16. COATINGS AND THE ENVIRONMENT

INTRODUCTION

There are few industrial activities in which environmental considerations are not looming large in both the way products are manufactured, and their long-term environmental impact.

Occupational health and safety, management of effluents and residues and greenhouse issues are becoming very important in driving specifications and the selection of materials.

In areas such as OH&S and waste management, government involvement in setting and administering standards has driven the agenda in most jurisdictions. In the areas of material sustainability and greenhouse management, the participation by industry has been largely voluntary.

Environmental controls are much more stringent where maintenance painting is required, even for non-hazardous coating. This navigation tower required full containment for its refurbishment.

ENVIRONMENTAL ISSUES FOR COATINGS

The fundamental environmental issues for coatings are:

- Is the coating itself environmentally acceptable - what does it contain?
- Is its manufacturing process environmentally acceptable?
- Is its application process environmentally acceptable?
- What are its long-term effects on the environment?
- Can it be recycled?
- Can the manufacture meet its carbon footprint obligations in the future.

Paint coatings have long been subject to scrutiny in all of these areas, and the paint industry has worked hard on its technology to provide coatings that comply with increasingly stringent regulations.

TOXICITY OF PAINT PIGMENTS

Red lead pigment in paint has been used as a rust inhibitor for centuries and is still used in some areas in maintenance painting in industrial situations: e.g. bridges and process plants. The reason for this is that oleoresinous red lead materials have had an unrivalled anticorrosive performance on compromised surfaces. Lead chromate pigments have been also been used, particularly in bright yellows and red colours, in decorative paint coatings.

Intact dried paint containing lead, in an industrial environment, represents little if any health hazard. Hazards arise during application, especially spray, but the main hazard occurs during removal of lead based paints. In construction projects, this removal may occur when welding, burning or abrasive blasting is performed on painted steel.

During burning and welding processes the temperature generated is high enough to vaporise the lead. Abrasive blasting of the coating generates very fine airborne particles, which present a serious hazard to workers and the public in close vicinity. Lead is a poison that serves no known useful function the body. In large enough doses it can kill in a matter of days. Exposure to smaller doses over long periods of time can cause severe damage to the blood forming, nervous, urinary and reproductive systems. Children born to parents who have been exposed to excessive lead levels have a greater chance of having birth defects, mental retardation, behavior disorders or dying during the first year of life.

Lead is a particularly insidious poison because severe, permanent damage can be done before any symptoms are felt, unless very large doses are involved. Removal of lead paints represents a significant cost penalty. Disposal of hazardous waste together with the problem of containment and capture is a difficult and expensive proposition. It is estimated that this could increase cleaning and painting costs between five and ten times more than normal.

EPA requirements on some repainting projects require full filtration of the extracted air.

Isocyanates

Isocyanates, in monomeric form, are used to manufacture pre-polymers that are in turn used in paint manufacture, specifically in polyurethane coatings that have a variety of end uses, for example as durable finishes or elastomers.

Most paints present some form of health hazard, but isocyanates have particular hazards and careful precautions must be taken by paint applicators to avoid these. Isocyanate containing coatings are safe to handle provided all precautions as specified on the Health and Safety Data Sheets are taken. In the case of two pack isocyanates, as well as the protective clothing worn for all paints; the precautions include the use of air fed hoods when spraying for this type of material.

Isocyanate monomers which are used to make pre-polymers (resins) are the largest contributors to ill health effects because of the small molecular size and hence volatility. Very small amounts remain together with larger less volatile pre-polymer molecules in paint. All the unreacted 'free' isocyanate represents a hazard particularly when sprayed.

Isocyanates are particularly hazardous to the respiratory system and atmospheric over-exposure can lead to varying conditions of ill-health. In mild cases, the afflicted may suffer irritation of the eyes, nose and throat. There may be a tightening of the chest and coughing. In more severe cases the symptoms experienced can be acute bronchial irritation and difficulty in breathing. The onset of such respiratory effects may be delayed for several hours after exposure.

Isocyanate-free technology is now available to provide coatings with a performance similar to that of polyurethanes, such as durability, weathering and colour and gloss retention, without the degree of risk of respiratory disease and sensitisation associated with 2-pack isocyanate paints. The Sydney 2000 Olympic Stadiums were finished in a 2-pack isocyanate free catalysed acrylic coating.

Other pigments and binders

Restrictions have been placed on a number of other paint technologies including coal tar and chromate pigmented paints because of the negative OH&S implications of these materials. From a performance point of view, these coating systems, along with lead pigments, are excellent technology for their design applications, but environmental criteria have overridden technical performance.

V.O.C.'S

The global problems attributed to Volatile Organic Compounds, VOCs, arise from the use of solvents in many industrial processes with the paint industry playing a very significant part. In Europe and the US paint and the painting industries have been targeted as a key area to receive legislative attention. Estimates in Australia alone are that in excess of 80,000 tonnes of VOC's are released into the atmosphere annually with the existing technology.

The environmental impact of any substance is related to how it is released into its surroundings. In the case of volatile materials (including solvents), they evaporate into the air and are then oxidised by photo degradation. This results in the three main air pollution problems of ozone layer depletion, a photochemical smog and global warming. problem is that of acid rain.

Galvanized coating slowly weather away, with the zinc ending up in the soil. Most soils are zinc deficient and this has no negative environmental impact in most instances. All protective coatings prolong the life of steel and make an energy saving contribution as a result.

Ozone Layer Depletion

The ozone layer in the upper atmosphere absorbs harmful UV irradiation which would otherwise promote skin cancers in human beings and animals and damage agricultural crops and marine organisms. The depletion of ozone in this region (18-40 km above ground), was first noted about 20 years ago but ozone levels are difficult to measure and it is only more recently that the evidence has been universally accepted.

Halogenated substances (including chlorinated solvents) are the main cause of this effect. They have a longer life than hydrocarbon solvents once released into the atmosphere, which allows them to reach the higher atmospheric layers. They are then decomposed by UV light to form halogen reactive groups which act as catalysts to the break down of ozone to form oxygen, so removing the ozone protective layer.

Photochemical Smog

Although hydrocarbon solvents rarely reach the upper atmosphere, they are retained in the lower atmosphere where they cause damage. They actually react under the influence of UV light with nitrogen oxides that are particularly dominant in the atmosphere of industrial and large built-up areas, to promote the concentration of ozone otherwise known as 'photochemical smog'. Whilst in the upper atmosphere, ozone is protective, its presence in the lower atmosphere causes acute human respiratory disorders such as asthma, especially in young children, and severe irritation of the eyes. In addition, the ozone has a damaging effect on agricultural crops.

Global Warming

The sun's radiation warms the earth's surface, which in turn heats the atmosphere by the emission of infra-red radiation. Higher molecular weight gases, including those attributable to solvent emissions into the atmosphere, absorb and trap some of this infrared radiation that would otherwise reach outer space. The result is an increase in the earth's atmospheric temperature, an effect known as global warming or the 'greenhouse effect'.

INDUSTRY ACTION

The international paint industry has been active in developing coating systems that eliminate or reduce the environmental impact of the older technologies. More water-based systems are now available that offer levels of performance equivalent to some solvent-based systems.

Low VOC or solventless systems are now readily available, and other technologies are emerging using inorganic or hybrid organic-inorganic coatings that offer superior technical performance. Unfortunately, in many developing countries, many older technologies such as lead-based paints are still used, as are many high VOC materials. International protocols for greenhouse reduction will ultimately have an impact and bring developing country standards up to those of the industrialised countries.

METALLIC COATINGS

Zinc is used almost exclusively as the metallic coating for protecting steel from corrosion. It is applied by various technologies, ranging from electroplating through continuous galvanizing to after fabrication galvanizing. All these processes have differing environmental impacts and produce coatings with varying levels of durability.

Zinc, being a reactive metal well up in the electrochemical series of metals, does not exist in nature as a metal, but, like most metals, is present as a mineral, frequently in concert with lead and other less abundant metals. As a result, the production of zinc metal requires that its ores be mined, milled, smelted and refined to produce zinc metal. Once in this form, zinc then takes its place in the manufacturing process and ends up as a coating (e.g. galvanizing), as an alloying metal (in brass), as a pigment (zinc dust), as a chemical, (e.g. zinc oxide used in rubber manufacture, fertilizer and medicine) or as a product itself (e.g. zinc die castings, zinc sheeting).

Although using more heat energy, powder coating are solventless and have zero ZOC's, significantly reducing their environmental impact.

These operations produce a stream of secondary zinc waste products (e.g. zinc drosses and oxides, scrap, zinc rich waste acid solutions) which are then subject to secondary processing operations to recover zinc and other components of commercial value for subsequent return to the material cycle.

ZINC AS AN ENVIRONMENTALLY SUSTAINABLE COATING MATERIAL

The issue of environmental sustainability is becoming increasingly significant at all levels of our society. It is not only on the political agenda as 'green' candidates represent an increasing proportion of the political landscape at local, state and federal level, but is also a high priority for the design professions and their clients in the 21st Century.

A simple method of rating materials is to compare them on the basis of their Gross Energy Requirements (GER.). This accounts for all the energy used in mining, smelting, refining and forming the material. For metals in particular, another factor called Gibbs Free Energy (GFE) is a measure of the energy required to convert the ores to the metal. Nature always seeks equilibrium at the lowest energy levels and the GFE makes all metals intrinsically unstable. Their stored energy constantly seeks an opportunity to get out. The GER and the GFE are not necessarily related. Some metals like copper have high GER requirements because of the nature of their ores, and low GFE requirements because of the nature of the material.

The following table illustrates this relationship:

Table 1.

Material	**Mineral**	**Gross Energy Requirement (MJ/kg)**	**Gibbs Free Energy (MJ/kg)**
Aluminium	Al_20_3	270	29.00
Copper	Cu_2S	115	0.70
Zinc	ZnS	70	3.00
Steel	Fe_20_3	35	6.60
Lead	PbS	30	0.45

It can be seen from this table that in the context of protective coatings for steel, zinc has double the GER of steel but has less than half the GFE.

Zinc, when used as a component in a protective coating for steel is by its nature, sacrificial. All zinc used as a protective coating for steel will be returned to the environment as it oxidises or corrodes sacrificially to prevent corrosion of the steel. Protective coatings of all kinds work on the principle that a small amount of coating can protect a large amount of steel.

On hot dip galvanized products, for example, the galvanized coating mass is typically about 5% of the mass of the steel that it is protecting. If unprotected, the steel would corrode at rates typically 20 times faster than zinc. Using adequate protective coatings systems on steel to delay the escape of its Gibbs Free Energy as long as possible is thus a major factor in determining environmental sustainability.

ZINC IN COATINGS - WHERE DOES IT GO?

Zinc is the most widely used metal for the protection of steel from corrosion as well as being present in a range of other manufactured products and in the natural environment. About 10 million tonnes of zinc metal are produced annually, of which about 20% is from recycled material and the rest from mining and refining.

From this, about 50% goes into coatings for corrosion prevention, 20% goes into brass, about 10% goes zinc chemicals 9with about half of this used for tyre manufacture), while the balance is consumed for products such as sheeting, dry cell batteries and diecastings.

As coatings and tyres are consumable products, it is logical to assume that the zinc in these products will eventually end up dispersed into the environment. Is this a health hazard? Does it represent a risk to the natural environment?

The important issue from an environmental point of view is that of where the zinc ends up after it becomes a corrosion product. Does it migrate far from its original source? Does it accumulate? Research on these subjects is starting to provide a better understanding of the behavior of zinc leached from coatings.

The International Lead-Zinc Research Organization (ILZRO) has undertaken research on the leaching of zinc from galvanized coatings on transmission towers. (See CORROSION MANAGEMENT Vol. 5 No I Feb-Mar 1996 Pp 11-17 for full report). This research concluded that even in aggressive acid rainfall zones, zinc concentrations in soil were at background levels within 6-9 metres of the tower base. Research continues in this area.

ZINC AS A SUSTAINABLE MATERIAL

Compared to other base metals zinc occupies a favorable position as an environmentally sustainable material. Energy consumption for primary zinc production is 25-50% higher than that of steel and only about 20% of aluminium.

About 20% of zinc used is recovered as scrap and this is likely to increase to over 60% as recovery process technology improves.

The galvanizing of steel as sheet, wire, tube and fabrications offers very good corrosion resistance on steel and greatly increases its life. On average, about 70 kg of zinc (which consumes 250 kWh of energy to produce) is consumed to prolong the service life of 1 tonne of steel as sheet, which consumes about 2900 kWh of energy to produce, by a factor of between 3x and 5x. At the end of its service life, the galvanized material can still be recycled, except for the zinc lost through corrosion and run-off.

As weathering occurs with these zinc-based coatings, the zinc is consumed in two ways. These are:

1. Oxidation of the zinc and physical removal of the zinc oxide products by washing or erosion.
2. Electrochemical dissolution of the zinc adjacent to exposed steel when an electrolyte (water) is present.

These zinc corrosion products are transported into the surrounding environment. It is their impact in this context that determines their viability as coatings for the foreseeable future. The rate at which zinc moves into its surrounding environment from the weathering of coatings is obviously determined by coating life.

CONCLUSION

The protective coatings industry internationally is well aware of the major environmental challenges facing the industry into the 21st Century. These are:

1. Minimising energy usage in the mining, processing and production of coatings raw materials and in the processes that utilise coatings.
2. Minimising effluents and contamination entering the ecosystem (rivers, groundwater, and the atmosphere) from the weathering and rehabilitation of coatings.
3. Responsible planning and operation of mining and processing sites, including rehabilitation of mine-sites.
4. Optimising the recycling of zinc coated materials, including galvanized scrap steel.
5. Development of by-products to ensure maximum usage of available zinc in a form that meets international standards of occupational health and safety and are free of long-term toxicity risks.
6. Technological improvement to enhance the durability of coatings and extend the service like of the material to which they are applied.
7. Reducing the carbon footprint of the industry producing the protective coating products to levels that are internationally acceptable.

INGAL
SPECIFIERS MANUAL

01 - SPECIFIERS MANUAL — THIRD EDITION

Industrial Galvanizers Australian Galvanizing Division (IGAG) operates nine galvanizing plants around Australia, ranging in size from large structural galvanizing facilities to specialised small plants designed to process small parts.

The Australian Galvanizing Division has galvanized in excess of 2 million tonnes of steel products in Australia since its first plant was commissioned in 1965 and is recognized for its ability to handle complex and difficult projects, as well as routine contracts.

This experience has been collated in the Specifiers Design Manual, to assist those involved in the design of steel products and projects to better understanding the galvanizing process and allow the most durable and cost-effective solutions to be delivered to these products and projects. All sections of this Third Edition have been completely updated and additional sections have been included to provide additional technical information related to the use of hot dip galvanized steel.

In addition to its Australian Galvanizing operations, Industrial Galvanizers Corporation has a network of manufacturing operations in Australia, as well as galvanizing and manufacturing businesses throughout Asia and in the USA.

The company's staff in all these locations will be pleased to assist with advice on design and performance of hot dip galvanized coatings and products. Contact details for each of these locations are located elsewhere in this manual.

This edition of the Industrial Galvanizers Specifiers Manual has been produced in both html and .pdf formats for ease of access and distribution and all documents in the Manual are in .pdf format and can be printed if paper documents are required.

The Specifiers Manual is also accessible in its entirety on the company's web site at www.ingal.com.au.

Additional copies of the Specifiers Manual are available on CD on request.

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