A Study of Liquid and Solid Wastes in Metal Finishing Industries in the City of Winnipeg

by

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A Practicum Submitted
In Partial Fulfillment of the
Requirements for the Degree,
Master of Natural Resources Management

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ABSTRACT

The study of liquid and solid wastes from the electroplating industry in the City of Winnipeg examines heavy metals (cadmium, chromium, copper, lead, nickel, zinc) and their main carrier liquid, cyanide.

Manual operations mean highly fluctuating levels of contaminants in the effluent. In order for both City officials and industry to determine precisely the materials lost to the sewer system more regular sampling must be undertaken. Costs to industry are a major deterrent though evidence suggests that the long-term benefits of this effort far exceed the costs involved. The data from this study, however, substantiates evidence from other metropolitan areas namely that electroplaters contribute only a small percentage of cadmium, and other heavy metals to the City influent.

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Chapter I

INTRODUCTION

1.1 PROBLEM STATEMENT

Increasing technology and the growth of industry have resulted in an increasing volume of wastes in Winnipeg, as in other metropolitan areas. The City of Winnipeg treats all domestic and industrial sewage with the resultant sludge being available as a soil conditioner for agricultural land.

Sludge has potential value as an "organic manure rich in nitrogen and phosphate" [Davies 1972] but is a potential hazard when accompanied by the presence of heavy metals, as once the soil is thus contaminated there is no known way for removal of the metals apart from scraping away the topsoil.

Primarily related to the industrial base in Winnipeg, there are significant concentrations of heavy metals present in the City's effluent and the resultant sludge. This is a limiting factor for the agricultural use of sludge because of cumulative effects and ramifications of heavy metals on food chains. There is particular concern over the presence of cadmium, as well as chromium, copper, lead, nickel and zinc.

The City of Winnipeg has determined the level of metal wastes in its influent and effluent but has insufficient detailed data concerning point of origin. Due to this lack of specific data, the City has found it difficult to formulate a comprehensive policy on the discharge of heavy metals into the sewer system.

This study documents heavy metal wastes and the accompanying carrier liquids which are generated by metal finishers in the City of Winnipeg, as a partial solution to the problem.

1.2 RESEARCH OBJECTIVES

The purpose of this study was to:

1. investigate liquid and solid wastes generated by the metal coating industry (with particular attention to heavy metal contaminants), the quantities involved, current means of disposal, current applicable legislation, and practical aspects of enforceability

2. determine if there is a correlation among actual sampling results of heavy metal contaminants, theoretical values and waterflow data

3. recommend, based on the data and literature reviews, the most efficacious handling of these wastes.

1.3 DELIMITATIONS

Delimitations were that:

1. only electroplating job shops were considered

2. only those heavy metals evident in electroplating wastes in Winnipeg were dealt with

3. only legislation in effect as of August 1, 1980 was considered

4. the related issues of collection, transportation and costs were not considered

5. the jurisdiction was the City of Winnipeg (map:figure 1).

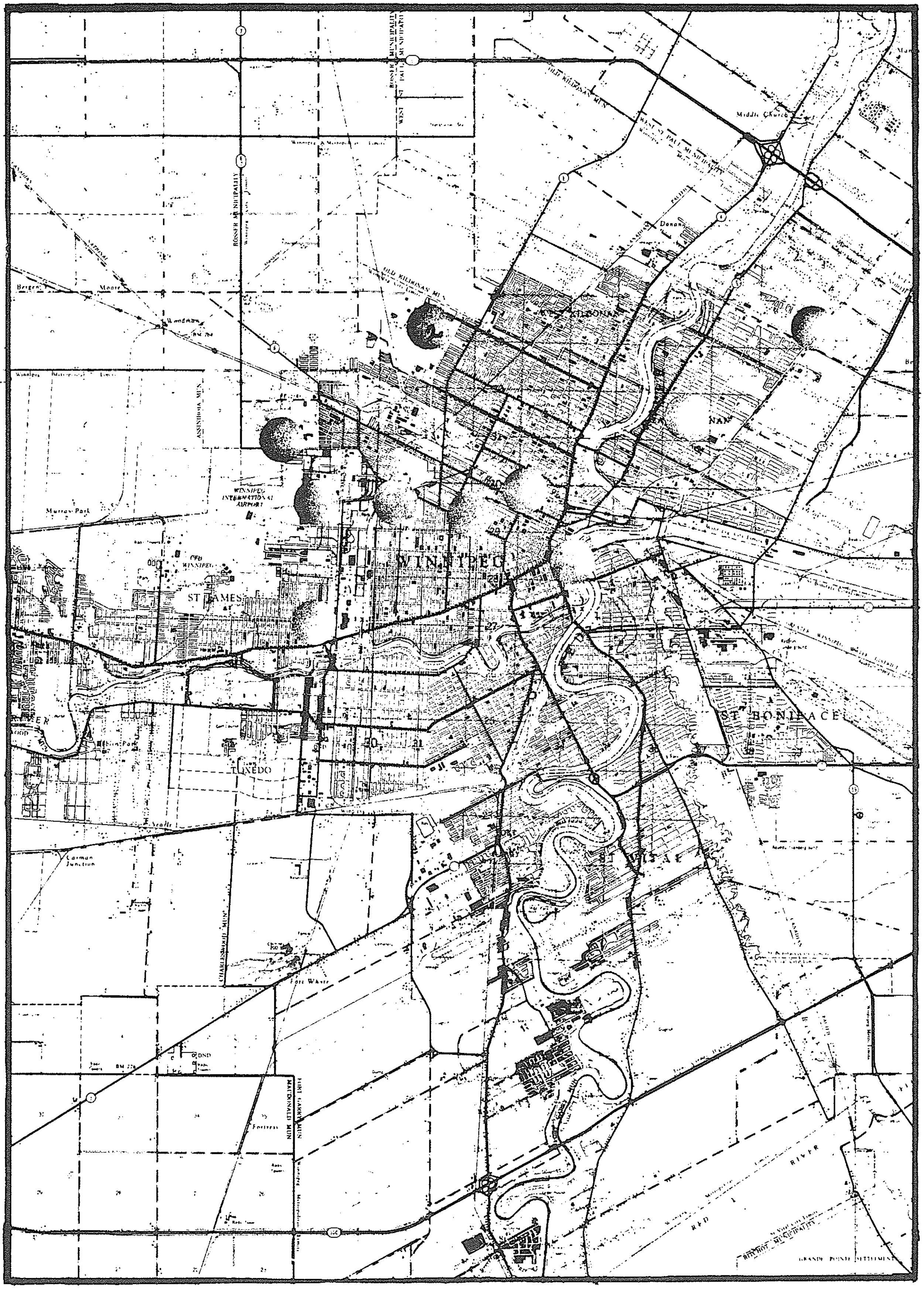

Fig. 1. City of Winnipeg and Location of Electroplaters.

WINNIPEG
MANITOBA
SCALE 1:50 000 ÉCHELLE

1.4 CLASSIFICATION OF THE INDUSTRY

Electroplaters are broadly defined to include platers, anodizers, and galvanizers. They are included in section 304 (Metal Stamping, Pressing and Coating Industry) of the Standard Industrial Classification (SIC) code for Canada [SIC 1970]. The industry includes:

> ...establishments primarily engaged in coating metal and metal products, such as vitreous enamelware, galvanizing, and electroplating except plating with precious metals (392· Jewellery and Silverware) [SIC 1970].

Industries which utilize brass, cadmium, chromium, copper, gold, lead, nickel, silver, tin, and zinc are found within the City of Winnipeg. This study pays specific attention to those industries producing heavy metal wastes (cadmium,chromium, copper, lead, nickel, zinc) and notes their carrier liquids. Concern over the presence of these particular heavy metals is detailed following the description of the relevant plating process.

1.5 METHODS

This research consisted of literature reviews and interviews, specifically:

1. a review of literature with respect to coating/plating processes to facilitate interviews and data analysis

2. a review of literature with respect to formal interview design, format and procedures

3. a review of relevant Federal, Provincial and Municipal statutes and regulations concerning hazardous wastes generally, and electroplaters specifically

4. a comparative examination of other Canadian jurisdictions to investigate the feasibility of enforcement of the regulations

5. an investigation of current U.S. legislation (Canadian legislation usually follows the American example)

6. designing and conducting formal interviews with members of the plating industry (because of the small number of shops all were contacted)

7. an aggregation and synthesis of data collected to answer the following questions:

   a) what types of wastes are being generated

   b) what quantities are involved

   c) what disposal methods are currently being used

   d) what is the preferential means of disposal from the municipal viewpoint?

Chapter II

OUTLINE OF PLATING PROCESSES AND SOURCES OF WASTES

The purpose of metal finishing is to improve the surface of the original material by:

Cleaning it
Hardening or Softening it
Smoothing or Roughening it
Depositing another metal on it
Converting its surface
Coating it with organic materials
Electroplating it with organic materials
Oxidizing by electrolisis.[EPA 1973]

These changes produce properties which enhance the item in appearance, corrosion resistance, wearability, or durability serving either aesthetic or engineering purposes. Among the various users of electroplated materials are industries such as: automotive, appliance, electronic, electrical, aircraft, agricultural, jewellery and many others.

The plating processes are done either in large establishments as one part of an overall operation, or in specialized job shops. The electroplating process can be segregated into three phases: pretreatment, plating, post-treatment.

2.1 PRETREATMENT

Pretreatment involves cleaning and degreasing, either chemically or mechanically for the purpose of removing all oil, grease, scale and dirt. This is of primary importance before plating to ensure proper bonding during plating. The general scheme is as follows:

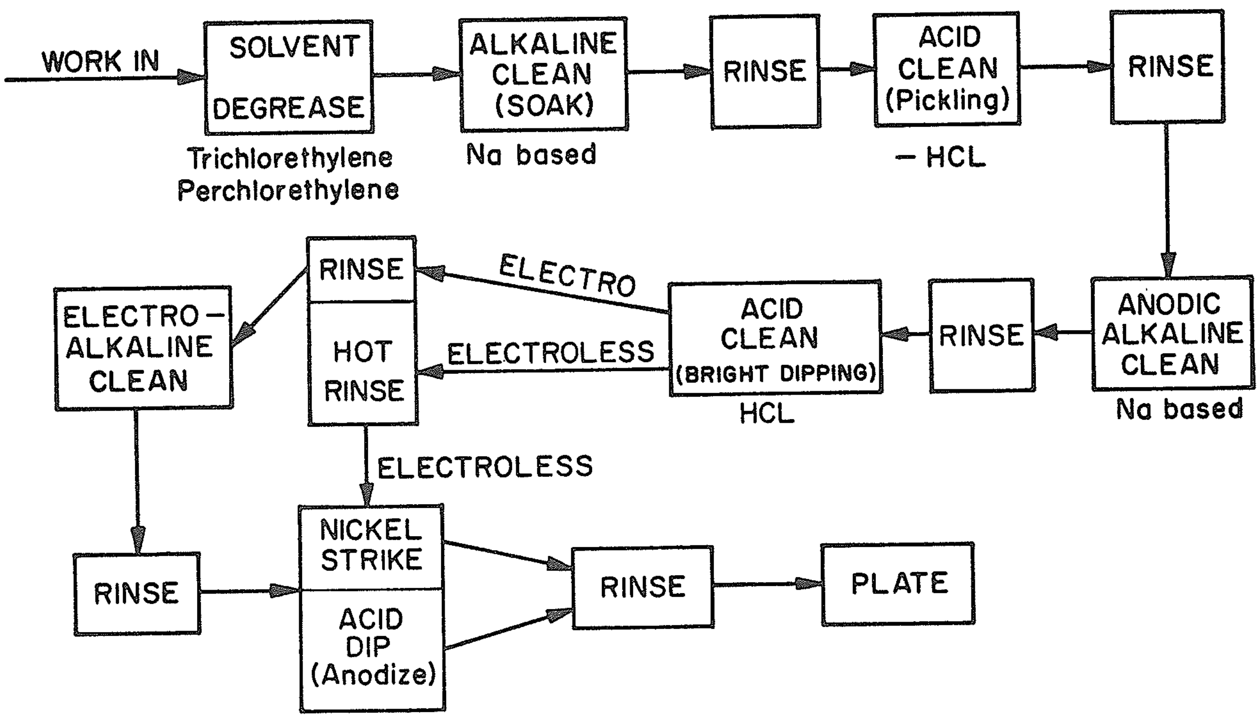

Figure 2 Cleaning Process

2.2 PLATING

Plating can be either electroplating, which is the most common, or electroless plating.

Electroplating is the electro-deposition of positively charged metal ions, from the anode and/or bath salts, onto the cathode, which is the workpiece. The degree to which the cathode is plated is a function of concentration of the solution, relative position of the anode and cathode (current density), and time.

Electroless plating is used for the plating of plastics and for a few metals (copper, nickel, tin). It is a "chemical reduction process which depends upon the catalytic reduction of a metallic ion in an aqueous solution containing a reducing agent" [Sittig 1978]. Advantages are uniform plating thickness regardless of shape, and the non-porousness of the surface providing better hardness and corrosion resistance. Electroless plating is less common because cleaning and rinsing must be more thorough, and this implies that it is more costly.

2.3 POSTTREATMENT

Posttreatment involves an additional coating which is sometimes applied by either electro or electroless techniques to polish, colour or prepare the surface for painting.

2.4 PLATING PROCESSES, WASTES, AND TOXICITY

Each plating process contributes different elements to municipal sewage and the resultant sludge. These elements, particularly the heavy metals affect people, animals, fish and plants in varying ways. An attempt has been made to outline the maximum acceptable level for each of these metals in drinking water and on agricultural land.

Toxicity reflects the degree of injury to the growth or metabolism of an organism above a specific concentration. This toxicity seems to relate to the poisoning of enzyme systems [US Federal Water Pollution Control Administration 1968]. For air breathers this critical/threshold dose is the maximum quantity that can be taken without causing death. For marine life the matter is more complex as there is no escape from their polluted environment. Crops vary in their sensitivity to metal toxicity: horticultural and root crops are the most sensitive, followed by cereal crops, and grasses are the least sensitive. Contaminated soil poses direct risks to vegetable and root crops, and has a high potential for metal poisoning of grazing animals through eating soil along with the fodder. No general agricultural limits relating to heavy metals were found, though extensive research is underway. This lack of information is due to the difficulty in making generalizations as many factors affect the uptake of and tolerance to various elements, not the least of which are the different soil types. It is important, however, to consider heavy metal leaching into ground water, considered negligible except for lead [US FWPCA 1968], and the quality of irrigation waters.

2.4.1 Cadmium Plating

Cadmium is used to coat parts for aircraft and outdoor military equipment because of its corrosion protectiveness. It is used on electrical pieces because of its excellent solderability and low contact resistance. It is also used for undercoating parts for zinc plating.

Plating is accomplished either in a cyanide bath after final pretreatment of cyanide or caustic dipping, or in a fluoborate bath after final pretreatment in an acid rinse.

If any posttreatment is done it is a bright dip in a weak solution of nitric or chromic acid.

2.4.1.1 Wastes

Principal sources of waste are from tank overflow, dragout into rinse water, leaks, and tank sludges. Contaminants are: cyanide, alkaline solutions, and cadmium metal ions.

2.4.1.2 Toxicity

Cadmium is toxic, hazardous to both mammals and fish because it is easily ingested through food, water and air, but cannot be excreted. In mammals it is a cumulative toxicant concentrating in the liver, kidney, pancreas, and thyroid. It can also "form organic compounds which might lead to mutagenic or teratogenic effects" [McKee and Wolf 1963; Sittig 1978]. Further, cadmium acts synergistically with other metals, particularly copper and zinc, to increase toxicity.

The maximum acceptable concentration of cadmium in drinking water is <.005 mg/l with the objective concentration ⩽.001 mg/l in Canada [Health and Welfare Canada 1978]. There are no World Health Organization (WHO) International Drinking Water Standards.

2.4.2 Chromium Plating

Chromium plating is categorized as being either "hard chrome" or "decorative chrome" which denotes only the thickness of metal applied. Thickness of hard chrome ranges from 2.5×10^{-4} to 5.1×10^{-2} cm [Sittig 1978] whereas, decorative chrome ranges from 2.5×10^{-5} to 5×10^{-5} cm. Chromium is a good protective, non-tarnishing surface finish.

Chromium, in solution, exists in both hexavalent and trivalent forms, with the chromic acid form generally used being hexavalent.

Plating occurs in a bath of chromic acid and sulphuric acid.

2.4.2.1 Wastes

Principal sources of waste are from tank overflow, dragout, spray resulting from the release of hydrogen gas at the cathode and oxygen at the anode, chromic acid aerosol which is usually drawn up into air ducts by fans, and tank sludges. Contaminants are: chromium, acetate, copper (from strike solutions), nickel, potassium, sodium, borate, cyanide, chloride and sulfates.

2.4.2.2 Toxicity

Chromium in both valence states appears to be hazardous to mammals, fish, and plants though some sources claim that only the hexavalent form is toxic [Sittig 1978]. It produces skin irritations, lung tumors when inhaled, and causes inflammation of the intestinal tract and kidneys when ingested. Evidence indicates that an increase in the environmental level of chromium affects ingestion-elimination imbalance towards the former. Effects on fish and other acquatic life forms vary with species, temperature, pH, valence and hardness of water.

The maximum acceptable concentration of chromium in drinking water is .05 mg/l in Canada with the objective concentration $\leqslant$.0002 mg/l [Health and Welfare Canada 1978]. The WHO International Drinking Water Standard is .05 mg/l for hexavalent chromium [McKee and Wolf 1963; Sittig 1978].

2.4.3 Copper Plating

Copper is sometimes used as an undercoat for nickel and chromium, as a decorative finish with an overcoat of clear lacquer, in printed circuit boards, or as a heavy coating on wire for electrical applications. Plating occurs in either a cyanide copper or an acid copper bath.

2.4.3.1 Wastes

Sources of waste are from tank overflow, dragout, leaks, solution filtration, and tank sludges. Contaminants are: cyanide, acid, copper sulphate and tartrates.

2.4.3.2 Toxicity

In excessive quantities copper is toxic to plants and mammals although it is an essential trace element for nutrition. It is, however, toxic to many species of fish and aquatic animals, particularly oysters, especially synergistically with cadmium, mercury, zinc, magnesium salts and phosphates [McKee and Wolf 1963; Sittig 1978]. The limiting factor of copper in drinking water is its metallic taste.

Maximum acceptable levels of copper in drinking water in Canada are <1.0 mg/l [Health and Welfare Canada 1979]. The WHO International Drinking Water standard is 1.0 mg/l (1.5 mg/l maximum).

2.4.4 Lead and Lead Alloy Plating

Lead and lead alloy coatings are used "to improve solderability and coating properties and performance of such basis metals as steels, copper, copper alloys, aluminum, and for strip plating of steel mill products" [Sittig 1978]. Plating occurs in fluoborate baths which contain fluoboric acid and boric acid.

2.4.4.1 Wastes

Sources of waste are from tank overflow, bath filtration, dragout, leaks, and tank sludges. Contaminants are: copper, lead, tin, borate, fluoride and fluoborate.

2.4.4.2 Toxicity

Lead is a toxic substance, and accumulates in the bones of mammals, birds, fish and other marine life. It is ingested from food and water, and is extremely difficult to excrete. Toxicity of lead in water is increased with a reduction in concentration of dissolved oxygen. The literature shows differing concentrations which result in lead poisoning [Sittig 1978].

Maximum acceptable limits for lead in drinking water in Canada are .05 with the objective concentration $\leq$.001 mg/l [Health and Welfare Canada 1978]. The WHO International Drinking Water limit is 0.1 mg/l [McKee and Wolf 1963].

2.4.5 Nickel Plating

Nickel is applied as an undercoat to chromium to act as a corrosion protector. It is also applied to improve a decorative, corrosion-resistant finish, to build up worn parts or to electroform parts too expensive to machine.

2.4.5.1 Electro Nickel Plating

Plating can occur in each of a Watts (sulfate-chloride-boric acid), sulfamate, fluoborate, or chloride baths.

2.4.5.2 Electroless Nickel Plating

After very careful cleaning of the part plating can occur in nickel chloride or nickel sulfate solutions.

2.4.5.3 Wastes

Electroplating wastes come primarily from tank overflows, dragout, leaks, incomplete washing of filters, and tank sludge. Contaminants are: copper, lead, nickel, phosphorus, sodium, cyanide, borate, phosphate, fluoborate, chloride, sulfate, and sulfamate.

Electroless plating wastes come from pretreatment, plating and posttreatment processes and include copper, nickel, cyanide, fluoride, phosphorous, total suspended solids and chelating agents.

2.4.5.4 Toxicity

Nickel is regarded as not being toxic to man, though it is extremely toxic to plants, especially citrus [McKee and Wolf 1963; Sittig 1978]. Nickel salts in sewage inhibit biochemical oxidation.

There are no maximum allowable concentration levels of nickel in drinking water from either Health and Welfare Canada or the World Health Organization.

2.4.6 Zinc Plating

Zinc is utilized as an anti-corrosion surface, particularly on iron and steel, to which it is anodic. Zinc is easily applied and is relatively inexpensive.

Zinc plate can be applied from either a zinc or sodium cyanide bath or an alkaline bath.

2.4.6.1 Wastes

Sources of waste are from bath overflow, dragout, leakage, and bath filtration. Contaminants are: aluminium, potassium, sodium, tin, zinc, acetate, cyanide, chloride, and sulfate.

2.4.6.2 Toxicity

Zinc is an abundant metal which is harmful to mammals at high concentrations. It is toxic to fish [McKee and Wolf

1963] at levels in excess of 0.1 mg/l in soft water, though sensitivity appears related to species, temperature, and pH. Studies indicate that a complex relationship exists amongst zinc concentrations, dissolved oxygen, pH, temperature, and calcium and magnesium concentrations [Sittig 1978]. The presence of zinc in drinking water in excess of 5 .0 mg/l has an undesirable taste.

Maximum acceptable concentration of zinc is 5.0 mg/l in Canada with the objective concentration <5.0 mg/l [Health and Welfare Canada 1979]. The WHO International Drinking Water standard is 5.0 mg/l [McKee and Wolf 1963].

Chapter III

METHODS, PRESENTATION OF RESULTS AND ANALYSIS

3.1 DESCRIPTION OF STUDY AREA

Within the jurisdiction of the City of Winnipeg there are fourteen plating job shops - nine of which were visited, one was closed for renovations, one was not yet operational, and three were not willing to discuss their operation. Forty-three different industrial groups were identified through the Manitoba Telephone System Winnipeg Telephone Directory (yellow pages) and contacted by telephone to see if they did "in-house" plating. Other than the job shops, plating is done by one aerospace company, jewellers (gold silver, copper), name platers (zinc), and railroad shops (cadmium) [See Appendix B].

3.2 METHOD: CITY OF WINNIPEG SAMPLING

City of Winnipeg Waterworks, Waste and Disposal Division:Laboratory Services Branch officials have been involved in sampling treatment plant influent, effluent and sludge since 1972 to obtain baseline data. One of their goals being establishing the feasibility of the removal of heavy metals at their source. Sample data used in this study was supplied by the City of Winnipeg.

Sampling of selected plating firms was conducted by City of Winnipeg laboratory staff in both 1977 and 1980. A composite sample was obtained over a one day period by means of a grab sample manually taken every 15 minutes. No attempt was made to determine what was being plated, what the effluent flow rate was, or if the sampling period was a true representation of normal plating operations.

Sample values (mg/l) were then multiplied by water-flow rates (l/yr) to yield yearly loading values (mg) - the quantity electroplaters contribute to the City sewer system [Table 1].

Municipal officials also provided average 5 year loading values (1974-1978) for each of the heavy metals under consideration. These values (used in Table 5) were the result of daily composite samples of treatment plant influent taken which yielded weekly composite samples which were then analyzed for heavy metal contaminants.

There are two statistical techniques for dealing with the analysis of contaminant data. First, an arithmetic mean and standard deviation can be calculated. Due to the nature of manual electroplating processes, however, which yield variations in the amount of work processed, drag out volume, and a dilution factor from continuously running water, this procedure is unsatisfactory because of the wide fluctuations in the levels of contaminants in a particular shop's effluent.

Table 1: Comparative Sample Results with Yearly Loading Rates

Firm	Waterflow (l/yr)	Sample Results (mg/l) 1977 / 1980: Cd	Cr	Cu	Ni	Pb	Zn	Yearly Loading (mg) 1977 / 1980: Cd	Cr	Cu	Ni	Pb	Zn
A	14,457,169	.02 .005	5.30 7.6	2.89 7.20	9.24 20.9	.046 <.02	.32 .65	289,143 72,286	76,622,995 109,874,484	41,781,218 104,091,616	133,584,241 302,154,832	665,029 <289,143	4,626,294 9,397,159
B	1,673,031	.025 not tested	2.72	3.00	18.2	.173	.37	41,825	4,550,644	5,019,093	30,449,164	289,434	619,021
C	363,702	.04 <.002	31.0 19.6	1.00 4.09	9.30 4.52	.184 .02	.20 .25	14,548 727	11,274,762 7,128,559	363,702 1,487,541	3,382,428 1,643,933	66,921 7,274	72,740 90,925
D	60,992,886	1.5 .34	.789 60.0	.582 .92	.055 .82	.161 2.65	22.0 .08	91,489,329 20,737,581	48,123,387 3,659,573,160	35,497,860 56,113,455	3,354,609 50,014,167	9,819,855 39,645,376	1,341,843,492 4,879,431
E	2,473,176*	not yet established not tested											
F	n.a.**	.04 .003	.029 <.02	.045 .04	.035 .18	.069 .05	.08 .16						
G	900,163*	not yet established not tested											
H	1,383,774	.08 <.002	.235 .62	4.67 4.50	6.06 5.30	.092 .04	.16 .14	110,701 2,768	325,187 857,940	6,462,224 6,226,983	8,385,670 7,334,002	127,307 55,350	221,403 193,728
TOTAL: 78,870,562								91,945,546 20,813,362	140,896,975 3,777,434,143	89,124,097 167,919,595	179,156,112 361,146,934	109,685,456 <39,997,143	1,347,382,950 14,561,242
							Total (Kg)	91.9 20.8	140.8 3777.4	89.1 167.9	179.16 361.15	109.69 <39.99	1.35 14.56

* figures not included in total
** figures not available as part of a commercial complex

TABLE 2

Plating Bath Salt Concentration Range (g/l)

BRASS PLATING:			
Cu	22.5 (min)	32.3 (mean)	42 (max)
Zn	7.2	12	17.3
CN	45	60	75
CADMIUM PLATING:			
(i) Still Plating			
Cd	20	25	30
CN	75	82.5	90
(ii) Barrell Plating			
Cd	15	17.3	20.2
CN	90	95	100
CHROMIUM PLATING:			
CrO_3	250	325	400
COPPER PLATING:			
(i) Copper Cyanide Strike			
Cu	9.8	12.8	15.8
CN	5.0	8.3	11.3
(ii) Copper Cyanide Plate			
Cu	33.8	61.5	89.3
CN	11.3	15	18.8
(iii) Copper Acid Plate			
Cu^+	38.3	51	64
NICKEL PLATING:			
$NiSO_4$	225	319	413
$NiCl_2$	30	45	60
Ni^+(Total)	57.8	81.8	107.3
SILVER PLATING:			
(i) Silver Cyanide Strike			
Ag	1.3	2.4	3.5
CN	70	80	90
(ii) Silver Cyanide Plate			
Ag	20.3	33	45
CN	50	64	78
ZINC PLATING:			
(i) Barrell Plating			
Zn	33	40	47
CN	46	58.5	70
(ii) Still Plating			
Zn	33	40	47
CN	42	56	70

The literature [EPA 1973] suggests plotting the data on probability paper and interpolating a linear relationship from the scattergram. The mean, (50% value) and standard deviation {(84.13%-15.87%)/2} could be obtained from the graph. These probability plots are considered to be more reliable as arithmetically, the mean is sensitive to extreme points.

3.3 METHOD· THEORETICAL RESULTS

Plating bath solutions can be used in a range of metal salt concentrations (Table 2). Theoretical values of wastewater contaminants were obtained by taking the mean salt concentration values, waterflow rates which were divided equally among the number of rinse tanks used (Table 3) and manipulated according to the relevant formulae (Table 4).
Other assumptions made were:

1. rate of work plated=10 square feet per minute for 7 hours

2. when plating, only those rinse tanks pertinent to that plating scheme are in operation, and the water flow is divided equally amongst the rinses (all tanks in each company are the same volume though size varies amongst the shops)

3. shops operated 241 days per year, 7 hours a day unless otherwise indicated

TABLE 3

Overview of Plating Shops

Shop	Plating Done	Number of Rinses
A	Brass Cr Cu Ni	14 (incl 2 HW)
B	Ag Cr Cu Ni	7 (incl 1 HW)
C	Cr	2 (1 still, 1 runnning, 1HW)
D	Ag Cd Cr Cu Ni Sn	17
E	Cd Sn Zn	6
F	Ag Brass Cr Cu Ni Sn	3
G	Cr	5 (all 2 tank CF)
H	Zn	4 (3-2 tank CF)
I	Cr Cu Ni	8 (incl 2 spray)

Note: HW=hot water
CF=counterflow rinsing

4. where applicable, drag out tanks have the same concentration as the plating bath

5. drag out rates, [Graham 1971] for automated operations have been doubled because all plating in Winnipeg is manually performed. The drag out rate is different for straight, curved and more complex designed pieces, and is in units of gallons/1000 square feet

6. drag out rate is halved in cases involving spray rinse [Graham 1971].

TABLE 4

Formulae Used in Calculations

(i) Rinse tank concentration (Cr)

Cr=Sr/Wr where: Sr = bath salt concentration
Wr = water flow per year

(ii) Bath salt concentration (Sr)

Sr=Vd(Cs) where: Vd = drag-in rate
Cs = drag-in salt concentration

(iii) Wr=F(Vd) where F=water flow

(iv) Single running rinse tank concentration

Cr=[Vd(Cs)]/F

(v) For multiple running rinses use Cr from previous rinse as Cs for subsequent Cr calculations.

3.4 RESULTS: SAMPLE COMPARISONS

Sample values from 1977 and 1980 are enumerated in Table 1. It is readily apparent that there are some significant differences between 1977 and 1980 values. In some cases this would be resultant from a compositional shift in plating. In other cases it could be from the spontaneous sampling procedures and the non-attempt to determine if the sampling day was representative of normal operations, or some degree of a Hawthorne Effect. Yearly loading values are summed and then these values (kg) are shown in Table 5 along with the 5 year average loading value for each metal. The percentage of the sample value for each test period to the 5 year average value was then determined.

TABLE 5

Percentage of Sample Results to Total Received

Metal	5 Yr Average (1974-78)	Sampling Total 1977(1980)	%of Total 1977(1980)	Mean % of Total
Cd	539.7	91.9 (20.8)	17 (3.9)	10.45
Cr	54084.5	140.8 (3777.4)	.26(6.9)	3.58
Cu	15080.6	89.1 (167.9)	.59(1.1)	.85
Pb	15824.9	109.69 (<39.99)	.69(<.25)	<.47
Ni	5678.5	179.16 (361.15)	3.2(6.4)	4.8
Zn	60507.9	1.35 (14.56)	.002(.02)	.01

In 1977 the amount of heavy metals contributed by electroplaters to the City influent was less than 4%, except for cadmium. In 1980 there is an increase in heavy metal contaminants from electroplaters, but in all cases they represent less than 7% of the 5 year average value. However, these percentages must be extrapolated to include the entire industry (14 shops), and this total percentage is shown in Table 6.

TABLE 6

Percentage of Heavy Metals Contributed by Platers

Metal	% Mean	% Total Industry (Extrapolated)
Cd	10.45	29.26
Cr	3.58	10.02
Cu	.85	2.38
Pb	<.47	<1.32
Ni	4.8	13.44
Zn	.01	.028

Note: Extrapolation implies a uniformity in operations and wastes throughout the industry: this is a powerful assumption!

The percentage for cadmium substantiates findings from other major metropolitan cities: Metropolitan Chicago traces 37.8% cadmium to all industrial sources - approximately 29% to electroplaters; New York City traces 33% to electroplaters [Lue-Hing et al. 1980].

3.4.1 Sample Results: Statistical Analysis

The standard statistical method for analyzing data notes the mean and standard deviation of the data. Table 7 shows this information for 1977 and 1980 data.

TABLE 7

Data Mean and (Standard Deviation)

Metal	1977	1980
Cd	.28 (±.59)	<.07 (±.15)
Cr	6.68 (±12.08)	17.57 (±24.9)
Cu	2.03 (±1.77)	3.35 (±2.89)
Ni	7.15 (±6.83)	6.34 (±8.44)
Pb	.12 (±.06)	.56 (±1.17)
Zn	3.86 (±8.89)	.26 (±.23)

The standard deviations, in most cases indicate that the data are too random to be predictive using this method.

Probability plots were attempted for cadmium data. Figures 3 and 4 show 1977 and 1980 sample results respectively. It is obvious that there are too few points too randomly spaced to be able to interpolate the angle of the linear relationship. Therefore, more data are needed for this technique to be useful.

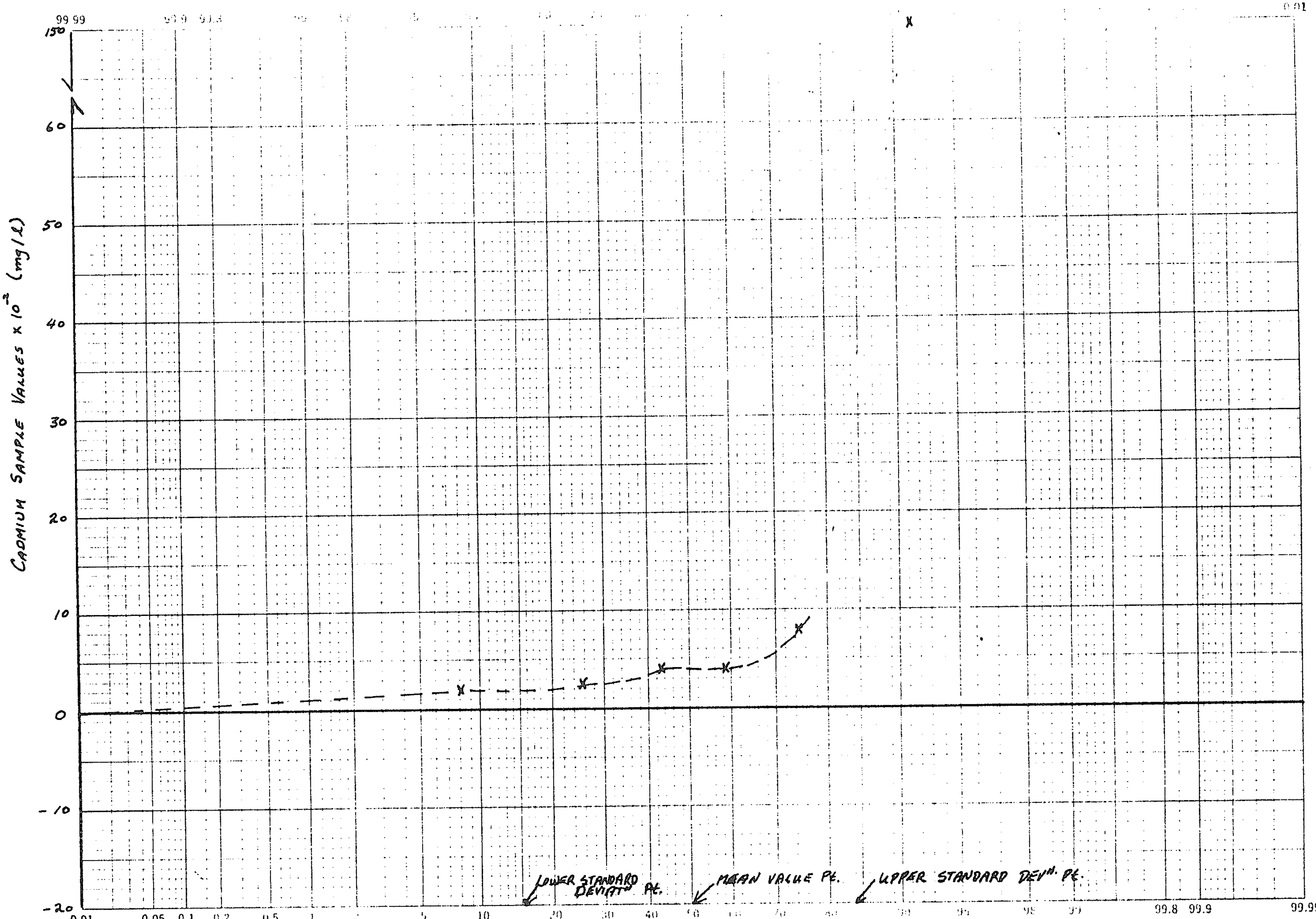

Figure 3: Probability Plot: 1977 Cadmium Sample Results

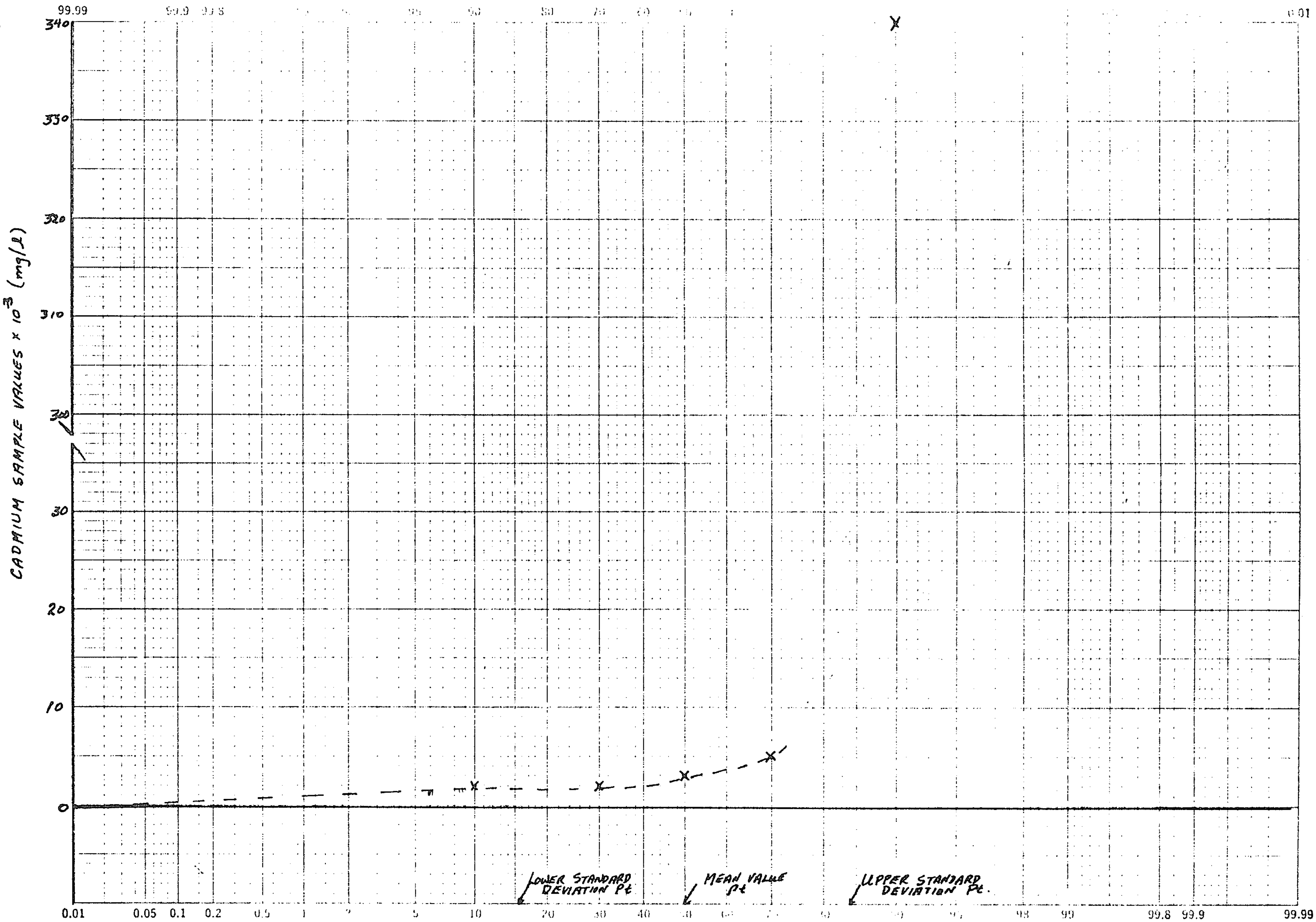

Figure 4: Probability Plot: 1980 Cadmium Sample Results

3.5 RESULTS: THEORETICAL VALUES

Theoretical values were calculated and are enumerated in Table 8. The three values shown for each firm are the minimum, mean and maximum concentration of contaminants in the effluent based on the original minimum, mean and maximum salt concentration in the plating bath. These values have been extrapolated to yearly loading figures using the mean concentration value multiplied by the waterflow (Table 9).

Table 8: Theorical Levels of Contaminants (mg/l/yr)

Firm	Waterflow (l/yr)	Drag-Out Rate	# Rinses	Cadmium	Chromium	Copper	Nickel	Silver	Zinc	Cyanide
A	14,457,169	10	14		1,477.6 1,921.7 2,365.9	256.3° 367.3° 478.3°	438.7 621.0 814.6		82.0° 136.7° 196.5°	512.5° 683.4° 854.1°
B	1,673,031	8	7		14,284 18,577 22,871	1,073.4 1,403.7 1,733.9	6,357.8 9,000. 11,807.3	2,229.4 3,633.0 4,954.1		3,042.6 4,004.2 4,912.8
C	363,702	10	2		16,424. 21,360.8 26,297.5					
D	60,992,886	8, 4•	17	.67• .82• .99•	267.8 348.2 428.7					2.5• 2.7• 3.0•
E	2,473,176	5	3				537.2 760.5 997.7			
F	n.a.	2.5	5		302.8 393.8 484.8		134.8 190.9 250.3			
G	900,163	5	4						1,362.5 1,641.5 1,920.	1,765.5 2,323.0 2,912.0
H	1,383,774	5, 2.5•	8		12,975 16,875 20,775	256. • 355. • 413.5•	3,176 4,496 5,899			131.8• 216.3• 295.1•

° Brass Plating
• Barrell Plating
· Counter-flow rinsing
n.a. as part of a commercial complex
All values are minimum, mean and maximum amounts calculated from min., mean and max. salt concentrations used

Table 9: Theoretical Values and Resultant Loading

Firm	Waterflow (l/yr)	Theoretical Values (mg/l) Cd	Cr	Cu	Ni	Zn	Cn	Yearly Loading (Kg) Cd	Cr	Cu	Ni	Zn	Cn
A	14,457,169		1,921.7	367.3	621	136.7	683.4		27,772	5,303	8,977	1,966	
B	1,673,031		18,577	1,403	9,000		4,004		31,079	2,347	15,057		
C	363,702		21,360						7,768				
D	60,992,886	.82	348				2.7	50	21,225				
E	2,473,176				760.5						1,879		
F	n.a.**		393		191								
G	900,163					1641	2,320					1,477	
H	1,383,774		18,075	335	4,496		216		15,048	463	6,221		
Total (Kg)								50	102,892	8,115	32,134	3,443	
Actual 5 yr average (Kg)								539.7	54,084.5	15,080.6	5,678.5	60,507.9	
%of actual value								9.26%	190%	53.8%	565%	5.69%	

**figures not available as part of commercial complex

The theoretical totals are then compared to the five year average value of total metals received and the resultant percentages shown. The evidence indicates that these theoretical values are not consistent enough to be useful. The factors that make these values uncertain are:

1. the assumption of plating 10 square feet per minute [Graham 1971]. A more preferable measure might be X kilograms per minute. However, no such information has been found, and the people interviewed did not have any comparable measure

2. the stated drag out rate, which is the volume of solution adhering to the workpiece when taken from one tank to the next, measured in units of gallons per 1000 square feet, is directly related to the shape of the workpiece. One rate per shop has been used. There is a direct relationship between drag out and the level of contaminants. The precise value(s) for each shop is unknown

3. the amount of water used in the plant for non-plating purposes has been assumed to be negligible.

The attempt to correlate:

1. sample data for each metal with water flows for each shop

2. theoretical data for each metal with water flows

3. sample values with theoretical values

was fruitless. Total level of contaminants for each shop was correlated with waterflows and the result (Pearson's r=-.05) shows almost no linear correlation exists.

3.6 TOUR OBSERVATIONS

Several similarities among these job shops were obvious as a result of the tours. First, most shops have a small number of production employees, that is, they operate with a production line of eight employees or less. All these smaller shops have not been included in the Wardrop Study (1979) [see Chapter 5] results, or the study of Metal Finishers by EPS(1975) as the smallest shops included in their statistics had five production employees. Statistics Canada must employ the same assumption as they report only four shops in Manitoba in 1977 and six in 1978 [Statistics Canada 1978]. (Outside of metropolitan Winnipeg one plating shop operates in Brandon.) In 1977 there were 11 shops and in 1978 12 shops in Winnipeg (Manitoba 1950-1980 inclusive).

Second, establishments operate in a highly competitive environment. Evidence shows(Manitoba 1950-1980) that over 30 years the number of job shops has remained relatively constant though closer examination of the information reveals that of the firms currently operating only two have been established for ten years or more.

Third, all shops process work manually, even though an automated line is easy to install with reasonable capital cost. Manual operations mean that the drag out rate is extremely variable, and the plating efficiency is very much dependant on the operator. For example, one shop indicated that when one employee left and was replaced by a more careful person, the volume of chemicals used dropped by approximately one-third: another said that after employees took part in a training course, the volume of chemicals used decreased significantly.

Four, all shops except one have continuously flowing rinses, even when no plating is being done. Two shops utilize counterflow rinses while the remainder use simple flowing rinses despite the fact that counterflow rinsing significantly decreases the volume of water used. Given comparable conditions, counterflow rinsing can decrease water flow from 340 litres (75 gallons) to 38 litres (8.4 gallons) per hour [Mohler 1969]. Implementation of a spray rinse, used by one shop, further decreases the volume of water used and halves the drag out rate. Current literature recommends installation of a solenoid valve in the rinse tank, which will control water flow in accordance with a predetermined level of contaminants in the water. In one example [Mohler 1969] a solenoid valve reduced the water flow to only 8 minutes, whereas, uncontrolled it would have flowed 8 hours. This obviously has implications for the efficient use of water, as well as for the economics pertaining to water flow/sewage flow rates.

3.7 MISCELLANEOUS OBSERVATIONS

It is suggested that the plating shops seem to be at the mercy of the chemical companies. Principally two chemical supply houses, both located in Ontario with only a storage warehouse in Winnipeg, supply the ingredients for any process a shop uses. Some of the specification sheets seen by the researcher [Appendix H] recommend a specific quantity of alkaline cleaner III or brightener II, with no indication as to the composition of that particular compound. When contacted the chemical firms indicated the composition of their compounds was proprietary information. Further, the recipies call for all plating and pretreatment baths to be operated at mean salt concentration despite the fact that current literature states that the same plating quality can be achieved using minimum salt concentration and adjusting the current density [Sittig 1978; EPA 1973]. If this was done the volume of chemicals sold would decrease, likely reducing the chemical companies' profit margin. Further, if solutions were operated at lower concentrations the volume of heavy metal contaminants in the rinse waters, and therefore, in the effluent would likely decrease, and the plating shops could decrease their yearly operating costs.

3.8 DISPOSAL

The current means of disposal for everything except tank bottom sludge is the sewer system. When the sludge is cleaned out (every 3-12 months depending on the process and the volume) evidence suggests that it is placed in 45 gallon drums to be hauled away - somewhere.

Chapter IV

EFFLUENT GUIDELINES (LEGISLATIVE REVIEW)

The results presented in the previous chapter must be interpreted within the existing legal framework. Therefore, an examination of relevant Federal, Provincial and Municipal legislation and regulations is presented. As well, an analysis of the Effluent Guidelines and Standards in the USA is included since Canadian regulations often subsequently follow similar patterns.

4.1 FEDERAL LEGISLATION

4.1.1 The Fisheries Act [R.S.C.1970, c.F-14 as am.]

The principal federal water pollution control enactment is the Fisheries Act. By developing sets of regulations to control contaminant discharges of a number of types of industries, the Act has become an important instrument for water quality control. The Act is mainly concerned with the management of fish resources, but as a result of this it also affects the control of pollution in other areas, namely, heavy metal discharges into sewage treatment systems.

The authority to regulate industrial discharges stems mainly from section 33 of the Act. Section 33(2) is the key to the prohibition for water pollution purposes:

> ...no person shall deposit or permit the deposit of a deleterious substance of any type in water frequented by fish or in any place under any condition where such deleterious substance or any other deleterious substance that results from the deposit of such deleterious substance may enter any such water.

Anyone who violates this provision is guilty of an offence and liable, on summary conviction, to a fine of up to $50,000 [s.33(5)]. Each day of continued violation is a separate offence [s.33(6)]. The court may also order the person convicted to refrain from committing any further offence or to cease to carry on activity likely to result in further offences [s.33(7)].

The term "deleterious substance" is defined by the Act [s.33(11)]. This definition has been treated as exhaustive by the courts. It also includes, by virtue of section 33 [11] (c),(d), substances and classes of substances prescribed by regulation. In other words, any substance that becomes the subject of regulation under the Act is by definition a deleterious substance.

The federal government has issued "Metal Finishing Liquid Effluent Guidelines" under the authority of the Minister of Fisheries. Section 1 of the guidelines makes it clear that the guidelines are not to be construed as regulations under section 33 of the Fisheries Act. But the federal government could at any time convert these guidelines into regulations pursuant to section 33 of the Act, making the objectives legally binding on the industry (regulations are legally binding whereas guidelines are not). It should also be noted that failure to comply with the guidelines may mean that the general provisions that prohibit the discharge of deleterious substances has been violated (c.f. section 33, The Fisheries Act).

Section 3 states that these guidelines apply to every metal finishing plant, which would include those plants discharging effluent into a Public Owned Treatment Waterworks (POTW) system. The term "metal finishing plant" is defined by the guidelines, very broadly and would include the electroplating industry.

The objectives of the guidelines are as follows:

1. In any day, total concentrations of each of the following substances in a composite sample must not exceed the following values:

TSS	30 mg/1
Cadmium	1.5
Chromium (total)	1.0
Copper	1.0
Lead	1.5
Zinc	2.0
Nickel	2.0
Cyanide (Oxidizable)	0.1
Cyanide (Total)	3.0

*TSS=Total Suspended Solids

2. The pH of the effluent must not be outside the range of 6.0-9.5 at any time during the discharge.

There are also provisions for a report to be filed with the Minister within 30 days of the end of each month. The report is to contain the values of the effluent composite sample from each plant during that month; that is, the concentrations of each of the substances and parameters considered in the objectives. At the present time, however, no effort has been made by the federal government to collect these data, and the plants involved are under no obligation to provide this information.

The Minister also has the power under the guidelines to exempt certain metal finishing plants from these guidelines [s.2(2)]. This can be done where the effluent has been treated to the satisfaction of the minister at a site outside the plant for the purpose of removing the substances described in the objectives. This would include the treatment by a POTW to remove the materials from the effluent eventually discharged into surface water. This approval will only be given where the off-site facility provides equivalent treatment to that required by the guidelines.

The Minister may also exempt metal finishing plants that are "captive of larger plants which are not intended primarily for surface finishing" [s.2(3) of guidelines].

The guidelines also stipulate the "Analytical Reference Test Methods" which should be used for determining concentrations of substances in liquid effluents (schedule II). But these methods can be modified by the owner if evidence can convince the Minister that the suggested alternate method will still enable the Minister to determine whether the owner is meeting the objectives of the guidelines. Provincial and local governments are free to impose more stringent requirements than the federal guidelines, in which case the more stringent requirements would prevail.

4.1.2 The Environmental Contaminants Act [S.C. 1974-75, c.72]

The Environmental Contaminants Act, which is binding on all provinces, is an attempt to prevent dangerous substances from entering the environment. The Act established a Board of Review to investigate a variety of substances. The Board has been given authority to impose necessary regulations to fulfill the terms of the Act, and categories were established to investigate specific chemicals as the danger level of certain compounds was unknown.

The Canada Gazette Notice of December 1, 1979, stated that cadmium had been put in Category II of the "List of Priority Chemicals - 1979". This list is comprised of "those substances which are being investigated to determine the nature and extent of the danger to human health or the environment and the appropriate means to alleviate that danger". Cadmium is the only chemical on the list relevant to electroplaters.

4.2 PROVINCE OF MANITOBA LEGISLATION

4.2.1 The Clean Environment Act [S.M. 1972, c.76]

Manitoba's principal pollution control provisions are found in the Clean Environment Act and its Regulations. Contamination of air, water and soil in excess of limits prescribed by the Clean Environment Commission(CEC), established under the Act, is prohibited. When the CEC chooses to establish limits for a particular industry it is empowered to hold public hearings at which time the public may make formal submissions.

Section 4 is concerned with contamination of soil:

> No person, either directly or indirectly shall cause, suffer or permit the contamination of soil in excess of prescribed limits.

This is significant as sludge is spread on agricultural land.

The Commission may order any person who, in its opinion, is contaminating the environment to cease [s.14(10)]. Where no action is taken, the Commission may act and charge the person responsible [s.14(12)]. No limits have yet been prescribed for the electroplating industry. All orders of the CEC are subject to appeal to the Minister who can, with the approval of the Lieutenant-Governor-in-Council, quash or vary any order of the Commission, or direct the Commission to issue a different order.

4.2.2 The Public Health Act [R.S.M.1970, c.P210]

The Act empowers the Lieutenant-Governor-in-Council to make regulations and other orders respecting, among other things, the construction, operation and maintenance of sewage systems, treatment plants and water systems [s.34]. To date no regulations have been made under this Act respecting the electroplating industry, or even respecting wastes of any kind entering the sewage system.

4.2.3 The City of Winnipeg Act [S.M.1971, c.105]

Section 454 [1](b)(c)(d) are the paragraphs which concern the electroplating industry. City Council has the power subject to the Clean Environment Act and The Public Health Act to pass by-laws:

> [s.(b)] preventing or restricting, controlling and regulating the discharge into any stream, watercourse, drain, sewer or wastewater system of any deleterious matter, substance or thing, whether liquid or solid, that would be injurious to health, life or property or injure pollute or damage any stream, watercourse, drain, sewer or wastewater system
>
> [s (c)] providing for and regulating and controlling the treatment of any wastewater or other deleterious matter, substance or thing, whether liquid or solid, before it is discharged into any stream, watercourse, drain, sewer or sewer system
>
> [s.(d)] compelling any owner or occupant of land to construct and properly maintain such works as

> the council considers necessary for the proper treatment of any wastewater or other deleterious matter, substance, or thing, whether liquid or solid, before it is discharged into any stream, watercourse, drain, sewer or sewer system and preventing any such discharge where such works have not been so constructed or are not so maintained.

These three subsections of the Act give the Council, by enacting by-laws, very broad powers over effluents entering the sewage system. City Council can pass by-laws to regulate the amount of certain wastes that can be discharged, or even prohibit the discharge of a substance completely. They can also compel an owner or occupant of land to set up treatment facilities to pre-treat wastes prior to discharge to the sewer system. Those sections include the discharge of wastes into public owned waste treatment facilities.

In 1973 the Council passed the "Sewer By-Law 505/73" which consolidated all the previous by-laws and which currently regulates the industrial waste discharges of the City's industries into the city's sewage system. In particular, part four of the by-law is concerned with regulating and licensing the discharge of industrial wastes.

4.3 CITY OF WINNIPEG (MUNICIPAL) REGULATIONS

4.3.1 The Sewer By-Law (505/73)

In order to control discharge of industrial waste, this by-law first prohibits the discharge of these wastes into the sewage system [s.2.4.1]. This prohibition, however, is subject to a licensing plan set out in part four of the by-law at an annual fee as listed in Schedule "B".

The by-law [s.2.4.1(11)] prohibits the discharge of "any industrial waste whatsoever" into any sewer or body of water within the City, subject to the licensing scheme in part four.

"Industrial waste" is defined [s.1.14] in very broad terms and includes any discharges from an electroplating plant.

In order to obtain a license pursuant to part four the following information must be submitted:

1. a chemical and physical analysis of the waste

2. quantity and rate of discharge

3. plans for pretreatment of the waste and "any other detailed information which may be required [s.4.5(2)]".

The designated officer, under the by-law must also conduct tests on the effluent himself to ensure that the requirements of the by-law are met [s.4.5(3)], the designated officer being the Commissioner of Works and Operations, or his designate [s.1.11]. Further, before a license is granted the designated officer can compel the applicant to install, at his own expense, any pretreatment equipment needed to make the sewage acceptable to the designated officer [s.4.5(5)].

Whenever the designated officer feels it is necessary, the person or firm must make tests or install approved monitoring equipment to determine the characteristics of the industrial waste discharged. The results of these tests must be submitted to the designated officer "at such intervals as he may specify" [s.4.7].

At the present time the only parameters controlled by the City are Biochemical Oxygen Demand (BOD) at 300 mg/l, suspended solids (TSS) at 350 mg/l and "significant" amounts of other materials set out in section 4.1. Section 4.1 includes the discharge of industrial wastes which would include electroplating effluent. These above parameters can be exceeded if authorized by license.

A surcharge can be levied on any industry that discharges effluent containing "an appreciable quantity of any prohibited substances contained in Section 4.1. This gives the designated officer the power to conduct further tests on the sewage being discharged and can enter the premises at any time for the purpose of gathering samples of sewage. The amount of the surcharge is based on the amount of the industrial waste discharged and an estimate as to the extra cost necessary to treat this waste.

Violation of the By-Law, upon conviction brings a maximum penalty of a fine of fifty dollars, costs of conviction and thirty days imprisonment.

4.4 OTHER CANADIAN JURISDICTIONS

Other Canadian provinces, Alberta and Ontario are aggressively pursuing environmental protection legislation, hence relevant enactments from these two regions follow.

4.4.1 Alberta

The principal statutes for the control of water pollution in the province of Alberta are the Clean Water Act, the Municipal Government Act, and the Hazardous Chemicals Act along with regulations made pursuant to the above.

At present there is no legislation directed specifically at the effluent of electroplaters. There are, however, various sections of general application in the statutes and regulations which would apply to that industry.

4.4.1.1 The Clean Water Act [R.S.A.1970,c.294]

No maximum permissible concentrations for particular water contaminants are included in the Act or regulations. There is, however, a general prohibition against the deposit of any deleterious substance in any watercourse or surface water or under any conditions where the deleterious substance may enter any watercourse or surface water [s.9(1)].

Presumably this last part would include a firm discharging its effluent into a wastewater treatment works where some of their deleterious substances are entering the surface water from the waste water treatment works.

The definition of "watercourse" in the Act is:

> (i) the bed and shore of a river, stream, lake, creek, lagoon, swamp, marsh or other natural body of water, or (ii) a canal, ditch, reservoir or other man-made surface feature.

"Surface water" means water in a watercourse.

Provision is made [S.3[1](e),(f), and (g)] so that regulations can be passed prescribing the maximum concentration, maximum amount and rate of discharge of a contaminant from a water facility. A "water facility" is defined to include a metal processing plant. Also, any plant or type of operation specified by regulation to be subject to section 4 is included as a "water facility". If a plant exceeds these limits the Director of Pollution Control may issue a "water quality control order" compelling the plant to reduce the rate of discharge of the contaminant or to install equipment to eliminate or control the discharge of the water contaminant. If the person fails to comply with the control order, a "stop order" can be issued by the Minister. Failure to comply with a stop order is an offence which carries a penalty upon conviction of a maximum of $10,000 for each day that the offence continues, or a term of imprisonment of not more than 12 months, or both.

Unfortunately, however, it appears that paragraphs 3[1](c),(f) and (g) do not apply to discharges of contaminants to sewage treatment works. They apply only to a water contaminant being discharged into surface water or a watercourse. Both definitions do not include discharges into sewage treatment works. Unlike section 9(1) they do not apply to a discharge under any condition where the contaminant may enter any watercourse.

Under section 11 of the Clean Water (General) Regulations [Alta.Reg. 35/73] there is a prohibition on the discharge into any watercourse, surface water or reservoir any substance capable of changing the quality of the water or causing water contamination. Again, it is only applicable to a discharge into a watercourse, surface water or reservoir. Reservoir is not defined in the Act or regulations.

Under section 9 of the same regulations the operator or person in charge must report the occurence of any accidental spill or discharge to the Director of Pollution Control within 24 hours of the discovery of the spill, or within 24 hours of the time the spill should have been discovered had the plant been operating efficiently.

Also, within 72 hours of the spill the following details must be submitted to the Director:

1. date and time of the occurance

2. location of the point of the spill

3. composition of the spill

   a) concentration

   b) emmission rate

   c) total weight, quantity or amount

   d) detailed description of the circumstances leading to the spill

   e) steps taken to control or stop the spill

   f) the steps that will be taken to prevent similar future spills.

The penalty for contravention of this section is a fine of not more than $1000 for each day that the offence occurs.

It should be noted that this section applies to any spill or discharge, and is not restricted to a spill or discharge to a watercourse or surface water.

4.4.1.2 The Municipal Government Act [R.S.A.1970, c.246]

The Municipal Government Act [para. 193(b),(c),(d)] reads exactly the same as the City of Winnipeg Act [454[1](b) (c) (d)]. The Municipal Council is given very broad powers to regulate discharges of deleterious substances into their sewage system. The Council can also compel an owner or occupant of the land to set up a treatment plant to pre-treat waste before discharge into a sewage system.

4.4.1.3 Department of the Environment Act [S.A.1971, c.24]

Pursuant to section 17 (g) and (h) regulations can be passed

> ...prohibiting or restricting the manufacture, sale or use of any substance that is or may be detrimental to the quality of the environment by reason of its toxicity or otherwise; or prescribing procedures for the disposal of any substance that is or may be detrimental to the quality of the environment.

To date no regulations have been promulgated in these areas under this Act.

4.4.1.4 Hazardous Chemicals Act [S.A.1978, c.18]

The Minister of the Environment and the Director of Pollution Control are empowered under the Act to control materials considered hazardous, either by toxicity or volume. "Hazardous chemicals" are defined as:

> ...any substance, class of substances or mixtures of substances that is entering or is likely to enter the environment in a quantity or concentration or under conditions that may constitute damage to the natural environment, plant or animal life, or human health.

The control of the hazardous chemical can be exercised at any stage in the life of that chemical. The Minister has the power under the Act to set up a Schedule of Hazardous Chemicals and restrictions governing them. The restrictions that can be applied through regulations include:

> ...prescribing the maximum quantity or concentration of a substance specified in the Schedule

> or forming part of a class of substances specified in the Schedule that may be released into the environment in the course of any commercial, manufacturing or processing activity. [s.16(a)].

No hazardous chemicals are currently scheduled.

4.4.2 Ontario

The two primary statutes for the control of water pollution in Ontario are the Ontario Water Resources Act and the Environmental Protection Act.

4.4.2.1 Ontario Water Resources Act [R.S.O. 1970,c.332 as am]

By this Act, the Minister of the Environment is given supervision of all surface and ground waters of the province [s.31(1)]. These waters are periodically examined to determine whether a pollution condition exists and the causes of that condition.

The purpose of the Act is to:

> ensure that surface waters of the province are of a quality which is satisfactory for aquatic life and recreation.

This is done by describing maximum levels of various pollutants which are allowed in any given sample of surface waters [Ontario 1978]. The starting point for the provincial regulations is the federal guidelines pursuant to the Fisheries Act. The "Metal Finishing Liquid Effluent Guidelines" would apply in Ontario under this Act until the Ontario government sets a more stringent standard.

Provincial water quality objectives have been set by these guidelines for the following metals relevant to the metal finishers:

Cadmium	0.0002 mg/l
Chromium	0.1
Copper	0.005
Iron	0.3
Cyanide	0.005
Nickel	0.025
Silver	0.0001
Zinc	0.03

These are the maximum concentrations allowed in surface water; effluent requirements are set on a case by case basis, looking at any federal or provincial effluent guidelines and the concentration of contaminants in the incoming water. As the density of industry increases, more stringent waste treatment will need to be provided by the industries responsible for the waste.

Also pursuant to this Act the Ontario government has set out "Objectives for the Control of Industrial Waste Discharges in Ontario". Contained in these objectives are maximum concentrations of component heavy metals in wastewater discharges:

Cadmium	0.001 mg/l
Chromium	1.0

Copper	1.0
Lead	1.0
Mercury	0.001
Nickel	1.0
Tin	1.0
Zinc	1.0
TSS	15.0 mg/l > incoming water

The Minister has the discretion to change these criteria. In setting out the criteria for the objectives, the Minister has used authority given under the Water Resources Act, which also gives authority to enforce these criteria.

The basic water pollution provision of the Act is section 32. Every person or municipality that discharges or deposits or permits the discharge or deposit of any material in or near any waters that may impair the quality of such waters is guilty of a summary conviction offence. Penalties range up to $5000 for the first offence, and to $10,000 or imprisonment for up to one year for each subsequent offence. Each day of continued contravention is a separate offence. All that the prosecution need show is that the material had the ability and the potential to cause impairment, and not that the material did, in fact, cause impairment.

This subsection also includes the words "or in any place that may impair the quality of the water of any well, lake, river, pond, spring, stream, reservoir or other water or watercourse". Presumably this would include a discharge into a sewage treatment plant. This prohibition applies equally to municipalities and therefore would apply to a municipal sewage treatment plant.

Section 70(1) also addresses this area. If a discharge of sewage into a sewage works may interfere with the proper operation of a sewage works, the Director can order the person to stop or to regulate such discharge. A person who contravenes such an order is liable to a fine of up to $200 per day. Whether a discharge into a sewage works interferes with the sewage works is at the discretion of the Director. The term "sewage" includes industrial wastes or anything designated as sewage by a regulation made under the Act.

Section 62(1)(i) gives the Minister power to make regulations to regulate and control the content of sewage entering sewage works. Power is also given to the Minster to prescribe standards of quality for sewage and industrial waste effluents [s.62(1)(k)].

4.4.2.2 Municipal Act [R.S.O. 1970,c.284]

Municipalities have the power to pass by-laws for the prevention and abatement of nuisances and regulation of sewage and drainage works. They may also regulate, by by-law the type of sewage or industrial waste that may enter municipal sewers and sewage treatment facilities [s. 354(1), Nos. 71,72,129].

4.4.2.3 Environmental Protection Act [S.O. 1971,c.86]

Ontario's general environment statute is very broad in scope and covers water and sewage systems, water quality, waste management and litter, air contaminants and air quality.

The purpose of the Act is to: "provide for the protection and conservation of the natural environment "[s.2]. Under the Act no one is to deposit into the natural environment any contaminant in an amount in excess of that prescribed by regulations [s.5]. Further, notwithstanding any provision of the Act or regulations, no one shall deposit a contaminant into the natural environment that, among other things causes, or is likely to cause impairment of the quality of the natural environment for any use that can be made of it [s.14(a)]. "Natural environment" is defined as "the air, land, water or any combination or part thereof of the Province of Ontario".

The government has set out "Guidelines for the Treatment and Disposal of Liquid Industrial Wastes in Ontario". The recommended treatment and disposal processes for various categories of hauled, liquid industrial waste is stipulated in Table 1. Metal Finishing Wastes are classified as No. 103 ; cyanides are classed as No. 104. The recommended treatment for classes 103 and 104, when in a sludge or solid, is solidification or disposal in a secure landfill. The recommended treatment for cyanides is alkaline chlorination or electrochemical oxidation. As well, the heavy metals, classified here as "inert organic" can only be disposed of at a landfill with the approval of the Minister of the Environment (that is, where the concentration of metals is greater than 100 mg/l).

The province has also established potential areas for setting up liquid industrial waste treatment facilities and solidification sites.

Anyone may gain standing to prosecute a breach of the Environmental Protection Act, not just the government.

4.5 U.S. ELECTROPLATING REGULATIONS

4.5.1 EPA Guidelines and Standards

Regulations (Effluent Guidelines and Standards: Electroplating Point Source Category; Pretreatment Standards for Existing Sources [EPA 9-7-79 Vol.44-No.175 Book 2 p.52590 40 CFR pt 413]) are promulgated pursuant to section 307 (b) of the Clean Water Act, [33 USC s.1317(b) as am]. This section requires the establishment of pretreatment standards for pollutants introduced into POTW.

The regulation limits the concentrations (or mass) and requires the pretreatment of certain pollutants which may be introduced into POTW operations in the "Electroplating Point Source Category". The purpose is to limit those pollutants which interfere with, pass through, or are otherwise incompatible with the operation of the treatment works. The Clean Water Act requires these standards to be issued.

The compliance date for these regulations is October 12, 1982.

The basis for the effluent limitation guidelines is the "best available technology economically achievable". In connection with this and pursuant to Federal requirements, an "economic impact analysis" was done and the results are included in these regulations.

The effluent guidelines were finalized only after public participation at various hearings held throughout the USA. A summary of some of the comments raised can be found in the regulation.

In general, the regulation establishes "categorical" pretreatment standards, containing specific numerical limitations based on the evaluation of available technologies in the particular industrial subcategory.

For plants with a daily flow of 38,000 litres per day or more, the standards limit indirect discharges of cadmium, chromium, copper, cyanide, lead, nickel, silver and zinc. Total metal discharges are also limited.

For plants with daily process wastewater flow less than 38,000 litres. these standards limit only cadmium, cyanide and lead in order to limit the closure rate in the industry while still contributing to significant environmental improvement.

As the regulation now stands, it is estimated that 20 per cent of the independent metal finishing job shops may close as a direct result of this regulation. This is a result of the Economic Impact Analysis results.

In the United States the Small Business Administration (SBA) has financial assistance available to the industry, which could significantly reduce according to the EPA, the impact of these standards, that is, the job shop closure rate of 20 per cent could be reduced to 5.4 per cent by the use of SBA loan programs by firms that meet the applicable criteria.

Another mitigating factor on the Economic Analysis is the compliance period. The EPA used a one year compliance period for the Economic Analysis when in reality there is a three year period. However, even the EPA admits that the magnitude of the impacts probably will change only slightly due to this factor.

In determining the appropriate levels of technology, the EPA considered various factors, including:

1. total cost of application of technology

2. age of the equipment and facilities

3. process employed

4. engineering aspects of the application of various types of control techniques

5. process changes

6. non-water quality environmental impacts (including energy requirements), and some other factors.

4.5.1.1 Regulation Provisions

The regulation first sets out general monitoring requirements, applicability requirements and processes to follow for an accident.

The regulation then specifically sets out the "pretreatment standards for existing sources" as follows: After October 12, 1982

1. no user introducing wastewater pollutants into a POTW under these regulations shall dilute the wastewater as a substitute for adequate treatment to achieve compliance with the standards

2. for a source discharging < 38,000 litres per day of plating process wastewater the following apply:

Metal	Daily Maximum	30 Day Average
CN	5.0 mg/l	1.5 mg/l
Cd	0.6	0.3
Pb	1.2	0.5

3. for plants discharging 38,000 litres or more per day of plating process wastewater the following apply:

Metal	Daily Maximum	30 Day Average
CN	0.8 mg/l	0.23 mg/l
Cd	1.2	0.5
Cr	7.0	2.5
Cu	4.5	1.8
Pb	0.6	0.3
Ni	4.1	1.8
Zn	4.2	1.8
Total Metals	10.5	5.0

4.6 ENFORCEMENT OF REGULATIONS IN MANITOBA

There is little reason to formulate legislation that cannot be enforced. Thus an integral part of the results must relate to this issue.

First, distinction must be made between a "regulation" and a "guideline". According to the Interpretations Act [R.S.C. 1967-68,c.7,s.2] a regulation includes:

> an order, regulation, order-in-council, order prescribing regulations, rule, rule of court, form, tariff of costs or fees, letters patent, commission, warrant, proclamation, by-law, resolution or other instrument issued, made or established, (a) in the execution of a power conferred by or under the authority of an Act, or (b) by or under authority of the Governor in Council.

A regulation, thus, is legally binding. On the other hand, a guideline

> is not a specific law but a statement indicating what practices will be considered by the Environmental Protection Service to be in compliance with the spirit of the law. Failure to comply with a guideline is not itself an offence; however, it may mean that the law itself is being violated. [EPS 1977].

At the federal level, the Fisheries Act recommends guidelines on daily levels of heavy metals as well as for the pH range of the effluent. Exemption of metal finishing plants from these guidelines by the Minister is only where the effluent has been treated satisfactorily. Since the government could convert these guidelines into regulations, it should do so with a caveat of a six month grace period. The motivation for industry to heed the regulations is adequate, as, for most establishments the fine would be significant, though cooperation is always preferential to the "stick" approach.

The Environmental Contaminants Act names cadmium in its List of Priority Chemicals to be investigated regarding toxicity, though it is not yet possible to prosecute for excessive cadmium levels.

Provincially, Manitoba operates with the Clean Environment Act, first formulated in 1968 though completely changed in 1972. Analysis of primary and secondary sources indicate that the problems of the first Act related to:

1. the CEC was given all necessary powers to act independently but was contradicted by the fact that the CEC consisted entirely of senior civil servants who were not in a position to act independantly. Also, the government must be able to control environmental policy and so the wording of independence of the Commission was an ambiguity

2. the CEC was given no technical staff as it was regarded as a coordinating body through which other government departments would assist

3. the CEC role was supposed to be that of legislator, administrator, enforcer, judge and watchdog which lead to uncertainty as to what was really expected

4. appeal of a decision from the Commission was to the Municipal Board which heard it as a "trial de novo". It was difficult to see how a more authoritative answer to environmental policy could be formulated here instead of by the CEC - a panel of experts

5. the problem of limiting the number of licenses that the CEC had to issue was done by placing provisions in the Act itself instead of by formulating regulations. This led to problems of interpretation

6. The Act stated that public hearings had to be held prior to the issuance of any license. In two years that meant the Commission had issued less than 60 licenses out of a needed 6000.

Advantages of the first Act were that:

1. it dealt with the environment in its totality - air, soil and water which are naturally inter-related

2. it made the preservation of the environment the specific concern of a single authority which was given extensive powers

3. it required public hearings as a normal prerequisite to any decision of importance.

The New Act brought changes such that:

1. the administrative location of the Commission changed from the Department of Health and Social Development to the Department of Mines and Natural Resources

2. the Minister, not the CEC was responsible for the supervision and control of all matters relating to the environment

3. the Act made all orders of the CEC subject to appeal to the Minister who can, with the approval of the Lieutenant- Governor-in-Council, quash or vary any order of the Commission or direct the Commission to issue a different order.

The result is that the Commission now has no teeth and has no incentive to establish an ideal for a reasonable, expedient, environmental policy.

Under the Public Health Act there is the possibility of creating regulations respecting wastes entering the sewage system, but to date no regulations have been formulated even though the Act is ten years old. Currently there is nothing to enforce.

Municipal authorities have broad powers over effluents entering the sewage system under the City of Winnipeg Act. The City can order firms to pretreat their wastes to a specified factor. The Sewer By-Law states, for example, that wastes entering the sewer cannot have a pH outside the range of 5.5-9.0 inclusive. The By-Law also allows for a licensing scheme. The fees however, for a firm are less than $100 annually, though this fee is regarded only as a filing fee.

No regulations have been formulated by City Council with respect to controlling effluent contaminants, as specific recommendations have not been given to them due to insufficient data concerning the point source of contaminants. It is one of the purposes of this study to assist in this way regarding electroplaters.

> Any useful policy regarding waste disposal must have regard to economics.... This is, however, no reason why the ideal should not be defined; indeed such a definition might well help to decide that which, though short of the ideal, is nevertheless acceptable in the circumstances of a case.... The law of diminishing returns applies to the safety in waste disposal as to many other things. [Patrick 1975].

4.7 INCOME TAX AND POLLUTION EQUIPMENT

Economics is an important consideration to industry, and pollution control equipment is an important factor in environmental quality control. Thus, these two spheres meet in the area relating to income tax deductions and payables.

Paragraph 1100(1)(t) of the Income Tax Act was enacted in 1966 to permit a taxpayer to write off, in two years, the entire cost of certain assets acquired to combat the pollution of Canadian waters by industrial waste. In 1971 this provision was extended to apply as well to assets acquired to control air pollution. The period within which eligible assets might be acquired was extended to December 31, 1974, and was later extended to December 31, 1979. In November 1978 this accelerated capital cost allowance was extended indefinitely.

Pollution, in this instance, refers to pollution of any inland, costal or boundary waters of Canada, or any lake, river, stream, watercourse, pond, swamp or well in Canada.

Normally, pollution control equipment would be limited to a 20% annual capital cost allowance on a declining balance basis. In response to increased sensitivity about pollution control, a capital cost allowance can be taken on pollution control equipment at a rate of 50% on a straight line basis.

The result is that a portion of a firm's tax liability is deferred. The government, in effect, makes an interest free, no collateral loan to the company in the amount of the saved tax. The granting of this loan tends to lower the effective cost of the asset and increase the firm's cash flow. This will probably lead firms to undertake a higher level of investment in pollution control equipment than otherwise would have occurred. In effect, the public bears a significant part of the cost of industrial pollution abatement.

The incentive only applies to specific pollution control equipment, thus it introduces a bias against more fundamental process changes, or shifts in production mixtures that might be more effective in controlling pollution, or more effective non- capital intensive techniques.

The provision only applies to firms in existence prior to 1974; the measure is of no assistance to firms that have become established since then.

Possible alternative methods of encouraging pollution control include

> direct grants, loans and the establishment of an effluent charge system. The most obvious method of "encouraging" the reduction of pollution is legislation, accompanied by strict enforcement, restricting the emmission of contaminants into the environment. [Allin 1979].

Chapter V

CRITICAL REVIEW: WASTE HANDLING PROCEEDURES AND POLICIES

5.1 WARDROP INTERIM REPORT

The Interim Report of the first major study reflecting an inventory of hazardous wastes which included Manitoba was released in January 1979 by W.L. Wardrop & Associates Ltd.. The firm had been commissioned by the Environmental Protection Service to compile an inventory of hazardous materials in the Northwest Region of the Department of Fisheries and Environment Canada which encompasses northwest Ontario, Manitoba, Saskatchewan, Alberta and the Northwest Territories. The Report states that:

> the proper disposal of these hazardous wastes is a major environmental problem. Current disposal practices are inadequate and no economical, accessible and environmentally acceptable disposal facilities exist for the proper disposal of hazardous wastes in the Region.

The Report further states that "at least 500 million Imperial gallons (2273×10^6 litres) of hazardous material are annually discharged to the municipal sewer systems in the Northwest Region". The data are listed by numerous broad categories (solvents, tank bottom sludges: see Appendix C) by region, which is considered to be in an unusable form for municipalities.

The information summarized, however, reflects the form of questionnaire used and the information sought may have been unknown to the respondent. The Report states that "initial responses often ignored significant hazardous wastes because the generator assumed erroneously that the current use of routine waste management techniques to dispose of the waste is satisfactory".

With respect to electroplaters, the Wardrop Report states that "the major waste types generated by electroplating operations consist of spent cleaning, pickling and stripping solutions, waste plating solutions, rinse waters and sludges and electroplating residues". Specifics, however, are not given. The lack of this type of detailed information is a serious weakness and must be available, not only in this area but in other industries as well, for the mutual benefit of the industry, the workers, civic authorities and those who must deal with emergency situations.

5.2 REID, CROWTHER REPORT

A Report on Hazardous Wastes in Alberta: An Inventory and Review of Practices and Technology was released in March 1980 by Reid, Crowther & Partners Limited (Calgary). This Report was done for the Waste Management Branch of Alberta Environment. The purpose of the Report was:

> to provide background information to the Environment Council...to assist in the Public Hearings which have been called by the Government of Alberta on the issue of Hazardous Waste Manage-

> ment. The specific objectives...are to upgrade existing inventory data. and describe and evaluate transportation and disposal practices in the Province.

The Report states, generally, that there is a direct correlation between the level of production and wastes generated. As well, an increase in stringent legislation means an increase in the amount of waste that must be handled in a specific manner.

With respect to metal finishing industries, the Report states that this industry is a "primary source of metal sludges, oils, solvents, contaminated soil and tank bottoms, [and] these wastes present significant environmental hazards".

The Report recommends the following legislation:

1. implementation of a manifest system for tracking wastes
2. the licensing of hazardous waste haulers
3. stricter licensing of landfills
4. manditory recycling of specific waste streams
5. penalties of a magnitude sufficient to discourage illegal disposal.

5.3 PROVINCE OF ALBERTA

The Environment Council of Alberta is pursuing the modification and updating of existing policies for the control, management and disposal of hazardous waste [Alberta 1979]. The report of the Hazardous Waste Management Committee contains three recommendations, namely:

1. implementation of appropriate procedures for the conversion of industrial wastes to non-objectionable forms should begin immediately

2. an integrated waste treatment system consisting of the best available technology as demonstrated in Europe should be established in Alberta

3. the Alberta Government should play a leadership role in the management of industrial wastes through the development of comprehensive legislation, and in the establishment of waste management facilities...for the protection of the environment and public health [Alberta 1979].

The Committee has identified a spectrum of related issues (public awareness and involvement, feasibility, risk and financing, transportation and transboundary movement, legislation, siting, environmental impact, definition and classification) and offers recommendations.

The Committee regards none of the issues as insurmountable in light of existing technology. The classification of wastes is adopted from the National Code on Dangerous Goods (associated with the Canada Transportation of Dangerous Goods Act) which are:

Class 1 - Expolsives

Class 2 - Gases

Class 3 - Flammable Liquids

Class 4 - Flammable Solids

Class 5 - Oxidizing Substances

Class 6 - Poisons

Class 7 - Radioactive Materials

Class 8 - Corrosives

Class 9 - Miscellaneous.

Characteristics of wastes have been classified into eleven groups, and emergency and response procedures have been outlined. Even the usually difficult area of financing has been ascertained with the conclusion that:

> due to uncertainities asociated with interest rates and material shortages. the costs of construction and operation cannot be determined with accuracy. Instead concepts such as contingency allowances, expected values and sensitivity analysis must be incorporated into estimates to determine commercial risk [Alberta 1979].

5.4 CANADIAN WASTE MATERIALS EXCHANGE: ONTARIO RESEARCH FOUNDATION

The Ontario Research Foundation operates a Waste Exchange Centre (CWME), where for a nominal fee anyone can both submit and receive information relating to unwanted substances.

The objectives for the Exchange are:

1. to save valuable raw materials
2. to save energy by not having to process raw materials
3. to avoid environmental damage:
   a) in the winning of raw materials and energy
   b) in the avoidance of having to dispose of waste [Laughlin 1980].

The factors, according to the CWME, in favour of reuse are:

1. increases in raw materials costs
2. substantial increases in energy costs
3. substantial increases in waste disposal costs.

Since its inception in October 1977 the Exchange has listed over 500 wastes per year, representing 5000 participants and has achieved a transfer rate of 14.5% (137,622 tons per year). This represents a recovery of value of approximately $4.12 million per year [Laughlin 1980].

The CWME states that industrial wastes should be handled by:

1. reducing the amount of waste produced

2. re-use as much as possible (the role of the CWME)

3. treat and dispose in an environmentally sound manner

4. store or dump the remainder.

According to Bulletin 15 (May 1980) there are firms desiring metal sludges and waste acids, but there are no supplies available. This may be due to either the logistical problems associated with our country, or to the current mismatch of supply and demand. The Exchange has, since its inception, listed: 40 acid wastes and transfered 3; 153 metallic wastes and transfered 19.

5.5 ENVIRONMENTAL PROTECTION AGENCY (USA)

The Environmental Protection Agency (EPA) has an Office of Solid Waste Management, which is pursuing the spectrum of hazardous waste management issues. The U.S.Congress has assisted by passing The Resource Conservation and Recovery Act [90 Stat.2795] and the Toxic Substances Control Act [90 Stat.2003]. These Acts, along with accompanying regulations, offer the means of knowing and controlling all aspects of waste management.

The EPA has examined four possible classification systems for dealing with hazardous wastes [EPA(SW-183c/11) 1979]. First, there is classification by source where wastes are grouped "according to the type of manufacturing process of which they are by-products". Second, classification of wastes by disposal method where wastes are grouped "according to the specific type of process used to dispose of or treat the waste" has been suggested. Third, classification of wastes by chemical properties groups wastes "according to their specific physical or chemical properties" (acid, alkaline, oxidizer). Fourth, classification of wastes by associated hazard has wastes grouped "according to the type of hazard the waste poses" (flammable, explosive, corrosive). Advantages and disadvantages for each of these classification systems were investigated (see Appendix D) to identify the system which would be the most comprehensive for dealing with all wastes now and in the future. EPA chose, as most preferable for the handling of wastes, classification by associated hazard. This area was then further subdivided for purposes of identification into:

1. origin of hazard

2. mode of transmission

3. environment of hazard

4. mode of attack

5. type of hazard [EPA 1979].

It is suggested that an inventory would be best accomplished by means of classification of wastes by source with reference to specific industrial sectors. Once an inventory has been compiled, management of the wastes would best be accomplished according to classification by associated hazard.

Another benefit of compiling an inventory by means of industrial sector is that regulations are often made pertaining to particular industries and the cross-referencing thus provided by utilizing the two methods of classification would be advantageous.

In 1978 the EPA issued regulations concerning industrial wastes discharged in public sewer systems: the electroplating industry was the first to be regulated. As a result, extensive research has been done on the process, wastes and materials recovery. The literature is current and detailed.

Concerning the issue of monitoring wastewater with its related costs, the EPA concluded that this type of program was desirable:

1. to assure responsible regulatory agencies of the manufacturer's compliance with effluent requirements and implementation of a discharge permit

2. to maintain sufficient control of in-plant operations to prevent violations of permit specifications

3. to develop necessary data for the design and operation of wastewater treatment facilities

4. to insure cognizance of product and material losses to the sewer [EPA 1973].

Costs to industry of monitoring are a major deterrent though evidence suggests that long term benefits accrue from the information gained respecting the mass materials balance. Costs can be controlled by carefully determining the parameters to be measured; for electroplaters this refers to chemical oxygen demand, oil and grease, heavy metals, suspended solids and cyanide [EPA 1973]. The information gained from waste monitoring can be used as a measure of the continued efficiency of the operation.

Chapter VI

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY

The City of Winnipeg treats its domestic and industrial sewage. The resultant sludge from this treatment is used as a soil conditioner on agricultural land. The presence of heavy metals in this sludge however, is a limiting factor. Municipal officials know the quantity of cadmium, chromium, copper, lead, nickel and zinc arriving at its treatment facility, but do not have sufficient specific data on the point of origin.

This study investigated the metal coating industrial sector (SIC 304) to discover what liquid and solid wastes constituted the effluent, what shops were generally doing with wastes, and what they should be doing.

Outlined in detail are the several electroplating processes, the resultant wastes, and the toxicity of each of the metals plated. Further, details of relevant Federal legislation (The Fisheries Act, The Environmental Contaminants Act), Provincial legislation (The Clean Environment Act, The Public Health Act, The City of Winnipeg Act) and Municipal by-laws (The Sewer By-Law) are outlined. As well, other jurisdictions (Alberta, Ontario, United States) were examined for purposes of comparison.

Reports which dealt with electroplaters were critiqued, (Wardrop, Reid-Crowther, EPA, EPS) and briefly commented on, especially in the area of recommendations.

Research was implemented by means of conducted tours of nine of the fourteen job shops in Winnipeg. The managers were generally receptive, and the tour situation enabled first- hand observations of the actual work situation, and afforded opportunity to notice the plating schemes, confirm plating bath concentrations, check leaks, overflows, the type of floor, fans, drag-out tanks,and disposal. All shops processed work manually, most with simple rinse systems, though two used counterflow rinsing, and one utilized spray rinsing. None of the shops used current processes (acid baths instead of cyanide baths: minimum salt concentrations instead of mean concentrations), nor recycled nor reclaimed any materials, except gold, or implemented water saving devices (solenoid valves, spring-loaded valves, ion exchanger).

Samples were taken by the City of Winnipeg Waterworks and Waste Disposal Division using a composite sample method during one working day. Sample results from 1977 and 1980 are shown in Table 4. These results were totalled and compared to the 5 year average value for each heavy metal, and the sample percentages of the total received are enumerated in Table 5. In all cases the amount contributed by electroplaters is less than 30%.

Theoretical levels of contaminants were calculated using waterflow volume, the number of rinses and the drag out rate. (Table 8). Reasons for the high values are outlined in the text.

The two methods for handling wastewater contaminant statistics are the arithmetic mean and standard deviation (Table 7), and the geometric interpolation of the same data (Figures 3 and 4).

6.2 CONCLUSIONS

1. Nine of 14 electroplating job shops were toured. Wastes generated are heavy metals (cadmium, chromium, copper, lead, nickel and zinc), cyanide, acids and alkaline solutions. Currently these substances are released, generally untreated, to the sewer system.

2. Sampling results of heavy metals taken in 1977 and 1980 are averaged and then extrapolated to represent the entire industry. The evidence indicates that the electroplaters contribute the following percentages to the Municipal influent: cadmium 29.26%, chromium 10.02%, copper 2.38%, lead <1.32%, nickel 13.44% and zinc .028%.

3. The attempt to correlate actual and theoretical values of heavy metal contaminants was not successful (Pearson r = -.05).

4. Sample values are from 1977 and 1980 and the theoretical values represent 1980. The water flow has remained constant, but there has been a compositional shift in plating over this three year period. This explains some differences in sample values obtained.

5. The theoretical values should be considered the maximum level of a particular contaminant in the effluent due to the assumptions made, particularly drag out rates.

6. The data are too inconclusive to be useful for predicting levels of wastewater contaminants. To utilize either statistical techniques for sample data, more values are needed because of the great variability of contaminants in the wastewater. Toxicity is a matter of concentration as well as composition.

7. There is little interest in conserving : water. chemicals or wastes. An obvious difference in attitude and care in plating is observed with those who plate gold and silver. In those

instances there is no waste and periodically plating baths are sealed and sent to Ontario where the metal ions are reclaimed and a rebate sent to the platers. The motivation, however, is clearly economic with gold in excess of $600.00 per ounce and silver in excess of $16.00 per ounce "One man's garbage is another man's gold" [Laughlin 1980].

8. Current legislation seems adequate when combined with problems of enforceability. Evidence in the United States indicates the great difficulty in enforcing more stringent regulations. Also, the evidence indicates that a significant percentage of contaminants may come from non-enforceable situations (cadmium on roads from tire wear).

6.3 RECOMMENDATIONS

1. Information on improved processes and technology should, through an authorative source be available to industry, namely:

   a) Process substitution from primarily high-cyanide plating baths to low-cyanide processes yields a reduction of up to 90% cyanide. A low-cyanide bath, especially for zinc is preferable to a non-cyanide bath as an acid bath requires chelates and sequestering agents to maintain zinc in solution, and these agents pose a more difficult task in the handling of the effluent. The aim always is to solve problems, not substitute one problem for a more complex one

b) Operation of the plating baths at minimum salt concentration decreases contaminant concentration in the effluent and saves chemicals, and hence decreases operating costs of the job shops. For example, a decrease of nickel sulphate and nickel chloride in a nickel plating bath from mean to minimum concentration means a saving of 431 kilograms (950 lbs) of nickel sulphate and 170 kilograms (375 lbs) of nickel chloride per year (based on 250 days operation, 12 hours per day, drag out rate=1.5, processing 600 square feet per hour [EPA 1973])

c) It is possible to decrease dragout volume by any of the following:

i) reducing the workpiece withdrawal speed

ii) allow greater drainage time over the process tank

iii) decrease chemical concentration of solutions which decreases viscosity, which in turn decreases dragout

iv) operate plating baths as hot as possible without affecting plating quality, as the increase in temperature reduces viscosity further reducing dragout

v) determine the most efficacious position which will maximize dragout.

d) It is equally important to use water as efficiently as possible in rinsing phases and this can be accomplished by any of the following:

i) counterflow rinsing

ii) multiple tank rinsing

iii) spray rinsing

iv) chemical rinsing

v) agitation of the workpiece and/or rinse water

vi) increasing temperature of the rinse water

vii) recirculate and reuse water by means of an ion exchange though it is admitted that this is more expensive and may not be a beneficial cost to a small shop.

2. Further reduction of wastewater pollution by more sophisticated, and hence more capital intensive means is available from several sources [EPA 1979; Sittig 1978; Yehaskel 1979].

3. More frequent samplings, of at least a few shops, by either Municipal officials or as a requirement for next year's license could be undertaken. This increase in data would make the probability plots more useful for predictive purposes.

4. Recommendations could be presented to the Federal government to make changes in the Income Tax Act to more expeditiously encourage consideration of the environment. This means setting standards of environmental quality improvement prior to having an allowable deduction, and some means of ensuring that the deduction facilitates pollution control not simply acts as a non-collateral loan.

5. Other industrial sectors could be investigated to determine the quantity of heavy metals contributed to City influent.

Appendix A

GLOSSARY OF TERMS AND ACRONYMS

ANODIZING: Anodic treatment of metals to form an oxide film of of controlled properties. [Lowenheim 1974]

BARREL PLATING: Mechanical plating or cleaning in which the work is processed in bulk in a rotating container. [Lowenheim 1974]

BRIGHT DIP: A solution used to produce a bright surface on a metal. [Lowenheim 1974]

BRIGHTENER: An addition agent which improves the brightness of the deposit over that which is obtained without its use. [Lowenheim 1974]

CHELATING COMPOUND: A type of complex ion or molecule in which the coordinated group occupies at least two positions in the coordination sphere. [Lowenheim 1974]

CHELATING AGENT: A compound capable of forming a chelate compound with a metal atom or ion. [Lowenheim 1974]

CEC: Clean Environment Commission, Province of Manitoba.

CLEANING: The removal of grease or other foreign material from a surface. [Lowenheim 1974]

Alkaline: Cleaning by means of an alkaline solution.

Anodic: Electrolytic cleaning in which the work is the anode.

Cathodic: Electrolytic cleaning in which the work is the cathode.

Electrolytic: Alkaline cleaning in which a current is passed through the solution, the work being one of the electrodes.

Emulsion: Cleaning by means of solutions containing organic solvents, water and emulsifying agents.

Soak: Alkaline cleaning without the use of current.

Solvent: Cleaning by means of organic solvents.

CONTACT PLATING: Deposition of a metal without the use of an outside source of current, by immersion of the work in solution in contact with another metal. [Lowenheim 1974]

DEGREASING: The removal of grease and oils from a surface. [Lowenhein 1974]

Solvent: Degreasing by immersion in liquid organic solvent.

DRAG-OUT: The solution that adheres to the objects removed from a bath. [Lowenheim 1974]

DRAG OUT RATE: The amount of drag-out measured in gallons per 1000 square feet.

ELECTRODEPOSITION: The process of depositing a substance on an electrode by electrolysis. [Lowenheim 1974]

ELECTROLESS PLATING: Deposition of a metallic coating by a controlled chemical reduction which is catalyzed by the metal being deposited. [Lowenheim 1974]

ELECTROPLATING: The electrodeposition of an adherent metallic coating on an electrode for the purpose of securing a surface with properties different from those of the base metal. [Lowenheim 1974]

EPA: Environmental Protection Agency; United States Government.

EPS: Environmental Protection Service; Government of Canada.

ESTABLISHMENT: The smallest unit that is a separate operating entity capable of reporting all elements of basis industrial statistics. [SIC].

GALVANIZING: Application of a deposit of zinc, usually on steel or a ferrous basis metal. [Lowenheim, 1974]

HARD CHROMIUM: Chromium plated for engineering rather than decorative applications. [Lowenheim 1974]

HAZARDOUS WASTE: Any waste or combination of wastes which pose a substantial present or potential hazard to human health or living organisms because such wastes are non-degradable or persistent in nature or because they can be biologically magnified, or because they can be lethal, or because they may otherwise cause or tend to cause detrimental cumulative effects. [EPA 1975].

INDUSTRY: A group of operating units including both primary industries and service industries. [SIC].

METALLIZING: (1) The application of an electrically conductive metallic layer to the surface of non-conductors.

(2) The application of metallic coatings by nonelectrolytic procedures such as spraying of molten metal and deposition from the vapour phase. [Lowenheim, 1974]

PICKLE: An acid solution used to remove oxides or other compounds from the surface of a metal by chemical or electrochemical action. [Lowenheim 1974]

Anodic Pickling: Electrolytic pickling where the metal is treated at the anode.

Cathodic Pickling: Electrolytic pickling where the metal is treated at the cathode.

POTW: Public Owned Treatment Waterworks.

SIC: Standard Industrial Classification.

STRIKE: (1) A thin initial film of a metal to be followed by other coatings. (2) To plate for a short time at a high initial current density which is then reduced to the normal operating current density. [Lowenheim 1974]

Appendix B

INDUSTRIAL SECTORS CONTACTED

Sector	No. Called	No. Plating
Aircraft Servicing & Maintence	3	1
Aluminum Fabrication	2	0
Auto Body Repair & Painting	4	0
Auto Repair & Servicing	1	0
Awnings & Canopies	4	0
Bakers Supplies	1	0
Boat Builders	1	0
Bolts & Nuts	3	0
Brakes Mfg & Distributors	1	0
Brass	1	0
Buses Distrib & Mfg	2	0
Bushings	1	0
Castings	3	0
Coating	1	0
Copper	2	0
Crankshaft Grinding	3	1
Doors	2	0
Drive Shafts	1	0
Electric Equipment Mfg	2	0

Fans Industrial & Commerc.	1	0
Farm Equipment Mfg.	3	0
Furniture Mfg	3	0
Glass & Aluminum	2	0
Gunsmith	2	0
Industrial Equipmemnt & Supp.	1	0
Iron Work	2	0
Jewellers	6	5
Kitchen Equipment	2	0
Ladders	1	0
Laundry Equipment	1	0
Lighting Fixtures	2	0
Machine Shops	3	0
Metallizing	3	0
Nameplates	2	1
Nickel	1	0
Office Furniture Repair	3	0
Sheet Metal Work	2	0
Silver Smiths	2	1
Tinsmiths	1	0
Tubing - metal	2	0
Wire Products	3	0

Appendix C

SUMMARY OF WARDROP INVENTORY RESULTS BY WASTE CATEGORY

WASTE	REPORTED VOLUME	PROJECTED VOLUME*	VOLUME FOR TREATMENT
Acid Solutions	2,600 MIGY	5,700 MIGY	10 MIGY
Alkaline Solutions	2,800 MIGY	23 BIGY	28 MIGY
Contaminated Soil and Sand	280 BPPY	6,800 BPY	2.8 MPPY
Drilling Mud	380 MPPY	14 BPPY	NONE
Oily Wastes	28 MIGY	450 MIGY	14 MIGY
Paint Sludges	840,000 IGY	970,000 IGY	NONE
Pathological	SOLID 260,000 PPY	---	>300,000 PPY
	LIQUID 440,000 IGY	---	>500,000 IGY
Solvents	870,000 IGY	5.9 MIGY	4.6 MIGY
Oil/Solvent Mix	340,000 IGY	4.8 MIGY	4.8 MIGY
Pesticides	31 MIGY	31 MIGY	100,000 IGY
Tank Bottom Sediment	400,000 IGY	1.7 MIGY	10,000 IGY
Tetraethyl Lead Sludges	3,000 IGY	42,000 IGY	42,000 IGY
Aqueous Chemical Wastes	2.7 BIGY	31 BIGY	5 MIGY
Oil-Based Chemical Wastes	100,000 IGY	500,000 IGY	500,000 IGY
Solid Chemical Wastes	1,100 MPPY	5,900 MPPY	87,000 PPY
Heavy Metal Wastes	15 MIGY	---	---
Aqueous Electrolyte	530 MIGY	3,000 MIGY	NONE
Photographic Wastes	110,000 IGY	1.0 MIGY	1.0 MIGY
Ink Wastes	80,000 IGY	100,000 IGY	100,000 IGY
PCB	1,500 IGY	5,000 IGY	5,000 IGY

* Reported Volume Plus Extrapolated Estimate for Non-Respondent Firms

BIGY = Billion Imperial Gallons/Year
MIGY = Million Imperial Gallons/Year
IGY = Imperial Gallons/Year

BPPY = Billion Pounds Per Year
MPPY = Million Pounds Per Year
PPY = Pounds Per year

Appendix D

FOUR WASTE CLASSIFICATION SYSTEMS (EPA)

D.1 CLASSIFICATION BY SOURCE

D.1.1 Advantages

1. SIC codes exist for a wide range of industries which are potential hazardous waste producers

D.1.2 Disadvantages

1. There are a large number of waste sources. This would lead to a large number of categories.

2. It would be very difficult to consolidate categories. If one did consolidate, so many generalities would be introduced into the classification that they would not be useful.

3. Some categories are not necessarily consistent with respect to chemical physical or hazardous properties. In other words, it is not possible to characterize uniquely a source. Therefore, it would not be possible to specify standards for contingency plans which would apply to it.

4. More specific SIC categories which relate to waste types are not available.

D.2 CLASSIFICATION BY DISPOSAL METHOD

D.2.1 Advantages

1. These type classes relate directly with facility type (by definition). Thus a large number of facility/event pairings will be not applicable. A smaller number of pairings will be less complex when related to contingency plan standards. The result will be easier to comprehend.

D.2.2 Disadvantages

1. The classifications for the most part do not relate to the types of hazards associated with a waste. As such, it is difficult to relate contingency plan standards to them.

D.3 CLASSIFICATION BY CHEMICAL PROPERTY

D.3.1 Advantages

1. A large amount of physical and chemical property data exists for pure materials.

2. Some chemical properties relate to the hazards associated with a substance. Thus, for these

categories a relationship to contingency standards can be made.

D.3.2 Disadvantages

1. Most wastes are not pure compounds. Although much data exists on the complex wastes, it is not necessarily applicable to waste streams.

2. Many properties do not relate to hazard categories. Therefore, even if the properties were defined for waste, the properties could in many cases not be related to specific contingency plan standards.

3. Chemical properties for the most part do not relate to "events" or "facilities".

D.4 CLASSIFICATION BY ASSOCIATED HAZARD

D.4.1 Advantages

1. Hazard categories, by definition, relate to the hazards associated with a waste. Therefore, these categories relate very well to contingency plan standards. This relationship is a primary objective to the classification process.

2. Hazard categories correlate well with event types.

D.4.2 Disadvantages

1. Hazard categories do not correlate to facilities.

2. A large number of properties fall into several areas associated with hazards. All of these must be considered simultaneously, requiring a large number of categories. In order to be useful, they will therefore have to be consolidated, which may introduce some undesired generalization.

Appendix E

PLATING INTERVIEW QUESTIONNAIRE AND RESULTS SUMMARY

Firm: ______________________

Date: ______________________

I. SIZE OF OPERATION:

1. Types of electroplating done: Ag Au Cd Cr Cu Brass Ni Pb Sn Zn

   electroplating __________ electroless ______________

2. Years of operation _______ Number of employees ________

3. Approximate number of accidents per year _____ Cause ________

4. Water flow _______ cu ft per ______; sewage flow ________

5. Do you regularly test your baths and rinse water for: Ph _____ contaminants ______ sludge ________

6. How often do you clean out tank bottom sludge ________. What is done with the sludge ______________________

II. PRETREATMENT:

7. What types of pretreatment are usually done:

   a) mechanical ______

   b) degreasing _____ what solvent ______________

      concentration ________________

   c) scaling _____ what acid ____________________

      concentration ________________

   d) pickling: acid dipping ______ acid? __________

      concentration ________________

   e) caustic dipping _____ what base ____________

      concentration ________________

   f) striking ______ what bath ___________________

      which part in scheme ___________

   g) catalysts _____ what _______________________

   h) organic additives? _____ what ______________

   i) wetting agents _____ what ones ______________

. . .

III. SEQUENCE:

IV. PLATING:

a) CADMIUM PLATING:

i) CN bath: CdO ____ Cd ____ NaCN ____ NaOH ____ Na_2CO_3 ____

OR

ii) Fluoborate bath: $Cd(BF_4)$ ____ Cd ____ NH_4CN ____

Boric Acid ____ Licorice ____

iii) Additives? ______________ Catylists? ___________________

b) CHROMIUM PLATING:

i) H_2CrO_4 ____ H_2SO_4 ____ Fluoride ion ____

temp. (43-49^{o}C) ____

c) COPPER PLATING:

i) Acid Bath: $CuSO_4$ ____ H_2SO_4 ____ $Cu(BF_4)_2$ ____

HBF_4 ____

OR

ii) CN bath: CuCN ____ NaCN ____ Na_2CO_3 ____ NaOH ____

Rochelle Salt ____

d) ZINC PLATING:

i) Cyanide bath: ZnCN ____ NaCN ____ NaOH ____

NaPolysulfide ____

OR

ii) Non-cyanide bath: Zn Pyrophosphate ____

Chelating agents (tetraNaPo_4,EDTA etc) ____

iii) Acid bath: $ZnSO_4$ ____ NH_4Cl ____ $NaC_2H_3O_2$ ____

Glucose ____

. . . Cont'd.

iv) Mercury bath: ZnCN ____ NaCN ____ naOH ____
Mercuric Oxide ____

e) NICKEL PLATING:

i) Watts bath: $NiSO_4$ ____ NiCl ____ NiSulfamate ____
$Ni(BF_4)$ ____ Ni ____ Boric Acid ____
Organic agents ____

f) LEAD PLATING:

Pb ____ Fluoboric Acid ____ Boric Acid ____

g) Do you treat solutions before disposal? __ How? __________

____

h) How often do you dump baths? ______________________

____

i) Size of bath tanks ______________________

V. RINSING:

a) Volume of rinse tank ______________________

b) Which rinse system used? single __ multiple __ counterflow __
separate acid/alkali rinse __ combined acid/alkali rinse __
separate pretreatment rinses __

c) Rate of flow in rinse tanks ______________________

d) Water flow is controlled manually ______ automatically ______

e) What is concentration of contaminants in rinse tank __________

f) What chemicals are added to rinse bath ______________

g) What is drag-in rate _______ drag-out rate __________

h) Is there any type of recovery system for either plating or rinsing? ______________________

i) Is rinse water treated to recover chemicals ______________
metals ______________________

j) How often do you discharge tanks ______________

. . . Cont'd.

VI. TREATMENT OF EFFLUENT:

a) Do you treat effluent before disposal ____ How ____________

____

b) Do you destruct oxidizable Cyanide ____ How? ____________
(alkaline chlorination?)

c) Do you reduce hexavalent Cr? ____ How? ____________

d) Do you precipitate metal ions? ____ How? ____________

e) Do you settle suspended solids? ____________

f) Do you know pH of effluent? ____________

g) Do you test your effluent? ____ How often ____ For what ____

h) How much sludge is produced yearly ____________

i) Are tanks or streams filtered? ____ What is done with the solids collected? ____________

VI. POST TREATMENT OF METAL

a) What processes are employed:

i) phosphate coating ____ Metal coating ____ Cn hardening ____
chromate conversion coating ____

VII. MISCELLANEOUS:

a) Type of floor ____________

____

b) ANY VISIBLE PIPE LEAKS? ____________

c) Overall impression of operation ____________

____

____

PLATING INTERVIEW QUESTIONNAIRE

Firm: SUMMARY

Date: ______

I. SIZE OF OPERATION:

1. Types of electroplating done: Ag 3, Au 1, Cd 2, Cr 7, Cu 6, Brass 3, Ni 5, Pb, Sn 3, Zn 2, Al 1

electroplating ✓ ______ electroless ✓ ______

2. Years of operation ______ Number of employees 2/3/3/3/5/8/8/26/35

3. Approximate number of accidents per year ______ Cause ______

4. Water flow ______ cu ft per ______; sewage flow ______

5. Do you regularly test your baths and rinse water for: Ph yes 2 ~~no~~ 8 contaminants ______ sludge ______

6. How often do you clean out tank bottom sludge ______.
What is done with the sludge ______

II. PRETREATMENT:

7. What types of pretreatment are usually done:

a) mechanical 7

b) degreasing 5 what solvent eg. Dyanadet
concentration ______

c) scaling 1 what acid HPO_3
concentration ______

d) pickling: acid dripping 9 acid? HCl
concentration ______

e) caustic dripping 4 what base ______
concentration ______

f) striking 6 what bath ______
which part in scheme ______

g) catalysts ______ what ______

h) organic additives? 3 what eg. glucose

i) wetting agents 1 what ones ______

. . .

III. SEQUENCE:

IV. PLATING:

✓a) CADMIUM PLATING:

✓i) CN bath: CdO ____ Cd ____ NaCN ____ NaOH ____ Na_2CO_3 ____

OR

✓ii) Fluoborate bath: $Cd(BF_4)$ ____ Cd ____ NH_4CN ____

Boric Acid ____ Licorice ____

iii) Additives? ____________ Catylists? ________________

✓b) CHROMIUM PLATING:

i) H_2CrO_4 ____ H_2SO_4 ____ Fluoride ion ____

temp. (43-49°C) ____

✓c) COPPER PLATING:

✓i) Acid Bath: $CuSO_4$ ____ H_2SO_4 ____ $Cu(BF_4)_2$ ____

HBF_4 ____

OR

✓i) CN bath: CuCN ____ NaCN ____ Na_2CO_3 ____ NaOH ____

Rochelle Salt ____

✓d) ZINC PLATING:

✓i) Cyanide bath: ZnCN ____ NaCN ____ NaOH ____

NaPolysulfide ____

OR

ii) Non-cyanide bath: Zn Pyrophosphate ____

Chelating agents (tetra$NaPo_4$,EDTA etc) ____

iii) Acid bath: $ZnSO_4$ ____ NH_4Cl ____ $NaC_2H_3O_2$ ____

Glucose ____

. . . Cont'd.

iv) Mercury bath: ZnCN ____ NaCN ____ naOH ____
Mercuric Oxide ____

✓e) NICKEL PLATING:

✓i) Watts bath: $NiSO_4$ ____ NiCl ____ NiSulfamate ____
$Ni(BF_4)$ ____ Ni ____ Boric Acid ____
Organic agents ____

f) LEAD PLATING:

Pb ____ Fluoboric Acid ____ Boric Acid ____

g) Do you treat solutions before disposal? no How? ____

h) How often do you dump baths? ____

i) Size of bath tanks 15 gal / 40 / 80 / 300 / 600 / 2600

V. RINSING:

a) Volume of rinse tank 80/100/100/200/250/600/900/1400 gal

b) Which rinse system used? single 9 multiple 2 counterflow 1 spray 1
separate acid/alkali rinse __ combined acid/alkali rinse __
separate pretreatment rinses __

c) Rate of flow in rinse tanks ?

d) Water flow is controlled manually 10 automatically ____

e) What is concentration of contaminants in rinse tank ____

f) What chemicals are added to rinse bath ____

g) What is drag-in rate ____ drag-out rate ____ manually

h) Is there any type of recovery system for either plating or rinsing? drag-out filtered in one

i) Is rinse water treated to recover chemicals no
metals no

j) How often do you discharge tanks from rinse tanks every week to yearly

. . . Cont'd.

VI. TREATMENT OF EFFLUENT:

a) Do you treat effluent before disposal No How ______

______

b) Do you destruct oxidizable Cyanide No How? ______ (alkaline chlorination?)

c) Do you reduce hexavalent Cr? No How? ______

d) Do you precipitate metal ions? No How? ______

e) Do you settle suspended solids? yes = 1 no = 9

f) Do you know pH of effluent? yes = 3 no = 7

g) Do you test your effluent? no = 8 yes = 2 How often ____ For what ____

h) How much sludge is produced yearly ______

i) Are tanks or streams filtered? yes = 1 What is done with the solids collected? ______

VI. POST TREATMENT OF METAL

a) What processes are employed:

i) phosphate coating ____ Metal coating ____ Cn hardening ____ chromate conversion coating 1

VII. MISCELLANEOUS:

a) Type of floor mostly concrete

______

b) ANY VISIBLE PIPE LEAKS? ______

c) Overall impression of operation ______

______

______

Appendix F

SAMPLE SPECIFICATION SHEET

SCHEDULE OF WEEKLY TESTS & CHEMICAL ADDITIONS

PLATING LINE No 1		MONDAY A.M	MONDAY P.M	TUESDAY A.M	TUESDAY P.M	WEDNESDAY A.M	WEDNESDAY P.M	THRUSDAY A.M	THRUSDAY P.M	FRIDAY A.M	FRIDAY P.M	PLATING LINE No 1
OKITE DYNAMITE SOAK CLEAN 3200 gal	TEMP.	Approx. 1200 lbs										MAX. 9-10 OZ/GAL 10 g/gal.
ELECT. CLEAN OKITE "90"	TEMP.	1400 gal		(700 lbs)								MAX. 8 OZ./GAL. 8 g/gal
ELECT. ACID AQUAPREP & H_2SO_4		1400 gal		C.W. Hanson "Aqua-Prep."								MAX. 14-15 °B
COPPER	TEMP.	1400 gal										
COPPER CYANIDE												
SODIUM CYANIDE												
CAUSTIC POTASH												
ACID RINSE		3000 gal					H_2SO_4 & water					MAX. 12 °B
NICKEL #4							HI SPEC #172 3,000 GAL					
TEMPERATURE °F												
P.H. (4.0-4.2)												
SULPHURIC ACID												
NICKEL SULPHITE												
NICKEL CHLORIDE												
BORIC ACID												
#172 (PRE-MIX)												
#72												
#17												
#72 ADJUSTER												
FILTER #4 CLEAN & RECHARGE		3000 gal										
NICKEL #5							HI SPEC #172 3,000 GAL					
TEMPERATURE °F												
P.H. (4.0-4.2)												
SULPHURIC ACID												
NICKEL SULPHITE												
NICKEL CHLORIDE												
BORIC ACID												
#172 (PRE-MIX)												
#72												
#17												
#72 ADJUSTER												
FILTER #5 CLEAN & RECHARGE												
BRASS #1	TEMP.	1300 gal										
AMMONIA CAUSTIC POTASH SOD. & COPPER CYANIDE												
CHROME #1	TEMP.	1600 gal										
BAUME 19 °B LUMACHROME CATALYST BARRIUM	M & T											

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