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Integrated Pollution Prevention and Control

Reference Document on Best Available Techniques for the Surface Treatment of Metals and Plastics

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Edificio EXPO, c/Inca Garcilaso s/n, E-41092 Sevilla - Spain
Telephone: direct line (+34-95) 4488-284, switchboard 4488-318. Fax: 4488-426.
Internet: http://eippcb.jrc.es; Email: JRC-IPTS-EIPPCB@cec.eu.int

This document is one of a series of foreseen documents as below (at the time of writing, not all documents have been drafted):

Full title	BREF code
Reference Document on Best Available Techniques for Intensive Rearing of Poultry and Pigs	ILF
Reference Document on the General Principles of Monitoring	MON
Reference Document on Best Available Techniques for the Tanning of Hides and Skins	TAN
Reference Document on Best Available Techniques in the Glass Manufacturing Industry	GLS
Reference Document on Best Available Techniques in the Pulp and Paper Industry	PP
Reference Document on Best Available Techniques on the Production of Iron and Steel	I&S
Reference Document on Best Available Techniques in the Cement and Lime Manufacturing Industries	CL
Reference Document on the Application of Best Available Techniques to Industrial Cooling Systems	CV
Reference Document on Best Available Techniques in the Chlor – Alkali Manufacturing Industry	CAK
Reference Document on Best Available Techniques in the Ferrous Metals Processing Industry	FMP
Reference Document on Best Available Techniques in the Non Ferrous Metals Industries	NFM
Reference Document on Best Available Techniques for the Textiles Industry	TXT
Reference Document on Best Available Techniques for Mineral Oil and Gas Refineries	REF
Reference Document on Best Available Techniques in the Large Volume Organic Chemical Industry	LVOC
Reference Document on Best Available Techniques in the Waste Water and Waste Gas Treatment/Management Systems in the Chemical Sector	CWW
Reference Document on Best Available Techniques in the Food, Drink and Milk Industry	FM
Reference Document on Best Available Techniques in the Smitheries and Foundries Industry	SF
Reference Document on Best Available Techniques on Emissions from Storage	ESB
Reference Document on Best Available Techniques on Economics and Cross-Media Effects	ECM
Reference Document on Best Available Techniques for Large Combustion Plants	LCP
Reference Document on Best Available Techniques in the Slaughterhouses and Animals By-products Industries	SA
Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities	MTWR
Reference Document on Best Available Techniques for the Surface Treatment of Metals	STM
Reference Document on Best Available Techniques for the Waste Treatments Industries	WT
Reference Document on Best Available Techniques for the Manufacture of Large Volume Inorganic Chemicals (Ammonia, Acids and Fertilisers)	LVIC-AAF
Reference Document on Best Available Techniques for Waste Incineration	WI
Reference Document on Best Available Techniques for Manufacture of Polymers	POL
Reference Document on Energy Efficiency Techniques	ENE
Reference Document on Best Available Techniques for the Manufacture of Organic Fine Chemicals	OFC
Reference Document on Best Available Techniques for the Manufacture of Specialty Inorganic Chemicals	SIC
Reference Document on Best Available Techniques for Surface Treatment Using Solvents	STS
Reference Document on Best Available Techniques for the Manufacture of Large Volume Inorganic Chemicals (Solids and Others)	LVIC-S
Reference Document on Best Available Techniques in Ceramic Manufacturing Industry	CER

EXECUTIVE SUMMARY

The BAT (Best Available Techniques) Reference Document (BREF) entitled 'Surface Treatment of Metals and Plastics (STM)' reflects an information exchange carried out under Article 16(2) of Council Directive 96/61/EC (IPPC Directive). This executive summary describes the main findings, a summary of the principal BAT conclusions and the associated consumption and emission levels. It should be read in conjunction with the preface, which explains this document's objectives; how it is intended to be used and legal terms. It can be read and understood as a standalone document but, as a summary, it does not present all the complexities of this full document. It is therefore not intended as a substitute for this full document as a tool in BAT decision making.

Scope of this document

The scope of this document is based on Section 2.6 of Annex 1 of the IPPC Directive 96/61/EC: *'Installations for the surface treatment of metals and plastics using an electrolytic or chemical process where the volume of the treatment vats exceeds 30 m^3'*. The interpretation of 'where the volume of the treatment vats exceeds 30 m^3' is important in deciding whether a specific installation requires an IPPC permit. The introduction to Annex I of the Directive is crucial: *'Where one operator carries out several activities falling under the same subheading in the same installation or on the same site, the capacities of such activities are added together'*. Many installations operate a mixture of small and large production lines, and a mixture of electrolytic and chemical processes, as well as associated activities. This means that all processes within the scope, irrespective of the scale on which they are carried out, were considered in the information exchange.

In practical terms, the electrolytic and chemical processes currently used are water-based. Directly associated activities are also described. The document does not deal with:

- hardening (with the exception of hydrogen de-embrittlement)
- other physical surface treatments such as vapour deposition of metals
- hot-dip galvanising and the bulk pickling of iron and steels: these are discussed in the BREF for the ferrous metals processing industry
- surface treatment processes that are discussed the BREF for surface treatment using solvents, although solvent degreasing is referred to in this document as a degreasing option
- electropainting (electrophoretic painting), which is also discussed in the STS BREF.

Surface treatment of metals and plastics (STM)

Metals and plastics are treated to change their surface properties for: decoration and reflectivity, improved hardness and wear resistance, corrosion prevention and as a base to improve adhesion of other treatments such as painting or photosensitive coatings for printing. Plastics, which are cheaply available and easily moulded or formed, retain their own properties such as insulation and flexibility while the surface can be given the properties of metals. Printed circuit boards (PCBs) are a special case where intricate electronic circuits are manufactured using metals on the surface of plastics.

STM does not in itself form a distinct vertical sector as it provides a service to a wide range of other industries. PCBs might be considered products but are widely used in manufacturing, for example, computers, mobile phones, white goods, vehicles, etc.

The market structure is approximately: automotive 22 %, construction 9 %, food and drink containers 8 %, electrical industry 7 %, electronics 7 %, steel semis (components for other assemblies) 7 %, industrial equipment 5 %, aerospace 5 %, others 30 %. The range of components treated varies from screws, nuts and bolts, jewellery and spectacle frames, components for automotive and other industries to steel rolls up to 32 tonnes and over 2 metres wide for pressing automotive bodies, food and drink containers, etc. The transport of workpieces or substrates varies according to their size, shape and finish specification required: jigs (or racks) for single or small numbers of workpieces and high quality, barrels (drums) for many workpieces with lower quality and continuous substrates (ranging from wires to large steel coils) are processed on a continuous basis. PCBs have particularly complex production sequences. All activities are carried out using jig equipment, therefore the activities are described and discussed for jig plants, with supporting sections describing specific issues for barrel, coil and PBC processing.

While no overall figures exist for production, in 2000 the large scale steel coil throughput was about 10.5 million tonnes and about 640000 tonnes of architectural components were anodised. Another measure of the industry size and importance is that each car contains over 4000 surface treated components, including body panels, while an Airbus aircraft contains over two million.

About 18000 installations (IPPC and non-IPPC) exist in EU-15, although the loss of engineering manufacturing, largely to Asia, has reduced the industry by over 30 % in recent years. More than 55 % are specialist sub-contractors (‘jobbing shops’) while the remainder provide surface treatment within another installation, usually an SME. A few large installations are owned by major companies although the vast majority are SMEs, typically employing between 10 and 80 people. Process lines are normally modular and assembled from a series of tanks. However, large installations are typically specialist and capital intensive.

Key environmental issues

The STM industry plays a major role in extending the life of metals, such as in automotive bodies and construction materials. It is also used in equipment that increases safety or reduces consumption of other raw materials (e.g. plating of aerospace and automotive braking and suspension systems, plating precision fuel injectors for automotive engines to reduce fuel consumption, plating materials for cans to preserve food, etc.). The main environmental impacts relate to energy and water consumption, the consumption of raw materials, emissions to surface and groundwaters, solid and liquid wastes and the site condition on cessation of activities.

As the processes covered by this document are predominantly water-based, the consumption of water and its management are central themes, as it also affects the usage of raw materials and their loss to the environment. Both in-process and end-of-pipe techniques affect the quantity and quality of waste waters, as well as the type and quantity of solid and liquid wastes produced. Although practice and infrastructure in the industry has improved, it is still responsible for a number of environmental accidents and the risk of unplanned releases and their impacts is seen to be high.

Electricity is consumed in electrochemical reactions and to operate plant equipment. Other fuels are predominantly used for heating process vats and work space, and for drying.

The key emissions of concern to water are metals which are used as soluble salts. Depending on the process, emissions may contain cyanides (although decreasingly), as well as surfactants which may have low biodegradability and accumulative effects, e.g. NPE and PFOS. Effluent treatment of cyanides with hypochlorite may result in the production of AOX. Complexing agents (including cyanides and EDTA) can interfere with the removal of metals in waste water treatment or remobilise metals in the aquatic environment. Other ions, e.g. chlorides, sulphates, phosphates, nitrates and anions containing boron may be significant at a local level.

The STM industry is not a major source of emissions to air, but some emissions which may be locally important are NO_X, HCl, HF and acid particulates from pickling operations, hexavalent chromium mist released from hexavalent chromium plating, and ammonia from copper etching in PCB manufacture and electroless plating. Dust, as a combination of abrasives and abraded substrate, is generated by the mechanical preparation of components. Solvents are used in some degreasing operations.

Applied processes and techniques

All but a few simple activities require some pretreatment (e.g. degreasing), followed by at least one core activity (e.g. electroplating, anodising or chemical processing) and finally drying. All processes have been developed for components hung on racks or jigs; some processes are also carried out on components in rotating barrels, and a few are carried out on reels or large coils of substrate. PCBs have complex manufacturing sequences that may comprise over 60 operations. Additional information is given for barrel, coil and PCB activities.

Consumptions and emissions

The best data would relate to production throughput based on surface (m^2) treated, but little is available on this basis. Most data are for emission concentrations for specific plants, or ranges for sectors or regions/countries. Apart from some cooling systems, the major use of water is in rinsing. Energy (fossil fuel and electricity) is used for heating processes and drying. Electricity is also used for cooling in some cases, as well as driving electrochemical processes, pumps and process equipment, supplementary vat heating, work space heating and lighting. For raw materials, the usage of metals is significant (although not globally, for example, only 4 % of the nickel marketed in Europe is used in surface treatment). Acids and alkalis are also used in bulk quantities, while other materials such as surfactants are often supplied in proprietary mixes.

Emissions are primarily to water, and about 300000 tonnes of hazardous waste is produced per year (an average of 16 tonnes per installation), mainly as sludge from waste water treatment or spent process solutions. There are some emissions to air of local significance, including noise.

Techniques to consider in the determination of BAT

Important issues for the implementation of IPPC in this sector are: effective management systems (including the prevention of environmental accidents and minimisation of their consequences, especially for soils, groundwater and site decommissioning), efficient raw material, energy and water usage, the substitution by less harmful substances, as well as minimisation, recovery and recycling of wastes and waste waters.

The issues above are addressed by a variety of process-integrated and end-of-pipe techniques. Over 200 techniques for pollution prevention and control are presented in this document, under the following 18 thematic headings:

*1. Environmental management tool*s: Environmental management systems are essential for minimising the environmental impact of industrial activities in general, with some measures that are specifically important to STM, including site decommissioning. Other tools include minimising reworking to reduce environmental impacts, benchmarking consumptions, optimisation of process lines (most easily achieved with software) and process control.

2. Installation design, construction and operation: A number of general measures can be applied to prevent and control unplanned releases, and these prevent the contamination of soil and groundwater.

3. General operational issues: Techniques to protect the materials to be treated reduce the amount of processing required and the consequent consumptions and emissions. The correct presentation of workpieces to the process liquid reduces drag-out of chemicals from process solutions, and agitation of the solutions ensures consistent solution concentration at the surface, as well as removing heat from the surface of aluminium in anodising.

4. Utility inputs and their management: There are techniques to optimise electricity consumption and to optimise the amount of energy and/or water used in cooling. Other fuels are primarily used for heating solutions, using direct or indirect systems, and heat losses can be controlled.

5. and 6. Drag-out reduction and control: Rinsing techniques and drag-out recovery: The main source of contamination in the sector is raw materials being dragged out of process solutions by the workpieces, and into rinse-waters. The retention of materials in the processes, as well as using rinsing techniques to recover the drag-out, are crucial in reducing raw material and water consumption, as well as reducing the waterborne emissions and amounts of wastes.

7. Other ways to optimise raw material usage: As well as the drag-out issue (above), poor process control can lead to overdosing which increases material consumption and losses to waste waters.

8. Electrode techniques: In some electrolytic processes, the metal anode operates at a higher efficiency than deposition, leading to metal build-up and increased losses, which in turn increase waste and quality problems.

9. Substitution: The IPPC Directive requires the consideration of using less hazardous substances. Various substitution options for chemicals and processes are discussed.

10. Process solution maintenance: Contaminants build up in solutions by drag-in or by breakdown of raw materials, etc. Techniques are discussed to remove these contaminants which will improve finished product quality and reduce reworking for rejects, as well as saving raw materials.

11. Process metals recovery: These techniques are often used in conjunction with drag-out controls to recover metals.

12: Post-treatment activities: These include drying and de-embrittlement, although no data have been provided.

13: Continuous coil – large scale steel coil: These are specific techniques which apply to the large scale treatment of steel coils and are in addition to techniques in other sections which are applicable. They may also be applicable to other coil or reel-to-reel activities

14: Printed circuit boards: These techniques are specific to PCB manufacture, although the general discussion of techniques applies to PCB production.

15: Air emission abatement: Some activities have emissions to air that require controlling to meet local environmental quality standards. In-process techniques are discussed, as well as extraction and treatment.

16: Waste water emission abatement: Waste water and the loss of raw materials can be reduced, but very rarely to zero discharge. Additional waste water treatment techniques will depend on the chemical species present, including metal cations, anions, oils and grease, and complexing agents.

17: Waste management: The minimisation of waste is dealt with by drag-out control and solution maintenance techniques. The main waste steams are sludges from waste water treatment, spent solutions and wastes from process maintenance. Internal techniques can aid the use of third party recycling techniques (although these are outside the scope of this document).

18: Noise management: Good practice and/or engineered techniques can reduce noise impacts.

BAT for the surface treatment of metals and plastics

The BAT chapter (Chapter 5) identifies those techniques that are considered to be BAT in a general sense, based mainly on the information in Chapter 4, taking into account the Article 2(11) definition of best available techniques and the considerations listed in Annex IV of the Directive. The BAT chapter does not set or propose emission limit values but suggests consumption and emission values that are associated with the use of a selection of BAT.

The following paragraphs summarise the key BAT conclusions relating to the most relevant environmental issues. Although the industry is complex in size and range of activities, the same generic BAT apply to all, and other BAT are given that apply to specific processes. The BAT elements will need to be adapted to the specific installation type.

Generic BAT

It is BAT to implement and adhere to environmental and other management systems. These include benchmarking consumptions and emissions (over time against internal and external data), optimising processes and minimising reworking. BAT is to protect the environment, particularly soil and groundwaters, by using simple risk management to design, construct and operate an installation, together with techniques described in this document and in the BAT reference document on emissions from storage when storing and using process chemicals and raw materials. These BAT aid site decommissioning by reducing unplanned emissions to the environment, recording the history of usage of priority and hazardous chemicals and dealing promptly with potential contamination.

BAT is to minimise electrical losses in the supply system as well as to reduce heat losses from heated processes. For cooling, it is BAT to minimise water usage by using evaporation and/or closed loop systems, and to design and operate systems to prevent the formation and transmission of legionella.

It is BAT to minimise material losses by retaining raw materials in process vats and at the same time minimise water use by controlling the drag-in and drag-out of process solutions, as well as rinsing stages. This can be achieved by jigging and barrelling workpieces to enable rapid draining, preventing overdosing of process solutions and using eco rinse tanks and multiple rinsing with countercurrent flows, especially with the return of rinse-water to the process vat. These techniques can be enhanced by using techniques to recover materials from the rinsing stages. The reference value for water usage using a combination of these techniques is 3 - 20 litres/m^2 of substrate surface/rinse stage and limiting factors for these techniques are described. Some material efficiency values associated with these retention and recovery techniques are given for a sample of installations.

In some cases, the rinse flow for a specific process in a line can be reduced until the materials loop is closed: this is BAT for precious metals, hexavalent chromium and cadmium. This is not ‘zero discharge’, which applies to a whole process line or installation: this can be achieved in specific cases but is not generally BAT.

Other BAT techniques to aid recycling and recovery are to identify potential waste streams for segregation and treatment, to re-use materials such as aluminium hydroxide suspension externally, and to recover externally certain acids and metals.

BAT includes prevention, separation of the waste water flow types, maximising internal recycling (by treating according to the use requirements) and applying adequate treatment for each final flow. This includes techniques such as chemical treatment, oil separation, sedimentation and/or filtration. Before using new types or new sources of process chemical solutions, it is BAT to test for any possible impact on the waste water treatment system and resolve potential problems.

The following values are achieved for a sample of STM installations each using several BAT. They should be interpreted with the assistance of the comments in Chapters 3 and 4, and the guidance of the reference document on the general principles of monitoring:

Emission levels associated with some plants using a range of BAT*				
	Jig, barrel, small scale coil and other processes other than large scale steel coil		**Large scale steel coil coating**	
All values are mg/l	Discharges to public sewer (PS) or surface water (SW)	Additional determinands only applicable for surface water (SW) discharges	**Tin or ECCS**	**Zn or Zn-Ni**
Ag	0.1 – 0.5			
Al		1 – 10		
Cd	0.10 – 0.2			
CN free	0.01 – 0.2			
CrVI	0.1 – 0.2		0.001 – 0.2	
Cr total	0.1 – 2.0		0.03 – 1.0	
Cu	0.2 – 2.0			
F		10 – 20		
Fe		0.1 – 5	2 – 10	
Ni	0.2 – 2.0			
Phosphate as P		0.5 – 10		
Pb	0.05 – 0.5			
Sn	0.2 – 2.0		0.03 – 1.0	
Zn	0.2 – 2.0		0.02 – 0.2	0.2 – 2.2
COD		100 – 500	120 – 200	
Total Hydrocarbons		1 – 5		
VOX		0.1 – 0.5		
Suspended Solids		5 – 30	4 – 40 (surface waters only)	
*These values are for daily composites unfiltered prior to analysis and taken after treatment and before any kind of dilution, such as by cooling water, other process waters or receiving waters				

Air emissions may affect local environmental quality and it is then BAT to prevent fugitive emissions from some processes by extraction and treatment. These techniques are described, with associated reference values for a sample of installations.

It is BAT to control noise by good practice techniques, e.g. closing bay doors, minimising deliveries and adjusting delivery times, or if necessary, by specific engineered solutions.

Specific BAT

It is a general BAT to use less hazardous substances. It is BAT to substitute for EDTA by biodegradable alternatives or to use alternative techniques. Where EDTA has to be used, it is BAT to minimise its loss and treat any remaining in waste waters. For PFOS, it is BAT to minimise its use by controlling additions, minimising fumes to be controlled by techniques including floating surface insulation sections: however, occupational health may be an important factor. It can be phased out in anodising and there are alternative processes to hexavalent chromium and alkali cyanide-free zinc plating.

It is not possible to replace cyanide in all applications, but cyanide degreasing is not BAT. The BAT substitutes for zinc cyanide are acid or alkali cyanide free zinc, and for cyanide copper, acid or pyrophosphate options, with some exceptions.

Hexavalent chromium cannot be replaced in hard chromium plating. BAT for decorative plating is trivalent chromium or alternative processes such as tin-cobalt, however, at an installation level there may be specification reasons such as wear resistance or colour that require hexavalent chromium processing. Where hexavalent chromium plating is used, it is BAT to reduce air emissions by techniques including covering the solution or vat and achieving closed loop for hexavalent chromium, and in new or rebuilt lines in certain situations, by enclosing the line. It is not currently possible to formulate a BAT for chromium passivation, although it is BAT to replace hexavalent chromium systems in phospho-chromium finishes with non-hexavalent chromium systems.

For degreasing, it is BAT to liaise with customers to minimise the grease or oil applied, and/or to remove excess oil by physical techniques. It is BAT to replace solvent degreasing by other techniques, usually water-based, except where these techniques can damage the substrate. In aqueous degreasing systems, it is BAT to reduce the amount of chemicals and energy used by using long-life systems with solution maintenance or regeneration.

It is BAT to increase process solution life, as well as preserving quality, by monitoring and maintaining solutions within established limits by using techniques described in Chapter 4.

For pickling on a large scale, it is BAT to extend the life of the acid by techniques including electrolysis. The acids may also be recovered externally.

There are specific BAT for anodising, including recovering the heat from sealing baths in certain circumstances. It is also BAT to recover caustic etch where there is high consumption, there are no interfering additives and the surface can meet specifications. It is not BAT to close rinse-water cycles using deionised water, because of the cross-media impacts of the regenerations.

For large scale continuous steel coil, in addition to the other relevant BAT, it is BAT to:

- use real time process controls to optimise processes
- replace worn motors by energy efficient motors
- use squeeze rollers to prevent process solution drag-in and drag-out
- switch the polarity of the electrodes at regular intervals in electrolytic degreasing and electrolytic pickling
- minimise oil use by using covered electrostatic oilers
- optimise the anode-cathode gap for electrolytic processes
- optimise conductor roll performance by polishing
- use edge polishers to remove metal build-up on the edge of the strip
- use edge masks to prevent excess metal build-up, and to prevent overthrow when plating one side only.

For PCBs, in addition to the other relevant BAT, it is BAT to:

- use squeeze rollers to prevent process solution drag-out and drag-in
- use low environmental impact techniques for inner layer bonding steps
- for dry resist: reduce drag-out, optimise the concentration and spraying of the developer and separate the developed resist from the waste water
- for etching: optimise the etchant chemical concentrations regularly, and for ammonia etching, regenerate the etching solution and recover the copper.

Emerging techniques

Some new techniques for the minimisation of environmental impacts are under development or in limited use and are considered emerging techniques. Five of these are discussed in Chapter 6: integrating the surface treatments into the manufacturing production has been successfully demonstrated in three situations but has failed to be fully implemented for various reasons. A trivalent chromium substitute process for hard chrome plating using a modified pulse current is well developed and has started pre-production verification in three typical applications. Equipment costs will be higher, but will be offset by reduced power, chemical and other costs. Substitutes for hexavalent chromium in passivation coatings are being developed to meet the requirements of two Directives. Aluminium and aluminium-alloy plating from organic electrolytes has successfully been demonstrated, but requires explosive and inflammable solvents. For PCBs, high density interconnects can use less material and imaging can be improved, with reduced chemical use, by using lasers.

Concluding remarks

The document is based on over 160 sources of information, with key information from both industry (mainly from operators rather than suppliers) and Member States. Details of data problems are given: primarily a lack of consistent quantitative information. The consumptions and emissions data given are predominantly for groups of techniques, rather than individual ones. This has resulted in some BAT being general, or no conclusions being reached, where specific conclusions would be helpful to the industry and regulators.

There was a good general level of consensus on the conclusions and no split views were recorded.

The information exchange and its result, i.e. this document, present an important step forward in achieving the integrated prevention and control of pollution from the surface treatment of metals and plastics. Further work could continue the process by providing:

- up to date information on the use of PFOS and its alternatives, as well as substitute techniques for hexavalent chromium passivation
- more quantitative data for achieved environmental benefits, cross-media effects and economics, particularly for heating, cooling, drying and water use/re-use
- further information on the emerging techniques identified in Chapter **Fehler! Verweisquelle konnte nicht gefunden werden.**
- software for process optimisation for a variety of processes and in a choice of languages.

Other important recommendations beyond the scope of this BREF but arising from the information exchange are:

- the development of strategic environmental goals for the industry as a whole
- a list of industry research priorities
- organising ‘club’ or co-operative activities, in particular to deliver some of this further work
- using a ‘club’ approach to develop third party recovery for certain wastes (particularly metals and pickling acids) where in-process techniques are not available
- development of the ‘infinitely recyclable’ concept for metals and metal finishing to advise producers and consumers
- development and promotion of performance-based standards to increase acceptance of new techniques with better environmental performance.

The information exchange has also exposed some areas that would benefit from R&D projects such as:

- extension of bath life and/or metal recovery for electroless plating. These baths have very limited life and are a major source of waste metals
- techniques to measure surface area of workpieces quickly and cheaply would assist the industry in controlling more readily its processes, costs, and in turn, consumptions and emissions. The techniques should include relating surface area to other throughout measures such as metal consumption or tonnage of substrate throughput
- options for further use of modulated current techniques and equipment. This technique can overcome some of the problems of traditional steady voltage electroplating
- improved materials efficiency of some identified processes.

The EC is launching and supporting, through its RTD programmes, a series of projects dealing with clean technologies, emerging effluent treatment and recycling technologies and management strategies. Potentially these projects could provide a useful contribution to future BREF reviews. Readers are therefore invited to inform the EIPPCB of any research results which are relevant to the scope of this document (see also the preface of this document).