ECOLOGICAL METAL RECOVERY

Ecometre

An Eco-Innovation Project to recover metals from waste.

A project sponsored by EACI (Executive Agency for Competitiveness & Innovation) under the Eco-Innovation Initiative
Background and Overview

Significant quantities of metal bearing waste either in solid or liquid form is generated by the aerospace, automotive, printed circuit board and metal finishing sectors without recovery of valuable materials from the waste streams. At the moment this is mainly destined for landfill, squandering natural resources and having an impact on the environment in that more materials need to be extracted to replace those thrown away. By combining existing technologies, electro-coagulation, material digestion and electrowinning, the project has developed a metal recycling system to enable the specified industrial sectors to recover metal from such generated waste. The targeted sectors are currently under extreme financial and environmental pressure both on raw material inputs and waste disposal and have been identified as important application areas for this eco-innovative material recovery (metal valorisation) process, in terms of energy efficiency, environmental and economic impact. Validation activity is continuing on this first application installed plant in respect of quantifying the scope of application and operational parameters across a range of input wastes.

The project has resulted in the first installation of an initial recovery plant at a partner SME site in France – Promet. Promet operates a variety of finishing processes within the surface engineering sector and has a client base embracing the aerospace and nuclear engineering industries. In common with many companies in the surface engineering sector, Promet wishes to move towards a more efficient treatment of its primarily solid nickel bearing wastes.

An important factor in the potential uptake of the developed technology is considered to be the increasing value of metals, which is projected to continue to rise inexorably due to escalating world demand. As a result, there is an opportunity for significant cost benefit via metal recovery from waste which would otherwise be consigned to landfill. The perceived market within Europe is the estimated 6000 surface engineering and PWB manufacturing companies which employ upwards of 80,000 people and have sales in excess of £8 billion. In respect of potential uptake of the developed technology it is considered that some 2,000 companies within Europe could adopt such within a ten to fifteen year timeframe. The market is driven by both cost and legislation and as both the cost of metals and the cost of disposal increases so will the number of companies adopting the technology. Due to the fragmented nature of the market it is possible that the technology may be adopted by landfill operators or waste contractors deploying the technology on a regionalised basis.

Uptake of the technology will have environmental, economic and societal sustainability benefits by virtue of reduction in greenhouse gas emissions from virgin material displacement savings, cost benefits of recovered metal as a manufacturing overhead reduction and greater competitiveness for the targeted manufacturing sectors within Europe.

The project has been co-ordinated by Env-Aqua Solutions Ltd (UK) and the project partners are:
C-Tech Innovation Ltd, UK;
Aguacure Ltd, UK;
Protection des Metaux SAS, France;
Union des Industries de Traitements de Surfaces, France;
Leitat Technological Centre, Spain
Project

Technologies

Heavy metal bearing waste, as exampled by nickel, copper and zinc, is generated within manufacturing sectors typified by the surface finishing and printed circuit board industries within solid or liquid form. Solid waste generally arises via the chemical treatment of outfall contaminated rinse waters which removes the contaminants from solution by conversion of the heavy metals into their insoluble hydroxide salts. These heavy metal hydroxides are precipitated and formed as a sludge-like mass with typical solids content of 3%; i.e. they contain some 97% water. The sludges thus formed may in turn be dewatered substantially within a filter press to form a more solid filter cake at some 30 – 35% solids content for off-site disposal. There are also occasions when concentrated liquid waste containing heavy metals in solution may arise as process chemicals are exhausted and require off-site disposal. In both instances heavy metals are thus consigned to landfill creating not only an environmental demand but perhaps more significantly representing the loss of a valuable non-sustainable resource which in turn increases the demand for virgin material to be sourced.

The Ecometre project has sought to bring together and integrate three separate technologies to enable the recovery of metal content from these wastes and whilst initially the project had the objective of treatment of wholly solid wastes generated from the deployment of electrocoagulation, the results obtained have enabled it to evolve to be able to treat solid wastes generated by other means and liquid wastes containing heavy metals in solution. Ecometre has concentrated primarily on the recovery of nickel due to its inherent value but the integrated technologies have the capability of recovering other heavy metals from solid and liquid wastes.

Electro-coagulation

The remediation of heavy metals rich effluents most often relies on chemical dosing using a base such as limestone (CaCO$_3$) or caustic soda (NaOH) to neutralise the pH and precipitate out the metals as their insoluble hydroxides (e.g. Ni(OH)$_2$). Alternatively, electrocoagulation can be employed to remove heavy metals from solution without the necessity of chemical pH adjustment. The technique relies on the in-situ formation of metal hydroxides resulting from the controlled corrosion of metal plates (electrodes) of mild steel or aluminium that are in direct contact with the effluent. The in-situ generation of iron hydroxides or aluminium hydroxides removes metal ions in solution via a co-precipitation mechanism (at the positive electrode) and by direct hydroxide formation (at the cathode). This technology is combined with a unique design of treatment chambers (EC cells) and electrode assemblies that overcome issues relating to uneven treatment wear and fouling of the electrode surfaces reported to occur in other systems.

Due to its compact design the technology has a small footprint and furthermore, because it is an in situ technique replacing chemical usage, not only the amount of waste (sludge) generated is reduced but also production, transport, storage and handling of chemicals is eliminated.

Electrocoagulation (EC) is a process that replaces chemical dosing with in situ treatment by employing the controlled corrosion of metallic plates (e.g. iron or aluminium) which are in direct contact with the waste stream (electrodes), to induce the removal of contaminants. The rate of treatment is regulated by the flow of current through the electrodes that can be adjusted at any time by using a controlling unit (power supply). The mechanism of
electrochemical treatment can also be altered by employing different types of electrode materials/alloys.

Fig 1: Electro-coagulation System

**Extraction and Metal Recovery**

The design and build of the electro winning system for the Ecometre project has successfully been undertaken by C-Tech Innovation and Env-Aqua. The system has been designed to recover nickel from a sludge or filter cake containing nickel hydroxide and aluminium hydroxide (from the EC process stage), leaving nickel free solid waste, water and high value metallic nickel.

The initial design specification was to process 20kg of sludge yielding 3kg of nickel. Following initial trials at lab scales a three stage approach was adopted for dissolving the solids, separating the nickel and recovering the metal from solution.

The process, involves acid digestion at 60C followed by controlled pH increase to preferentially precipitate aluminium hydroxide. The aluminium hydroxide solids can then be filtered out producing a concentrated nickel solution low dissolved aluminium levels, suitable for electro winning. The extraction system consists of two process vessels with a filter placed between. Electrowinning is carried out in a fluidised bed type of cell in which the electrodes are sited within a fluidised bed of glass ballotini (average particle size of 400 microns) which via its constant level of fine abrasive agitation enables the metal to be recovered in pure form down to residual levels of <5 parts per million.
Results

The system has been demonstrated to produce pure nickel metal commencing from a wastewater stream containing nickel as a salt contaminant in rinse water via a route comprising electrocoagulation, extraction and electrowinning. The system has additionally been demonstrated as capable of accepting input of any nickel bearing filter cake by input of such at the extraction stage and has also been able to recover pure nickel by inputting spent process solutions including electroless nickel ones at the electrowinning stage.

Running parallel to and following on from such activities as detailed analytical work on filter cake samples and market analysis within a selected geographic domain (Spain), activity was concentrated on optimising the electrocoagulation system to maximise nickel removal from solution and on optimising the subsequent dissolution of thus generated sludges and filter cakes within a variety of acidic media. Pure nickel metal was able to be produced from a range of nickel bearing sources including EC-generated sludges and cake and sludges general from all common types of nickel bearing solutions in general use.

Fig 3: Process Flow Schematic

The laboratory work on optimisation and validation of the recovery system was translated to the first application plant which was installed at Promet (France). An example of recovered nickel from a treated sample of their nickel bearing waste stream is as shown in Fig 4 below.
The results from the project have demonstrated the capability of a metal recovery system based around the integration of electro-coagulation, acid extraction and electrowinning to recover nickel in pure metallic form for either sale or re-use from a range of input material sources.

**The Market**

The manufacturing processes to which the new technology could be applied play a critical role in industries of strategic importance to the EU, for example civil and military aerospace, maritime, electronics, engine manufacture, automotive manufacture, chemicals and general engineering. The broad SME base within the metal finishing and surface engineering sectors represent key elements of the supply chain to these industries. The top industries served by electroplating SMEs are: Automotive (34%); Heavy Industrial (30%); Aerospace (27%) and others 5%. The products incorporating surface engineering are also widely used in the production of a large number of items for domestic and commercial use. The function of coatings produced in the sector is split between corrosion (42%), decorative (31%), abrasion resistance (22%) and others 5%.

It is considered that the market barriers across Europe have a synergy in that there are few regional issues distorting the legislative drivers, which are European, and the cost drivers, which are global. Within such a scenario it is felt that the recovery of metals from waste not only enables significant reductions in environmental impact to be realised but does so in a manner that will offer tangible benefits in reducing a major contribution to direct manufacturing costs within the targeted sectors. This is in itself considered to be a real contributory factor in enhancing competitiveness within these sectors of the European economy.

In respect of potential uptake of the developed technology it is considered that some 2,000 companies within Europe could adopt such within a ten to fifteen year timeframe. As noted, the market is driven by both cost and legislation and as both the cost of metals and the cost of disposal increases so will the number of companies adopting the technology. Due to the fragmented nature of the market it is possible that the technology may be adopted by landfill operators or waste contractors deploying the technology on a regionalised basis.
Further Information

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