GPQMC:5-88

POLLUTION AND THE METAL FINISHING INDUSTRY

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INTRODUCTION

The metal finishing industry incorporates a wide range of processes and potential products. These range from simple everyday products such as the humble staple to highly sophisticated components for the aerospace industry Of the various unit processes, a variety are employed but most fall into one of the four categories of cleaning, machining, electroplating and painting. These processes have associated waste-streams such as wastewater, waste oil, spent solvents and spent process solutions. It is perhaps the wastewater and to an extent spent process solutions which have attracted the most environmental scrutiny to date. This is a result of their visibly damaging effects upon the aquatic systems to which they have been introduced. The cost of disposal of wastes from all processes will inevitably rise as landfill sites become scarcer and stringent restrictions are applied to discharges into watercourses and municipal sewers.

There has been an increasing tendency at European Community level to pass legislation to control the entry of dangerous substances into the environment. Mercury, cadmium and chromium directives are no doubt familiar as examples. Undoubtedly, the list will enlarge to embrace a large number of materials currently in use by the industry as their environmental effects are more fully understood. This too will inevitably increase costs to some extent particularly capital costs in the short term as plant is commissioned and brought on stream for the purposes of pollution control.

The metal finishing industry may be regarded as a sector of industry requiring access to all the specialised waste disposal routes currently available. By nature the industry is both diffuse and competitive. Hence waste arisings are also diffuse which neccessitates local or on the spot waste management facilities. The establishment of centralised "plating parks" is unlikely to be attractive given the regional nature of much of the industry and the unrealistic demand for skilled labour in local terms that this might create. It must be assumed, therefore, that the structure of the sector is unlikely to change substantially in the foreseeable future unless the demand for metal products declines substantially. This is most unlikely.

The purpose of this paper is to consider the potential problems caused by the processes used in metal finishing, why they are important on a global scale and to review some of the methods available for waste reduction. Where possible, examples are quoted to show how a policy of source reduction can actually increase profitability.

LEGISLATIVE CONTROL

EEC Directives are what might be regarded as "heavyweight control". They seek to impose a blanket value upon emissions of environmentally inimical substances. In mainland Europe this is most often interpreted as a "fixed emission" and most countries have a system of fixed limits modified in some cases by sectoral requirements of industry. In the UK by contrast, in the absence of directives, a system of Environmental Quality Standards are generally imposed coupled with Environmental Quality Objectives to define parameters for control and improvement. These standards are theoretically achieved through the consents granted by the Water Authorities.

Quite apart from the inevitable economic and political uncertainties engendered by the existence of the two systems, they both suffer from disadvantages. A "fixed emission" policy can and does lead to totally inappropriate discharges while an EQS/EQO policy can encourage complacency about water quality improvement. Axiomatic to both approaches is an extensive understanding of the behaviour of contaminants in the environment. It is widely accepted by toxicologists that there are large gaps in our knowledge of precisely how individual and combined toxicants behave in the environment. These gaps probably constitute the greatest problem in formulating any robust and certain protocol of environmental management.

The UK system is, moreover, viewed abroad as likely to confer a commercial advantage on UK companies who might be spared the cost of pollution abatement measures on account of Britain's fast flowing rivers and estauries. It has been argued that a merging of the two philosophies is necessary to facilitate control of the discharge of dangerous substances to the environment.

It is important to realise that whatever combination is employed, environmental improvement is likely to result only on a local level reflected, perhaps, in more fish and animals in receiving waters. The global problems will continue to grow albeit at a slower rate. This, simply is because most pollution control strategies are designed to address problems in areas which are already showing visible signs of stress. Examples are the Great Lakes, Chesapeake and San Francisco Bays and the North and Irish Seas. Ultimately, the concept of the "zero option" must be embraced if control measures are likely to be effective on a global basis. Slowing the contamination of our environment, or contaminating it less in more places (the dilution solution) are not long term solutions to the global problem. Indeed, dilution cannot even be regarded as a suitable short term measure given the current scrutiny and constant revision of "safe levels".

It is apparent that the "zero option" cannot be achieved overnight for the huge number of industries upon which society has come to depend. If the precautionary principle is the lynchpin (as it should be) of sensible environmental policy, then application of best available technology to emission control is a useful interim step.

Current legislation therefore reflects the philosophies underlying it. At best they are confused, at worst little more than embryonic. It is apparent that this situation needs to be improved but commercial sense would suggest that whatever system is eventually adopted it must be uniformly applied to avoid competetive advantage at the ultimate expense of environmental quality.

Legislation to control the 129 EEC "blacklist" substances is inevitable. It therefore makes sense to anticipate this and introduce voluntary controls which not only contribute to improvement of environmental quality but also make sound commercial sense. This is an area where the metal finishing industry could make unique progress through bodies such as the Metal Finishing Association.

METAL FINISHING WASTES

Metal finishing wastes may be broadly categorised into four major streams: wastewater and treatment residues, waste oil, waste solvents and spent process solutions. Of these, wastewater is the largest stream with most plants producing around 100,000 gallons per day. The bulk of this arises from rinsing operations between process baths and hence wastewaters contain dilute concentrations of metals, cyanides, oils and other chemicals. Bath drag-out is not the only source of materials in the wastewater. Dumps of process solutions, scrubber water and and cleanup wastes all contribute. Treatment of this wastewater will produce metal hydroxides in the form of sludges with a highly variable water content depending on the dewatering process used. These need suitable disposal, a topic which will be addressed further in the afternoon session. Other, though potentially no less important waste streams include oil and solvent wastes. The significance of these wastes and the methods used to reduce them are outlined below.

a) Wastewaters

Environmental discharges of heavy metals are coming under increasing scrutiny. In addition to those metals already regulated at the EEC level, the UK Water Research Centre has recently published proposed Environmental Quality Standards for nine EEC list II materials including vanadium, inorganic tin, organic tin and iron. Others for which EQS levels have been proposed include inorganic lead, arsenic, zinc, copper and nickel. Chrome, mercury and cadmium are regulated by EEC directives.

At first sight it is perhaps difficult to understand why control is neccessary. After all it may be argued that mobilisation of metals is the mobilisation of natural materials. Indeed the global mobilisation of mercury from natural sources far exceeds anthropogenic mobilisation. However the effect of metal discharges upon ecosystems is significant given their ability to interfere with a wide range of metabolic function. This is equally true of non-essential and essential trace metals. The fact that many invertebrates may acquire resistance to elevated metal levels in aquatic ecosytems as noted in Cornwall in metal mining areas is far from a cause for optimism. This further mobilises metals in the food chain and may exert deleterious effects upon, for example, bird and fish populations. The trace metals may exert significant effects upon reproduction, development and health of these organisms.

Recently two papers have been published which promise to open a renewed, fierce debate on the subject of heavy metals. One of these papers is provocatively entitled "A silent epidemic of environmental metal poisoning?" and the author, Jerome Nriagu, states " Over one billion human guinea pigs are now being exposed to elevated levels of toxic metals and metalloids in the environment. The number of persons suffering from sub-clinical metal poisoning is believed to be several million.......As a global problem, the potential health effects of metallic hazards should be a matter of public health concern, especially if emissions of toxic metals into the environment continue at the present rate."

Nriagu goes on to note that estimates of the toxicity of all metals being released annually, into the environment, far exceed the combined total toxicity of all the radioactive and organic wastes as guaged by the quantity of water needed to dilute such wastes to the drinking water standards. The picture is complicated however by the fact that sediments can act as sinks for dissolved metals. Further, the global bias of industrial development may mean that the effects of these contaminants are more serious in developed countries than might seem the case if only global averaging is considered.

The scale of the problem may be illustrated by historical changes in primary production of metals in the table below.

Primary production (x1000 tonnes per annum)

Element	1930	1940	1950	1960	1970	1980	1985
Cadmium	-	1.4	1.4	2.4	3.7	6.6	8.3
Arsenic	-	71	47	47	49.6	-	45
Chromite	560	1300	2270	4421	6057	11248	9940
Copper	1611	2050	2650	4212	6026	7660	8114
Lead	1696	1730	1670	2378	3395	3096	3077
Nickel	22	133	144	326	629	759	778
Tin	179	240	172	183	232	251	194
Zinc	1394	1640	1970	3286	5465	5229	6042
Vanadium	-	3.1	1.8	6.4	18	35	34

The emission of these materials into the atmosphere water and soil has been estimated in the following table. This of course includes not only material wastage but the unitentional mobilisation of these materials due to the burning of fossil fuels, for example:

Global emissions per annum (x1000 tonnes)

Element	Air	Water	Soil
Arsenic	18.8	41	82
Cadmium	7.6	9.4	22
Chromium	30	142	896
Copper	35	112	954
Nickel	56	113	325
Lead	332	138	796
Tin	6.4	-	-
Vanadium	86	12	132
Zinc	132	226	1372

Finally, estimates are available for anthropogenic inputs by sectors of industry into the aquatic environment, and while the figures are somewhat uncertain they do provide an indication of the possible contribution of the metal finishing industry sector to the overall figures. It must be realised however that these figures relate to all sectors of industry classified as metals manufacturing processes but excluding mining, dressing, smelting and refining.

Element	tonnes per annum	upper%
Arsenic	250-1500	3.6
Cadmium	500-1800	19
Chromium	15000-58000	40.8
Copper	10000-38000	33.9
Nickel	200-7500	68.1
Lead	2500-22000	15.9
Vanadium	0-750	6.25
Zinc	25000-138000	61.06

Anthropogenic inputs of trace metals into the aquatic environment by the metals manufacturing industry. Figures for all tables from Nriagu (1988) and Nriagu & Pacyna (1988)

Using the figures above, it can be seen that this sector of industry contributes variable but significant quantities to the global budget. It seems likely therefore that legislation will continue to be applied as part of an overall control policy.

This again seems to indicate that anticipatory and if possible ultimately profitable action should be taken. So what can be done?

In the field of waste management literature, there is probably more relating to the metal finishing industry and in particular, electroplating processes, than in any other field. Many of these relate to end of pipeline treatments with many of the suitable treatments dating back to the 1950's. Little attention has been paid to internal waste minimisation although strict effluent controls, the high cost of treatment and management of resultant residues are likely to change this. Broad attention to water conservation using countercurrent and reactive rinse techniques has been found to reduce water consumption by as much as 97% over a single rinse. Simple attention to rinse tank design can cut water usage by 50%. Obviously care is needed in the use of such techniques to avoid contamination of process solutions and poor quality finishes but the power of these methods should not be underestimated.

Drag-out reduction can significantly reduce the amount of waste requiring treatment. This may be achieved by operational changes such as reducing metal levels in process baths or increasing drain time (without allowing drying). Process bath substitution can in some cases reduce or eliminate a chemical of concern but may cause other waste management problems.

Drag-out recovery can be effected using non flowing rinse tanks between flowing tanks and can facilitate the reuse of solutions in heated tanks. Where dilution is a problem techniques can be used to concentrate up the solution before return to the process tank. Alternatively, off-site recovery can be used. The use of two such drag-out tanks can reduce waste at this stage to 30% of the former value.

The major problem associated with drag-out return is the introduction of contaminants into the process tank. This is true for most forms of drag-out management including reverse osmosis, ion exchange, evaporation and electro dialysis. Each also has its own set of peculiar advantages and disadvantages. Hence an active bath management programme is an essential part of any recovery system.

A number of case studies exist which show the profitability of applying these techniques but nonetheless experts in the field consider that recovery systems should be considered after assessment of the effect of all other low cost options involving water conservation and material practices. It seems likely, however, that increasing legislative control will eventually make the use of such systems mandatory. As noted above, the viability and profitability of many companies will depend upon the fair and simultaneous application of conditions across the industry.

b) Metal-working fluid wastes

These wastes arise primarily from machining operations although lesser quantities may arise as a result of cleaning operations. Regulation of these materials at least in the UK is generally controlled by a group parameter for visible oil and grease or occasionally as carbon tetrachloride extractables. Many of the cutting fluids used in metal finishing are soluble oil based products. Others are a variable blend of petroleum and vegetable oils. Additives are used to create oils with precise properties. Oil wastes arise after the material has become too severely contaminated with tramp oils and solids to be of further use and it is then usually disposed of to an off site facility. A significant reduction of these arisings can be achieved through a metal working fluid management system and a recovery system. A fluid management system must include a maintenance element to prevent the contamination of fluids by tramp oils escaping from fittings and seals and a rigid regime of removal and replacement. Recovery systems may be relatively simple gravity settling tanks or complex centrifugation systems with the latter more expensive equipment able to remove the greatest range of contaminants.

Oily discharges have always been fairly tightly regulated since oil in discharges is extremely unsightly. However there is a hidden component in many oils and particularly used oils which have been subjected to a degree of thermal stress. These are known as the poly-nuclear aromatic hydrocarbons and are complex multi-ring structures. Many are now regarded by the US EPA as priority pollutants and have been shown to be capable of effecting a number of undesirable changes at the cellular level. At present their effect in water remains largely unknown, but a considerable degree of interest is being shown in this. The Water Research Centre has recently started a research programme on the problem, whilst interest is also being shown in their behaviour in water treatment plants where chlorination is used. It is probable that oily wastes will assume an increased management importance in the future. A recovery process for oils in a large machine shop may halve fluid consumption and have a payback time of less than two years when lowered disposal costs are taken into account.

c) Solvent wastes

The various solvents in use in the metal finishing industry are employed for diverse purposes ranging from cleaning applications to paint thinning. One group of these solvents is, like the poly-nuclear aromatic hydrocarbons beginning to attract a great deal of attention. This group consists of the chlorinated solvents examples of which are perchloroethylene, methyl chloride and trichloroethylene. Scrutiny has arisen in part due to contamination of groundwater with these materials and the prejudice of water supply quality. Moreover, despite their desirable non-flammable properties, they have been found to exert deleterious health effects upon workers exposed to them. These range from simple narcosis to neoplastic changes in the liver. Simple ventilation procedures can do much to reduce the risk but this may expose the public to undue risk. An example of this is a recent study of such solvents in foodstuffs. Margarine bought in a certain supermarket was consistently found to contain higher levels of chlorinated solvent than margarine bought elsewhere. The source was eventually tracked down to a nearby dry cleaners which used these substances.

Venting solvent vapours to the atmosphere is to contribute to what is probably the greatest environmental threat of all: destruction of the ozone layer. Although traditionally associated with aerosol propellants, the chlorofluorocarbons (CFCs) the chlorinated solvents are also suspected of playing a significant role. Accordingly, it is likely that for this reason as well as the more widely known problems of water pollution, these compounds will be subjected to legislative control. Using water soluble degreasers and cleaning fluids is an obvious possible answer although the more conventional solvents such as MEK and xylene are not without problems either. Solvent recovery systems also give rise to difficult still bottom residues. Methods need to be devised to minimise the consumption of all these biologically inimical materials and their release to the wider environment.

CONCLUSIONS

The metal finishing industry is an integral part of modern society. It is virtually impossible to find a product in the home in which this industrial sector has played no part. Equally, the potential of the industry to bring about undesirable environmental change is in no doubt. The increasing regulation of this sector of industry is inevitable. This should not be looked upon as undesirable but rather as a challenge and a responsibility to improve the quality of the environment upon which all depend as well as continuing to improve the quality of life through the products manufactured. The intention of this paper has been to point out both the potential significance of this industrial sector in environmental terms and some of the ways in which this impact may be lessened. At this stage it is probably worth pointing out that a commitment to waste reduction requires more than lip-service. It requires full commitment from the management, of time, personnel and financing. Lack of this commitment is the greatest impediment to source reduction schemes.

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RESUME

Awarded a degree in Marine and Freshwater Biology at Westfield College, University of London. A period of research on the aquatic toxiclogy of selenium led to the award of a Ph.D. from London University and this was followed by periods of postdoctoral research in fields as diverse as radiation biology and alternative pesticides. These studies all involved toxicological investigations of metals used for example as radiosensitisers or systemic poisons.

Since 1986 I have been working as Greenpeace Research Fellow at Queen Mary College, University of London, providing scientific backup to a variety of campaigns in the UK and abroad. This has involved dealing with organic contaminants as well as trace metals in the environment.

Current areas of interest include the role of trace metals in diseases of aquatic organisms and the study of organic contaminants in biological systems.