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THE DEVELOPMENT OF ENVIRONMENTAL MANAGEMENT GUIDELINES FOR METAL FINISHERS IN WESTERN AUSTRALIA

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SUMMARY Investigations were conducted in 1988/89 towards characterizing the sources, types, volumes, management and disposal of wastes produced by the metal finishing industry in W.A. These revealed that generally, metal finishing premises disposed of their wastes untreated or ineffectively treated and did not comply with discharge criteria applicable in W.A. In response to existing industry waste management problems and the likelihood that non-compliance would persist "Environmental Management Guidelines for Metal Finishers in W.A." have been prepared. The purpose of the guidelines is to provide a reference source that will aid both industry members and government authorities to manage metal finishing wastes in an environmentally acceptable manner.

1. INTRODUCTION

Environmental pollution from metal finishing industry arises from the discharge of wastewaters which contain the hazardous raw materials used in surface coating and ancillary processes. The pollution potential of metal finishing has been cause for common concern throughout the world with organizations such as the North Atlantic Treaty Organization (NATO,1981), United States Environment Protection Agency (U.S.EPA,1982) and the United Nations Environment Programme (UNEP,1989) investigating the management of wastes generated by the industry.

The regulatory authorities which are responsible for the management of wastes and prevention of pollution in Western Australia include:

(a) Environmental Protection Authority; responsible for the issue of pollution control licences and the setting and implementation of licence conditions.
(b) Water Authority of Western Australia; responsible for the protection of the State's inland water resources and the issue of waste permits to industry discharging to sewer.
(c) Health Department; responsible for the licensing of liquid waste transport and disposal to off-site treatment facilities.

The development of Environmental Management Guidelines for Metal Finishers in W.A. was initiated due to the growing concerns of these regulatory authorities and the difficulties experienced by the metal finishing industry in meeting criteria established in statutory pollution control legislation. The development of the guidelines involved determining the sources and types of wastes produced, quantifying the characteristics and volumes of wastes generated, identifying existing waste management problems and management options to improve environmental performance, and finally, preparation of appropriate guidelines.

2. CHARACTERIZATION OF METAL FINISHING INDUSTRY WASTES

2.1 Industry Survey

At inception it was decided that the scope of the study would be restricted to inorganic wastes of the metal finishing industry. These include metal bearing wastes, cyanide bearing wastes, acidic wastes and alkali wastes. Thus for the purposes of the study the metal finishing industry was defined as any premises which conducted electroplating, anodizing, chemical conversion coating, etching, metal cleaning and/or galvanizing.

The sources, generation, disposal and management of metal finishing industry of WA was collected from premises conducting the aforementioned unit operations as follows:

(a) Visual inspection of 27 metal finishers within the Perth Metropolitan Region was conducted to gather data pertaining to unit operations employed, workpiece rinsing procedures, pollutants likely to be present in wastewaters and, waste management and disposal practices.
(b) Seven plants were then selected for a sampling programme to quantify the pollutants present in wastewaters from the various unit operations. The criteria used to select plants for sampling were:
   (i) The majority of the plant's wastewater discharge should originate from metal finishing unit operations.
   (ii) The physical layout of plant plumbing should facilitate the segregation of waste types and enable the taking of samples.
   (iii) The mix of plants sampled should be representative of the industry in terms of unit operations employed, pollutants present in wastewater, workpiece rinsing procedures and wastewater management practices.
(c) Data relating to wastewater quality and water consumption were also gathered from regulatory authorities and self monitoring by members of the industry. Suppliers and manufactures of raw materials for the metal finishing industry were also contacted to obtain information relating to the properties and constituents of process chemicals.

2.2 Results of Survey

The combined capacity of unit operation process baths and the number of metal finishers utilizing them is summarized in Table I. The table shows that the majority of metal finishers in W.A. were electroplaters. The relatively low capacity of electroplating facilities however, indicates that most were small "job shops". Metal cleaning was employed at all premises and represented the unit operation of largest capacity. Significantly, over 70% of the volumetric capacity of acid baths were located at galvanizing plants for descaling iron workpieces prior to hot dip galvanizing.

TABLE I
CAPACITY FOR UNIT OPERATION PROCESS BATHS IN WA (1988)

Unit Operation (No.# of Plants)	Sub Total (L)	Total (L)	%
ELECTROPLATING(18)			
Copper Cyanide(7)	9 400		
Copper Acid(2)	6 300		
Thin Chromium(9)	29 700		
Thick Chromium(5)	111 700		
Nickel(11)	41 600		
Cadmium Cyanide(2)	10 600		
Brass Cyanide(4)	13 700		
Zinc Cyanide(5)	126 800		
Tin(2)	8 200	358 000	20
ANODIZING(3)			
Anodizing(3)	91 000		
Cold Sealing(2)	50 000	141 000	8
CONVERSION COATING(10)			
Passivating/Chromating(10)	129 400		
Metal Colouring(4)	31 000	160 400	9
ETCHING/CHEM MILLING(11)			
Aluminium Etching(2)	106 000		
Nickel Stripping(7)	12 300		
Chromium Stripping(7)	9 800	128 100	7
METAL CLEANING(27)			
Acid -			
Hydrochloric(17)	388 500		
Hydrofluoric(3)	7 900		
Nitric(4)	7 200		
Sulfuric(9)	210 000		
Alkaline -			
Electrolytic(4)	24 800		
Non Electrolytic(18)	224 100		
Cyaniding(2)	46 900	909 400	51
GALVANIZING(6)		96 600	5
		1 793 500	100

Eighty percent of metal finishers have relatively small flow rates of less than 5 $ML.yr^{-1}$ (20 $kL.day^{-1}$). The distribution of discharge volumes less than 5 $ML.yr^{-1}$ is shown in Figure 1.

The concentrations of pollutants in rinse water waste streams and concentrated wastes such as spent process fluids are compiled in Tables II and III respectively.

Waste discharges by metal finishers were to one or a combination of ground, sewer and/or liquid waste disposal site (LWDS)(Table IV).

Wastes discharged to sewer and ground were predominantly dilute rinse waters whilst the majority of wastes disposed to LWDS were highly concentrated spent process solutions. As indicated in Table III, very high concentrations of pollutants exist in spent process fluids. Consequently, although the quantity of wastes discharged to LWDS may be the least, the mass pollutant load is probably the greatest.

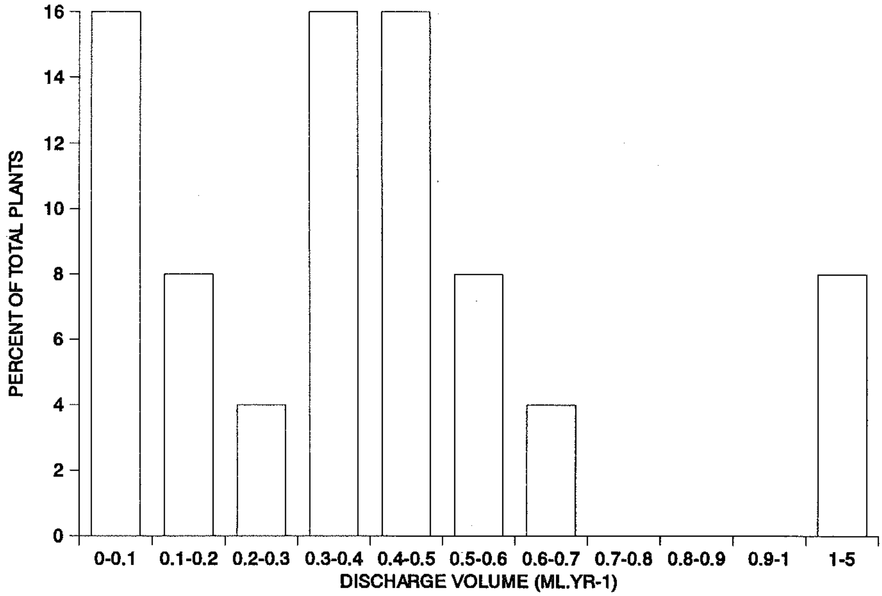

Figure 1 Distribution of waste discharge volumes less than 5 $ML.yr^{-1}$

TABLE II
RAW WASTE CHARACTERISTICS OF PROCESS RINSE WATERS (1988)

Pollutant Parameter	No.# Sample Points	Concentration ($mg.L^{-1}$) Range	Ave.	Flow Proportioned Ave.	Mass Loading ($g.day^{-1}$) Range	Ave.
Hexavalent Chromium	4	15.0-150	35	37	4- 228	93
Cyanide	3	107 -950	237	148	61-1780	758
Cadmium	1	2.6- 57	11	11	218	218
Copper	2	13.3-340	66	21	21- 28	24
Iron	4	2.4-650	130	50	4- 473	143
Nickel	4	1.2- 70	28	36	1- 60	33
Zinc	2	62.7-466	184	102	412- 809	611

TABLE III
RAW WASTE CHARACTERISTICS OF SPENT PROCESS FLUIDS (1988)

Pollutant Parameter	No.# Sample Points	Concentration Range ($mg.L^{-1}$)
Hexavalent Chromium	1	1 500*
Iron	3	75 000-90 000
Nickel	2	16 000-24 000*
Zinc	2	360- 1 100

*:-samples were collected from chemical milling solutions that were not exhausted at time of sampling and therefore concentrations are likely to be higher on disposal.

TABLE IV
WASTE VOLUMES DISCHARGED BY THREE DISPOSAL METHODS (1988)

Disposal Method	No#* Plants	Range ($kL.yr^{-1}$)	Average ($kL.yr^{-1}$)	Total ($kL.yr^{-1}$)
Ground	9 (5)	113- 5 114	1 163	5 816
Sewer	6 (3)	5 686-48 276	21 643	64 930
LWDS	12(12)	26- 494	248	2 983
Total	27(20)			73 730

*:- number in brackets indicates the number of plants for which accurate data was available.

3. EXISTING WASTE MANAGEMENT PROBLEMS

A major and significant task of the study was to evaluate current waste management practices and identify specific problems within the industry. The following is a discussion of a number of waste management/disposal problems that were identified during the industry survey.

3.1 Non Treatment Prior to Disposal

The majority of metal finishers dispose of their wastes without attempting treatment with only 22%, 33% and 8% of plants discharging to ground, sewer and LWDS respectively, treating their wastes for the waste types present.

Table V compares the characteristics of discharged rinse waters with ground and sewer discharge criteria applicable in W.A. The minimum pollutant concentrations in raw wastewaters generally exceed effluent discharge criteria and therefore disposal of untreated wastes inevitably leads to violation of pollution licences.

TABLE V
COMPARISON OF RAW WASTE CHARACTERISTICS
AND EFFLUENT DISCHARGE CRITERIA

Pollutant Parameter	Raw Waste Concentrations ($mg.L^{-1}$) Minimum	Average	Effluent Discharge Criteria ($mg.L^{-1}$) Ground[a]	Sewer
Hexavalent Chromium	15	35	0.5	1[b]
Cyanide	107	237	1	-
Cadmium	2.6	11	0.05	1[b]
Copper	13.3	66	10	1[b]
Iron	2.4	130	3	-
Nickel	1.2	28	1	10[c]
Zinc	62.7	184	50	10[c]

a:- criteria may differ for individual plants
b:- for discharge > 2g.day-1
c:- for discharge > 20g.day-1

Inadequacies of the disposal of untreated wastes to LWDS may be summarized as follows:

(a) Inadequate process control whilst administering reagents for metal precipitation and cyanide destruction may lead to ineffective detoxification and/or stabilization of wastes.
(b) Chromium in its hexavalent form and complexed metals are not effectively immobilized by simple pH adjustment.

(c) Cyanide when present in some metal complex forms is not amenable to conventional chlorination treatment.
(d) The high aqueous content of wastes has the potential to increase the leaching of metals and other soluble toxic compounds and the migration of contaminated leachate.

3.2 Excessive Rinse Water Consumption

A number of plants achieved substantially lower pollutant concentrations in their waste streams by running rinse waters at excessive rates. Pollution control legislation in W.A. adopts the concept of waste management by best practicable means. Recognizing that both the capital and operational cost of treatment increases with the volume of wastewater the belief that dilute wastes are the best wastes is a costly misconception. Water conservation by industry is also encouraged and promoted by regulatory authorities.

3.3 Inadequate Waste Treatment System Design

Of the metal finishers treating their wastes 78% employed makeshift treatment systems of inadequate design. The concentration of pollutants contained in effluents from inadequately designed systems exceeded discharge criteria by at least a factor of ten but more commonly by a factor of 30 to 40.

3.4 Inefficient Operation and Maintenance

The performance of well designed systems may be seriously affected by improper operation. Although some premises treated their wastes with appropriate reagents they did not regularly meet discharge criteria. Thus industry personnel were familiar with the chemicals used to treat metal finishing wastes but were not conversant with process operation factors which influence treatment system performance. Consequently, even metal finishers with adequately designed systems regularly exceeded discharge criteria.

4. MANAGEMENT OPTIONS FOR METAL FINISHING WASTES IN WA

Three basic options were identified for the management of metal finishing wastes in W.A. The advantages and advantages of each are detailed as follows:

4.1 Option 1: Continue with Existing Situation

Advantages
(a) Lowest capital expenditure.

Disadvantages
(a) Pollutant flux to environment and threat of environment and resource contamination from individual plant locations and LWDS is greatest.
(b) Facilities that are not treating wastes and persistently exceed discharge criteria may be shut down if government authorities responsible for pollution control employ powers provided within relevant legislation.
(c) Metal finishers employing treatment are economically disadvantaged.

4.2 Option 2: Individual On-site Treatment

Advantages
(a) Decrease pollution flux to environment
(b) Wastes discharged to landfill are more stable.

(c) Decrease in transport of hazardous waste.

Disadvantages
(a) Highest capital expenditure.
(b) Likely to be variation in the level of waste treatment and quality of effluent at each facility.
(c) Staff with high level of technical competence required by each plant location.
(d) Low potential for recovery of raw materials.
(c) Monitoring and surveillance complex and time consuming.

4.3 Option 3: Establish a Centralized Treatment Facility

Advantages
(a) Lower collective capital expenditure than option 2.
(b) All wastes treated to same level.
(c) Greater potential for advanced treatment of wastes to a better quality.
(d) Greater potential for materials recovery.
(e) Greater potential for employment of skilled staff.
(f) Simpler monitoring and surveillance than for option 2.

Disadvantages
(a) Higher capital expenditure than Option 1.
(b) Greater level of hazardous waste transport than Option 2.
(c) Requires the development of administrative procedures.
(d) Individuals have minimal control over treatment/disposal costs.

4.4 Recommendations

As a result of the investigations, and subsequent to the evaluation of management options the following recommendations were made:

(a) The disposal of untreated metal finishing wastes to ground, sewer and industrial liquid wastes disposal site should be phased out as quickly as possible.
(b) The economic impact of individual on-site treatment on the future viability of industry members should be evaluated.
(c) The feasibility of the establishment of a centralized treatment facility should be evaluated in comparison to individual on-site treatment. (a) and (b) should be joint industry/government projects and should be conducted simultaneously. Specific aspects addressed in this project should include but not be limited to economic comparison of centralized treatment with individual treatment, feasibility and benefit of advanced treatment and/or materials recovery technologies and environmental acceptability of hazardous waste transport.
(d) Recognizing that metal finishers have been unsuccessful in complying with State environmental legislation, a reference document should be prepared that will aid metal finishers to operate and the State's environmental managers to administer the industry in a manner that is practical to industry but not damaging to the environment.

However, since the completion of the draft guidelines the disposal of untreated wastes to LWDS has been effectively terminated by the introduction of stringent off-site disposal licensing conditions and the commissioning of a modern liquid waste treatment plant at Forrestdale by the Health Department.

5. ENVIRONMENTAL MANAGEMENT GUIDELINES FOR METAL FINISHERS IN W.A.

In response to 4.4(d) "Environmental Management Guidelines for Metal Finishers in W.A." have been prepared (Smith, 1989). The main text of the guidelines is of a general nature. It includes a brief description of:

(a) The potential effects that metal finishing wastes may have on the environment.
(b) The environmental legislation that governs waste management practices of the industry.
(c) An overview of current waste management practices, existing problems and future management options of the industry as presented in this paper.
(d) Factors to consider when selecting a site for metal finishing.
(e) A brief introduction to available waste treatment technology and factors to consider when selecting treatment plant.

The main text is supported with technical appendices. These identify and describe, in detail, treatment and recovery alternatives to the disposal of untreated wastes. Important design and process control factors for treatment and recovery systems are explained to assist industry and their consultants to meet discharge requirements.

The document has been released to industry for comment and discussions between industry and government authorities are planned. These discussions will have two objectives:

(a) Define the preferred approach to regulatory compliance by industry.
(b) Obtain funding should the preferred approach require further investigation.

Forrestdale liquid waste treatment plant is expected to be of major interest to industry members during discussions and the guidelines will need updating to explain its role and implications in the management of metal finishing wastes.

Nonetheless, following these discussions it is hoped that a waste management strategy that is both practical to industry and environmentally acceptable will be defined.

6. REFERENCES

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