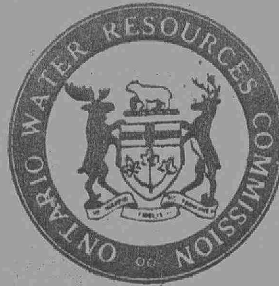


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THE
ONTARIO WATER RESOURCES
COMMISSION

INDUSTRIAL WASTES SURVEY

of the

INTERNATIONAL NICKEL COMPANY OF CANADA

DISTRICT OF SUDBURY

1967

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Report On

An Industrial Wastes Survey

of

THE INTERNATIONAL NICKEL COMPANY OF CANADA, LIMITED

in the

DISTRICT OF SUDBURY

JUNE, JULY

and

AUGUST, 1967

by

DIVISION OF INDUSTRIAL WASTES
ONTARIO WATER RESOURCES COMMISSION

AN INDUSTRIAL WASTES SURVEY OF
THE INTERNATIONAL NICKEL COMPANY OF CANADA, LIMITED
DISTRICT OF SUDBURY

INTRODUCTION

During June, July and August, 1967, an industrial wastes survey was conducted at the mines and surface plants owned by The International Nickel Company of Canada, Limited in the District of Sudbury.

This and similar reports presenting the findings of surveys at Falconbridge Nickel Mines Limited, National Steel Corporation of Canada Limited, and the Copper Cliff Works of Canadian Industries Limited are intended to complement the biological survey report entitled "Biological Survey of the Streams and Lakes of the Sudbury Area: 1965" issued by the Ontario Water Resources Commission in 1967. Frequent reference will be made to the results contained in the report prepared following that survey.

The purposes of the 1967 industrial wastes survey were to obtain up-to-date information on the quantities and characteristics of the liquid wastes discharged by The International Nickel Company of Canada, Limited to the receiving watercourses, and to indicate where new or improved waste control facilities or procedures would be required to eliminate existing sources of stream impairment. Evaluations of the sanitary sewage treatment and disposal methods at the various mining complexes were not made, although the manner of treatment is indicated in most cases.

The International Nickel Company complex in the Sudbury area in 1967 consisted of nine producing underground mines, five mines in various stages of development, three operating ore concentrators, one concentrator under construction at the time of the survey, two smelters, a copper refining division, and an iron ore recovery plant. Each installation is discussed individually in

the report. However, because of the many interrelationships of various aspects of the Company's operations, a number of sections deal with groups of mines or surface plants in order to simplify the discussions. A summary dealing with the Company's operations in the area is also presented.

SUMMARY

The results of the industrial wastes survey conducted at The International Nickel Company of Canada, Limited in the Sudbury area revealed a number of industrial waste effluents that were unsatisfactory for discharge to natural watercourses with respect to one or more waste constituents.

In general, the characteristic of most importance was the low pH of many of the discharges. The acidities of these discharges were not usually high, indicating very little buffering action and the presence of mineral acids. This problem is not unique in the Sudbury area, and may be attributable to the oxidation of soluble sulphur compounds contained in the ore. Oxidation converts the soluble sulphur compounds to sulphuric acid which results in an acid condition in the receiving watercourse. The reaction mechanisms are not completely understood, and therefore the full impairment potential of a waste is difficult to determine from an analysis of the waste alone. However, since the over-all reaction is known to be time-dependent, one approach to determine if there is a potential problem is to compare the pH of a waste effluent at the time of sampling with the value obtained after a period of a few days or a week has elapsed. If the pH has fallen significantly in that time, the analyst can be reasonably confident that some acid-producing reactions have occurred.

Other waste constituents of importance were copper, nickel, and iron. The iron content of one waste stream in particular, namely, the overflow from

the pyrrhotite storage pond in Copper Cliff, was extremely high (180-300 ppm). This situation should be rectified as quickly as possible.

Nickel in objectionable concentrations was present in many of the waste streams. Although it is generally recognized that this metal is more difficult to precipitate than some of the other heavy metals, as for example, copper, most of the nickel initially present in a waste can be removed from solution by elevation of the pH.

A number of improvements in the Company's liquid waste treatment and disposal methods have been made in the last few years. These improvements have included the provision of settling areas at many of the mines, the re-routing of some wastes to the tailings disposal area for settling, and the tests which have been conducted on a full-scale basis to neutralize the waste effluents from the Murray and Froot Mines. The use of cemented-sand back-fill at some of the mines, although used essentially to simplify and provide greater flexibility in the underground mining operations, has also resulted in improved mine waste effluents.

The next step in the waste control programme at The International Nickel Company of Canada, Limited would appear to be the Company-wide adoption of a neutralization system at those locations requiring treatment. Not only would this form of treatment raise the pH to more satisfactory levels, but, it would also, if designed to do so, precipitate out the metal values for subsequent removal from the waste stream.

The waste effluents from the mines under development at the time of the survey, i.e., where shaft sinking was being performed, were not sampled. However, it is emphasized that a waste having objectionable characteristics should not be allowed to enter a watercourse at any time, particularly from a

new development where there is sufficient opportunity to plan and construct the appropriate treatment facilities before they are actually required. As discussed later in this report, a toxic waste discharged for only a relatively short period of time can cause long-term effects on the aquatic life of a stream. Therefore, the waste treatment facilities must be available for use from the time they are first required.

A tabulated summary of the waste characteristics and the treatment methods employed at each of the Company's installations, as found during the survey, is presented at the end of this summary.

From the table, and as discussed in the body of this report, those industrial operations which were capable of causing severe water impairment or contamination in the receiving streams were:

1. the pyrrhotite storage pond in Copper Cliff,
2. the Copper Cliff Smelter,
3. the Stobie section of the Froid-Stobie Mine,
4. the Murray Mine,
5. the Totten Mine, and
6. the Crean Hill Mine

Those complexes requiring close surveillance by frequent sampling or which required some improvements in the waste handling procedures were:

1. the Garson Mine,
2. the North Mine,
3. the Creighton Mine and Mill,
4. the Copper Refining Division,
5. the effluent from the "P" and "Q" tailings disposal area in Copper Cliff, and
6. the Iron Ore Plant cooling pond overflow to Kelly Lake.

The operations not seriously impairing the receiving watercourses as a result of the liquid waste effluents discharged were:

1. the Levack Mine and Mill,
2. the Froot section of the Froot-Stobie Mine,
3. the Coniston Smelter, and
4. the MacLennan Mine

Areas under development at the time of the survey or where major expansions were planned included:

1. the Kirkwood Mine,
2. the Coleman Mine,
3. the Totten Mine,
4. the Copper Cliff North Mine,
5. the Clarabelle Open Pit,
6. the Copper Cliff South Mine,
7. the Crean Hill Open Pit,
8. the Little Stobie Mine,
9. the Murray Open Pit,
10. the North Range Mine,
11. the Copper Refining Division,
12. the Iron Ore Recovery Plant, and
13. the Froot-Stobie Mill

SUMMARY OF RESULTS

<u>NAME OF INSTALLATION</u>	<u>VOLUME OF WASTE (USGPD)</u>	<u>TREATMENT PROVIDED</u>	<u>RECEIVING STREAM</u>	<u>CHARACTERISTICS OF (TREATED) WASTE EFFLUENT (PPM)</u>	<u>WASTE LOADING (LBS./DAY)</u>	<u>COMMENTS</u>
TOTTEN MINE	UNKNOWN; ESTIMATED BY COMPARISON WITH SIMILAR OPERATING MINES AT 50,000 - 100,000 USGPD	VERY SMALL SETTLING PIT.	MARSHY AREA TO VICTORIA CREEK.	SUSP.SOLIDS: 22-62 PH: 7.3 COPPER: 0.3 - 0.87 NICKEL: 1.1 - 3.8 IRON: 2.5 - 5.6	SUSP.SOLIDS: 17 - COPPER: 0.5 NICKEL: 2.1 IRON: 3.4	IMPROVED TREATMENT REQUIRED
LEVACK MINE AND CONCENTRATOR	2,596,000	LARGE SETTLING AND IMPOUNDMENT AREA.	GRASSY CREEK TO MOOSE CREEK.	SUSP.SOLIDS: 2.7 -37 PH: 6.5 - 8.5 COPPER: 0.07- 0.1 NICKEL: 0.2 - 0.55 IRON: 0.1 - 4.25	SUSP.SOLIDS:427 - COPPER: 1.8 NICKEL: 8.1 IRON: 47.5	MINE WATER COMBINED WITH MILL TAILINGS FOR SETTLING IN THE TAILINGS IMPOUNDMENT AREA. HIGH WINDS AFFECTED THE QUALITY OF THE DECANT.
COLEMAN MINE	UNDER DEVELOPMENT	-	MOOSE CREEK	-	-	TREATMENT FACILITIES UNDER DEVELOPMENT.
VICTORIA MINE	UNDER INVESTIGATION	-	SMALL LAKE NEAR THE MINE.	-	-	THE MINE WAS PARTIALLY PUMPED OUT TO EXAMINE THE DRIFTS. LIME WAS ADDED TO NEUTRALIZE POSSIBLE ACID WATER.
CREAN HILL MINE	210,000	SETTLING	A SMALL TRIBUTARY OF THE VERMILION RIVER.	SUSP.SOLIDS: 6-8 PH: 6.8 - 6.9 COPPER: 0.02- 0.15 NICKEL: 8.4 -25 IRON: 0.01- 0.80	SUSP.SOLIDS: 12.2 - COPPER: 0.2 NICKEL: 29.2 IRON: 0.7	THE HIGH NICKEL CONCENTRATION SHOULD BE REDUCED.
GARSON MINE	460,000	SETTLING	JUNCTION CREEK	SUSP.SOLIDS: 8-24 PH: 7.5 - 9.1 COPPER: 0.0 - 0.04 NICKEL: 0.0 - 3.3 IRON: 0.18- 0.75	SUSP.SOLIDS: 61.3 - COPPER: 0.08 NICKEL: 63.2 IRON: 1.8	SETTLING SHOULD BE PROVIDED ON A CONTINUOUS BASIS.

NAME OF INSTALLATION	VOLUME OF WASTE (USGPD)	TREATMENT PROVIDED	RECEIVING STREAM	CHARACTERISTICS OF (TREATED) WASTE EFFLUENT (PPM)	WASTE LOADING (LBS./DAY)	COMMENTS
KIRKWOOD MINE	UNDER DEVELOPMENT	-	TRIBUTARY OF JUNCTION CREEK.	-	-	WASTE TREATMENT FACILITY UNDER DEVELOPMENT.
FROOD-STOBIE MINE:						
A) FROOD SECTION	1,000,000	NEUTRALIZATION BY LIME ON AN EXPERIMENTAL BASIS FOLLOWED BY SETTLING.	JUNCTION CREEK WEST BRANCH	SUSP.SOLIDS: 5-7 PH: 6.6 COPPER: 0.03- 0.15 NICKEL: 1.0 - 1.4 IRON: 0.34- 0.46	SUSP.SOLIDS: 50 - COPPER: 0.8 NICKEL: 10 IRON: 3.3	LIME NEUTRALIZATION SHOULD BE CONTINUED ON A PERMANENT BASIS.
B) STOBIE SECTION	1,000,000	SETTLING	JUNCTION CREEK WEST BRANCH	SUSP.SOLIDS: 11-13 ACIDITY: 36-40 PH: 4.1 - 4.3 COPPER: 0.30 NICKEL: 17.5 -19.0 IRON: 2.1 - 4.0	SUSP.SOLIDS:100 ACIDITY:316 - COPPER: 2.5 NICKEL:152 IRON: 25.4	NEUTRALIZATION AND REMOVAL OF NICKEL REQUIRED.
LITTLE STOBIE MINE	UNDER DEVELOPMENT	-	PROBABLY JUNCTION CREEK WEST BRANCH	-	-	WASTE TREATMENT ALTERNATIVES UNDER STUDY.
FROOD-STOBIE CONCENTRATOR	UNDER CONSTRUCTION AT TIME OF SURVEY. FLOW IN DEC. 1967, WAS 8,200,000 USGPD.	TAILINGS WERE TO BE IMPOUNDED IN THE CENTRAL TAILINGS AREA. AN EMERGENCY TAILINGS AREA ON NOLIN CREEK WAS ALSO TO BE USED.	ULTIMATELY COPPER CLIFF CREEK; NOLIN CREEK DURING START-UP AND EMERGENCIES.	-	-	CLOSE SURVEILLANCE OF NOLIN CREEK AND THE DISCHARGE TO NOLIN CREEK IS REQUIRED.

NAME OF INSTALLATION	VOLUME OF WASTE (USGPD)	TREATMENT PROVIDED	RECEIVING STREAM	CHARACTERISTICS OF (TREATED) WASTE EFFLUENT (PPM)	WASTE LOADING (LBS./DAY)	COMMENTS
MURRAY MINE	600,000	SETTLING	NOLIN CREEK	SUSP.SOLIDS: 3-9 ACIDITY: 26-96 PH: 4.5 - 4.6 COPPER: 0.07- 0.17 NICKEL: 16.2 -25 IRON: 0.02- 1.36	SUSP.SOLIDS: 30 ACIDITY: 26-96 - COPPER:0.6 NICKEL: 103 IRON:3.5	NEUTRALIZATION AND NICKEL REMOVAL FACILITIES REQUIRED.
COPPER CLIFF NORTH MINE	186,000 (WILL INCREASE TO 500,00 USGPD)	UNDERGROUND NEUTRALIZATION AND SETTLING PROPOSED.	COPPER CLIFF CREEK	SUSP.SOLIDS: 16-20 PH: 6.1 - 9.6 COPPER: 0.03- 0.05 NICKEL: 2.3 - 5.7 IRON: 1.43- 2.42	SUSP.SOLIDS: 27.9 - COPPER: 0.1 NICKEL: 6.2 IRON: 3.0	THE NICKEL CONCENTRATION SHOULD BE REDUCED.
COPPER CLIFF CONCENTRATOR:						
A) TAILINGS	6,200,000	SETTLING AND IMPOUNDMENT.	COPPER CLIFF CREEK	(ENTERED UNDER "P" AND "Q" TAILINGS AREA DECANT)	-	-
B) GENERAL WASTES	306,000	NONE	COPPER CLIFF CREEK	(ENTERED UNDER SMELTER EFFLUENT)	-	-
COPPER CLIFF SMELTER	2,372,000 PLUS 306,000 FROM CONCENTRATOR TOTAL:2,678,000	SEGREGATION AND SETTLING	COPPER CLIFF CREEK	SUSP.SOLIDS: 72-216 ACIDITY: 24 PH: 5.0 - 5.8 COPPER: 1.4 - 3.8 NICKEL: 5.2 - 8.3 IRON: 12.7 -17.0 PHENOLS: 20 PPB	SUSP.SOLIDS: 3210 ACIDITY: 535 - COPPER: 58 NICKEL: 151 IRON: 331	A LARGER CLARIFIER WAS TO BE INSTALLED. THE WASTE WAS VERY OBJECTIONABLE CONTAINING HIGH CONCENTRATIONS OF SUSPENDED SOLIDS, COPPER AND NICKEL AND HAVING A LOW PH.

NAME OF INSTALLATION	VOLUME OF WASTE (USGPD)	TREATMENT PROVIDED	RECEIVING STREAM	CHARACTERISTICS OF (TREATED) WASTE EFFLUENT (PPM)	WASTE LOADING (LBS./DAY)	COMMENTS
COPPER REFINING DIVISION:						
A) BOSH COOLING POND OVERFLOW	550,000	NONE	COPPER CLIFF CREEK	SUSP.SOLIDS: 10-20 PH: 5.4 - 8.9 COPPER: 0.55- 0.95 NICKEL: 0.45- 0.95 IRON: 1.1 - 1.25	SUSP.SOLIDS: 73 - COPPER: 3.4 NICKEL: 3.2 IRON: 5.4	THE WASTE WAS OF FAIR QUALITY.
B) STORM SEWER	1,000,000	NONE	COPPER CLIFF CREEK	SUSP.SOLIDS: 11-22 PH: 5.5 - 6.5 COPPER: 0.28- 2.6 NICKEL: 0.97- 1.25 IRON: 1.13-7	SUSP.SOLIDS:137 - COPPER: 12 NICKEL: 9 IRON: 34	THE COPPER CONTENT WAS HIGH ON THE ONE GRAB SAMPLE. THE PH WAS APPROACHING LOW VALUES.
C) ACID PLANT POND OVERFLOW	93,000	NEUTRALIZATION	COPPER CLIFF CREEK	SUSP.SOLIDS: 15-16 PH: 7.9 - 8.5 COPPER: 0.15- 0.19 NICKEL: 2.1 - 5.3 IRON: 0.07- 0.50	SUSP.SOLIDS: 12 - COPPER: 0.1 NICKEL: 2.9 IRON: 2.2	THE NICKEL CONTENT WAS HIGH
D) SILVER REFINERY	144,000	NONE	COPPER CLIFF CREEK	SUSP.SOLIDS: 9-19 ACIDITY: 4-380 PH: 2.7 - 7.9 COPPER: 0.22- 0.25 NICKEL: 1.05- 2.3 IRON: 1.38- 1.40	SUSP.SOLIDS: 16.8 ACIDITY:230 - COPPER: 0.3 NICKEL: 2.1 IRON: 1.7	THE PH WAS VERY LOW DURING ONE SAMPLING PERIOD AND SHOULD BE MAINTAINED AT HIGHER LEVELS.

NAME OF INSTALLATION	VOLUME OF WASTE (USGPD)	TREATMENT PROVIDED	RECEIVING STREAM	CHARACTERISTICS OF (TREATED) WASTE EFFLUENT (PPM)	WASTE LOADING (LBS./DAY)	COMMENTS
IRON ORE RECOVERY PLANT:						
A) WASTE FROM "M" TAILINGS AREA	6,900,000	SETTLING AND IMPOUNDMENT IN TAILINGS AREA.	COPPER CLIFF CREEK	SUSP.SOLIDS: 6-7 PH: 7.6 - 8.2 COPPER: 0.0 - 0.3 NICKEL: 0.20- 0.95 IRON: 0.28- 2.25	SUSP.SOLIDS: 373 - COPPER: 8.6 NICKEL: 33 IRON: 73	THE WASTE WAS OF FAIR QUALITY.
B) PYRRHO-TITE STORAGE POND OVERFLOW	1,270,000	NONE	COPPER CLIFF CREEK	SUSP.SOLIDS: 33-52 ACIDITY: 552-1600 PH: 3.1 - 3.4 COPPER: 0.10- 0.57 NICKEL: 1.0 - 8.7 IRON: 8.1 -78	SUSP.SOLIDS: 450 ACIDITY: 11,400 - COPPER: 3.5 NICKEL: 51 IRON: 455	THIS WASTE WAS OF EXTREMELY POOR QUALITY.
C) COOLING WATER RESERVOIR	VARIABLE: NIL AT TIME OF SURVEY.	NONE	KELLY LAKE	SUSP.SOLIDS: 16-26 PH: 8.8 - 9.1 COPPER: 0.16- 0.25 NICKEL: 0.22- 0.6 IRON: 0.75- 3.90		THIS WATER WAS OF FAIR QUALITY WHEN SAMPLED. A WELL POLLUTION PROBLEM AS A RESULT OF EQUIPMENT FAILURE IN THE PLANT WAS EXPERIENCED HERE DURING FEBRUARY, 1968.
"P" AND "Q" TAILINGS IMPOUNDMENT AREA DEOANT.	10,300,000 AFTER START-UP OF FROOD-STOBIE MILL, THE VOLUME WOULD BE 18,500,000 USGPD	NONE	COPPER CLIFF CREEK	SUSP.SOLIDS: 9-40 ACIDITY: 18-66 PH: 3.6 - 5.7 COPPER: 0.02- 0.13 NICKEL: 0.10- 1.25 IRON: 2.73- 5.75	SUSP.SOLIDS: 2100 ACIDITY: 3600 - COPPER: 6.5 NICKEL: 58 IRON: 364	OXIDATION OF THE SULPHIDES IN THE WASTE TO ACID SULPHATES MAY BE OCCURRING AFTER DISCHARGE TO THE RECEIVING STREAM.

NAME OF INSTALLATION	VOLUME OF WASTE (USGPD)	TREATMENT PROVIDED	RECEIVING STREAM	CHARACTERISTICS OF (TREATED) WASTE EFFLUENT (PPM)	WASTE LOADING (LBS./DAY)	COMMENTS
COPPER CLIFF CREEK AT HWY. # 17	-	-	-	SUSP.SOLIDS: 41-874 ACIDITY: 12-30 PH: 3.8 - 7.3 COPPER: 0.4 - 2.1 NICKEL: 1.0 - 8.7 IRON: 8.1 -78.0	-	THE WATER IN COPPER CLIFF CREEK WAS OF VERY POOR QUALITY.
KELLY LAKE OUTLET	-	-	-	SUSP.SOLIDS: 6 -32 ACIDITY: 12 PH: 4.4 - 4.9 COPPER: 0.28- 0.42 NICKEL: 1.4 - 2.4 IRON: 0.98- 2.75	-	THE OUTFLOW FROM KELLY LAKE WAS ALSO OF POOR QUALITY.
CREIGHTON MINE AND MILL	3,360,000	SETTLING AND IMPOUNDMENT	NORMALLY COPPER CLIFF CREEK; OCCASIONALLY MUD LAKE AND MEATBIRD CREEK.	(ENTERED UNDER "P" AND "Q" TAILINGS AREA DECANT)	-	SUFFICIENT PUMPING CAPACITY TO PUMP ALL WASTES TO THE TAILINGS DISPOSAL AREA SHOULD BE PROVIDED.
MUD LAKE OUTLET	-	-	-	SUSP.SOLIDS: 9 ACIDITY: 18-24 PH: 4.7 - 6.1 COPPER: 0.03- 0.04 NICKEL: 3.8 - 5.7 IRON: 0.58- 1.07	-	THE WATER LEAVING MUD LAKE CONTAINED HIGH CONCENTRATIONS OF NICKEL.

NAME OF INSTALLATION	VOLUME OF WASTE (USGPD)	TREATMENT PROVIDED	RECEIVING STREAM	CHARACTERISTICS OF (TREATED) WASTE EFFLUENT (PPM)	WASTE LOADING (LBS./DAY)	COMMENTS
MACLENNAN MINE	15,000	SEEPAGE PIT	BOWLANDS CREEK	-	-	THERE MAY BE A PHENOL POLLUTION PROBLEM IN BOWLANDS BAY. INVESTIGATIONS MUST BE CONTINUED.
BOWLANDS CREEK BELOW MINE	-	-	-	SUSP.SOLIDS: 2-5 PH: 7.0 - 7.6 COPPER: 0.0 - 0.05 NICKEL: 0.0 - 0.02 IRON: 0.03- 0.40 PHENOLS: 0-80 PPB	-	-
CONISTON SMELTER	2,450,000	SETTLING	CONISTON CREEK	SUSP.SOLIDS: 7 PH: 6.3 COPPER: 0.51 NICKEL: 2.6 IRON: 1.8	SUSP.SOLIDS: 143 - COPPER: 10.6 NICKEL: 53 IRON: 37	THE WASTE WAS OF FAIR QUALITY ALTHOUGH THE NICKEL CONCENTRATION EXCEEDED OWRG OBJECTIVES.
TOTAL VOLUME DISCHARGED AT ALL PLANTS WAS 38,962,000 USGPD						

GENERAL DISCUSSION AND RECOMMENDATIONS

1. The analytical results obtained for the samples collected during this survey showed that, at a number of locations, the quality of the wastewater had improved over the conditions existing in 1963 and 1965. However, the results also showed that there were numerous areas in the Company's industrial waste treatment and disposal programme that required improvement. The areas where the most severely contaminated waste streams originated have been mentioned in the summary. Detailed discussions, conclusions and recommendations pertaining to each industrial operation surveyed are presented in Section II of this report.

2. Company representatives have verbally reported difficulty in precipitating nickel by the addition of lime to the waste effluents. A study by Kantawals and Tomlinson (Ref. 1) comparing the effectiveness of recovering nickel from two waste streams (a simulated waste containing 100 ppm nickel and a plating shop rinse effluent) by ion exchange and precipitation by lime gave the following results:

<u>Lime Added</u> <u>(ppm)</u>	<u>pH</u>	<u>Recovery Percent</u> <u>(based on 100 ppm</u> <u>Ni initially present)</u>
0	7.5	55
20	8.2	62
125	8.8	96
170	9.1	98
210	9.5	99
250	9.9	98.5

Jenkins, Keight and Humphreys (Ref. 2), after a study on the solubility of nickel hydroxide concluded that nickel hydroxide had a solubility of about 1 ppm nickel at a pH of approximately 7 but the solubility rose several-fold as the solution became exposed to air. At pH 10, obtained by addition of limewater, the solubility of nickel fell to 0.01 ppm nickel.

These results may or may not be applicable to mining and milling wastes.

3. In Section II of this report the importance of providing a good quality waste effluent at all times is emphasized. As is pointed out, a toxic waste allowed to enter a natural body of water even for only a limited time is capable of damaging the natural aquatic environment for extended periods of time. This is caused by upsetting the natural chemical and biological balance of life in the aquatic habitat. It is therefore important that adequate waste control be provided during the development stages of a mine or other industrial operation as well as at all times after the operations have commenced.

4. All accidental spills of toxic or other undesirable materials to a watercourse should be reported to the Division of Industrial Wastes, Ontario Water Resources Commission, immediately after discovery. This procedure is necessary to enable downstream users to take the appropriate action, if any is possible, to alleviate the possible detrimental effects of the foreign material in their water supplies. The company should also take all reasonable steps to minimize the effects of the material on the quality of the water.

5. All waste treatment facilities proposed by the Company to treat existing waste effluents or waste effluents expected from new industrial developments must be approved by the Commission before construction of the facilities commences. Section 31(1) of the Ontario Water Resources Commission Act, Revised Statutes of Ontario, 1960, states:

"When any municipality or any person contemplates the establishment of any sewage works, or the extension of or any change in any existing sewage works, the plans, specifications and an engineer's report of the works to be undertaken, and the location of the discharge of effluent, together with such information as the Commission may require, shall be submitted to the Commission, and no such works shall be undertaken or proceeded with and no by-law for raising money to finance such works shall be passed until the proposed works have been approved by the Commission."

"Sewage works" is defined as any works for the collection, transmission, treatment and disposal of sewage, or any part of any such works.

"Sewage" includes drainage, storm water, commercial wastes and industrial wastes.

It should be noted that the Commission is not required to specifically request this information. Instead, the industry is required to submit the information to the Commission when the details of the proposed works have been finalized but before construction begins. The "Application for Approval" form, copies of which have been given to the Company, was developed to simplify this procedure.

The Division of Industrial Wastes is prepared to discuss with

industry any problems relating to the treatment and disposal of industrial wastes, both before and after the formal "Application for Approval" is submitted.

6. It is recommended that the Company provide the Division of Industrial Wastes with annual reports outlining the following:

- a) any major changes in plant operations which may have taken place during the past year and which would have a significant effect on the nature of the waste effluents discharged,
- b) any major changes proposed for the future having the same effects as outlined above,
- c) the results of the Company's waste effluent sampling programme for the year, and
- d) the results of the evaluations performed on any new treatment facilities installed during the year. Such facilities would include the new clarifier which was to be installed in the Copper Cliff smelter, the lime neutralization system at the Froot Mine, the underground neutralization and settling facility proposed for the North Mine, and the large settling pond at the Copper Cliff smelter.

Reports of this type, including some of the material outlined above have been prepared by the Company and received by the Division in the past. These reports should be continued and expanded.

7. A comparison between the field and laboratory pH test results reported in Section II of this report indicated that the oxidation of metallic or other sulphides to acidic compounds, possibly sulphuric acid,

could have been occurring at one location, namely, the "P" and "Q" tailings area near Copper Cliff. If the reactions were not completed in the tailings area the possibility that they would continue in the receiving stream existed, thereby causing impairment of the water quality some distance downstream of the discharge. It is recommended that the Company undertake studies to determine the degree of completion of the reactions in the tailings area. Of particular significance is the possible temperature dependent nature of the reactions and therefore the study should be conducted during both the summer and winter seasons of the year.

CONDUCT OF THE SURVEY

The bulk of the field survey work required for the preparation of this report was carried out during June and August, 1967. During these months, samples of the waste effluents at each mine and surface plant were collected.

Samples of a "grab" nature were collected wherever the waste characteristics in a particular discharge were expected to remain relatively stable for reasonably long periods of time. Where the contaminant concentrations were suspected of fluctuating significantly over short time intervals, samples composited for periods up to 6-1/2 hours were obtained. The nature of each sample is clearly identified in the report. All waste discharges except one were sampled on at least two different days during the survey. It was felt that sampling of this nature would be sufficient to locate any problem areas that existed.

All waste samples collected during the survey were shipped to the OWRC

Laboratory in Toronto by express freight, usually on the day they were collected. The analytical procedures followed were for the most part in accordance with those described in "Standard Methods for the Examination of Water and Wastewater," Twelfth Edition. Copper and nickel analyses were performed using the atomic absorption technique on a digested sample. Results represent the total dissolved and undissolved metal in the sample. Phenol analyses were performed using Gibbs Method with modifications.

In addition, because of the distinct possibility that the pH values of many of the samples could change while in transit by chemical oxidation of the sulphur compounds to acid sulphates, pH measurements on most samples were taken in the field on the day of collection using a portable Beckman pH meter as well as at the OWRC Laboratory in Toronto, a few days to a week after collection.

Background information necessary to an understanding of the Company's position in the area of waste handling presented in this report includes the location of the mine or surface plant, an indication of its size, a brief description of the processes, a description of the sources of wastewater and the methods by which they are handled and ultimately disposed. This information was obtained by consultation and correspondence with representatives of the Company, from previously published reports, and from visual observations made in the field.

OWRC personnel participating in the field survey were:

Messrs: J. D. Luyt - Engineer
J. R. Hawley - Chemical Technologist, and
R. M. Purdy - Student, all from the Division of
Industrial Wastes.

INTERPRETATION OF ANALYTICAL RESULTS

The analyses performed on samples collected during the survey are listed below with a brief discussion of each as an aid in interpreting the significance of the analytical results.

Acidity - The acidity of water is usually caused by small amounts of carbonic acid in equilibrium with dissolved carbon dioxide, mineral acids, and salts of strong acids and weak bases. The acidity of minewater is commonly caused by the presence of mineral acids or the hydrolyzable salts of mineral acids. Acidity, in itself, is not a direct pollutant but is a measure of the effects of a combination of substances and conditions in the water. Acidity measurements may be used to estimate the amount of lime or other neutralizing agents required to elevate the pH to an acceptable level. However, the measurement may be misleading in cases where chemical reactions take place in a waste discharge downstream of the point of sampling or where the reactions have not gone to completion before the acidity test is performed. Of particular importance in the Sudbury area is the oxidation of sulphur-bearing compounds such as pyrites and pyrrhotite to sulphuric acid. The mechanism of the reactions is not clearly understood at present but is known to be dependent on a number of factors including time, temperature and pH. A waste which has a low acidity and neutral pH and is apparently satisfactory for discharge to a natural watercourse at the point and time of sampling may have a higher acidity and lower pH at some point downstream of the

sampling location and, therefore, may be capable of seriously impairing the receiving watercourse. In such a case, neutralization of the waste must be performed after the reactions have gone to near completion to ensure that no impairment takes place in the watercourse at some point downstream of the discharge.

An attempt to locate any discharges as described above was made by taking pH measurements in the field on the day of collection and comparing the results with pH values obtained at the OWRC Laboratory approximately one week after collection. A significant drop in pH would indicate that some form of a time - dependent acid-producing reaction had occurred.

Alkalinity - The alkalinity of water is usually caused by its bicarbonate, carbonate and hydroxide contents and to a lesser extent by phosphates, silicates and some organic compounds. Domestic sewage is usually somewhat alkaline.

It is generally recognized that slightly alkaline water conditions are desirable for a diversified aquatic biological community. A pH value between 7 and 8 and a total alkalinity of 100 parts per million (ppm) appears to be optimum.

Both acidity and alkalinity are reported in parts per million of calcium carbonate (CaCO_3) and represent "total acidity" and "total alkalinity".

pH - The symbol "pH" is used to designate the reciprocal of the logarithm of the hydrogen ion concentration and is reported in numbers

ranging from zero, very acidic, to 14, very basic. The neutral point is pH 7. Acidity and alkalinity include the buffering action of a water while the pH represents the instantaneous hydrogen ion concentration.

Since an excessive concentration of hydrogen ions may adversely affect water, pH is, therefore, a measure of a potential pollutant. Waters of low pH are aggressive and may cause corrosion problems as well as being unfavourable for most biological life.

In addition, the toxicity of the metallic ions such as copper, nickel and iron are markedly affected by a depressed pH. For example, it has been reported that fish that can tolerate pH values as low as 4.8, will die at pH 5.5 if the water simultaneously contains 0.9 ppm iron (Ref. 3).

Another striking example involves nickel cyanide, the toxicity of which increased over 1,000-fold as the pH was decreased from 8.0 to 6.5. (Ref. 4).

It should also be noted that when the pH falls below 5.0, specialized flora and fauna will develop and some species have been observed at pH values as low as 2.9 (Ref.5).

A second item which should be considered is the increased solubility of nickel and copper compounds in waters of low pH. In acid waters, almost all the metallic content is in the dissolved form while, as the water is made more alkaline, the metals precipitate out in the solid form and can be removed from the water or waste effluent by settling or filtration.

Total, Suspended and Dissolved Solids - Solids in water are classified as either "dissolved", i.e., capable of passing a fine mat of asbestos fibre in a Gooch crucible, or "suspended", i.e., retained on the asbestos mat.

In natural waters, suspended solids consist of erosion silt, organic detritus and plankton. The suspended solids in surface waters may be increased by the erosion of deforested areas, by mine tailings, by dusts blown onto the stream, and by many industrial wastes. The effects of suspended solids in water are reflected in unsightly conditions, injury to the habitat of fish, and difficulties in water purification.

Dissolved solids consist of material in solution and in natural waters are mainly composed of carbonates, bicarbonates, chlorides, sulphates, phosphates with traces of the metals. Dissolved solids and suspended solids make up the "total solids".

Results are reported in parts per million.

Copper - Copper salts occur in natural surface waters only in trace amounts. Therefore, their presence is generally attributable to some form of copper addition to the stream. The toxicity of copper to aquatic organisms varies widely, not only with the species, but also with the physical and chemical characteristics of the water. The effect of pH on the toxicity of certain compounds has been discussed.

Copper concentrations varying from 0.1 to 1.0 ppm have been found by various investigators to be not toxic for most fish. On the

other hand, concentrations of 0.015 to 3.0 ppm have been reported to be toxic to many kinds of fish, crustacea, insects, phytoplankton and zooplankton (Ref.6).

The results are reported in parts per million and represent the total (suspended and dissolved) copper content of the sample.

Nickel - Most of the preceding comments pertaining to copper are also applicable to nickel. Nickel salts are toxic to aquatic life at low concentrations and do not normally occur naturally in surface waters.

The lethal limit for sticklebacks has been reported as 0.8 ppm (Ref.7).

The results are reported in parts per million and again represent the total nickel content of the sample.

Iron - Very small quantities of iron will adversely affect a water supply and, in larger quantities, will affect the aesthetic qualities of a watercourse by oxidation to the insoluble ferric state under the proper conditions and subsequent precipitation. Investigations have shown that carp will die at concentrations of 0.9 ppm with a simultaneous pH of 5.5 or less (Ref.8). Pike and trout died at concentrations of 1-2 ppm at a pH of 5.0 to 6.7 (Ref. 9 and 10).

The results represent total iron and are reported in parts per million.

Phenols or phenolic equivalents - This test is sensitive to phenolic derivatives as well as to phenol itself. These compounds are present in many industrial waste effluents especially where oil or oily material has been discharged to or contacted a body of water. They may also occur naturally in surface waters as the result of the decomposition of organic matter such as leaves, fallen trees, and other decaying plant life.

At minute concentrations they have the ability to taint the flesh of fish and will cause an objectionable taste in drinking water supplies which is accentuated by chlorination.

Phenolic equivalents are reported in parts per billion (ppb).

Sulphide - Sulphide occurs naturally in many well waters and sometimes is formed in lakes or surface waters as a result of bacterial action on organic matter under anaerobic conditions. Concentrations of a few hundredths of a part per million cause a noticeable odour. In waters free of suspended solids, sulphide exists as a mixture of HS^- and H_2S . The test results reported here do not include the insoluble copper, nickel and iron sulphides.

GUIDELINES FOR INDUSTRIAL WASTE CONTROL

Acceptable waste effluent characteristics as outlined in the OWRC "Objectives for Industrial Waste Control in Ontario" include the following:

- 1) Toxic substances - materials or waste components that are toxic to aquatic life or render the water unsuitable for potable or recreational uses shall be eliminated or destroyed.

- 2) Taste and Odour - waste materials or components that impart tastes and odours to the receiving waters or to fish, that would render the waters or fish unsuitable for use, shall be eliminated or destroyed.

Phenol or phenolic equivalents should not exceed an average of 2 parts per billion or a maximum of 5 parts per billion in the receiving waters following initial dilution.

- 3) Aesthetic Qualities - treatment or control shall be effected to ensure that waste discharges do not impair the aesthetic qualities of the receiving stream by imparting colour, by giving rise to accumulations of solids, oils or greases, by inducing foaming, or by other adverse effects.

The following table summarizes the OWRC objectives for maximum concentrations of various substances found in industrial waste waters which are normally permitted to enter natural watercourses. The concentrations given have been developed for general use throughout the Province of Ontario. In certain cases, depending on local circumstances or requirements or on the nature and size of the receiving stream, it is necessary to modify certain of these parameters to ensure that no impairment of the receiving stream will develop, or, to reduce or eliminate existing impairment in a stream.

<u>Contaminant</u>	<u>Maximum concentrations normally considered satisfactory for discharge to natural watercourses.</u>
BOD ₅	15 parts per million
Temperature	150°F
Ether solubles (any origin)	15 parts per million
pH	5.5 - 10.6
Suspended solids	15 parts per million
Copper as Cu (total)	1 part per million
Nickel as Ni (total)	1 part per million
Iron as Fe (total)	17 parts per million
Sulphates as SO ₄	1,500 parts per million
Cyanides as HCN	0.1 parts per million
Phenols or phenolic equivalents	20 parts per billion

In the Sudbury area, by far the largest volume of industrial wastewater discharged contained certain quantities of copper, nickel and iron and had a low pH. In addition, most of the receiving streams already contained these metals, were of an acid nature, and generally had a poor buffering capacity. Therefore, when considering the area as a whole, these chemical parameters become exceedingly important. It is evident that no waste discharge in the area should contain concentrations of the metals exceeding the Commission's general objectives or be of a pH lower than 5.5. Efforts to raise the pH to higher than 5.5 and to reduce the metal concentrations to less than the objectives would be extremely desirable and may, in fact, be necessary.

GENERAL DESCRIPTION OF THE AREA

The Sudbury Basin is roughly oval in shape with the major axis about 37 miles long, lying in a south-west to north-east direction. The nickel irruptive occurs on the outer edge of the oval. (Figure 1). The principal ores are pyrrhotite ($\text{Fe}_{n-1}\text{S}_n$), pentlandite ($(\text{Ni}, \text{Fe})_9\text{S}_8$), and chalcopyrite (CuFeS_2).

Drainage is disordered and consists of many lakes and meandering streams. The two major rivers draining the mining area are the Vermilion River (tributaries of interest being the Onaping River, Moose Creek and Junction Creek) flowing in a southwesterly direction to the Spanish River which in turn empties into the North Channel, and the Wanapitei River (tributaries of interest being Emery Creek and Coniston Creek) flowing southwards to the French River and Georgian Bay. Victoria Creek, a tributary of the Spanish River also drains a small part of the mining area in the southwestern area. (Figure 2)

Most of INCO's mining and related activities in operation or under development at the time of the survey were located in the Junction Creek watershed. Included were the Garson, Kirkwood, Frood-Stobie, Little Stobie, Murray, North and Creighton Mines, the Copper Cliff and Creighton concentrators, the new Frood-Stobie concentrator, the Copper Cliff smelter, refinery and the iron ore recovery plant. Other installations included the Levack and Coleman Mines and the Levack concentrator on the Onaping River, the Victoria and Crean Hill Mines on small tributaries of the Vermilion River. The Totten Mine was near Victoria Creek emptying into the Spanish River; the MacLennan Mine was

located near the southwest corner of Lake Wanapitei, and the Coniston smelter was located in the Coniston Creek drainage area.

In the latter half of this report, the installations listed above will be grouped on the basis of the watershed in which they were located but will be discussed as separate entities as far as possible.



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