LANDFILL AS A FUTURE OPTION FOR THE DISPOSAL OF TREATED ELECTROPLATING CHEMICALS SUCH AS METAL BEARING SLUDGES AND FILTERCAKES IN IRELAND.

by

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ABSTRACT.

Currently the fifteen Irish electroplating plant that have applied for an IPC licence produce 394.6 tonnes/annum electroplating sludge and 33.6 cubic metres of waste solution. This electroplating sludge is exported for recovery, exported for disposal or landfilled in Ireland. Prior to the 4th of February 1998 the EPA had received sixteen Waste Licence applications for the operation of a landfill. Of these nine have applied to accept non hazardous industrial sludge but only four are containment sites, which are suitable for the acceptance of metal bearing electroplating sludge.

Should electroplating sludge be categorised as hazardous this will pose special problems for the Irish electroplating industry if the European Commission Directive on Landfill is accepted, as Ireland presently has no hazardous waste landfill.

The continuance of landfill as a disposal option for electroplating sludge in the short and intermediate term can be assured by recategorising electroplating sludge as non-hazardous using EWC/HWC codes and the use of solidification and stabilisation to produce a non-hazardous product suitable for landfill.

The long-term continuance of landfill as a disposal option for electroplating sludge requires the urgent provision of an Irish hazardous waste landfill facility.

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CONTENTS.

1.0. INTRODUCTION.

Electroplating systems involve the passage of current through a solution of metal ions resulting in the deposition of these metal ions on the cathode electrode. A wide variety of metals are capable of being electroplated. The Irish electroplating industry services a diverse group including jewellery manufacture, electronic component manufacture and speciality applications.

Typically waste treatment operations for an electroplating facility may include any of the following; chemical oxidisation or reduction, neutralisation, precipitation and sedimentation. The resultant residue from these waste treatment operations is metal hydroxide sludge which must be disposed of in an environmentally sound manner. The main treatment options are dewatering on site and landfill, removal to licensed waste treatment facility for dewatering and then landfill or export for recovery or incineration.

The problem with the landfill of metal hydroxide sludges is the potential for leachate to contaminate surface or groundwater with metals that are harmful to humans and the environment.

All new electroplating facilities with treatment vats greater than 30 cubic metres are required to apply to the Environmental Protection Agency (EPA) for an Integrated Pollution Control (IPC) Licence before commencing operation while existing facilities were required to have applied by 1st of July

1997. The EPA requires best available technology not entailing excessive costs to prevent, eliminate or, where that is not practical, limit, abate or reduce an emission from an activity, as the benchmark when issuing a licence, issuing a licence with conditions, or refusing a licence application.

Prior to the enactment of the Waste Management Act,1996, Local Authorities had primary responsibility for the control of waste in Ireland. In particular, Local Authorities did not require permits for their own waste activities within in their own functional area.

Since 1st May 1997 this situation has changed with all new waste disposal activities requiring a Waste Licence before operation can commence. Existing waste disposal activities are required to apply for Waste Licences on a phased basis, starting with the larger facilities. As with the IPC Licences, the EPA may grant a waste Licence, grant a waste Licence with conditions or refuse a Waste Licence Application. The point being that the EPA will decide what criteria of waste each landfill can accept.

1.1. Aims and Objectives.

The aim of this thesis is to determine the future viability of landfill as an option for the disposal of metal hydroxide sludge from Irish electroplating plants. In order to determine this, the following issues have been examined. The quantity of electroplating sludge being produced, what the landfills have applied in their waste licence to accept it and what alternative waste technologies are available.

2.0. LITERATURE REVIEW.

2.1.1. Metals.

Metals and non metals are separated in the periodic table by a diagonal line of elements. Elements to the left of this diagonal are metals, and elements to the right are non metals. Elements that make up this diagonal are boron, silicon, germanium, arsenic, antimony, tellurium, polonium, and astatine have both metallic and non metallic properties. The common metallic elements include the following aluminium, barium, beryllium, cadmium, chromium, cobalt, copper, gold, iridium, iron, lead, lithium, magnesium, manganese, nickel, palladium, rhodium, silver, sodium, tin, titanium, tungsten, and zinc. Metallic elements can combine with one and another and with certain other elements, either as compounds, as solutions, or as intimate mixtures. A substance composed of two or more metals, or a substance composed of a metal and certain non-metals such as carbon are called alloys (Gaus, 1997).

Metals have unique chemical and physical properties due to metallic bonding. Band Stock and Hanson (1974) listed metallic properties as follows:

(a) **Conductivity:** High electrical conductivity in metals results from the ease of electron movement from one place in the metal crystal to another. High thermal conductivity in metals is largely due to the movement of their mobile electrons.

(b) **Metallic lustre:** Metals are crystalline and their flat crystal surfaces are able to reflect light. This may also be explained, in part, by the surface mobile electrons absorbing and re-emitting light energy.

(C) **Malleability and ductility:** In contrast to ionic and covalent crystal, which are brittle, metals have high malleability and ductility, because it is relatively easy for metal atoms to be moved about within the lattice, without destroying the bonding.

Metals are elements whose atoms easily detach outer electrons. The atoms are thus all positively charged ions. The geometrical arrangement of atoms in a metal is determined by the packing of the positively charged ions. However the detached electrons are not lost completely from the ions but are considered as being dispersed among the ions and as possessing rather high mobility, which accounts for the good electrical and thermal conductivity of metals. The electrons do not leave the structure, but are continually mobile throughout the structure. The bonds from any one atom are considered to be spherically distributed, and the bonds are capable of acting on as many neighbours as can be packed around an atom. (Tennissen, 1974).

2.1.2. Metal Toxicity.

Metals are a unique class of toxicants. They occur in nature but their chemical form may be altered because of physiological, biological or anthropogenic activities. Toxicity varies drastically with different chemical forms. Metals have a wide range of toxicity lead and mercury are very toxic while titanium is virtually non toxic. Toxicity is dependent on the following factors:

- **(i)** Level and duration of exposure.
- **(ii)** Chemical form.
- **(iii)** Formation of metal protein complexes.
- **(iv)** Host factors.

The main toxic metals are mercury, lead, cadmium, arsenic, beryllium, chromium and nickel (lu,1990).

2.2.1. Electroplating.

Electroplating is a process that involves the depositing of a thin layer of metal on a metallic base. Objects are electroplated to prevent corrosion, to obtain a hard surface or attractive finish, to purify metals, to separate metals for quantitative analysis, or, as in electrotyping, to reproduce a form from a mould. Cadmium, chromium, copper, gold, nickel, silver, and tin are metals often used in plating. Typical products of electroplating are silver-plated tableware, chromium-plated vehicle accessories and tin plated food containers.

With the electroplating process, the object to be plated is placed in a solution of a salt of the coating metal, called a bath, and is connected to the negative terminal of an external source of direct current electricity. Another electrode, often made of the coating material, is connected to the positive terminal of the electric source. A steady direct current of low voltage, usually from 1 to 6 V, is required for the process. When the current is passed through the solution, atoms of the plating solution migrate and deposit out on the cathode, the negative electrode. These atoms are replaced in the bath by atoms from the anode (positive electrode), if it is composed of the same metal as with copper and silver, otherwise they are replaced by regular additions of the salt to the plating bath, as with gold and chromium. In either case an equilibrium between the metal coming out of solution and the metal entering is maintained until the object is plated (Microsoft, 1997).

2.2.2. Electroplating Waste Treatment.

The pollutants of major concern in electroplating shops are metals, cyanide, and toxic organics. Suspended solids and oil and grease also occur. Common waste streams include contaminated rinse waters, spent plating baths, spent cleaning solutions, degreaser solvents, waste water treatment sludge, and miscellaneous solid waste (O'Leary *et al.*, 1997).

Typical electroplating waste treatment systems can involve the following processes; chemical oxidisation or reduction, neutralisation, precipitation and sedimentation or dewatering (See figure 2.1.). Alternative treatment may be required using membranes or, ion exchange. O'Leary *et al.* (1997) divided the typical electroplating waste treatment system into five main sections.

(1) **Detoxification:** This involves the reduction of hexavalent chromium to trivalent chromium using sulphur dioxide, sodium metabisulphate or ferrous sulphate under acidic conditions or cyanide oxidisation using sodium hypochlorite and chlorine on weak cyanide solutions and electrolytic decomposition of concentrated cyanide wastes. Other processes involving hydrogen peroxide, ozonation and ultra violet ozonation and ferrous sulphate precipitation are common.

(2) **Averaging:** This is where all the wastes from the electroplating plant are combined so as to present a consistent waste to the treatment plant, thus minimising fluctuations.

(3) **Neutralisation and precipitation:** This involves the adjusting of pH, the addition of agents to react with soluble pollutants to form a sludge of metal hydroxides or sulphates. Lime and caustic soda are the two common chemicals used for neutralisation and hydroxide precipitation.

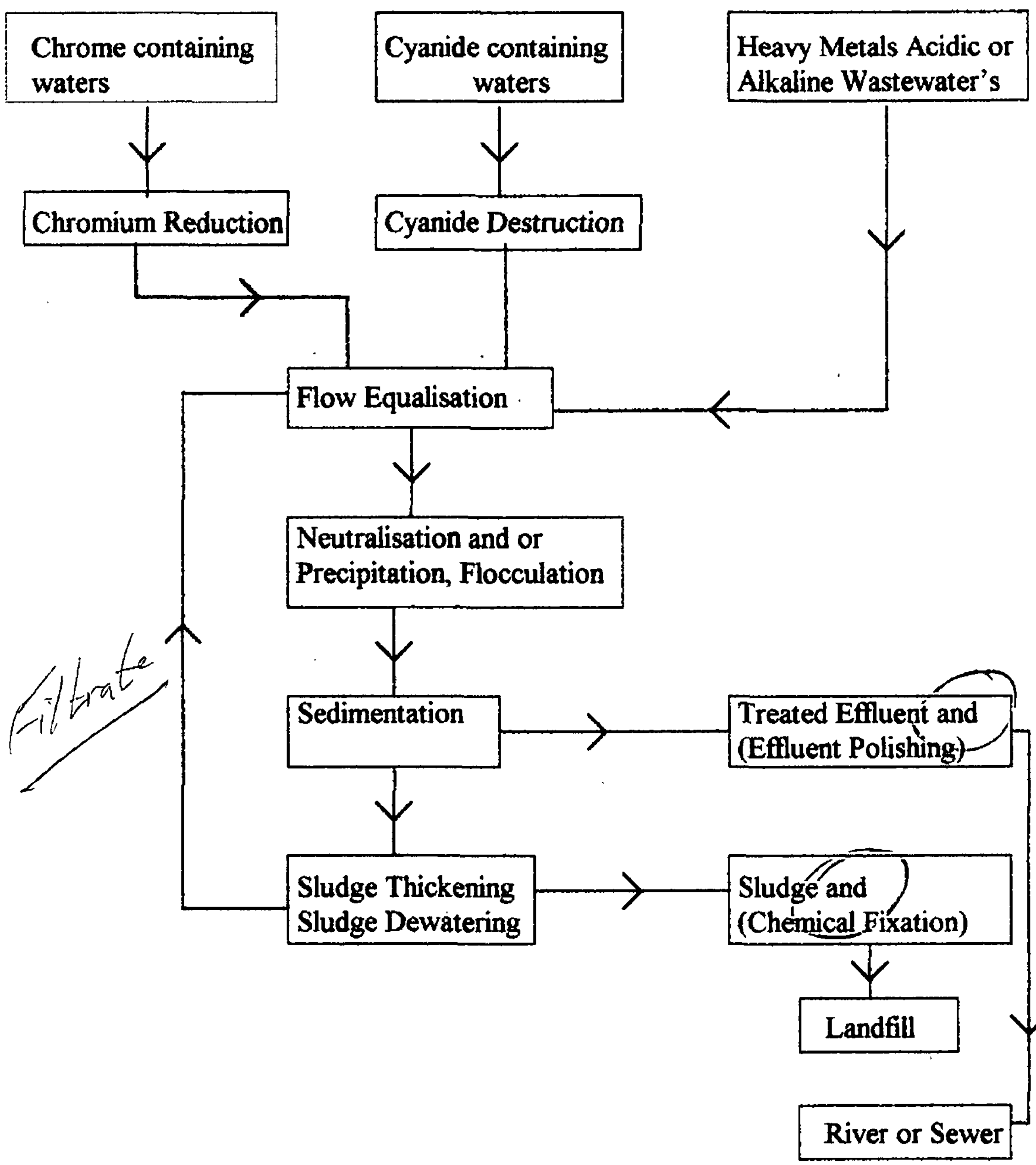

Figure 2.1. Flow diagram of electroplating waste treatment operations (O'Leary *et al.* 1997).

$$\underset{\text{Metal ion}}{M^{++}} + \underset{\text{Lime}}{Ca(OH)_2} \longrightarrow \underset{\text{Metal Hydroxide}}{M(OH)_2} + \underset{\text{Calcium ion}}{Ca^{++}}$$

(4) **Separation:** The solid particles are removed as a wet sludge by filtration or flotation and the water is discharged. Coagulants and flocculants may be added to promote precipitation and settling. Aluminium sulphate and ferric chloride are commonly employed as coagulating agents to improve floc formation.

(5) **Sludge dewatering:** The diluted sludge is usually thickened and mechanically dewatered before being removed from the waste producers site by licensed hauliers.

The effluent concentration levels attainable by metal hydroxide precipitation are dependent on the metal present, the precipitant used, the reaction conditions, especially pH and the presence of other materials which may inhibit precipitation. Metal hydroxides are amphoteric; i.e., they are increasingly soluble at both low and high pH and the point of minimum solubility (optimum pH for precipitation) occurs at different pH value for every metal (See figure 2.2.), (Freeman, 1988).

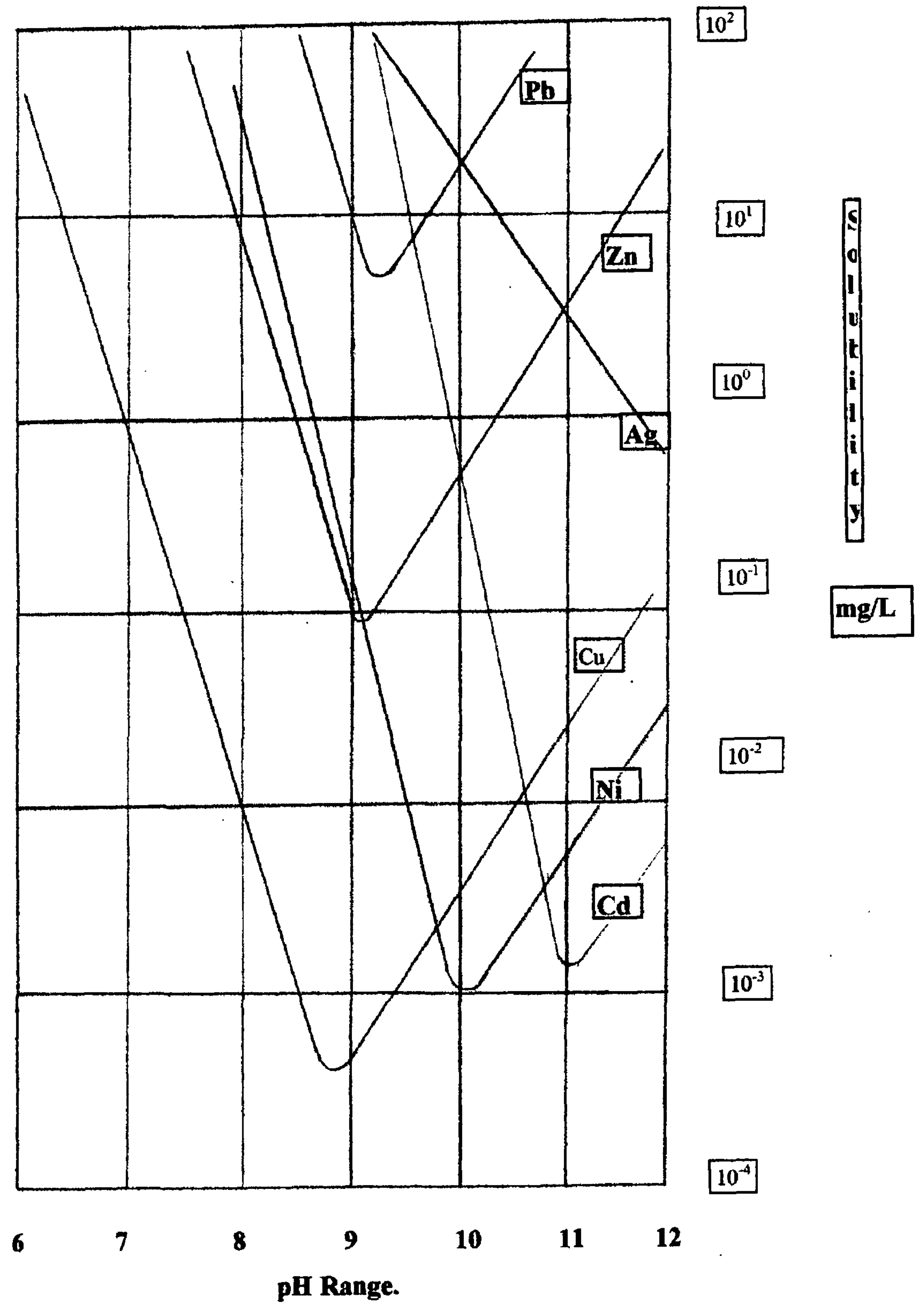

Figure 2.2 **Graph of solubilities of metal hydroxides as a function of pH (Freeman, 1988).**

2.3. European Union Environmental Policy.

According to Turner (1997) the emergence of European Union (EU) environmental policy can be dated to 1972 and the first United Nations Conference on the Environment held in Stockholm. This was the first time that the international community acknowledged the need to address the issue of global environmental degradation and resolved to adopt international and national laws to tackle this growing problem.

The communities powers to legislate on the environment were further expanded and strengthened in 1992 by the Treaty on European Union (Maastricht Treaty) and again at the Intergovernmental Conference to review the Masstricht Treaty.

Article 130r(1) of the European Community (EC) Treaty provides that

> Community environmental policy must contribute to the pursuit of the following objectives.
>
> **(i)** Preserving, protecting and improving the quality of the environment.
>
> **(ii)** Protecting human health.
>
> **(iii)** Prudent and rational utilisation of natural resources.
>
> **(iv)** Promoting measures at international level to deal with regional or world wide environmental problems.

The key principles underlying contemporary EC environmental policy are set out in Article 130r(2) of the EC treaty which provides that Community policy on the environment shall aim at a high level of protection taking in to account the diversity of situations in various regions of the Community. It is based on the precautionary principle and on the principle that preventative action should be taken, that environmental damage should as a priority be rectified at source and that the polluter should pay. Environmental protection requirements must be integrated into definition and implementation of other Communities policies.

Since the adoption of the First Action Programme, the Community has adopted four further Action Programmes. These Action Programmes set out specific proposals which the Commission intends to submit in the future, and secondly, set out the Commissions views on nature and direction for EC Environmental Policy for the coming years.

The current Action Programme, the Fifth, covers the years 1993-2000, the European Union set itself ambitious objectives for the year 2000, in response to the Brundtland report, the Rio process and the new requirements of the Maastricht Treaty. This programme is the foundation for the achievement of sustainable development. The world commission on Environment and Development defined sustainable development;

"as development which meets the needs of the present generation without compromising the ability of future generations to meet their own needs" (Department of the Environment, 1997).

This action plan has identified five target sectors manufacturing, transport, energy, agriculture and tourism for the integration of the environment into policy and practice.

2.4. Environmental Protection Agency.

The Environmental Protection Agency Act, 1992, was enacted on 23rd of April, 1992, and under this legislation the Agency was formally established on 26th of July, 1993. The Agency has the following responsibilities:

(i) The licensing and regulation of large/complex industrial and other processes with significant polluting potential, on the basis of integrated pollution control (IPC) and the application of best available technologies for this purpose.

(ii) The monitoring of environmental quality including the establishment of databases to which the public will have access, and the periodic reports on the state of the environment.

(iii) Advising public authorities in respect of environmental functions and assisting Local Authorities in the performance of their environmental protection functions.

(iv) The promotion of environmentally sound practices through, for example the encouragement of the use of environmental audits, the establishment of an eco-labelling scheme, the setting of environmental quality objectives and the issuing of codes of practice on matters affecting the environment.

(v) The promotion and co-ordination of environmental research.

(vi) The licensing and regulation of all significant waste disposal and recovery activities, including landfills and the periodic updating of a national hazardous waste plan for implementation by other bodies.

(vii) Preparation and implementation of a national hydrometric programme for the collection, analysis and publication of information on the levels, volumes and flows of water in rivers, lakes and groundwaters.

(viii) Generally overseeing the performance by Local Authorities of their statutory functions (Environmental Protection Agency, 1997a).

2.5.1. Integrated Pollution Licence.

With the Integrated Pollution Control (IPC) approach only one licence will be issued to a facility to control all aspects of air, water, waste, and noise pollution. The IPC licence takes account of the effect the activity has on the environment as a whole. The agency has to investigate if each facility is utilising Best Available Technology Not Exceeding Excessive Cost (BATNEEC) to eliminate or reduce its emissions to the environment.

The licensing function of the EPA commenced in May 1994 and will eventually cover over one thousand facilities. Due to the large number of facilities applying, IPC licensing is being implemented on a phased basis. There are thirteen sectors listed in the First Schedule of the EPA Act, 1992 to which IPC licensing applies (See table 2.1). These thirteen sectors can be subdivided into sixty one classes of activity. The phasing-in period for new activities extended from May 1994 to September 1996 while a much longer phasing-in period is required for the licensing of established activities. By June 1998, forty eight of the sixty one classes of established activities will be covered by the IPC licensing system. The remaining thirteen classes will be covered by 1999 (Environmental Protection Agency, 1997b).

Number	Sectors	Date	Number	Sectors	Date
1	Mineral and other material	16/05/94	8	Wood, Paper, Textiles, Leather	16/05/94
2	Energy	16/05/94	9	Fossil Fuels	03/09/96
3	Metals	03/04/95	10	Cement	16/05/94
4	Mineral Fibres and Glass	16/05/94	11	Waste	16/05/94
5	Chemicals	16/05/94	12	Surface Coating	03/04/95
6	Intensive Agriculture	03/09/96	13	Other Activities	03/04/95
7	Food and Drink	16/05/94			

Table 2.1. Specified dates for new activities from which IPC applicable (Environmental Protection Agency, 1997b).

2.5.2. BATNEEC.

As described in the EPA Act, 1992, BATNEEC will be used to prevent, eliminate or, where that is not practicable, limit, abate, or reduce an emission from an activity which is listed in the First Schedule of the Act. The use of BATNEEC is construed in the act to mean the provision and proper maintenance, operation, use and supervision of facilities which are the most suitable for the purposes.

In determining BATNEEC for an activity, the following should be considered:

- The current state of technical knowledge.
- The requirements of environmental protection.
- The application of measures for these purposes, which do not entail excessive costs, having regard to the risk of significant environmental pollution which, in the opinion of the agency, exists.

For existing facilities, the following should be considered as well:

- The nature, extent and effect of the emission concerned.
- The nature and age of the existing facilities connected with the activity and the period during which the facilities are likely to be used or to continue in operation.

- The costs which would be incurred in improving or replacing these existing facilities in relation to the economic situation of activities of the class concerned (Department of the Environment, 1992).

2.5.3. BATNEEC Technologies for the Treatment and Disposal of Electroplating Operation Wastes.

The EPA, in its Integrated Pollution Control Licensing BATNEEC Guidance Note for Electroplating Operations (Environmental Protection Agency, 1996) recommends the following technologies for the treatment and disposal of wastes.

(1) Sludge treatment.

- Gravity thickening.
- Filtration.

(2) Disposal.

- Engineered landfill.
- Recovery and reuse in down stream processing or another industry.
- Waste encapsulation.

2.6. Waste Catalogue and Hazardous Waste List.

The EPA has adopted the European Waste Catalogue and Hazardous List system of waste classification for the National Waste Database. The European Waste Catalogue (94/3/EC) originated in the European Directive 75/442/EEC on waste (the Framework Directive) which was amended in 1991 (91/156/EC), Article 1 requires the Commission to draw up a list of wastes belonging to general categories set out in Annex 1 of the directive. This list of wastes has become known as the European Waste Catalogue (EWC) and applies to all waste whether they are destined for recovery or disposal. The European Hazardous Waste List (HWL) 94/904/EC is a subset of EWC containing wastes considered to be hazardous or harmful. The properties which render a waste hazardous are set out in Annex III of directive 91/689/EC.

The EPA published EWC and HWC as one combined list entitled Waste Catalogue and Hazardous Waste List, Environmental Protection Agency, 1996. This is a harmonised non-exhaustive list of wastes which will be periodically reviewed and updated. In general an EWC/HWC consists of a six digit code which defines wastes according to their origin rather than chemical composition (Carey *et al*, 1996).

2.7. Integrated Pollution Control Licence for Electroplating Plants.

Electroplating activities are mentioned in the First Schedule to the EPA Act, 1992 in Sector twelve, Surface Coating. All established electroplating plants are required to apply for an IPC licence where the volume of the treatment vats exceeds thirty cubic metres by 1st of July 1997. As of the 19th of February 1998 fifteen electroplating operations have applied for an IPC licence (See table 2.2.). These electroplating operations are distributed throughout Ireland (See figure 2.3.). Currently three electroplating operations have been licensed, one is at proposed determination (draft licence) stage and the other applications are being processed (Environmental Protection Agency, 1998).

2.8. Definition of a Landfill.

The proposed EU Directive on the landfill of waste, defines a landfill as a waste disposal site for the deposit of waste on to or into land, including internal waste disposal sites (i.e. landfill where the producer is carrying out its own waste disposal at the place of production). It excludes facilities where waste is unloaded in order to permit its preparation for further transport for recovery, treatment or disposal elsewhere and temporary (i.e. less than one year) deposit of waste prior to recovery, treatment or disposal (European Commission, 1997).

IPC Reg. No	Name	Address	Classes	Licence Status Description	Licence Issue Date	PD Issue Date
269	Bast Hardware Ltd.	Tubercurry, Co Sligo.	12.3/	Licensed	6/01/98	11/09/97
271	A.T. Cross Ltd.	Ballinasloe Co Galway.	12.3/	Licensed	11/12/97	06/10/97
272	Ossian Ltd.	Macroom, Co. Cork.	12.3/	Applied		
274	Arlington Ltd.	Portarlington, Co Laois.	12.3/	Applied		
276	Hitech Plating.	Walkinstown, Dublin 12.	12.3/	Applied		
277	Plateco ZN Ltd.	Greenhills Rd., Dublin 12.	12.3/	Applied		
278	Computer Plating Specialists Ltd.	Santry Ave., Dublin 9.	12.3/	Applied		
279	Galway Plating Ltd.	Tuam Rd., Galway.	12.3/	Licensed	14/11/97	10/09/97
280	Waterford Plating Co. Ltd.	Northern Ind. Est., Waterford.	12.3/	Applied		
281	Loredo Ltd.	Ashbourne, Co. Meath.	12.3/ 3.4/	Applied		
282	Andresen Irl. Ltd.	Rathkeale, Co. Limerick.	12.3/	Applied		
287	Braun Irl. Ltd.	Dublin Rd., Carlow.	12.3/	Applied		
288	Molex Irl Ltd.	Shannon, Co. Clare.	12.3/	Applied		08/12/97
291	Galvotech Irl. Ltd.	Childers Rd, Limerick.	12.3/	Applied		
292	Galvotech Int. Ltd.	Childers Rd, Limerick.	12.3/	Applied		

Table 2.2. Table of Electroplating IPC Applications up to 19th of February 1998 (Environmental Protection Agency, 1998).

Figure 2.3. **Location of Electroplating Plant with treatment vat greater than 30 cubic metres.**

2.9. Landfills, the Irish Situation.

In Ireland, landfill is the primary means of disposal for household, commercial and industrial wastes, accepting a total of at least two million tonnes of waste per year. This extensive use of landfill is likely to continue in the future, despite great efforts to encourage recycling and waste minimisation (Environmental Protection Agency, 1997c).

In 1995, there were one hundred and eighteen active landfill sites in Ireland (See figure 2.4). The Local Authorities operated eighty seven of these landfill sites, while the other thirty one sites were privately operated. The majority of these sites are relatively small, with 58% accepting less than 15,000 tonnes per annum. A further 34% accept up to 50,000 tonnes per annum with only 7% accepting greater than 50,000 tonnes per annum. Many of the existing landfills in 1995 are nearing capacity, with fewer than 5% having a remaining capacity of more than twenty years and a further 45% having between five and twenty years remaining capacity (See figure 2.5.), (Carey *et al*, 1996).

Landfills can be classified as either a containment site or an attenuation site. The aim of the containment site is to isolate wastes and leachates from the external environment for a considerable period, while with attenuation the aim is to reduce the polluting characteristics of the waste and its leachate by using the biological, chemical and physical processes which occur in the ground and

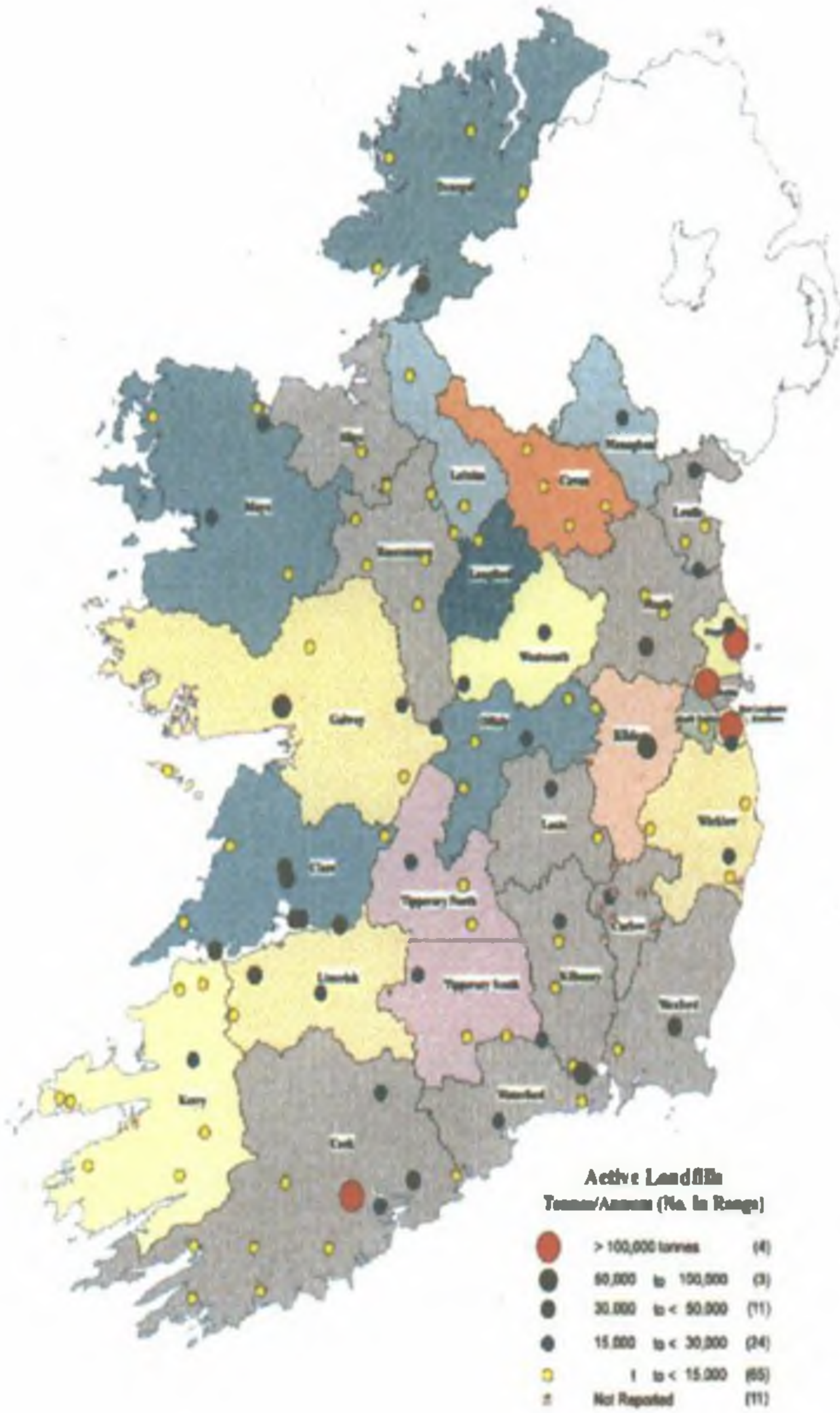

Figure 2.4. Location and Size of Active Landfills (Carey *et al.*, *1996*).

Figure 2.5 **Remaining Capacity of Active Landfills (Carey *et al.* 1996).**

landfills surrounding strata. These have a very bad environmental protection record.

In the past, landfill sites were rarely engineered to containment status resulting in various environmental problems occurring. These include possible contamination of the groundwater and surface water and uncontrolled migration of landfill gas. Shorter term impacts include the generation of odour, noise, litter, and visual nuisance. It is important therefore that landfills are located, designed, operated and monitored to ensure that they do not, to any significant extent:

- Harm the environment.
- Endanger human health.
- Create an unacceptable risk to water, soil, atmosphere, plants or animals.
- Create unacceptable nuisances through noise or odours; and adversely affect the countryside or places of special interest (Environmental Protection Agency, 1997c).

2.10. Major Stages of Waste Degradation in a Landfill.

Microbes, living organisms which consume organic material in the landfill resulting in decomposition products being produced. Microbes can be aerobic (these require oxygen) or anaerobic (these do not require oxygen). Microbes:

- Obtain energy and generate heat when they consume and metabolise.
- Require nitrogen, phosphorous and potassium for their growth.
- Generate gaseous by products.

When microbes attack the cellulose chain (See Figure 2.6.) which is present in municipal solid waste, they:-

(1) Break it down in to simple sugars.

(2) If oxygen is present, these sugars are then broken down to carbon dioxide and water vapour.

(3) As the oxygen level falls fatty acids ($H.(CH_2)_n.COOH$) are formed.

(4) The fatty acids are broken down to acetic acid (CH_3COOH).

(5) Methanogenic microbes in the absence of oxygen break down acetic acid to methane and carbon dioxide.

$$CH_3COOH \longrightarrow CH_4 + C0_2$$

Acetic Acid	Methane	Carbon Dioxide

(Environmental Protection Agency, 1997c).

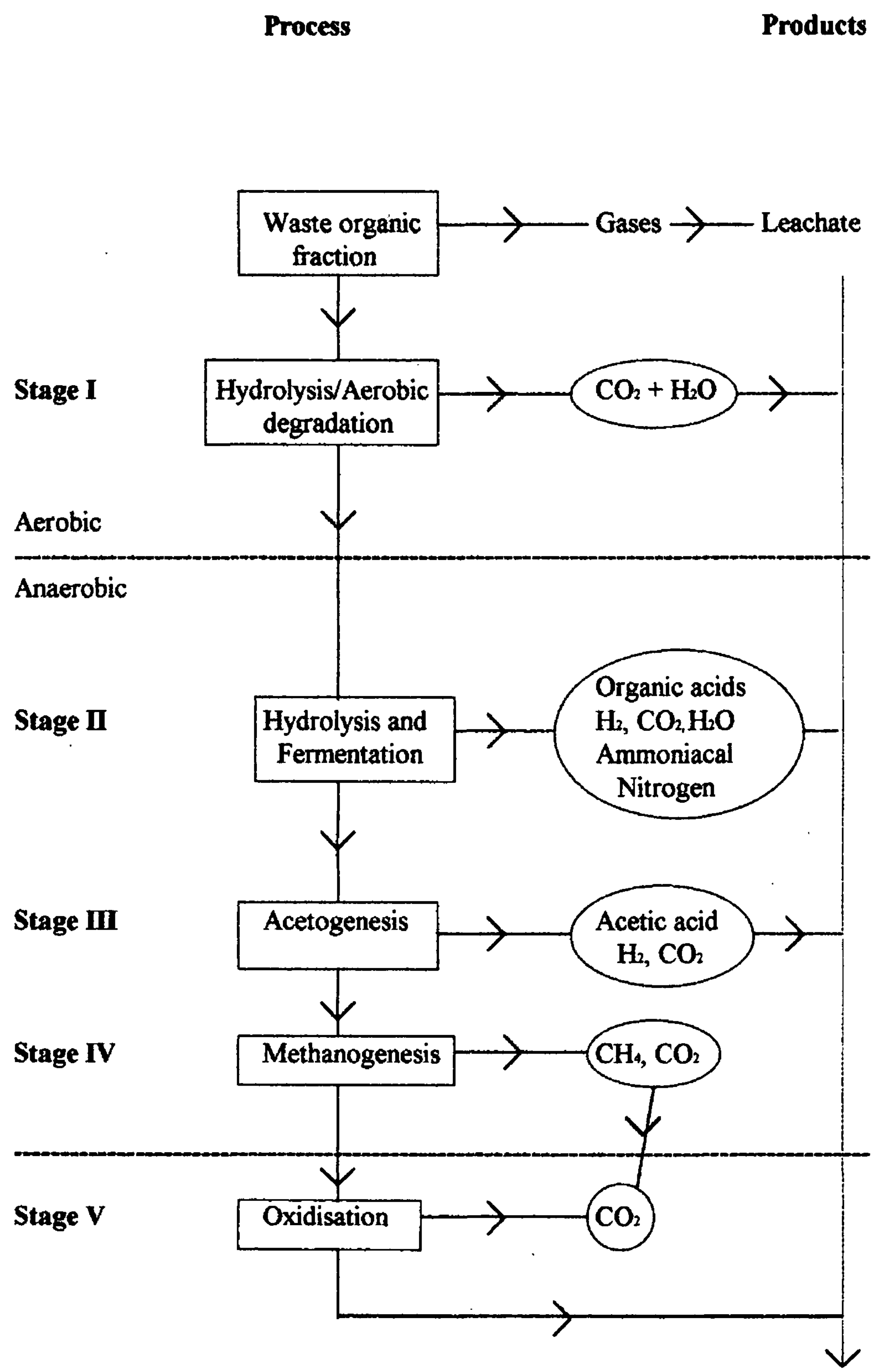

Figure 2.6. **Major Stages of Waste Degradation in a Landfill (Environmental Protection Agency, 1997c).**

2.11.1. Leachate.

Leachate is defined as any liquid percolating through the deposited wastes and emitted from or contained within a landfill. The Composition and characteristics of leachate are dependent on following factors:

- Waste type deposited.
- Amount of rainfall and other climatic factors.
- The degree of surface and groundwater ingress.
- The age of deposited waste.
- The degree of compaction.
- The type of cover, capping and restoration.

Leachate generation in landfills poses a potential threat to both surface and groundwaters (Environmental Protection Agency, 1997c).

2.11.2. Leachate Generation.

The amount of leachate produced by a landfill site is dependent on the quantity of liquids entering the deposited wastes. Leachate quality varies with the age of the landfill (See figure 2.7.). Sources of liquid in landfill include the following:

- Liquids in the wastes deposited.
- Rainfall.
- Surface water inflow.

- Groundwater intrusion (Environmental Protection Agency, 1997c).

2.11.3. Leachate Control at Landfills

(1) Control water from precipitation from entering the landfill body.

(2) Prevention of surface and/or groundwater from entering into the landfilled waste.

(3) Collection of contaminated water and leachate.

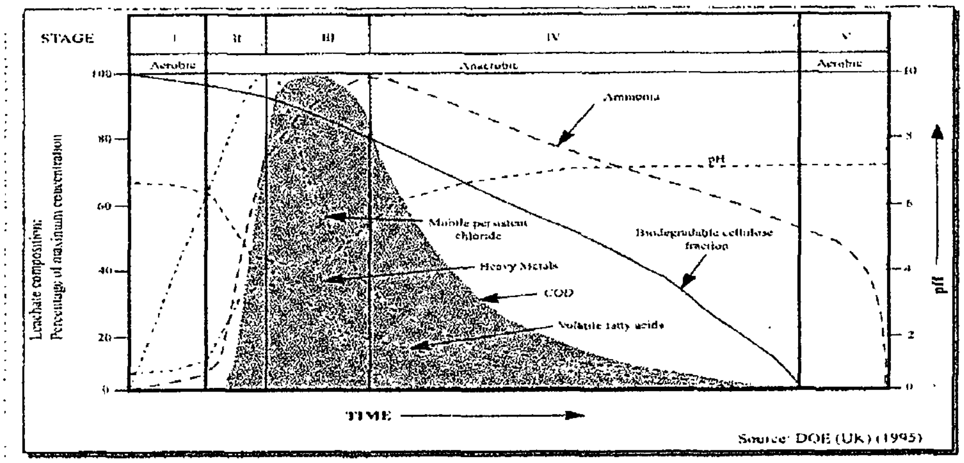

Figure 2.7. Changes in Leachate Composition (Environmental Protection Agency, 1997c).

(4) Treatment of contaminated water and leachate collected from landfill to the appropriate standard required for their discharge (Environmental Protection Agency, 1997c).

2.12. The European Communities (Waste Regulations), 1979 S.I. No. 390.

These regulations originated from Council Directive. (75/442/EEC) the framework directive on waste. Both waste and disposal are not defined but assume the same meaning as in the Directive.

Waste means;

> *"any substance or object which the holder disposes of or is required to dispose of pursuant to the provisions of national law in force."*

Disposal means;

> *"the collection, sorting, transport and treatment of waste as well as its storage and tipping above or under ground; transformation operations necessary for its re-use, recovery or recycling."*

Waste operation means;

> *"any operation comprised in the disposal of waste."*

Section 3, states it is an offence for the holder of the waste to permit the disposal of waste on his behalf by another person other than;

- a public waste collector (Local or Sanitary Authorities),
- a person holding an appropriate permit.

Section 4, states that each Local Authority is responsible for planning, authorisation and supervision of waste operations within their area and must prepare a waste plan.

Section 5, allows a Local Authority to issue permits for the treating, tipping or sorting waste in their area on behalf of another person.

Section 6, requires a permit holder to maintain a waste register and details the powers of an authorised person.

Section 7, deals with prosecutions.

Section 8, details the exemptions to these regulations (Department of the Environment, 1979).

2.13. The European Communities (Toxic and Dangerous) Waste Regulations, 1982 S.I. No. 33.

These regulations implemented the Council Directive (78/319/EEC) on Toxic and Dangerous Waste.

Toxic and Dangerous Waste is defined in the Directive as;

> *"any waste containing or contaminated by the substances or materials listed in the annex of the Directive of such a nature, in such a quantity, or in such concentrations as to constitute a risk to health or the environment."*

The Annex to the Directive includes 27 categories of materials.

Under Section 3, Local Authorities are responsible for the planning, organisation and supervision of operations for the disposal of toxic and dangerous waste within their functional area and the authorisation of storage, treatment and depositing of such waste.

Under Section 4, the Local Authority must prepare a Special Waste Plan.

Under Section 5, the Local Authority may issue permits to persons engaged in the storage, treatment or depositing of toxic and dangerous waste in their area. Local Authorities do not require a permit in their own functional area.

Under Section 7, any person producing, holding or depositing toxic and dangerous waste must maintain a register of such waste.

Under section 8, a consignment note must be completed for every consignment of toxic and dangerous wastes other than those movement of wastes within the premises where they were produced (Department of the Environment, 1982).

2.14. Local Government (Water Pollution) Regulations, 1992 S.I. No. 271.

In 1980, the European Commission introduced a Directive on the Protection of Groundwater against Pollution caused by Certain Dangerous Substances (80/68/EEC). This was implemented into Irish legislation by the Local

Government (Water Pollution) Regulations 1992 (S.I. No. 271). The directive is aimed at controlling discharges to groundwater of two specific lists of substances (List I and List II) which, because of their toxicity, persistence and bioaccumulation pose a particular hazard to the integrity and quality of groundwater.

List I substances: direct discharges of these substances to groundwater is prohibited, while indirect discharges must be subject to prior investigation and authorisation.

(i) Organohalogen compounds and substances which may form such compounds in the aquatic environment.

(ii) Organophosphorous compounds.

(iii) Organotin compounds.

(iv) Substances which possess carcinogenic, mutagenic or teratogenic properties in or via the aquatic environment.

(v) Mercury and its compounds.

(vi) Cadmium and its compounds.

(vii) Mineral oils and hydrocarbons.

(ix) Cyanides.

List II Substances: contains individual substances and the categories of substances belonging to the families and groups of substances listed below which could have a harmful effect on groundwater. Discharges of these substances to groundwater should be minimised.

(i) The following metalloids and metals and their compounds.

Zinc	Tin	Copper	Barium
Nickel	Beryllium	Chrome	Boron
Lead	Uranium	Selenium	Vanadium
Arsenic	Cobalt	Antimony	Thallium
Molybdenum	Tellurium	Titanium	Silver

(ii) Biocides and their derivatives not appearing in list I.

(iii) Substances which have a deleterious effect on the taste and/or odour of groundwater, and compounds liable to cause the formation of such substances in such water and to render it unfit for human consumption.

(iv) Toxic or persistent organic compounds of silicon, and substances which may cause the formation of such compounds in water, excluding those which are biologically harmless or are rapidly converted in water into harmless substances

(v) Inorganic compounds of phosphorous and elemental phosphorous.

(vi) Fluorides.

(vii) Ammonia and nitrites.

Where certain substances in list II are carcinogenic, mutagenic or teratogenic, they are included in Category iv of List I (Department of the Environment, 1992).

2.15. Waste Management Act, 1996.

Prior to the enactment of the Waste Management Act in July of 1996, Local Authorities had primary responsibility for the control of waste in Ireland. Their powers mainly derived from a number of European Community Regulations on waste. These regulations gave powers to Local Authorities to control waste activities mainly through the issuing of permits for waste disposal and movement. However Local Authorities, who were responsible for the collection and disposal of waste in their own area did not require permits for their own waste activities such as waste collection and landfill operation. Generally, the situation was unsatisfactory and what was required was comprehensive reform by way of framework waste management legislation which would provide measures for controlling all links in the waste chain. This situation has been rectified by the enactment of the Waste Management Act.

The principal objective of the Act is to ensure that the holding, transportation, recovery or disposal of waste does not cause environmental pollution. In order to achieve this aim each step in the waste chain, from the point at which the waste is produced to the point at which it is recovered or disposed of, must be regulated and controlled (Environmental Protection Agency, 1997a).

An operator of a waste management facility is required to apply for a licence under section 39 of the Waste Management Act, 1996. The purpose of a waste licence is to ensure that any waste management activity is operated in a manner which will not cause environmental pollution or be harmful to humans, animals and plant life. All new waste disposal activities require a Waste Licence prior to commencing operation since the 1st May 1997 (See table 2.3.). The requirement to apply for a waste licence for existing facilities is to be implemented on a phased basis as was IPC licensing. The first phase of applications is set down in the Waste Management (Licensing) Regulations 1997 (S.I. No. 133), which establishes the nature and size of the disposal activity which are required to be licensed by particular dates set down (See table 2.4.) (Environmental Protection Agency, 1997a).

Waste Activity Requiring a Waste Licence.
The disposal of waste at a landfill facility (other than an existing facility) The disposal of hazardous waste (other than at an existing facility or a landfill facility). The disposal of waste at a certified facility. The disposal of waste at a facility where the annual intake exceeds 25,000 tonnes (other than an existing facility, a landfill facility or a facility for the disposal of hazardous waste).

Table 2.3. Waste disposal activities which require a waste licence from the EPA before commencing operations (Environmental Protection Agency, 1998).

The Waste Management Act, 1996, sets out the criteria by which the Agency must judge a waste licence application. Section 40(4) states that the Agency shall not grant a licence unless it is satisfied that:

- The waste management activity will be operated in compliance with all relevant standards or emission limit values.

Apply Before	Waste Activity
01/10/97	The disposal of waste at landfill facility which is existing (but is not a certified facility where the annual intake exceeds 40,000 tonnes.
01/03/98	The disposal of waste at a landfill facility which is an existing facility (but is not a certified facility) where the annual intake exceeds 20,000 tonnes but does not exceed 40,000 tonnes.
01/05/98	The disposal of waste at a landfill facility which is an existing facility where the annual intake does not exceed 20,000 tonnes, other than such a landfill operated by or on behalf of a County Council, a County Borough Corporation, a Borough Corporation or an Urban District Council. The disposal of waste at a facility which is an existing facility (but is not a landfill facility or a certified facility) with an annual intake greater than 25,000 tonnes. The disposal of hazardous waste at an existing facility (other than a landfill).
01/10/98 District	The disposal of waste at a landfill facility which is an existing facility (but is not a certified facility) operated by or on behalf of a County Council, a County Borough Corporation, a Borough Corporation or an Urban Council where the annual intake exceeds 5,000 tonnes but doesn't exceed 20,000 tonnes.
01/03/99	The disposal of waste at a landfill facility which is an existing facility (but is not a certified facility) operated by or on behalf of a County Council, a County Borough Corporation, a Borough Corporation or an Urban District Council where the annual intake does not exceed 5,000 tonnes.

Table 2.4. Existing waste disposal activities and dates by which they must apply for a waste licence (Environmental Protection Agency, 1998).

- The activity after it has been licensed, will not cause environmental pollution.
- The best available technology not entailing excessive costs (BATNEEC) is used to deal with any emission from the site.
- The applicant and any other relevant person is a fit and proper person to hold a licence.
- That the Agency's requirements (if any) in respect of the making of the appropriate financial provisions in respect of the licence is satisfied.

A Waste Licence is a single integrated licence which deals with emission to all environmental media, in addition to the environmental management of the facility. All related waste operations carried out by the applicant in, on or adjacent to the facility are taken into consideration. Once granted, a Waste Licence supersedes any licence issued under the following legislation:

- Air Pollution Act 1987.
- Local Government (Water Pollution) Acts 1977 and 1990.
- Fisheries (Consolidation) Act 1959.
- Foreshore Act 1933.

A Waste Licence also supersedes any permits issued by the Local Authorities under the following regulations:

- The European Communities (Waste) Regulations 1979.

- The European Communities (Toxic and Dangerous Waste) Regulations 1982.
- The European Communities (Waste oils) regulations 1982.
- The European Communities (Waste) Regulations 1984.

The Waste Management Act, 1996, defines waste;

> *"as any substance or object belonging to a category of waste specified in the first schedule or for the time being included in the European Waste Catalogue which the holder discards or intends or is required to discard, and any thing which is discarded or otherwise dealt with as if it were waste shall be presumed to be waste until the contrary is proved."*

Hazardous Waste means, waste mentioned in the list prepared pursuant to Article 1 (4) of Council Directive 91/689/EEC of 12th of December, 1991, being either:

(i) Category I waste that has any of the properties specified in Part II of the second schedule, or

(ii) Category II waste that:

   (a) Contains any of the constituents specified in Part II of the second Schedule.

   (b) Has any of the properties specified in Part III of said schedule.

(iii) Such other waste, having any of the properties specified in part III of the Second Schedule, as may be prescribed for the purposes of this definition (Department of the Environment, 1996).

2.16. Hazardous Waste Management Plan.

Under Section 26 of the Waste Management Act, 1996 the EPA is responsible for producing a National Hazardous Waste Management Plan. There were two formal periods for public consultation during which the EPA sought the opinion of citizens, business interests, community groups, environmental groups etc. The first period commenced on 16th of July 1997 and the second period of consultation will take place after the Proposed Plan has been published in the Spring of 1998.

The principal aim of the National Hazardous Waste Management Plan is to determine the most effective methods of managing hazardous waste and controlling its impact on the environment and to prevent its generation, to reduce its hazardous nature and to reuse and recycle it wherever possible. Disposal of hazardous waste is the last and least acceptable solution and should be considered only where preferred options are not available. In implementing the National Hazardous Waste Management Plan the EPA intends to work with industry and with local government in finding alternative solutions to disposal. The plan will cover a ten year period and will attempt to provide a practicable, economical and environmentally safe solution to management of Irish produced Hazardous Wastes (Environmental Protection Agency, 1997a).

2.17. The Proposed Council Directive on the Landfill of Waste.

The aim of this proposed directive is to introduce uniform standards for landfills throughout the European Union. Articles of particular interest to the disposal of electroplating sludges are:

Article 3, classifies landfills into 3 categories: for hazardous waste, for non-hazardous waste and for inert waste.

Article 6, states that all Member States must ensure that:

- All waste has been subject to treatment before landfill. Treatment is defined as physical, chemical or biological processes, including sorting, that change the characteristics of the waste in order to reduce its volume or hazardous nature, facilitate its handling or enhance recovery.
- Only hazardous waste that fulfils the criteria in Annex II can be assigned to a hazardous landfill.
- Landfill for non-hazardous waste can be used for municipal and non hazardous waste.

- Inert waste landfills can only be used for inert waste (European Commission, 1997).

2.18. Waste Licence Applications.

As of 4th of February 1998 the EPA had received nineteen Waste Licence Applications (See table 2.5.) and has yet to issue a Waste Licence. These waste facilities are distributed throughout Ireland (See figure 2.9.). Currently the EPA is processing thirteen existing landfill and three proposed landfill Waste Licence applications. All of these applications are at various stages of the licence application process (Environmental Protection Agency, 1998).

2.19. Engineered Landfill Technology.

Modern landfills must be situated and designed in such a way as to prevent pollution to the soil, surface and ground waters. This is achieved by a combination of a geological barrier and a bottom liner during operational phase and by a geological barrier and top liner during closure phase. The EU Council Directive on the Landfill of Waste stipulates that the base and sides of a landfill shall consist of a mineral layer as follows where K is permeability,

- Hazardous waste landfill $K \leq 1.0 \times 10^{-9}$; thickness $\geq$ 5m.
- Non-hazardous landfill $K \leq 1.0 \times 10^{-9}$; thickness $\geq$ 1m.
- Inert landfill $K \leq 1.0 \times 10^{-7}$; thickness $\geq$ 1m.

If the geological barrier does not meet these requirements an artificial geological barrier greater than 0.5 m must be added to enhance protection.

Waste Licence	Applicant Name	Facility Location	Activity Type
W001	Kerry Co. Co.	Muingnaminnane, Tralee.	Landfill
W002	Cork Co. Co,	Ballyguyrue, Mallow.	Landfill
W003	South Dublin Co. Co.	Ballymount, Co Dublin.	Baling Station
W004	South Dublin Co. Co.	Kill Arthurstown, Co. Kildare.	Landfill
W005	Wicklow Co. Co.	Ballynagran, Coolbeg and Kilcandra, Co Wicklow.	Proposed Landfill
W006	Limerick Co. Co.	Slieve Felim-Buffanoky and Forkeala.	Proposed Landfill
W008	GaelSafe Ltd.	GaelSafe Ltd. Unit 430, Western Industrial Estate, Dublin12.	Hazardous Waste Disposal
W009	Fingal Co. Co.	Balleally.	Landfill
W010	Meath Co. CO.	Basketstown.	Landfill
W011	Wicklow Co. Co.	Ballymurtagh.	landfill
W012	Cork Corporation	Kinsale Road.	Landfill
W013	Galway Corporation	Carrowbrowne.	Landfill
W014	Kildare Co. Co.	Sillott Hill.	Landfill
W015	Dun Laoghaire Rathdown Co. Co.	Ballyogan.	Landfill
W016	Wexford Co. Co.	Killurin.	Landfill
W017	Limerick Co. Co.	Gortadroma.	Landfill
W018	Waterford Corporation	Kilbarry.	Landfill
W019	Tipperary(SR) Co. Co.	Hardbog, Grangemockler.	Proposed landfill

Table 2.5. Waste Licence Applications being processed by the EPA (Environmental Protection Agency, 1998).

Figure 2.9. Location of existing and proposed Waste Operations whose Waste Licence Applications are currently being processed by the EPA

Both hazardous and non hazardous landfills require a leachate collection and sealing system while surface sealing is required for hazardous landfills (European Commission, 1997).

Liners may be of a number of types:

(1) Geomembranes: these are manufactured from synthetic materials. Geomembranes exhibit flexibility and can remain intact even when differential settlement and shifting occurs in the landfill. Most geomembranes are manufactured from high density polyethylene (HDPE), polypropylene (PP) and linear low density polyethylene (LLDPE).

(2) Compacted soil or clay liner: blended soils with sodium bentonite or calcium bentonite are employed when native soils cannot offer acceptable protection when compacted. Other additives that have been used include lime and cement. The major problem with this type of liner is ensuring equal protection throughout the landfill.

(3) Geosynthetic clay liner: these are high strength bentonite composites which employ a geo-textile outer layer with an inner layer of low permeability bentonite. Upon contact with water based liquids the bentonite layer swells to form a low-permeability clay layer similar to a layer of several feet of compacted clay (FLI International Lining Systems, 1997).

2.20. Co-disposal Landfill.

Co-disposal of hazardous waste is the most common route for hazardous waste disposal in the UK accounting for 50% of total. The basic principle involved in co-disposal is that the landfill site acts as a bio-reactor in which the micro organisms in municipal solid waste break down the components of the hazardous waste with the associated biological, physical and chemical processes.

Currently in the UK there are 360 co-disposal landfill sites accepting industrial waste mostly in solid form. The UK Department of the Environment in it Landfill Co-disposal Waste Management paper, recommends co-disposal using a flushing bioreactor in mature waste i.e. 1-5 years, as the best practicable environmental option (BPEO) for wastes containing components of acids, heavy metals, phenols, degradable organic. In particular metal finishing waste and industrial effluent treatment sludges and filtercakes are deemed suitable.

The disadvantage with co-disposal is the possibility of the interaction of the wastes to produce a toxic product which may harm humans or the environment.

The future of this type of landfill is currently in doubt, as it is being subjected to increasing opposition from the European Commission (Williams, 1998).

2.21. Entombment Dry Landfill.

This type of landfill is in common use in the USA for hazardous waste disposal. This operates on the principle that waste is kept dry and is contained indefinitely. The prevention of infiltration of water into the waste prevent decomposition and therefore leachate is negligible. The advantages of this landfill is that it produces very low levels of leachate and that the waste can be stored for future generations to develop new technologies to treat or use the waste. The disadvantages are that stabilisation take longer, liner failure will eventually occur and water will be present in the waste resulting in some biodegradation occurring (Williams, 1998).

2.22.1. Solidification and Stabilisation.

Conner (1990), states that the use of Chemical fixation and stabilisation (CFS) with general waste residues dates back only to about 1971. However most modern CFS processes originated in one of the following areas:

(1) Solidification and disposal of radioactive waste.

(2) Mine backfilling.

(3) Soil stabilisation and grouting.

(4) Production of stabilised base courses for road construction.

The objectives of both solidification or stabilisation as a treatment process is to achieve one or more of the following:

- Improve the physical characteristic and handling of the waste.
- Reduce the waste surface area.
- Reduce the solubility of the waste, detoxify the waste.

Solidification is a process where material is added to waste to produce a solid this generally results in an increase in waste volume. Chemical bonding between the toxic contaminant may occur, while with stabilisation the waste is converted to a more chemically stable form. Chemical fixation is the transformation of the toxic contaminant to a new non toxic form. Encapsulation is a process that involves the complete coating of a toxic particle with a new substance. Encapsulation can be divided into macro-encapsulation i.e. the encapsulation of an agglomeration of waste particles or micro-encapsulation i.e. the encapsulation of individual waste particles.

Solidification and stabilisation technology are characterised according to the binders or binding mechanisms used. Binders may be divided into:

(1) Inorganic type such as hydraulic cements, lime, pozzolans, gypsum and silicates.

(2) Organic type such as epoxy, polyester, asphalt, polyolefins and urea-formaldehyde.

While binding mechanisms are grouped as follows:

(1) Sorption; this involves adding a solid to take-up any free liquid in a waste. Most sorption processes simply remove the liquid onto the surface of the solid. Selected sorbents can be used to improve the performance of solidification and stabilisation processes.

(2) Pozzolan reactions; this process uses a fine non crystalline silica in flyash and the calcium in lime to produce a low strength cementation. Physical trapping of the contaminant is the primary containment mechanism.

(3) Pozzolan-Portland cement reactions; the Portland cement is mixed with flyash or other pozzolans to produce a relatively high strength waste and concrete matrix. Waste containment occurs through entrapment of the waste particles. Soluble silicates are added to aid processing and help in the containment of metals through the formation of silicate gels. This process is the oldest and most widely used. It has proved to be very versatile through the use of additives to enhance performances for particular applications.

(4) Thermoplastic micro-encapsulation; this involves the blending of the waste particles with melted asphalt or similar material. Physical entrapment is the containment mechanism.

(5) Macro-encapsulation; this involves the isolation of a large volume of waste by a jacketing polyethylenes or other resins (Freeman, 1988).

2.22.2. The Ceramicrete Process.

This Chemically Bonded Phosphate Ceramic (CBPC) process was originally developed at Argonne National Laboratory in response to a need at the U.S. Department of Energy sites to treat low-level mixed waste by non thermal means, it involves the dual process of stabilisation, chemical fixation by conversion of soluble contaminants into insoluble phosphates, and physical encapsulation in a dense ceramic matrix. Solid waste such as inorganic solids, sludges or liquids are mixed with magnesium oxide and reacted with an aqueous solution of phosphoric acid or acid phosphates at room temperature to form a slurry that sets in approximately two hours to form a hard dense ceramic waste form. Between 50-75% of the final ceramic waste form is waste with no significant increase in volume as the binders and water occupy the empty spaces in the solid waste. The resultant product is extremely leach-resistant as demonstrated by the Toxicity Characteristic Leaching Procedure (TCLP) tests which indicate that leachate levels are 1 to 2 orders of magnitude lower than the U.S. EPA Land Disposal Regulations (LDRs) limits. Also accelerated leaching tests such as the American Nuclear Society's ANS16.1 showed that the retention of contaminants is superior to other methods such as cement stabilisation.

Ceramicrete has the following advantages over other systems:

(1) No secondary wastes are produced.

(2) This process operates at room temperature.

(3) Unlike Pozzalinic reaction based technologies which can treat neutral or alkaline waste only it can treat acidic wastes as well.

(4) Waste loading are higher than alternative systems and less sensitive to waste chemistry.

(5) The contaminants are converted to phosphates or sulphides that are less soluble than hydroxides that form in cement.

(6) Ceramicrete is very versatile and can be applied to a wide variety of wastes (Argonne National Laboratory, 1997).

2.22.3. Terrafix Micro-encapsulation.

This process has been developed by Dirk European Holdings and involves the usage of special selected and modified pulverised fuel ash (PFA) from coal fired stations. The PFA spheres have been broken and provide a holding space for the waste. This PFA has a glass-like character which is ideally suited for containment of waste. The process involves the mixing of Terrafix with the toxic material which has been reduced to a smaller particle size than the Terrafix spheres. Then a specialist method of affecting the surface tension allows the encapsulation of the toxic material into the PFA spheres. The process then re-adjusts the surface tension permanently encapsulating the waste. This process has been successfully tested on a number of wastes such as paints, paint sludges, resins and lacquers. The resultant product from treatment of waste with Terrafix is an inert grey powder which has been tested for leachability to the German DIN Standard 38414, Part 4 for sludge and sediments. The powder can be then landfilled or possibly incorporated into building material for the construction industry i.e. cement blocks to produce a non-toxic by-product (Casa, 1997).

2.24. Thermal Bonding.

Thermal bonding involves the mixing of dewatered sludge with clay and the heating it in order to form alumna-silicate bonds which fixate metals in a leach-resistant matrix.

Rohr Industries in San Diego, USA have developed a process that involves mixing one part metal sludge with four parts montmorillonite clay. The alumna-silicate materials in the clay initially form weal co-ordinate bonds with the metals in sludge soon after mixing. The mix is then fired in a rotary kiln at up to 1100°C to form string chemical bonds. The main disadvantage with this process is the need for a rotary kiln and the associated high energy costs. The resultant product is a ceramic aggregate whose strength is enhanced by the presence of metal.

Ceramic Bonding, Inc (CBI) in California, USA, have made an number of modifications to this process. CBI replaced the rotary kiln with a compact thermal processing unit that is continuously fed with clay/ sludge pellets. The energy requirement for this process is quite low requiring 80,000Btu/hr when in operation. After 4 hours in the thermal processor unit at 1100°C the metal in the sludge has become locked into the clay matrix. Tests on these pellets with nitric acid indicate that the metal remains firmly bound up.

The above thermal processing techniques have the capability to produce a construction type aggregate which eliminates the need to landfill. Also the presence of metal in the aggregate increase it strength and reduce its weight by 7% making a desirable construction media (City of Los Angeles,1996).

2.25. Sludge Slagging.

Sludge slagging is similar to thermal bonding, however with this technique it is possible to recover some of the metal contained in the metal sludge. Rostoker, Inc. of Illinois, USA has developed a system that can deal with electroplating, chemical milling, and pickling sludges. The process can be divided into 5 sections.

(1) The sludge is dried to reduce water content to less than 20%.

(2) Fine particles of dried sludge are blended with silica and soda ash. Any silica rich material such as scrap glass, foundry sands, or concrete can be used. The silica is responsible for forming the slag while the soda ash is employed to depress the fusion

temperature below 1250°C. The viscosity of the mix can be adjusted with lime, iron oxides, fluoride and borax.

(3) A smelting furnace to attain the required fusion temperature.

(4) A fume extraction and scrubber system to deal with any air emissions.

At the fusion temperature of the slag, a large percentage of the metal content can be reduced to its elemental form by the addition of carbon. Once the slag is removed from the furnace and allowed to cool the slag can be separated from the metal. This process is not able to recover chromium, titanium or aluminium but the unrecoverable metals remain in a crystal state and become bound up in the slag matrix as it cools. Rostoker claim the slag residue is non-toxic and has potential as a construction aggregate (City of Los Angeles, 1996).

2.26. Hydrometallurgical Processing.

This method uses wet chemistry to extract usable metals from sludges and has been practised for a number of years in the USA.. Recontek, Inc, San Diego, USA have developed a plant for the extraction of metals from sludges. The process involves digesting the metal hydroxide sludge in sulphuric acid which converts the metal in to more soluble sulphate form. Various techniques such as filtration, distillation, selective precipitation, electrowinning, and ion exchange are used to separate and extract the metals in the sludge. The remaining residues are deemed non hazardous.

2.27. Smelter Feed.

Electroplating sludge contain metals in concentrated form which are of value as smelter feed. World Resources Company of the USA is a broker that accepts non-organic metal-bearing sludges world wide, dries them and then sends them for metal recovery to various smelters. The type of smelter is dependent on the type of metal present in the sludge and percentage metal that it contains. Metal which has not been recovered during smelting is encapsulated in a silica-rich smelting slag which is not considered hazardous under the USA Resource Conversation and Recovery Act (RCRA) 1976 (City of Los Angeles, 1996).

Williams (1998) states that slag from the UK Iron and Steel industry are used as aggregate for road construction, as concrete filler and in building blocks.

2.28. Molten-Glass Processes.

These processes destroy combustible and some toxic portions of hazardous waste while at the same time residues, such as ash and non-volatile heavy metal are incorporated into a leachate resistant and stable glass matrix. Molten-glass process operate by the principle of joule heating. Electrodes are placed in a molten glass and an electrical current passed between them. The electrical resistance of the molten glass create heat around the electrode up to 2000°C. The high temperatures result in the organic portion being destroyed by pyrolysis. Molten-Glass processes fall into 3 categories;

(1) In Situ Vitrification (ISV).

(2) Vertical joule-heated glass melters.

(3) Horizontal joule-heated glass melters.

These processes have been applied to a wide variety of wastes. Heavy metals, radionuclides, combustion ash, other non-volatile and semivolatile constituents such as alumna and alkaline oxides (Freeman, 1988).

3.0. Results of Review of Electroplating IPC Applications and Licences.

3.1. Basta Hardware Ltd., IPC Licence Application.

Basta employs 80 people and its core business is the manufacture and sale of zinc die cast builders hardware. It supplements its core business by:

(1) The purchase and sale of other builders hardware products.

(2) The manufacture and sale of an architectural range aluminium, brass and stainless steel.

(3) The manufacture of zinc die cast components on a sub contract basis.

Zinc is melted in a base and tilt furnace and then cast by pneumatic die cast. The zinc castings are then either put through vibrio-polishing or barrelling to ensure a smooth component surface. The castings are then transported to either the electroplating area where they receive a chrome, nickel or brass coat on a zinc base or to the powder treatment area where it receives a powder spray finish.

The company has installed a waste treatment facility to provide complete treatment of the process water prior to being released to sewer. This has allowed the elimination of toxic compounds such as cyanide, hexavalent chromium, trivalent chromium and heavy metal ions such as zinc, copper and nickel from the plant effluent. Approximately 80% of effluent water is reused while 20% is released to the sewer. At the end of 1997 the treatment plant was upgraded to include a microfiltration unit and a centrifuge to create a solid cake contaminated with metals. Currently, Basta produces the following hazardous wastes:

(i) Zinc sludge (EWC 060405): 2.27 tonnes/annum from the dredging of the effluent stream.

(ii) Zinc oxide sludge (EWC 120203): 30.2 tonnes/annum from the deburring and polishing processes.

(iii) Nickel, copper/nickel carbon sludge with traces of cyanide (EWC 060405): 9.6 tonnes/annum from the nickel, copper and chrome plating lines.

(iv) Waste oil.

All sludges and liquids are periodically removed by Dee Environmental Services Ltd. and are transported to Shannon Environmental Services Ltd., for further treatment, which includes oxidisation of cyanide, precipitation of metals as a hydroxide sludge which is dewatered on a plate and frame press. The resulting sludge is landfilled.

3.2. A.T. Cross Ltd., IPC Licence Application.

A.T. Cross Ltd., has 167 permanent and up to 130 temporary employees involved in the manufacture of fine writing instruments. It has gold, chrome and nickel electroplating facilities. All waste water treated in the effluent plant originates from the chrome and gold plating lines or the chromating line. There are two waste streams:

(1) Acidic streams consisting of chrome and nickel dragout, dry acid, neutraliser dragout and associated rinse waters.

(2) Alkaline streams consists of gold dragout, cathodic and anodic cleaner dragout and associated rinse waters.

The objectives of the effluent treatment plant is as follows:

(i) Oxidisation of cyanide wastewaters.

(ii) Reduction of hexavalent chromium to trivalent chromium and precipitate it out of solution as a metal hydroxide sludge.

(iii) Convert the remaining metals in the wastewater stream into hydroxide so they can be precipitated out of solution as a metal hydroxide sludge.

(iv) Metal hydroxides are dewatered on a filter press and the remaining sludge is stored for disposal via an external hazardous waste disposal contractor.

Currently, A.T. Cross Ltd., produce the following hazardous wastes:

(i) Metal hydroxide solutions (EWC 110103): 23 tonnes/annum from the annual clean out of the effluent treatment system tanks.

(ii) Trichloroethylene (EWC 140102).

(iii) Coolant (EWC 120113): 0.5 tonnes/annum from toolroom operations.

(iv) Soda ash (EWC 060301): 1.5 tonnes/annum used as a cleaning degreaser.

(v) Jig stripper and sludge (EWC 110103): 0.2 tonnes/annum from the stripping chrome plating jig.

(vi) Chrome solutions (EWC 110103): 0.6 tonnes/annum from chrome plating solutions.

(vii) Maskwash (EWC 140102).

(viii) Nickel solution (EWC 110104): 1 tonnes/annum from the nickel plating solution.

(ix) Lab smalls (EWC 080110).

(x) Machine oil (EWC 120107).

(xi) Light tubing (EWC 200121).

(xii) Gold solutions (EWC 110101): 0.6 tonnes/annum from gold plating.

(xiii) Metal hydroxide sludge (EWC 110103): 3 tonnes/annum from the electroplating plant.

All metal hydroxide solutions, coolant, soda ash, jig stripper and sludge, chrome solution and nickel solution are further treated at Shannon Environmental Services Ltd., and the resulting sludge is landfilled. However, the gold solutions are sent to UK for recovery via Irish Environmental

Services Technology and the metal hydroxide sludge is sent to Belgium for incineration via Cara Environmental Technology.

3.3. Ossian Ltd., IPC Licence Application.

Ossian employs 43 people and it manufactures small metal components and provides a heat treatment and electroplating service for copper, zinc, tin, nickel and other metals. Post plating operations include conversion coating and heat treatment. The following hazardous waste is produced at the plant,

- **(i)** Effluent sludge (EWC 060501 and 060505): 36 tonnes/annum from the wastewater treatment plant, which is landfilled in the Kinsale Road landfill.
- **(ii)** Cation resin (EWC 060405).
- **(iii)** Sandfilter sand (EWC 060405).
- **(iv)** Used filters (EWC 060405).

3.4. Arlington Ltd., IPC Licence Application.

Arlington employs 335 people. It produces costume jewellery and soap products for export. It has various electroplating operations including copper, rhodium, nickel and gold lines. It has its own waste water treatment plant which can deal with cyanide, chrome and other metal bearing streams. The sludge from the waste water treatment plant is dewatered on a filterpress the resulting sludge is removed by WRC World Resource Company Gmbh for recycling. The treated effluent is released to the Laois County Council sewers.

The following hazardous wastes are disposed of:

(i) Waste paints.

(ii) Waste from paint varnish removal.

(iii) Aqueous suspension.

(iv) liquid waste from coating metals.

(v) Heavy metal waste with no chromium: 350L/annum from manufacturing is exported to the United Kingdom for incineration.

(vi) Cyanide free waste (no chromium): 500l/annum from manufacturing is exported to the United Kingdom for incineration.

(vii) Hydroxide sludges from honing, grinding and waste water : 20 tonnes/annum is exported to World Resources Corporation for recovery in the USA.

(viii) Lubricating oil.

(ix) Inorganic chemicals.

(x) Laboratory waste.

3.5. Hitech Plating Ltd., IPC Licence Application

This company employs 40 people and carries out the following three activities at it's plant, spray painting, electroplating and powder coating. The range of processes offered by the company include:

(1) E.M.I./R.F.I. shielding - plating on plastic.

(2) Electroless nickel.

(3) Silver.

(4) Tin.

(5) E.M.I shielding - plating on metal, copper - nickel - tin.

(6) Bright nickel.

(7) Copper.

(8) Powder coating.

A batch effluent treatment system is operated. The batch treatment tank has 2.5 cubic metres capacity. Cyanide oxidisation chromium reductions neutralisation and precipation of metal is possible in this system. Amersep Mp-3, a cabamate is added to the wastewater containing heavy metal in complexed form and the pH is then adjusted. The resulting sludge is dewatered on a filter press and the filter sludge is collected awaiting disposal. Currently, the following hazardous wastes are disposed of at Hitech Plating Ltd.

(i) 111 Trichloroethane (EWC 120199).

(ii) Chromic acid (EWC 110103): 4.8 tonnes/annum produced from plating on plastic.

(iii) Dry sludge cake (EWC 110204): tonnes/annum not available for quantity produced by the effluent system.

The chromic acid is removed to Shannon Environmental Services Ltd., for further treatment and the resulting sludge is landfilled. The dry sludge cake will be removed for disposal by Shannon Environmental Services Ltd., or Dee Environmental Services Ltd.

3.6. Plateco ZN Ltd., IPC Licence Application.

Plateco ZN Ltd., is a subcontracting facility which operates for both the general engineering industry and the shop fitting industry. It has 4 employees. Activities include electroplating and powder coating. The following processes are performed at the plant:

(i) Cleaning.

(ii) Rinsing.

(iii) Descaling/activation.

(iv) Zinc plating.

(v) Passivation of zinc coating.

(vi) Drying.

There is also a gold and nickel plating facility sited on the premises operated by Aritech Ltd. All rinse waters are treated on an automatic basis by chemical dosing and settlement, while all spent process chemicals are treated on a batch basis by chemical dosing and settlement. The treated wastewater is then discharged to the foul sewer. Plateco ZN Ltd. reports no hazardous waste production on its IPC licence application.

3.7. Computer Plating Specialists Ltd., IPC Licence Application.

This company currently employs 24 people and is a producer of electro-deposited zinc onto steel components. Computer Plating Specialists carries out work for electronic assemblers and metal engineering companies. The main processes in the plant are zinc, nickel and tin-lead plating and aluminium anodising.

The company has an effluent plant which releases to the Dublin Corporation sewer where it is further treated at Ringsend sewage works. Currently some emissions are outside the BATNEEC guidance limits, most notably these are zinc, chrome and cyanide. The effluent treatment plant is capable of pH adjustment, cyanide oxidisation, settlement and neutralisation. The sludge produced is dewatered on a filter press.

The following hazardous waste are disposed by Computer Plating Specialists Ltd.

- **(i)** Lab waste (liquid) (EWC 110100).
- **(ii)** Water effluent (EWC 110100).
- **(iii)** Empty chemical drums (EWC 120105).

(iv) Sludge cake (EWC 110100): 24 tonnes/annum from precipitated metals and neutralised solutions are sent for export via Irish Environmental Services Ltd.

Other sludge disposal options are also being considered given the difficulty in disposing of cake:

(a) The disposal of wet sludge to Shannon Environmental Services who can no longer dispose of cake which has not been generated on their own site.

(b) Export of cake for disposal by other companies yet to be determined.

(c) Disposal of cake/sludge by other companies yet to be determined.

3.8. Galway Plating Ltd., IPC Licence Application.

Galway Plating Ltd., employs 18 people at its plant. It electro-deposits zinc on to steel components supplied by customers from the electronic assembly and metal engineering industry. It also provides non-electrolytic chromate conversion coating on aluminium pre-formed parts. Plating rinsewaters containing zinc metal and cyanide are oxidised with sodium hypochlorite while acid rinsewaters are kept separate. All rinsewaters are then pH adjusted to 9.5-10.0. An insoluble zinc hydroxide precipitate is formed and a ferric solution is added to aid settleability. Chrome containing solutions are reduced with sodium metabisulphite before pH adjustment to form a chrome hydroxide precipitate. The Precipitated metal hydroxide sludge is removed from the settlement tank and dewatered on a filter press.

Currently the following hazardous wastes are disposed of by the Galway Plating Ltd. plant:

- **(i)** Lab waste (liquid) (EWC 110100).
- **(ii)** Water effluent (EWC 110100).
- **(iii)** Empty chemical drums (EWC 120105).
- **(iv)** Sludge cake (EWC 110100): 36 tonnes/annum, the main source within the plant is precipitated metal/neutralised solutions which are removed by Irish Environmental Services Ltd. and exported.

3.9. Waterford Plating Co Ltd., IPC Licence Application.

The Waterford Plating Company Ltd., employs 15 people and electro-deposits zinc onto steel components. The company also provides chromate coating on aluminium parts as well as phosphate coating onto steel parts. The company also performs wet and dry painting operations. Its main customers are electronic assemblers and metal engineering companies.

The effluent treatment system is based on a continuous flow treatment operation combined with a treatment unit. All process rinses are continuously treated for chromium and cyanide with a pH adjustment facility prior to settlement of metal hydroxides in the settlement tank.

The batch system consists of a dump tank to which solutions are periodically transferred and manually treated. The settled sludge is transferred to a holding tank where, together with sludge from the settlement tank it is dewatered on a filterpress.

The company has the following hazardous wastes:

- **(i)** Lab waste (liquid) (EWC 110100).
- **(ii)** Water effluent (EWC 110100).
- **(iii)** Empty chemical drums (EWC 120105).
- **(iv)** Sludge cake (EWC 110100): 36 tonnes/annum from precipitated/neutralised solutions which are removed by Irish Environmental Services Ltd., for export.

3.10. Loredo Ltd., IPC Licence Application.

Loredo Ltd., is a steel fabrication company employing 43 people and it specialises in tubular steel and wire work for the display and shopfitting industry. The range of activities carried out at the plant include zinc electroplating, powder coating and steel fabrication. The company has proposed to install a buffer tank prior to discharge, an automated pH adjustment and settlement unit and a filter press.

Currently the only hazardous waste disposal by the company is 26.4 cubic metres/annum of spent process solutions (pH adjusted) (EWC N/A) from the plating line.

3.11. Andersen Ireland Ltd., IPC Licence Application.

Andersen Ireland Ltd., currently employ 350 people. The company manufactures costume jewellery for the fashion markets of Europe. A number of electroplating operations are carried out including copper, silver, gold, palladium and rhodium. The effluent treatment can be divided into a number of sections:

(1) Here acid and alkali concentrates are collected in separate storage tanks. The streams are pumped into acid-alkali batch reactor for treatment with ferric chloride and followed by neutralisation and then discharge to the settlement tank.

(2) Cyanide rinse water and waste concentrates are collected in separate storage tanks. These are pumped into the cyanide batch reactor for treatment. Cyanide treatment involves additions of sodium hypochlorite, hydrochloric acid sodium hydroxide, sodium sulphide, caroat and ferric chloride before pH adjustment, and discharge to the settlement tank.

(3) This is an extra batch system using precision neutralisation before discharge to final filtration and neutralisation.

(4) Recirculating water system much of the rinsing water in the plating plant is reused by recirculating through a gravel filters and ion exchange resins.

(5) Tumbling waste water treatment is treated with ferric chloride and the pH is corrected with calcium hydroxide. The treated water is allowed to settle.

All settled sludge is dewatered on a filter press.

Currently the plant produces the following hazardous wastes:

(i) Waste cyanide solution (EWC 110101).

(ii) Waste cyanide filters/sludges (EWC 110101).

(iii) Waste acetone/waste regenerator DD (EWC 080302).

(iv) Waste halogenated solvent (EWC 080405).

(v) Dried cake from gold reactor (EWC 110102).

(vi) Miscellaneous cake from gold process (EWC 110102).

(vii) Dried cake from palladium dragouts (EWC 110401).

(viii) Filters from rhodium, palladium and gold (EWC 110401).

(ix) Rhodium solutions (EWC 110106).

It should be noted that under other wastes the following are listed:

(i) Metal hydroxide cake (EWC 110104): 18 tonnes/annum from the filter press from the cyanide waste water treatment plant which is landfilled by Cork County Council via Shannon Environmental Services Ltd.

(ii) Metal hydroxide cake (EWC 110104): 66 tonnes/annum from the filter press from the acid/alkali waste water treatment plant which is landfilled by Cork County Council via Shannon Environmental Services Ltd.

(iii) Waste from mechanical surface treatment processes (EWC 120203): 102 tonnes/annum from the filter press from the polishing sludges which is landfilled by Cork County Council via Shannon Environmental Services Ltd.

3.12. Braun Ireland Ltd., IPC Licence Application.

Braun currently employs 750 people. The manufacturing process consists of three main phases moulding, assembly and packaging. Assembly can be divided into hairdryers, curlers, shaver foils, gas cartridges and shaver brushes. The shaver foil process involves standard electroplating with nickel, palladium and platinum. The company has an effluent treatment plant that produces nickel sludge.

The following hazardous wastes are disposed of by Braun Ireland Ltd:

(i) Solder dross (EWC 120113).

(ii) Nickel sludge (EWC 110204) from shaver foil is recovered by KMK Metals who dispose of it in the United Kingdom. KMK Recycling Ltd., Tullamore, Co. Offaly have a permit from Offaly County Council to treat, dry and store waste.

(iii) Methylated spirits.

(iv) De-ionising resin.

(v) Solder flux.

(vi) Solvent.

(vii) Waste oil (EWC 130202).

(viii) Batteries (EWC 2001200.

(ix) Ink wipes (EWC 150201).

(x) Fluorescent tubes (EWC 200121).

(xi) Solder extract filters pre main (EWC 150200).

(xii) Filters (oil mist) pre main.

3.13. Molex Ireland Ltd., IPC Licence Application.

Molex Ireland Ltd., currently employs 415 people. It produces a variety of electrical connectors used in the computer, electrical, automotive and telecommunications industries. The plant operations can be divided into four sections:

(1) Stamping.

(2) Electroplating.

(3) Moulding.

(4) Assembly.

There are five plating lines in the plant that electroplate the following metals nickel, copper, gold, tin-lead and palladium.

The company has an effluent treatment plant that allows 90% of water used in the plating process to be recovered and reused. Metal (copper, tin/lead, nickel and palladium) dragouts are fed into the effluent treatment plant by continuous flow. The metals are precipitated by pH adjustment and are removed by filtration. The sludge generated from water treatment is sent to the US for reclamation of metals.

The following hazardous wastes are disposed of at Molex Ireland Ltd.

- **(i)** Metal dust (EWC 110401).
- **(ii)** Caustic usage (EWC 060202).
- **(iii)** Acid usage (EWC 060303).
- **(iv)** Acid salt usage (EWC 060399).
- **(v)** Nickel dragout (EWC 060405).
- **(vi)** Copper dragout (EWC 060405).
- **(vii)** Gold dragout, brush wash (EWC 060405).
- **(viii)** Tin dragout (EWC 060405).
- **(ix)** Lead dragout (EWC 060405).
- **(x)** Palladium dragout (EWC 060405).
- **(xi)** Cyanide usage (EWC 060311).
- **(xii)** Sludge (EWC 190804): 3.4 tonnes/annum produced from the waste water treatment plant. The heavy metals are recovered by World Resources Company, USA and the remaining demineralised sludge is landfilled.

3.14 Galvotech Ireland Ltd., IPC Licence Application.

Galvotech Ireland Ltd., currently employs 18 people. It is involved in the electro deposition of metallic coatings on mainly ferrous metals. The finishes include zinc, copper, nickel and chromium as electro deposited coatings. In addition supplementary chromate treatments are used for the passivation of zinc and aluminium. Currently Galvotech Ireland Ltd., discharges effluent to the Limerick Corporation foul sewer in accordance with the appropriate discharge licence limits, where practicable effluent is batch treated prior to discharge.

The following hazardous waste is disposed at Galvotech Ireland Ltd:

(i) Waste tank sludge (EWC 110101): 0.5-1.0 tonnes/annum from tank desludging.

(ii) Waste acid (EWC 110105): 10 cubic metres/annum from hydrochloric acid pickling.

(iii) Hydrated metal sludge, chrome containing (EWC 110103): 3.5 tonnes/annum from effluent plant sludge.

(iv) Hydrated metal sludge, chrome and cyanide free (EWC 110104): 3.5 tonnes/annum from effluent plant sludge.

All hazardous wastes are removed by Shannon Environmental Services Ltd.

3.15. Galvotech International Ltd., IPC Licence Application.

This is not an established activity and the proposed location of the plant is at the Smithstown Industrial Estate, Shannon, Co. Clare. Initially the plant will employ 20 people. The principal scope of the activity will involve electro deposition of metallic coatings on mainly ferrous metals. The products involved will be zinc, copper, nickel and chromium electro deposits. In addition to these products there will be supplementary chromate treatments for the passivation of zinc deposits and for the surface treatment of aluminium. The plant will include an ancillary treatment works.

The expected hazardous waste disposed by Galvotech International Ltd. are as follows:

- **(i)** Waste tank sludge (EWC 110101): 0.5-1.0 tonnes/annum from tank desludging.
- **(ii)** Waste Acid (EWC 110105): 10 cubic metres/annum from hydrochloric acid pickling.
- **(iii)** Hydrated metal sludge, chrome containing (EWC 110103): 3.5 tonnes/annum from effluent plant sludge.
- **(iv)** Hydrated metal sludge, chrome and cyanide free (EWC 110104): 3.5 tonnes/annum from effluent plant sludge.

It is intended that all hazardous waste is to be removed by Shannon Environmental Services Ltd.

3.16. Integrated Pollution Control Licence.

As of the 19TH of February 1998 there were only three electroplating operations licences granted by the EPA. However only two were available from the EPA website. Basta Hardware Ltd., (Licence Register Number 269) and A.T. Cross Ltd., (Licence Register Number 271). These have the following common Waste Management Conditions:

- Disposal or recovery of waste shall take place only as specified in schedule Hazardous Wastes for Disposal/Recovery and the Schedule other Wastes for Disposal/recovery of this licence and in accordance with the appropriate National and European Legislation and protocols. No other waste shall be disposed of/recovered either on-site or off-site without prior notice to, and prior written agreement of, the agency.
- Waste sent offsite for recovery or disposal shall only be conveyed to a waste contractor, as agreed by the Agency, and only transported from the site of the activity to the site of recovery/disposal in a manner which will not adversely affect the environment.
- A full record, which shall be open to inspection by authorised persons of the Agency at all times, shall be kept by the licensee on matters relating to the waste management operations and practices at this site.

4.0. Results of Review of Waste Licence Applications for Landfill.

Waste Licence	Landfill Name	Containment Facility	Waste Applied to Accept		
			Inert or inactive	Biodegradable	others
W001	North Kerry Landfill	Yes	Yes	Yes	Yes
W002	Ballyguyroe Landfill	Yes	Yes	Yes	Yes
W004	Arthurstown Landfill	Yes	Yes	Yes	Yes
W005	East Wicklow Landfill	Yes	Yes	Yes	Yes
W006	East Limerick Landfill	Yes	Yes	Yes	Yes
W009	Balleally Landfill	No	Yes	Yes	Yes

Table 4.1. Results of Landfill licence Review.

Waste Licence	Landfill Name	Containment Facility	Waste Applied to Accept							
			House -hold	Commercial	Sewage Sludge	Construction Demolition	Industrial Non-Hazardous			Hazar - dous
							Liquid	Sludge	Solid	
W010	Basketstown Landfill	No	Yes	Yes	Yes	Yes	No	2,260 tonnes	No	No
W011	Ballymurtagh Landfill	No	Yes	Yes	Yes	Yes	Yes	12,500 tonnes	Yes	No
W012	Kinsale Road Landfill	No	Yes	Yes	No	Yes	No	12,500 tonnes	No	No
W013	Carrowbrowne Landfill	Yes	Yes	Yes	No	Yes	No	No	No	No

Table 4.2 Results of Landfill Licence Review

Waste Licence	Landfill Name	Containment Facility	Waste Applied to Accept							
			House -hold	Commercial	Sewage Sludge	Construction Demolition	Industrial Non -Hazardous			Hazar dous
							Liquid	Sludge	Solid	
W014	Silliot Hill Landfill	Yes	Yes	Yes	Yes	Yes	Yes	9,880 tonnes	Yes	Yes
W015	Ballyogan Landfill	Yes	Yes	Yes	No	Yes	No	No	No	No
W016	Killurin Landfill	No	Yes	Yes	Yes	Yes	No	500 tonnes	No	No
W017	Gortadroma Landfill	Yes	Yes	Yes	Yes	No	No	1,014 tonnes	Yes	No
W018	Kilbarry Landfill	Yes	Yes	Yes	Yes	Yes	No	1080 tonnes	Yes	No
W019	Hardbog Landfill	Yes	Yes	Yes	Yes	Yes	No	2,000 tonnes	Yes	No

All industrial non-hazardous sludge values are per annum.

Table 4.2. Continued (Results of Licence Review.)

The following were also noted:

- The Cork County Council Waste Licence application (W002) states that no industrial waste is accepted or will be accepted.
- The South Dublin County Council Waste Licence application (W004) states that only baled municipal waste will be accepted.
- In the Fingal County Council Waste Licence (W009) application nickel hydroxide sludge that is classified as non-hazardous by Fobairt is specified under the other wastes acceptance section.

- The Wicklow County Council Waste Licence application (W011) states that only household and non-hazardous/commercial waste arising in County Wicklow will be accepted.

- The Cork Corporation Waste Licence Application states that the following companies are allowed deposit non-hazardous industrial sludges:

  (1) Sifco Ireland Ltd.

  (2) Shannon Environmental Services Ltd.

  (3) Ossian Ltd. — listed as haz in 3.3

  Also from the 1st January 1999 it intends only to accept non-hazardous industrial sludge from within its administrative area.

5.0. Discussion.

Electroplating is an activity that is listed in the first schedule of the EPA Act, 1992 under sector twelve, surface coating. As of 1st of July 1997, established electroplating plant with treatment vats greater than 30,000 litres are required to have applied for an IPC Licence.

Prior to the 19th of February 1998 fifteen electroplating plant had applied for an IPC Licence. These included fourteen established plant and one proposed development. To date three licences have been granted, one is at draft licence stage and the remaining applications are at present being processed. These electroplating plant are dispersed throughout Ireland and are involved in a variety of processes, which are responsible for employing 2432 employees.

Metal hydroxide sludge is an electroplating waste generally generated by an on site effluent treatment plant. Some electroplating plant do not generate sludge themselves but contract out its effluent treatment and disposal to off site hazardous waste treatment companies. The fourteen established electroplating plant produce 394.6 tonnes/annum of sludge and 33.6 cubic metres of waste solution. The current disposal outlets for electroplating sludges in Ireland are, direct landfill from waste producer site, indirect landfill via hazardous waste treatment companies in Ireland, export for treatment and export for recovery (see table 5.1.).

IPC No.	Electro -plating Plant	Waste Type	Quantity	Destination
269	Basta	Zinc sludge	2.2 tonnes/annum	SES and landfill.
		Zinc oxide sludge	30.2 tonnes/annum	SES and landfill.
		Nickel, copper/nickel	9.6 tonnes/annum	SES and landfill.
		Carbon sludge		
271	A.T. Cross	Metal hydroxide solution	23 tonnes/annum	SES and landfill.
		Jig stripper sludge	0.2 tonnes/annum	SES and landfill.
		Chrome solution	0.6 tonnes/annum	SES and landfill.
		Metal hydroxide sludge	3 tonnes/annum	Incineration.
272	Ossian	Effluent sludge	36 tonnes/annum	Landfill.
274	Arlington	Hydroxide sludges	20 tonnes/annum	Recovery in US.
276	Hitech Plating	Chromic acid	4.8 tonnes/annum	SES and landfill.
		Dry sludge cake	Quantities not available	SES and landfill or export.
277	Plateco ZN	None	None	None.
278	Computer Plating	Sludge cake	24 tonnes/annum	Exported.
279	Galway Plating	Sludge cake	36 tonnes/annum	Exported.
280	Waterford Plating	Sludge Cake	36 tonnes/annum	Exported.

Table 5.1. Electroplating plant sludge production and waste destination.

IPC No.	Electro -plating Plant	Waste Type	Quantity	Destination
281	Loredo	None	None	None.
282	Andresen	Metal hydroxide	18 tonnes /annum	SES and landfill.
		Metal hydroxide	66 tonnes/annum	SES and landfill.
		Mechanical surface treatment waste	102 tonnes/annum	SES and landfill.
287	Braun	Nickel sludge	Quantities not available	Recovery in UK.
288	Molex	Sludge	3.4 tonnes/annum	Recovery in US.
291	Galvotech Irl	Tank sludge	05-1.0 tonnes/annum	SES and landfill.
		Acid	10,000L/annum	SES and landfill.
		Metal sludge (chrome)	3.5 tonnes/annum	SES and landfill.
		Metal sludge	3,5 tonnes/annum	SES and landfill.
292	Galvotech Int	Tank sludge	0.5-1.0 tonnes/annum	SES and landfill.
		Waste acid	10,000L/annum	SES and landfill.
		Metal sludge (chrome)	3.5 tonnes/annum	SES and landfill.
		Metal sludge	3.5 tonnes/annum	SES and landfill.

Table 5.1.Continued (Electroplating plant sludge production and waste destination.)

It would be environmentally desirable and comply with the European Union waste management hierarchy if all electroplating sludges were reused or recovered but the feasibility of occurring this is dependent on economics, the metals contained in the sludge and the degree of contamination.

Presently in Ireland landfill is the primary waste disposal route for household, commercial and industrial waste. Prior to the enactment of the Waste Management Act, 1996, the Local Authorities were the primary agency responsible for the control of waste in Ireland as a result of powers derived from European Community Regulations on waste. Under these regulations Local Authorities did not require a permit to operate a landfill in their own functional area. The Waste Management Act, 1996 rectified this unsatisfactory situation by requiring operators of existing and proposed landfill sites to apply to the EPA for a Waste Licence. This process was implemented on a phased basis for existing landfill sites, commencing with the larger landfill sites. The EPA has the power to refuse a Waste Licence, issue a licence or issue a licence subject to certain conditions. In relation to landfill this means that the EPA may restrict the waste type and quantity to be accepted.

As of 4th of February 1998 the EPA has received sixteen Waste Licence applications for what are effectively non-hazardous landfills. This included thirteen existing landfills and three proposed landfill sites. At present no Waste Licence has yet been issued. From the review of the Waste Licence Applications it was determined that nine landfills have applied to accept non-hazardous industrial sludges (See Table 5.2.).

Licence No	Location	Containment site
W009	Balleally Landfill	no
W010	Baskertown Landfill	no
W011	Ballymurtagh Landfill	no
W012	Kinsale Road Landfill	no
W014	Silliot Hill Landfill	yes
W016	Killurin Landfill	no
W017	Gortadroma Landfill	yes
W018	Kilbarry Landfill	yes
W019	Hardbog Landfill	yes

Table 5.2. Landfills that have applied to accept non hazardous industrial sludges

The greatest potential environmental effect with the landfill of electroplating sludge is the possibility of heavy metal contaminated leachate escaping from the landfill mass and polluting the surrounding surface and groundwater. Leachate is any liquid emitted from a landfill. In the Local Government (Water Pollution) Regulations, 1992 metalloids and metal and their compounds are specified as List II substances. The Regulations encourage the minimisation of discharges of such substances to groundwater. Also the EPA BATNEEC recommendation for the treatment and disposal of electroplating operation wastes advocate for sludge treatment; gravity thickening and filtration and for disposal; engineered landfill, recovery and waste encapsulation. The EPA will have to take account of the above when issuing a Waste Licence for a landfill, therefore it must be assumed that it is not likely that the EPA will grant Waste Licences to non-containment landfills to accept non-hazardous industrial sludge that includes electroplating sludge. Presently the nine landfills which have applied to accept non hazardous industrial sludges. Using the above assumption this can be reduced to four that are likely to be granted a licence to accept non hazardous sludge that includes electroplating sludge. One of these landfills is a proposed development. Therefore presently only three functioning landfill have a realistic chance of being licensed to accept electroplating sludge. The lack of suitable engineered landfill is the essence of the problem facing the landfill of electroplating sludge and this trend is likely to continue as the smaller landfills are assessed by the EPA.

The future landfill of electroplating sludge must next be considered in the context of the Proposed Council Directive on Landfill of Waste. Of particular interest is the classification of landfills into hazardous, non hazardous and inert resulting in the effective banning of co-disposal. There is a requirement that all waste is to be subject to treatment before landfill, in the case of electroplating sludge this may mean further processing to reduce the hazardous nature of the waste. The adoption of the Proposed Council Directive on Landfill will have serious implications for Ireland as the country currently practices co-disposal at most landfills and has no engineered hazardous waste landfill.

The EPA has adopted the EWC/HWC list system as their mechanism of waste classification. The HWC are a subset of the EWC containing wastes which are considered to be hazardous. An EWC/HWC consists of a six digit code which defines wastes according to their origin, rather than chemical composition. The IPC application process requires the producer to classify their waste in accordance with these codes. A number of electroplating plant categorised their sludges as hazardous using the following EWC/HWC codes 060405 (waste containing heavy metals), 110100 (liquid wastes and sludges from metal treatment and coating of metals, this is a major heading and only one of the sub-headings are non-hazardous) and 110103 (cyanide free waste containing chromium). However Hitech Plating Ltd., use 110204 (sludges not otherwise specified), Andresen Irl. Ltd., use 110104 (cyanide free wastes not containing chromium), Braun Irl. Ltd., use 110204, Molex Irl. Ltd., use 190804 (sludges from treatment of industrial waste water), Galvotech Irl. Ltd., use 110404 and Galvotech Int. Ltd., use 110404. Ossian Irl Ltd., use both 060501 (sludges from on-site effluent treatment) which is non hazardous and 060405 (wastes containing other heavy metals) which is hazardous to describe their waste water treatment sludge. This is one of the weaknesses of the EWC/HWC system as it allows similar waste types to be categorised differently, even to the point that they may be deemed hazardous in one case and not in another.

Even if the electroplating sludge is categorised as a non-hazardous waste and accepted as such by the EPA, there is always the possibility that the EPA may place restrictions on individual landfill waste acceptance criteria via the waste licensing system. If it is classified as hazardous waste and accepted as so by the EPA, it will prevent it from being landfilled in any of the current Irish landfills should the Proposed Directive on Landfill be adopted. Should this happen it will mean the cessation of direct landfill of electroplating sludge in Ireland in the short and intermediate term.

The future of landfill as a disposal option for electroplating sludge must be considered under two headings:

(1) Short and intermediate term.

(2) Long term.

Given that Ireland currently has no hazardous waste landfill it will be necessary to further process the sludge to reduce its hazardous nature. Solidification and stabilisation allows such a possibility and also allows the waste to be recategorised using EWC/HWC as stabilised/solidified wastes which is non hazardous. The objectives of solidification and stabilisation are to improve the physical characteristics and handling of the waste, reduce the surface area and reduce the solubility.

There are a number of binding mechanisms used in solidification and stabilisation but the Pozzolan-Portland cement reaction is the most appropriate binding mechanism for Irish electroplating sludge. It uses commonly available and cheap additives, is tried and tested technology, and processing equipment similar to the preparation of concrete is required. These advantages far out weigh the main disadvantage of solidification and stabilisation which are the cost of the extra processing and the significant increase in the waste volume and hence an increase in landfill costs. The disadvantages of other binding mechanisms such as thermoplastic micro-encapsulation and macro-encapsulation, is that the long-term survival of the containment mechanism is in doubt and sorption technology is only appropriate for liquid wastes.

Two novel commercial solidification and stabilisation processes were assessed in greater detail.

(1) The Ceramicrete process.

(2) The Terrafix micro-encapsulation.

The Ceramicrete process appears very attractive as an insoluble product is formed through chemical fixation, waste loadings are high, it operates at room temperature and low technology equipment is required. The Terrafix process requires specialised equipment and unlike Ceramicrete containment is the means of hazard reduction. The Terrafix requires specialised processing equipment and produces a product which has potential uses in cement manufacture. Of the two the Ceramicrete process is the most suitable for Irish waste applications. Both of these processes offer alternative solidification and stabilisation strategies but are relatively new processes with little long term historical evidence of environmental protection. Further research into their suitability must be conducted before they can be recommended.

Another possibility to ensure the continued landfill of electroplating sludge is to reclassifies it as non hazardous, using EWC/HWC codes. Already the EPA has issued Molex Ireland Ltd. with an IPC Licence that allows it to classify its electroplating sludge as non hazardous. It must be stressed that these are transitional solutions to the current landfill problem facing the Irish electroplating industry and must not be seen as a final solution.

As already mentioned the future of landfill as a disposal option for electroplating sludge must also be considered in the long term, to do this we must assess the following areas:

(1) Alternatives to landfill of electroplating sludge.

(2) The development of a hazardous waste landfill in Ireland.

Alternatives to the disposal of electroplating sludge in landfills have been developed mainly in the USA and these include such processes as thermal bonding, sludge slagging, hydrometallurgical processing, smelter feed and molten glass processes.

Thermal bonding involves the mixing of sludge with clay and applying heat to form alumna silicate bonds that fix the metals in a leachate resistant matrix.

Heat is supplied by a rotary kiln or a heater operating at 1100^{0}C. The end product has uses as a construction aggregate.

Sludge slagging is similar to thermal bonding in that a leachate resistant matrix is formed but it also has the added advantage of allowing the elemental recovery of some metals which can then be reused The end product has potential construction uses as aggregate.

Hydrometallurgical processing, this involves using wet chemistry to extract metals from the sludge. The resultant demineralised residues require landfill.

Molten glass processes are a high energy input operation that produces a leachate resistant and stable glass matrix which may require landfill.

All the above alternatives to disposal of electroplating sludges offer attractive environmental solutions either forming a leachate resistant matrix which has construction potential or producing a reduced amount non hazardous sludge which is landfilled. Given the small quantity of Irish electroplating sludge produced annually, the high energy and associated operating costs and the fact that most of these processes are specific to electroplating sludge. These processes have no part to play in the future of Irish electroplating waste management.

Electroplating sludge contains valuable metals in a concentrated form and has been used as smelter feed. The advantages of electroplating sludge as a smelter feed is that it allows a valuable resource to be recovered and any remaining residues are contained in a leachate resistant matrix. From an Irish point of view the disadvantages of smelter feed are as follows:

(1) Ireland has one smelter and this is a ferrous type smelter.

(2) Irish plating operations tend to plate a variety of metals thus the resulting electroplating sludge tends to contain many metals therefore it is not a very pure source.

(3) Ireland produces a small quantity of electroplating sludge.

The use of electroplating sludge as smelter feed would not be viable in Ireland for the above reasons but the continued export of selective high value and high purity sludge such as Braun (Irl) Ltd. nickel hydroxide is the only option that smelter feed can be part of the Irish electroplating waste management strategy.

Already some electroplating plating sludge is being exported for disposal due to the difficulties associated with landfill in Ireland the continuation of this situation is undesirable for the following reasons:

(1) The export of electroplating sludge is a significant extra cost to the Irish electroplating industry. Current costs for the export of electroplating sludge range from £300-1000/tonne. These extra

costs can not be sustained and will eventually put the Irish electroplating industry at a competitive disadvantage.

(2) Over reliance on foreign disposal facilities is not in the National interest and hinder the development of a national hazardous waste management strategy.

While the alternatives to landfill may be appropriate in larger economic nations, these are very specific waste disposal options and given the relative small quantities of metal hydroxide sludge produced by the Irish electroplating industry a dedicated system for electroplating sludge can not be justified. Therefore it is essential that work begin on the preparation and construction of an engineered hazardous waste landfill. The provision of a hazardous waste landfill will allow the acceptance of other suitable industrial wastes thus spreading the operational costs across a wide variety of industrial sector.

The provision of a hazardous waste landfill would make Ireland more self-sufficient in hazardous waste management and would reduce the amount of waste being exported and the reliance on foreign hazardous waste treatment systems. It would also redress the competitive imbalance that the Irish electroplating industry is experiencing providing disposal options other than landfill in Ireland. Table 5.3 demonstrates the extra costs that the Irish electroplating plant requiring an IPC Licence must carry as the traditional landfill options disappear. The operational costs of a engineered hazardous waste landfill would be significantly higher than a current Irish landfill due to the provision of required environmental protection systems, however even allowing for a quadrupling of current landfill costs this would still result in a reduction in costs to the Irish electroplating industry that are required to apply for an IPC Licence.

Electroplating sludge Treatment/disposal options	**Cost/tonne**	**IPC Electroplating Plant annual costs**
Current Irish landfill	£35/tonne	£13,825
Export for disposal	£300-1000/tonne	£118,500-395,000
Export for recovery	£350/tonne	£138,250
Solidification and stabilisation	£500/tonne	£197,500

Table 5.3 Treatment/disposal costs of options for electroplating sludge other than hazard waste landfill.

It is essential that the sludge disposal problem facing Irish electroplating operations be tackled with more urgency, already the national hazardous waste plan is well behind schedule. The continued success of these electroplating plants which employs over 2000 people must be ensured and ultimately this means the provision of an Irish engineered hazardous waste landfill.

6.0. Conclusion.

- The disposal of treated electroplating chemicals such as metal bearing sludge and filtercake in Ireland has a definite future in the short, intermediate and long term.
- The ultimate long term objective is the provision of an engineered hazardous waste landfill.
- Solidification/stabilisation and EWC/HWC reclassification of electroplating sludge as non-hazardous, will in the short and intermediate term allow the continued use of existing landfills as disposal route until such a facility is available.
- It must be stressed that these options are only interim and the definitive answer to Irish electroplating plant sludge disposal is the provision of a hazardous waste landfill

7.0. Recommendations.

- It is essential that at least one if not two hazardous waste landfills are provided in the near future and that these are strategically located in order to minimise transport costs.
- If individual Local Authorities are unable or unwilling to provide such a hazardous waste landfill. Consideration should be given to the provision and operation of a hazardous waste landfill by a joint venture between a number of Local Authorities, a joint venture between private enterprise and Local Authorities or private enterprise on it own.
- The Department of the Environment should encourage the construction of a solidification and stabilisation plant by allocating recycling and hazardous waste grants for such a project.

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