated with $BaCl_2$ for radium removal.		0.01		0.02	0.01	L	7.8	Met guidelines.
			Dissolved Ra-226: 3.2 pCi/L (0.12 Bq/L)							
e) Pronto	Inactive uranium tailings area	$BaCl_2$ treatment for radium removal.		0.01		0.01	0.01	9	7.0	Met guidelines.
			Total Ra-226: 3.0 pCi/L (0.11 Bq/L)							
9. Mattabi (Noranda), Ignace	Zinc, copper, lead (silver, gold) 2700 tpd Underground	Tailings pond, treatment plant for acid mine drainage.	L	0.01	0.01	0.04	0.61	9.5	10.7	Above guideline for zinc (7 months). Failed 4/4 toxicity tests.
10. Geco (Noranda), Manitouwadge	Copper, zinc, lead (silver) 3700 tpd Underground	Tailings pond with partial recycle, acid mine drainage treatment plant.		0.51			0.27	21.2	9.1	Above guidelines for copper (10 months), TSM (4 months) and zinc (2 months). Failed 3/3 toxicity tests.
11. Kidd Creek (Falconbridge), Timmins	Zinc, copper, lead (silver, cadmium) 13 000 tpd Underground	Tailings pond with partial recycle, pH adjustment, metal precipitation.	Tailings pond effluent: L	L		L	L	12.5	9.8	Mine water above guideline for zinc (6 months).
			Mine water L	0.03		L	0.82	17.5	10.5	
12. Lyon Lake Division (Noranda), Ignace	Copper, zinc, lead (silver) 1100 tpd Underground	Tailings pond.	L	0.03	0.02	0.09	1.26	10	8.2	Above regulation for zinc. Failed 3/3 toxicity tests.
13. Shebandowan (INCO), Shebandowan	Copper, nickel 1800 tpd Underground (Mine on standby since early 1980)	Tailings pond with partial recycle.	Samples taken in January only:	0.01	0.20	0.03	0.02	L	7.1	Met guidelines.
14. Silver Division (Agnico Eagle), Cobalt	Silver 270 tpd Underground	Tailings pond.	Mill burned in February 1986; under reconstruction. 0.48	L	0.07			L	8.2	Above guideline for arsenic 1 month out of the 2 operating.

TABLE 9 TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN QUEBEC IN 1986

Mine (Company), Location	Products (By-products), Rated Milling Capacity, Mining Method	Treatment Facilities	1986 Average Quality of Liquid Effluent — Metals and TSM in mg/L							Comments on Regulations or Guidelines
			As	Cu	Ni	Pb	Zn	TSM	pH	
1. Mount Wright (Québec Cartier), Fermont	Iron ore concentrate 50 000 tpd Open pit	Tailings pond with recycle; treatment plant for red water.						9	6.8	Met guidelines.
2. Lac Tio (QIT), Havre St-Pierre	Iron ore 7500 tpd Open pit	Settling pond.						L	6.9	Met guidelines.
3. Opemiska Division (Minnova)*, Chapais	Copper (gold) 2700 tpd Underground	Tailings pond; polishing pond; settling pond for mine water.	Tailings pond effluent:	0.02	0.02	0.01		13	7.5	Met guidelines.
			Cooke mine water (intermittent):					48	7.8	Above TSM regulations.
4. Lac Dufault Division (Minnova)*, Noranda	Copper, zinc (silver, gold) 1600 tpd Underground	Tailings pond, polishing pond, settling pond for mine water.	Tailings pond effluent:	0.02	0.06	0.04	0.11	13	9.9	Tailings pond effluent met guidelines. Corbet mine water above regulation for zinc based on one grab sample.
			Corbet mine (closed but kept dewatered): L	0.03	0.01	0.01	4.07	L	7.5	
5. Selbaie (BP Canada), Joutel	Copper, zinc (silver) 2900 tpd Underground	Thickened tailings disposal, settling pond for mine water, polishing pond.		0.05		L	0.06	L	8	Complied with regulations.
6. Camchib (Campbell Resources), Chibougamau	Copper (gold) 3200 tpd Underground	Tailings pond and polishing pond.	Tailings pond effluent: 0.01	0.08		0.02	0.10		8.5	Met guidelines.
			Henderson No. 2 mine water: 0.01	0.02	0.01	0.02	0.03	L	7.9	Met guidelines.
7. Northgate, Chibougamau	Copper (gold) 3400 tpd Underground	Tailings pond; settling pond for mine water.	Tailings pond discharge to Camchib polishing pond. Portage mine water (1 grab sample):	0.04	0.02	0.01	0.07	27	7.6	Met guidelines. Above monthly average guideline for TSM.
			Copper Rand mine water (1 grab sample):	0.44	0.03	0.01	0.12	34	7.9	Above monthly average guideline for copper.
			Cedar Bay mine water (1 grab sample): L	0.40	L	L	L	L	7.0	Above monthly average guideline for copper.
8. Mines Gaspé (Noranda), Murdochville	Copper (molybdenum) 4000 tpd Underground	Tailings pond with partial recycle; settling pond for mine water.		0.09				L	7.5	Met guidelines. Considerable dilution from stream entering tailings pond.
9. Matagami Division (Noranda), Matagami	Copper, zinc 4100 tpd Underground	Tailings pond.		0.05	0.04	0.04	0.29	12.9	7.4	Above guidelines for TSM (1 month) and zinc (2 months).
Norita Mine	Mine closed but kept dewatered.	Settling pond.		0.02	0.03	0.03	1.15	17.7	7.0	Above guidelines for TSM (2 months) and zinc (12 months).
10. Horne Division (Noranda), Noranda	Horne mill and smelter; mills ore from Gallen, Chadbourne and Remnor.	Tailings ponds with lime addition.	Pelletier Lake tailings area:	0.02	0.05	0.05	0.14	8.4	7.6	Met guidelines.
			Osisko Lake (drainage from site and old tailings):	1.62	0.05	0.07	3.33	L	3.8	Above guidelines for Cu and Zn; below pH guideline (12 months).
Remnor	Reopened Horne mine.	Tailings deposited in old Quemont-2 tailings area.		L	L	L	0.06	L	9.9	Complied with regulations.
11. Waite Amulet (Noranda), Noranda	Mine closed. Effluent from inactive tailings ponds.	Acid mine drainage treatment plant.		L	L	L	0.02	L	9.0	Met guidelines.
12. Niobec (Teck), Chicoutimi	Niobium 2100 tpd Underground	Tailings pond with recycle; settling pond for mine water.		0.44	0.49	L	0.35	87	7.0	Above guidelines for copper (6 months), nickel (2 months) and TSM (6 months).
13. Abcourt, Barraute	Silver, zinc 400 tpd Underground (no milling on site)	Settling pond for mine water.					2.55	13		Above regulation for zinc.
14. Mines Gallen (Noranda), Noranda	Zinc 1500 tpd Open pit	Treatment plant for acid mine drainage.		L	L		0.42		9.8	Complied with regulations.
15. Mobrun Mine (Audrey Resources), Noranda	Copper, zinc gold, silver 100 tpd Underground. Ore treated at Lac Dufault.	Settling pond for mine water.	L	0.02	L	L	0.15	13	8.0	Complied with regulations.

* Name changed in April 1987 from Corporation Falconbridge Copper.

TABLE 10 TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN NEW BRUNSWICK IN 1986

Mine (Company), Location	Products (By-products), Rated Milling Capacity, Mining Method	Treatment Facilities	1986 Average Quality of Liquid Effluent — Metals and TSM in mg/L As	Cu	Ni	Pb	Zn	TSM	pH	Comments on Regulations or Guidelines
1. Brunswick Mining and Smelting (Noranda), Bathurst	Zinc, lead, copper 10 000 tpd Underground	Tailings pond with recycle; treatment plant for acid mine drainage; bio-stabilisation pond for thiosalts removal.		0.02		0.13	1.48		6.5	Above guideline for zinc (8 months), below pH guideline (3 months). Failed 1/1 toxicity test.
		No. 6 site acid drainage treatment plant. Treated acidic drainage is discharged to mined out pit.	No surface effluent.							Met guidelines.
2. Caribou (Anaconda), Bathurst	Mine closed but kept dewatered	Lime addition, settling in old tailings pond.	Generally no surface discharge. No effluent at time of Environment Canada survey.							Increased level of zinc, copper and manganese in brook below mine site due to seepage from underground works and/or tailings pond.
3. Lake George Antimony (Durham Resources), Lake George	Antimony 500 tpd Underground	Tailings pond, lime and ferric chloride addition for arsenic and antimony removal.	0.01	L	0.02	L	L	L	7.9	Met guidelines. Passed 1/1 toxicity test.
4. Heath Steele (Noranda), Newcastle	Zinc, lead, copper. On standby, but mine kept dewatered.	Lime added to mine water before its discharge to the tailings pond.	L	0.14	L	0.16	0.26	L	10.2	Above guidelines for copper (1 month), lead (3 months) and zinc (1 month). Passed 1/1 toxicity test.

TABLE 11 TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN NOVA SCOTIA IN 1986

Mine (Company), Location	Products (By-products), Rated Milling Capacity, Mining Method	Treatment Facilities	1986 Average Quality of Liquid Effluent — Metals and TSM in mg/L As	Cu	Ni	Pb	Zn	TSM	pH	Comments on Regulations or Guidelines
1. East Kemptville Mine* (East Kemptville Tin Corporation), East Kemptville	Tin 9000 tpd Open pit	Tailings pond with partial recycle; flocculant and lime addition.	0.04	0.08	0.02	0.01	0.52	43	6.8	Occasionally above regulations for TSM and zinc; occasionally below regulation for pH. Passed 1/1 toxicity test.

* Operated by Rio Algom until December 1986.

TABLE 12 TREATMENT FACILITIES AND LIQUID EFFLUENT QUALITY FOR METAL MINES IN NEWFOUNDLAND IN 1986

Mine (Company), Location	Products (By-products), Rated Milling Capacity, Mining Method	Treatment Facilities	1986 Average Quality of Liquid Effluent — Metals and TSM in mg/L As	Cu	Ni	Pb	Zn	TSM	pH	Comments on Regulations or Guidelines
1. Newfoundland Zinc (Teck), Daniel's Harbour	Zinc 1500 tpd Mine on standby since June 1986	Tailings pond; mine water treatment.					0.17	7.8	7.7	Met guidelines.
2. Iron Ore of Canada, Labrador City	Iron ore pellets 30 000 tpd Open pit	Partial thickening of tailings before deposit in lake, partial recycle.	Tailings deposited directly into Wabush Lake. The IOCC dykes in Wabush Lake do not constitute a tailings impoundment area as defined in the federal guidelines although Newfoundland has leased this portion of the lake to IOCC for tailings disposal.							Above guideline for TSM.
3. Wabush (Pickands Mather), Wabush	Iron ore 16 500 tpd Open pit	Tailings thickening before deposit in lake, partial recycle.	Tailings deposited into dyked area at side of Flora Lake, but this is not a tailings impoundment area as defined in the federal guidelines. Newfoundland has leased Flora Lake to Wabush for tailings disposal and the discharge from Flora Lake meets provincial requirements.							Above guideline for TSM.

3.4 Summary of Compliance by Region

3.4.1 Pacific and Yukon Region. During 1986, 18 base metal mines were operating in the Pacific and Yukon Region: 16 in British Columbia and 2 in the Yukon. Eight of the mines in the region are subject to the regulations, seven of these in British Columbia. Four of the regulated mines did not comply with the regulations for at least part of 1986. A minor spill and spring floods caused non-compliance at one mine (Equity Silver). In another case (Westmin), uncontrolled acid mine drainage from waste rock road fill caused high metal concentrations to escape to downstream fish habitats. The third (Blackdome) had difficulties removing the fine suspended clay fraction from the tailings decant. Temporary startup difficulties and large volumes of contaminated water from pit dewatering were responsible for problems at the fourth mine (Curragh).

Of the remaining 10 mines, nine are located in British Columbia and one in the Yukon. Three of these mines did not meet the guidelines. One of these mines (Island Copper) practices unconfined tailings disposal. This practice was sanctioned by the provincial and federal agencies before the guidelines came into effect.

In 1986, seven of the 18 operating mines did not have a surface effluent discharge. Most of these mines are located in the interior of British Columbia, where low rainfall and net annual evaporation simplifies the recycle of all mine site effluents.

Among the specified substances, the limit for zinc was most often exceeded.

3.4.2 Western and Northern Region. This region comprises the provinces of Alberta, Saskatchewan and Manitoba, as well as the Northwest Territories. In 1986, 17 base metal mines and three uranium mines were operating in the region: five in the Northwest Territories, three in Saskatchewan and 12 in Manitoba. In addition, effluent was generated at two closed mines that were kept dewatered. Half of the mines in Manitoba were operated by the Hudson Bay Mining and Smelting Company. The mines in Saskatchewan are among the biggest uranium producers in the world.

Nine mines in the Western and Northern Region were subject to the regulations; three were not in compliance for at least part of 1986. In the case of the Key Lake Mining Corporation, in Saskatchewan, the company closely controls the pH as close as possible to the minimum allowed, in order to maintain the ammonia in its effluent in its non-toxic form. As a result, the average monthly pH was slightly below limits for two months in 1986; this was preferable to a possible ammonia toxicity problem. In the other cases of non-compliance, located in Manitoba, attempts made so far by the company

to solve the problem have proven unsuccessful. Manitoba Environment and the company are seeking ways to correct the situation. Seven mines did not meet the guidelines.

The limit for zinc was the most frequently exceeded.

3.4.3 Ontario Region. The Ontario Region had 25 base metal mines, four iron ore mines and four uranium mines operating in 1986. In addition, the effluents from the inactive tailings impoundments at four closed mines were treated, and various effluents were treated in two wastewater treatment plants at the Inco complex in Sudbury. Inco Limited and Falconbridge Limited were the major producers. Of the five mines subject to the regulations, one was not in compliance. Of the 34 operations that were under the guidelines, nine did not meet them. Nickel and zinc were the parameters most often exceeded.

3.4.4 Quebec Region. In 1986, there were 17 operating base metal mines and two iron ore mines in the Quebec Region. One treatment plant was treating drainage from an inactive tailings area and one closed mine produced an effluent. Of the seven operations subject to the regulations, two were found not be in compliance. Available data for one mine subject to the regulations were considered insufficient to determine its state of compliance. Five mines exceeded the guidelines. The amount of data available to Environment Canada from the mines in the Quebec Region varied greatly. For some mines little information was reported. However, considerable improvement has been made in both the number of mines monitored and the frequency of reporting. Zinc and copper were the parameters most frequently exceeded by the mines in the region.

3.4.5 Atlantic Region. This region includes the provinces of New Brunswick, Nova Scotia, Prince Edward Island and Newfoundland. There are three base metal mines in New Brunswick, one in Nova Scotia and three in Newfoundland. One closed mine was kept dewatered and a treatment plant for acid mine drainage was in operation at another closed facility. The only mine subject to the regulations was found not to be in compliance in 1986. At this operation, modifications to the wastewater treatment system appear to have solved the problems encountered in the early months of the year. Four mines did not meet the guidelines. Two of these mines practice tailings disposal into sections of lakes that were leased to them by the provincial authority for that purpose before promulgation of the federal guidelines.

4 WATER POLLUTION CONTROL TECHNOLOGY AT MINING AND MILLING OPERATIONS

The water pollution control methods available and practiced at Canadian metal mining and milling operations, if properly applied, can produce effluents of sufficient quality to meet the requirements prescribed in the Metal Mining Liquid Effluent Regulations and Guidelines. The complexity of water pollution problems varies considerably between mines. At some mines, the application of very basic treatment technology can provide full environmental protection, while at others the application of more advanced methods is essential. New methods, and improvements in the application of current technology continue to be put in place.

Treatment of wastes at metal mining and milling operations to avoid negative effects on the aquatic environment include removal of suspended solids and dissolved metals and neutralization of acidic waters. In the case of uranium mines, radionuclides must also be removed and at gold milling operations, cyanide has to be destroyed prior to the release of wastewaters. A brief review of the pollution control methods employed is provided below. A much more complete description of the methods can be found in the Environment Canada report entitled "Mine and Mill Wastewater Treatment" published in 1987 (4).

4.1 Removal of Solids

The milling (concentrating) of an ore begins with the crushing and grinding of the ore to the form of finely sized particles. The valuable metals contained in the ore are concentrated and recovered in their mineral forms by essentially physical methods. In the milling of uranium ores, uranium is recovered by a chemical process, dissolution in sulphuric acid. During the milling process the bulk of the ore treated is rejected as waste in the form of finely ground rock particles. Consequently, mills produce very large quantities of solid wastes, referred to as tailings. Tailings are discharged from a mill as a slurry of solids in water. The first step in water pollution control is the removal and permanent retention of the solid tailings (total suspended matter). This is accomplished by discharging the tailings slurry to a tailings pond where the solids are settled out and permanently retained and the freed water is discharged to the environment or re-used.

In most cases, part of the tailings pond water is recirculated for further re-use in the mill. In a number of instances, where evaporation is high, total water recirculation is practiced; no water is discharged from the tailings pond to receiving water bodies.

Careful design, construction and operation of tailings ponds are essential to achieve the levels of total suspended matter prescribed in the Metal Mining Liquid Effluent and Guidelines. Mine water or surface drainage, which contain fine particles of rock, often require treatment in tailings ponds or separate settling ponds.

A typical flowsheet for the treatment of waste effluents at a mine-mill complex is shown in Figure 1.

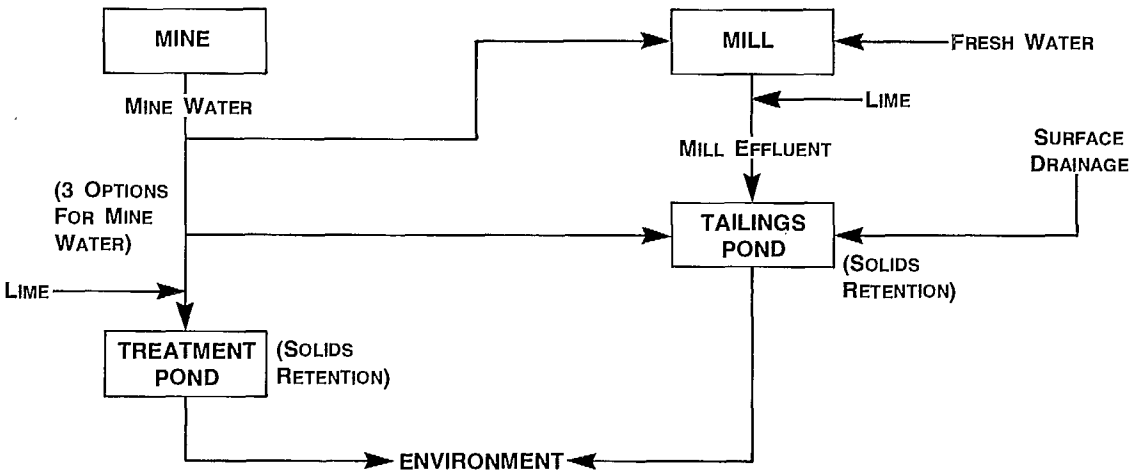


FIGURE 1 MINE - MILL EFFLUENT TREATMENT FLOWSHEET

4.2 Neutralization and Removal of Metals

Effluents high in acidity (sulphuric acid) and dissolved metals, commonly copper, iron, lead, nickel and zinc, are often problems at metal mines where the ore, tailings or waste rock contain significant amounts of iron sulphides, particularly the reactive sulphides pyrite and pyrrhotite. The oxidation of sulphides can produce acidic water, which in turn can dissolve associated metals. Such effluents are commonly referred to as acid mine drainage (AMD), which is characterized by its high acid (low pH) and metal contents. AMD is treated by the addition of an alkaline reagent, almost always lime, to neutralize the contained acidity and increase the water pH, often to pH 9-10, to precipitate the metals as hydroxides. Lime is usually added in the mill so that the metal hydroxide precipitates form ahead of the tailings pond, settle out and are retained in the pond with the regular mill tailings. Acidic water from mines or surface drainages may be limed ahead of tailings ponds or separate settling ponds. While perhaps only one-third of

the mines in Canada have acid mine water, it is a particularly significant problem because fish are extremely sensitive to acidity and heavy metals.

4.3 Removal of Radium-226

Uranium is recovered from finely ground ore by leaching in sulphuric acid. Other metals present in the ore, including radionuclides, i.e., radium-226, thorium-230, thorium-232 and lead-210 enter solution simultaneously with uranium.

The first step in the treatment of a uranium mill tailing slurry is the addition of lime in the mill followed by separation of the solid tailings in a tailings pond. Most of the dissolved radioactive and non-radioactive metals present in the tailings slurry form precipitates upon the addition of lime, settle out in the tailings pond and are covered by normal mill tailings. However, since the activity of Ra-226 remains relatively high in the tailings pond overflow, additional treatment is required for its reduction. Radium-226 is removed from tailings pond water by the addition of a dilute solution of barium chloride to produce a precipitate of barium-radium-sulphate which is settled out in sedimentation ponds or removed by sand filters. The recovered precipitate sludges are returned to the tailings pond for storage.

4.4 Removal of Cyanide

Cyanide is commonly used in the milling of some base metal ores, but rarely in quantities of concern. Cyanide in tailings pond water can be reduced by natural degradation provided sufficient retention time is available. Up until recently, one base metal mill, which used unusually large amounts of cyanide, treated mill effluent using the process of alkaline chlorination for the effective destruction of cyanide.

A number of chemical processes are now available for the removal of cyanide in mill effluents. One has already been mentioned, that of alkaline chlorination. Most of these processes, some newly developed, have been installed at gold mills over the past few years. Because cyanide is used extensively in gold mills for the dissolution and recovery of gold from its ores, there is always the need to remove cyanide and cyanide-metal compounds from wastewaters discharged from these mills. Historically, this has been done through the natural degradation of cyanide and its metal complexes by detaining the water in tailings ponds for a considerable length of time. Although the removal of cyanide by this means has proven satisfactory at some mines where sufficient retention time has been provided, this frequently has not been the case. The unreliability of this method lead to the installation of chemical treatment systems for cyanide removal, often

coupled with natural degradation. These chemical systems, all based on the oxidation of cyanide, employ one of the following reagents: chlorine, hydrogen peroxide or a combination of sulphur dioxide and air. A mine located in South Dakota operates a biological system for cyanide removal. A Canadian company has developed and is currently testing a system for cyanide recovery from gold mill effluents. This process is based on a combination of ion exchange, volatization and absorption of hydrogen cyanide in sodium or calcium hydroxides. If it is successful, this method will offer two advantages: cyanide recovery coupled with environmental protection.

4.5 Effluent Treatment Plants

As already described, most effluents from mines and mills are treated by the addition of a neutralizing reagent, usually lime. In the case of mine water, lime is usually added to the water in a mixing box or the mine water line ahead of a settling pond in which the precipitated metal hydroxides are collected. For mill effluents, the lime is added in the mill before the tailings are discharged to the tailings pond. Over the past 10 or 15 years a number of mechanical effluent treatment plants have been installed to improve the quality of mine water or tailings pond overflow before they are released to the environment. About 18 treatment plants are in operation at Canadian metal mines and mills, 14 at base metal operations and four at uranium mills. At base metal operations the effluents are treated by the addition of lime to increase pH, neutralize acidity and precipitate metals as hydroxides. Gypsum is concurrently precipitated with the metals.

A flowsheet for a typical mechanical-type effluent treatment plant is shown in Figure 2. Typically, treatment is done by the addition of the alkali in a series of mechanically-agitated reactor tanks, some with aeration to oxidize ferrous iron to ferric iron where necessary. The metal hydroxide-gypsum precipitates are separated from the bulk of the water by settling in thickeners or clarifiers, and disposed of in a tailings pond or in a separate impoundment area, when a tailings pond is not available. The solids-free treated water is released to the environment. In some plants the "high density sludge" process is used, in which a portion of the thickened underflow sludge is recirculated to the neutralization reactors to increase the percentage of solids in the sludge pumped to the disposal facility.

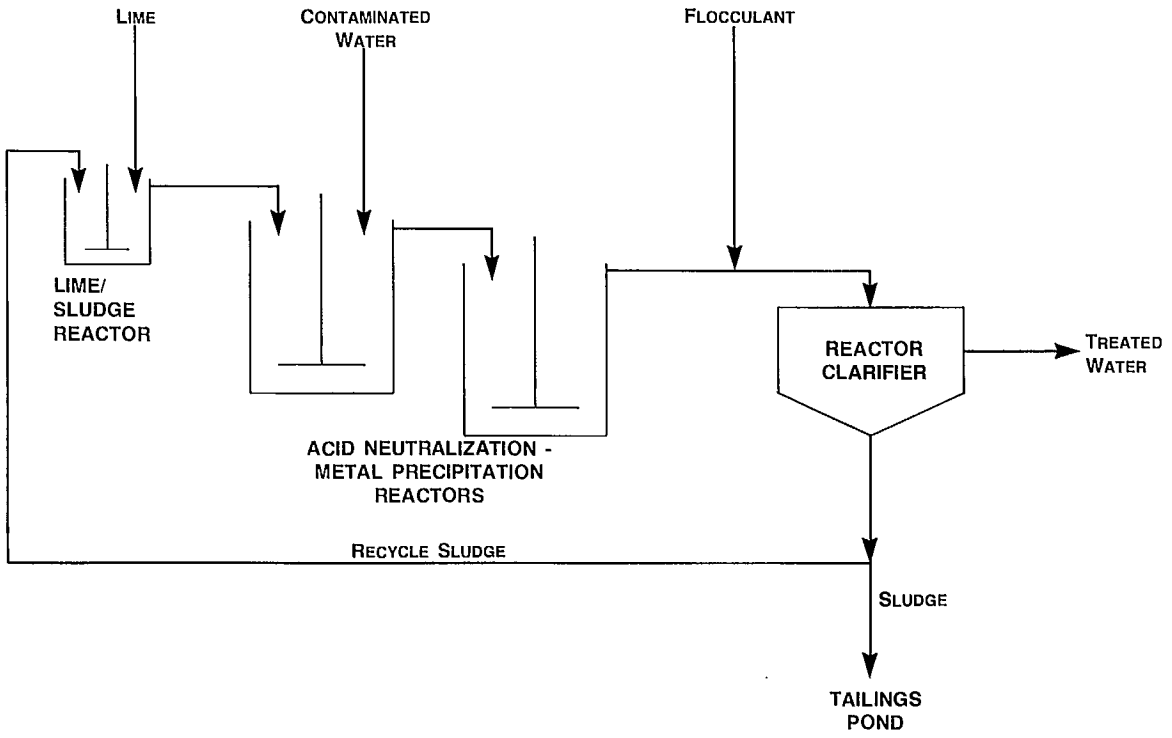


FIGURE 2 MECHANICAL EFFLUENT TREATMENT PLANT FLOWSHEET

The mechanical effluent treatment plants in operation at uranium mines usually consist of a series of mechanically operated reactor tanks (up to five at one plant), followed by sand filters. Lime and barium chloride are added to the reactor tanks to form a barium-radium-sulphate precipitate which is separated from the water by filtration. The precipitate is back-washed regularly from the filters and discharged to the tailings pond.

REFERENCES

1) Environment Canada. Status Report on Water Pollution Control in the Canadian Metal Mining Industry (1982), Industrial Programs Branch, Environmental Protection Service Report EPS 1/MM/2, Ottawa, 1985.

2) Environment Canada. Metal Mining Liquid Effluent Regulations and Guidelines (includes explanatory notes and Environmental Code of Practice for Mines). Report EPS 1-WP-77-1, Ottawa, 1977.

3) Canada. Revised Statutes Committee. Consolidated Regulations of Canada, Chapter 819, Ottawa, 1978.

4) Environment Canada. Mine and Mill Wastewater Treatment, Environmental Protection Directorate, Conservation and Protection, Report EPS 2/MM/3, Ottawa, 1987.

APPENDIX

FULL NAMES OF MINING COMPANIES ASSESSED FOR COMPLIANCE IN 1986 STATUS REPORT

Agnico-Eagle Mines Ltd.
Algoma Steel Corp. Ltd.
Amok Ltd.
Anaconda Canada Exploration Ltd.
Audrey Resources Inc.
BP Canada Ltd.
Bishop Resources Dev. Ltd.
Blackdome Mining Corp.
Brunswick Mining & Smelting Corp. Ltd.
Campbell Resources Inc.
Canada Tungsten Mining Corp. Ltd.
Cominco Ltd.
Curragh Resources Corp.
Denison Mines Ltd.
Dickenson Mines Ltd.
Dofasco Inc.
Durham Resources Inc. (Landmark Corp.)
Eldorado Resources Ltd.
Falconbridge Ltd.
Hudson Bay Mining & Smelting Co. Ltd.
INCO Ltd.
Iron Ore Co. of Canada
Key Lake Mining Corp.
Lornex Mining Corporation Ltd.
Mines Abcourt Inc.
Minnova Inc.
Nanisivik Mines Ltd.
Newmont Mines Ltd.
Noranda Inc.
Northgate Mines Inc.
Pickands Mather (Wabush Mines)
Placer Development Ltd.
QIT-Fer et Titane Inc.
Quebec Cartier Mining Co.
Rio Algom Ltd.
Sherritt Gordon Mines Ltd.
Stelco Inc.
Tantalum Mining Corp. of Canada Ltd.
Teck Corporation
Terra Mines Ltd.
Total Erickson Resources
United Keno Hill Mines Ltd.
Utah Mines Ltd.
Westmin Resources Ltd.