



Commission of the European Communities

environment and quality of life

Identification and quantification of atmospheric emission sources of heavy metals and dust from metallurgical processes and waste incineration



Report

EUR 11086 EN

~~GN 85~~

Commission of the European Communities

Identification and quantification of atmospheric emission sources of heavy metals and dust from metallurgical processes and waste incineration

Christopher F.P. Bevington

Metra Consulting Group Ltd
1 Queen Anne's Gate
London SW1H 9BT, United Kingdom

Contract No 85-B6600-11-049-11-N

Final report

Directorate-General
Environment, Consumer Protection and Nuclear Safety

**Published by the
COMMISSION OF THE EUROPEAN COMMUNITIES
Directorate-General
Telecommunications, Information Industries and Innovation
Bâtiment Jean Monnet
LUXEMBOURG**

LEGAL NOTICE

Neither the Commission of the European Communities nor any person acting on behalf of the Commission is responsible for the use which might be made of the following information

Cataloguing data can be found at the end of this publication

Luxembourg: Office for Official Publications of the European Communities, 1987

ISBN 92-825-7478-4

Catalogue number: CD-NA-11086-EN-C

© ECSC-EEC-EAEC, Brussels · Luxembourg, 1987

Printed in Belgium

CONTENTS

	<u>Page</u>
EXECUTIVE SUMMARY & CONCLUSIONS	VII
Résumé général et conclusions	XI
Abschliessende Zusammenfassung und Ergebnisse	XV
1. INTRODUCTION	1
1.1 Background and Purpose of Study	1
1.2 Scope of Inventory	2
1.3 Approach to Compilation	5
1.4 Acknowledgement	6
2. DATA COLLECTION AND PRESENTATION	7
2.1 Constraints and Problems	7
2.2 Sources of Information	9
2.3 Nature of Emission Source Data Available	10
2.4 Presentation	11
3. IRON AND STEEL WORKS	13
3.1 Statistics and Location	13
3.2 Emission Levels	22
3.3 Emission Limits	26
3.4 References in Section 3	29
4. NON-FERROUS METALLURGICAL PROCESS PLANTS	30
4.1 Numbers and Locations	30
4.2 Emissions from Non-Ferrous Metallurgical Processes	39
4.3 Emission Limits for Non-Ferrous Metallurgical Processes	46
4.4 References in Section 4	52
5. WASTE INCINERATION PLANTS	53
5.1 Preface	53
5.2 Plant Inventories	54
5.3 Comment of Inventories	55
5.4 Particulate and Heavy Metal Emissions from Waste Incineration	90
5.5 Refuse Derived Fuel (RDF)	96
5.6 Chemical and Other Industrial Wastes	100
5.7 Emission Standards for Waste Incineration	101
5.8 References in Section 5	105

TABLES

		<u>Page</u>
Table III - 1	Size of EC Iron and Steelworks : EUR 10	15
Table III - 2	Blast-furnaces by Dimensions : EEC	15
Table III - 3	Crude Iron and Steel Production Plant Capacity and Capacity Utilisation in Year 1984	16
Table III - 4	Steelmaking Plants by Type and Capacity : EC	17
Table III - 5	EC Crude Steel Production by Process in 1984	18
Table III - 6	Consumption of Iron Ore, Sinter, Coke and Scrap by Department in the EC Iron and Steel Industry in 1984	19
Table III - 7	Location of EC Iron and Steel Plants	20
Table III - 8	EC Iron & Steel Foundries: 1981 & 1982	21
Table III - 9	Dust Emission Factors for Iron and Steel works	23
Table III -10	Examples of Iron & Steel Works Dust Analysis	24
Table III -11	Atmospheric Releases of Trace Elements from UK Iron and Steel Production:1983	25
Table III -12	Emission Limits applied to UK Coke Ovens and Iron and Steel Plants	27
Table III -13	FR Germany: Emission Limits for Particulates from Iron & Steel Plants and for Metals in Particulates	27
Table IV - 1A	Primary Aluminium Smelters	31
Table IV - 1B	Secondary Aluminium Plants	32
Table IV - 2	Copper Production Works in the EC	33
Table IV - 3	Primary EC Lead Works	34
Table IV - 4	Secondary EC Lead Plants	35
Table IV - 5	Primary EC Zinc Works	37
Table IV - 6	Other EC Non-Ferrous Metal Production Plants	38
Table IV - 7	Emission Tests on a 1 Tonne Melting Furnace	42
Table IV - 8	Estimates of Copper Emissions in the United States	43
Table IV - 9	Dust and Antimony Emissions from a Metallurgical Plant in Belgium	45

TABLES CONT'D

		Page
Table V - 1	Waste Incineration Plants : BELGIUM	62
Table V - 2	Waste Incineration Plants : DENMARK (1984)	63
Table V - 3a	Household Waste Treatment Installations in France: 1975, 1981 & 1985	66
Table V - 3b	Waste Incineration Plants: FRANCE (1985)	67
Table V - 4	Waste Incineration Plants: FR GERMANY	77
Table V - 5	Waste Incineration Plants: ITALY	79
Table V - 6	Waste Incineration Plants: LUXEMBOURG	83
Table V - 7	Waste Incineration Plants: THE NERTHELANDS	84
Table V - 8	Waste Incineration Plants: SPAIN (1986)	85
Table V - 9a	Example of Computer File Record of Waste Disposal Facility Licence Data UNITED KINGDOM	86
Table V - 9b	Waste Incineration Plants: UNITED KINGDOM	87
Table V - 10	Sorting Analysis & Cadmium Contents OF Household Refuse	92
Table V - 11	Cadmium Distribution in Municipal Incinerator Feedstock and Outputs	94
Table V - 12	Concentrations of Heavy Metals in Particulates Emitted from City of Paris Incineration Plants	96
Table V - 13	Pollutant Contents of Wastes, Refuse Derived Fuels and Coals	99
Table V - 14	FR Germany Emission Limits Applicable to Waste Incineration	103
Map 5 - 1a	Incineration Plants in France without Energy Recovery (1985)	64
Map 5 - 1b	Incineration Plants in Furnace with Energy Recovery (1985)	65

EXECUTIVE SUMMARY AND CONCLUSIONS

The objective was to compile inventories of the principal sources in the European Community of atmospheric emissions of heavy metals and dusts from metallurgical processes and the incineration of wastes. The information was sought by the Commission to complement a review of the technologies available for controlling these categories of emissions, and relates to the Council Directive of 28 June 1984 (84/360/EEC) on the combating of air pollution from industrial plants. The heavy metals of particular concern were cadmium, lead and mercury, but attention was also to be given to antimony, arsenic, beryllium, chromium, cobalt, copper, manganese, nickel and zinc.

While it proved possible to identify metallurgical process emission sources in terms of plant location and activity, there are problems in obtaining details about individual atmospheric discharges. This type of information is frequently treated as confidential both by the operating companies and also by the licensing authorities, which are mostly local government departments and too numerous to have been interrogated within the context of the present study. Emission inventories on a plant basis are seldom held by central government authorities. Exceptions are the national emission register in the Netherlands (the 'Emissieregistratie') and the registers of scheduled processes maintained by the Industrial Air Pollution Inspectorates in the United Kingdom, but in both cases information on individual plants is not accessible.

The position in respect of municipal waste incineration plants is somewhat easier, and lists are often available from sources such as the national branches of the International Solid Wastes and Public Cleansing Associations (ISWA). But even in this sector the details provided vary from one region or country to another, and may also be out-of-date.

The report includes tabulations of primary aluminium, primary and secondary lead, and primary zinc works by location, type of process and capacity. Other non-ferrous metal production plants are listed by country and number of enterprises. Iron and steel plants are tabulated by country, in terms of numbers, types and capacities. Domestic waste incineration plants are listed by location and capacity; together with other relevant details where

available, such as the type of dust arrestment equipment. The total numbers of works in the tabulations for the 12 EC Member States are listed below.

Number of Works

Iron and Steel

Integrated iron and steel plants	55
Iron making plants	11
Steel making: (mostly electric arc)	230
Iron and steel foundries	1998

Non-ferrous Metals

Aluminium - primary smelters	24
" - secondary plants (excl. in-house melting of production scrap)	67
Copper production - number of enterprises (excluding powder/flake/paste)	25
Lead - primary works	12
" - secondary works	43
Zinc - primary smelters	17
Other non-ferrous metal production, (Sb, As, Be, Cd, Cr, Co, Mn, Hg, Ni)	54

The numbers of non-ferrous metal foundries and melting plants for alloy production purposes were not enumerated.

Waste Incineration

Domestic waste incineration: plants of ~ 2 tonnes/hour treatment capacity and over.	577
---	-----

Emission standards for metallurgical and waste incineration plants mostly relate to particulate concentrations and mass flow limits in stack gases, and are generally established by local authorities on a plant by plant basis. National standards are issued in the Federal Republic of Germany, Spain and the United Kingdom, and those relevant to the study are summarised.

Particulate and heavy metal emission levels depend on a number of variable factors including the type and condition

of the dust extraction equipment, the process operating parameters and the composition of the raw materials. In metallurgical plants there are also fugitive and often uncontrolled emissions such as occur during metal tapping and converter charging, and these are especially difficult to estimate.

Examples are given of the wide ranges of emission levels reported in the literature, and these support the findings of a panel of the NATO Committee on the Challenges of Modern Society which reported in 1983 on the control of heavy metal emissions from stationary sources. The panel concluded that it was seldom possible to provide 'representative' heavy metal emission factors which could be used for such purposes as assessing country or industry sector emission totals, standard setting or cost estimation. This is still the position today but, on the positive side, control technologies are available for reducing particulate concentrations in gas streams to very low levels. Fugitive emissions are less readily controllable because they are difficult to capture efficiently.

CONCLUSIONS

1. The compilation of detailed inventories of metallurgical process and waste incineration sources of dust and heavy metal emissions in the EC is impeded by the scarcity of central registers, and by restrictions on accessibility to information.
2. Heavy metal emission rates depend on a number of very variable factors and are difficult to quantify, but the emissions occur largely as constituents of particulates whose concentration in gas streams can be reduced to low levels by available dust removal techniques.
3. Heavy metal emissions from waste incineration and steel scrap recycling can also be reduced by measures to restrict the entry of these metals into the raw materials. Such measures include better sorting of refuse to eliminate metals and plastics before incineration, and action to reduce the entry of scrap cadmium and mercury batteries into domestic waste.

RESUME GENERAL ET CONCLUSION

Notre objectif a été de dresser une liste complète des sources principales d'émissions atmosphériques de métaux lourds et de poussière venant de procédé métallurgiques aussi que de l'incinération des déchets dans la Communauté Européenne. Cette recherche a été effectuée par la Commission afin d'apporter d'autres renseignements sur le compte-rendu des technologies disponibles pour contrôler ces catégories d'émissions et se rapporte à la Directive du Conseil du 28 juin 1984 (84/360/EC) sur la lutte contre la pollution atmosphérique en provenance des installations industrielles. Les métaux lourds d'intérêts en particuliers étaient le cadmium, le plomb et le mercure mais on a également parlé de l'antimoine, de l'arsenic, du beryllium, du chrome, du cobalt, du cuivre, du manganese, du nickel et du zinc.

Bien qu'il soit possible d'identifier les sources d'émission de procédés métallurgiques en tant qu'emplacement d'usine et d'activité, il est difficile d'obtenir des renseignements sur les rejets atmosphériques individuels. Ce genre de renseignement est généralement gardé confidentiel par les sociétés opérantes et des autorités agréées qui font, pour la plus part, partie des services des administrations locales et qui sont de trop nombreuses pour être contactées dans le contexte de cette étude. Les inventaires d'émissions venant d'usines sont rarement effectués par les administrations locales à l'exception du registre d'émissions nationales des Pays-Bas ('Emissieregistratie') et les registres soutenus par les inspecteurs de la pollution industrielle de l'air du Royaume Uni (Industrial Air Pollution Inspectorate) mais dans ces deux cas, on ne peut avoir accès aux renseignements sur chaque usine séparément.

La situation en ce qui concerne les usines d'incinération de déchets municipaux est plus facile à observer et on peut souvent obtenir des listes dans des agences nationales de l'association du nettoyage public (ISWA) mais même dans ce secteur, les renseignements fournis varient de région à région ou de pays à pays et peuvent également ne plus être valables.

Le rapport comprend également des tabulations sur l'aluminium primaire, le plomb primaire et secondaire et le zinc primaire, aussi bien que l'emplacement de l'installation, les types du procédé et la capacité. Des installations d'incinération d'ordures ménagères sont répertoriés par emplacement et capacité et donnent également des renseignements importants lorsqu'ils sont disponibles comme par exemple, le genre d'équipement d'arrêt de poussière. Le nombre total d'études en tabulation pour des 12 pays de la Communauté Européenne sont établis comme suit:

	Nombre d'installations
Fer et acier	
Installations intégrées fer et acier	55
Installations de fabrication du fer	11
Fabrication de l'acier (principalement arc électrique)	230
Fonderies fer et acier	1998
Métaux non-ferreux	
Aluminium - primaires	24
- secondaires (non compris refonte sur place des déchets de production)	67
Production de cuivre - nombre d'entreprises (non compris poudre, flocon, pâte)	25
Plomb - primaires	12
- secondaires	43
Zinc - fontes primaires	17
Production d'autres métaux non-ferreux (Sb, As, Be, Cd, Cr, Co, Mn, Hg, Ni)	54

Le nombre de fonderies de métaux non-ferreux et d'usines de production d'alliage n'ont pas été repertoriés.

Incinération des Déchets

Incinération des déchets domestiques:

Usines de capacité de traitement pouvant aller ~ 2 tonnes à l'heure	577
---	-----

Les limites d'émission pour la métallurgie et les usines d'incinération de déchets se rapportent principalement aux concentrations de particules et de limites de coulés de messes dans les cheminés à gaz généralement établies par les autorités locales. Des limites nationales sont fixées en République Fédérale d'Allemagne, en Espagne et au Royaume-Uni et celles applicable à l'étude y sont resumées.

Le niveau d'émissions de particules et de métaux lourds dépend d'un nombre variable de facteurs incluant le genre et les conditions d'équipements d'extractions de poussières, les parametres opérants du procédé et la composition des matières premières. Dans le cas des usines métallurgiques, des émissions toxiques rapides et souvent incontrôlées se produisent aussi lorsqu'on coule les métaux ou charge les convertisseurs mais ceci reste particulièrement difficile à estimer.

On peut trouver des exemples dans les livres prouvant combien vaste sont les variétés de niveaux d'émissions. Ceci confirme les listes du Comité de l'OTAN sur "Les Defis de la Société Moderne" qui en 1983 traitait du contrôle d'émissions de métaux lourds depuis des sources stationnaires. La liste mentionnait qu'il était rarement possible de fournir des facteurs d'émissions 'représentatifs' de métaux lourds pouvant être utilisés à des fins comme par exemple fixer les secteurs totaux d'émissions par pays et industrie, établir des limites ou estimer un prix. De nos jours, ceci n'a pas changé mais pour être plus positif, des technologies de contrôle sont disponibles afin de réduire à un très bas niveau. La concentration se trouvant dans des courants de gaz, les émissions rapides sont moins contrôlables car il est difficile de les capturer efficacement.

CONCLUSIONS

1. Compilation des inventaires détaillés de traitement métallurgique et de source d'incinération de déchets de poussière et d'émissions de métaux lourds dans les pays du marché commun est freiné par le manque d'administrations centrales et par la restriction de possibilité d'accès à l'information.

2. Les taux d'émission de métaux lourds dépendent d'un nombre très variable de facteurs et est donc difficile à quantifier, mais ces émissions se présentent principalement comme des éléments de particules dont la concentration en courant de gaz peut être réduite à un niveau très bas par les techniques disponibles de ramassage de poussière.

3. L'émission de métaux lourds à partir d'incinération de déchets et de recyclage de ferraille d'acier peut aussi être réduite afin de restreindre le mélange de ces métaux aux matières premières. Ceci inclue un meilleur tri des déchets de métal et de plastique avant l'incinération ainsi qu'une réduction des restes de batteries à cadmium et mercure dans les ordures ménagères.

Abschliessende Zusammenfassung und Ergebnisse

Die Aufgabe dieses Berichtes war es den Bestand der hauptsächlichlichen Quellen von Schwermetallemissionen von Staubemissionen durch metallverarbeitende Prozesse, sowie von Emissionen durch Abfall verbrennung in der Europäischen Gemeinschaft zusammenzutragen. Die Information war von der Kommission nachgesucht worden, als Ergänzung zu einer Untersuchung der verfügbaren Technologien zur Kontrolle der erwähnten Emissionen, in Bezug auf die Richtlinie des Rates vom 28 juni 1984 (84/360/EWG), zur Bekämpfung der Luftverschmutzung durch die Industrie. Von besonderer Bedeutung waren die Schwermetalle Kadmium, Blei und Quecksilber, doch Metalle wie Antimon, Arsen, Beryllium, Chrom, Kobalt, Kupfer, Mangan, Nickel und Zink sollten ebenso berücksichtigt werden.

Es war möglich die Quellen der Emissionen aus metallverarbeitenden Prozessen in Bezug auf die Lage und Aktivität des Werkes zu identifizieren. Problematisch war es genaue Angaben über die einzelnen Abgabemengen in die Atmosphäre zu erhalten. Diese Art von Information wird teilweise als vertraulich gehandhabt, sowohl von den verantwortlichen Firmen wie auch den genehmigenden Behörden. Dieses sind meist örtliche Gemeindeverwaltungen und wurden auf Grund ihrer Vielzahl nicht in den Rahmen dieser Studie miteinbezogen. Emissionsangaben auf Werkbasis werden selten von Bundesbehörden gesammelt. Ausnahmen sind das Nationale Emissionsregister in den Niederlanden ('Emissieregistratie') sowie das Amt für Industrielle Luftverschmutzung im Vereinigten Königreich (Industrial Air Pollution Inspectorate), welches Register über planmassige Prozesse (scheduled processes) unterhält. In beiden Fällen jedoch sind Informationen über einzelne Werke nicht verfügbar.

Die Situation bezüglich der öffentlichen Müllverbrennungsanlagen sieht besser aus. Hier sind des öfteren Listen von Organisationen wie der Internationalen Vereinigung für Festmüll und Öffentliche Reinigung (International Solid Wastes and Public Cleansing Associations (ISWA)) und deren nationalen Zweigen erhältlich. Doch auch in diesem Bereich variieren die erhältlichen Angaben von einer Region oder einem Land nächsten und sind oft veraltet.

Der Bericht beinhaltet Tabellen über Ortsangaben, Kategorie und Kapazität von Werken zur Aluminiumgewinnung, zur Gewinnung und Weiterverarbeitung von Blei und zur Gewinnung von Zink. Weitere Nichteisenmetall produzierende Werke sind nach Land und Anzahl der Unternehmungen aufgeführt. Eisen- und Stahlwerke sind aufgeführt nach Land, Anzahl, sowie Typ und Produktionskapazität. Lokale Müllverbrennungsanlagen sind aufgeführt nach geographischer Lage und Kapazitäten, und wo verfügbar mit weiteren wichtigen Angaben, wie z.B. Staubauffanganlagen. Die Gesamtzahl der Werke in den einzelnen Tabellen für die 12 EG- Staaten sind im folgenden aufgeführt.

	Anzahl der Werke
Eisen und Stahl	
Eisen - und Stahlwerke	55
Eisenproduzierende Werke	11
Stahlproduzierende Werke (haupts. Elektroschmelze)	230
Eisen- und Stahlgießereien	1998
Nichteisen-Metalle	
Aluminium: Primär	24
: Sekundär (ausschl. der Einschmelzung Hauseig Produktionsabfalles)	67
Kupferproduktion: Anzahl der Unternehmungen (ausschl. Pulver/Flocken/Paste)	25
Blei : Primär	12
: Sekundär	43
Zink : Gewinnung (Hütte)	17
Weitere Nichteisenmetall Produktionsstätten (Sb, As, Be, Cd, Cr, Co, Mn, Hg, Ni)	54

Die Anzahl von Nichteisenmetall-Gießereien und Hüttenwerken zum Zwecke der Legierungsherstellung sind hier nicht aufgeführt.

Müllverbrennung

Örtliche Müllverbrennungsanlagen:
Anlagen mit ~ 2 Tonnen/Std Fassungsvermögen
und größe.

577

Emissionsleitwerte für metallproduzierende und Müllverbrennungsanlagen beziehen sich meist auf Partikelkonzentrationen und Mengenflussgrenzen in Abgas. Sie werden in der Regel von den örtlichen Behörden von Werk zu Werk individuell festgelegt. Nationale Standardwerte liegen vor in der Bundesrepublik Deutschland, Spanien und dem Vereinigten Königreich. Die Werte, die für diese Untersuchung wichtig sind, sind hier zusammengefasst worden.

Partikel und Schwermetallemissionsdichte sind abhängig von einer Anzahl von Variablen, einschliesslich des Typs und Zustands der Entstaubungsanlage, die für den Prozess verantwortlichen Parameter und die Zusammensetzung der einzelnen Grundstoffe. Man findet in metallverarbeitenden Werken auch unbemerkte und oft nicht kontrollierte Emissionen, die während des Hochofenanstichs und Anblasen des Konverters auftreten und daher besonders schwierig einzuschätzen sind. Es werden Beispiele aus der Vielzahl in der Literatur genannten Emissionswerte gegeben. Diese Werte unterstützen die Resultate eines Ausschusses der NATO-Kommission über die 'Herausforderungen in der Modernen Gesellschaft', die 1983 einen Bericht zur Kontrolle von Schwermetallemissionen durch stationäre Quellen vorlegte. Der Ausschuss stimmte überein, dass es selten möglich war 'representative' Schwermetallemissionsfaktoren, die zum Zwecke der Einschätzung der Gesamtemissionen in Land- oder Industrieregionen, dem Festlegen von Standardwerten oder Kostenkalkulation benutzt werden könnten, zugrunde zu legen. Diese Position hat sich bis heute nicht verändert. Was jedoch positiv zu vermerken ist, es stehen Technologien für die Kontrolle der Reduzierung von Partikelkonzentrationen in Gasströmen auf sehr geringe Werte zur Verfügung. Versteckte Emissionen sind weniger leicht kontrollierbar, weil sie auf effizienter Basis schwer zu messen sind.

ERGIBNISSE

1. Auflistung detaillierter Bestände von metallverarbeitenden- und Müllverbrennungsanlagen als Quellen für Staub- und Schwermetallemissionen in der EG ist unvollkommen, weil zentrale Register kaum existieren und der Zugang zu den Vorhandenen Informationen erschwert wird.

2. Schwermetallemissionsraten hängen von einer Anzahl von Faktoren ab, die sehr variable sind und schwierig zu quantifizieren sind. Die Emissionen treten meistens als Bestandteile von Partikeln auf, deren Konzentrationen in Gasströmen auch durch verfügbare Entstaubungstechniken auf sehr geringe Werte reduziert werden können.

3. Schwermetallemissionen aus Müllverbrennung und Stahlschrottwiederverwendung können ebenso verringert werden, indem das Hinzufügen dieser Metalle zu den Rohstoffen stark gesenkt wird. Massnahmen hierfür sind besseres Sortieren des Abfalls, um Metalle und Plastikmaterialien vor dem Verbrennen auszusondern, sowie Aktionen in der Bevölkerung keine Kadmium und Quecksilberbatterien dem Hausmüll zu zufügen.

1. INTRODUCTION

1.1 Background and Purpose of Study

The study relates to the provisions of the Council Directive of 28 June 1984 on the combating of air pollution from industrial plants (84/360/EEC)*, and in particular to a requirement of Article 4 that authorisations to operate certain categories of plant may be issued only when the competent authority is satisfied that: 'all appropriate preventive measures against air pollution have been taken, including the application of the best available technology, provided that the application of such measures does not entail excessive costs'.

The Commission plans to review the technologies available for controlling atmospheric emissions of heavy metals and dusts from two of the six categories of industrial plant covered by the Directive, namely metallurgical process and waste incineration plants. As a preparatory step to that review an inventory is required of the principal emission sources in those two categories, and the identification and quantification of these sources was the purpose of this study.

* OJ No. L 188, 16.7.1984, P.20

1.2 Scope of Inventory

1.2.1 Plant categories and pollutants: definitions in the Directive

Annex I of Council Directive 84/360/EEC defines the two categories of plant for which the emission source inventory is required as follows:

Production and processing of metals

- i) Roasting and sintering plants with a capacity of more than 1000 tonnes of metal ore per year
- ii) Integrated plants for the production of pig iron and crude steel
- iii) Ferrous metal foundries having melting installations with a total capacity of over 5 tonnes
- iv) Plants for the production and melting of non-ferrous metals having installations with a total capacity of over 1 tonne of heavy metals or 0.5 tonne for light metals.

(b) Waste disposal

- i) Plants for the disposal of toxic and dangerous waste by incineration.
- ii) Plants for the treatment by incineration of other solid and liquid waste.

The two groups of pollutants to be covered are listed in Annex II of the Directive in the following terms:

- Heavy metals and their compounds
- Dust excluding asbestos (suspended particulates and fibres), glass and mineral fibres.

1.2.2 Additional definitions

Some amplification of the foregoing definitions was needed for adequate delineation of the scope of the inventory, and decisions were taken on four items as follows:

a) Steel Plants

It was decided to include electric arc steel making units irrespective of whether they form part of an integrated iron and steel plant.

b) Metallurgical plant capacity

It is understood that the term 'capacity', as applied to ferrous metal foundries and non-ferrous melting installations in Annex I of the Directive relates to the amounts of molten metal which can be held in the cupolas. This is not a satisfactory definition for inventory purposes because pollutant emission is related more to the rate at which metal is melted and poured rather than holding capacity, and published lists of foundries usually refer to melting rate and maximum casting size rather than cupola capacity. Many plants have continuous casting facilities where, again, it is melting and pouring rates which are significant. Furthermore, in non-ferrous metal production plants operation is often continuous and emissions relate to production rate, but the capacity definition in Annex I relates only to casting.

The problem of devising a suitable definition of foundry size or capacity apparently caused difficulties during the drafting of the Directive, and it was not found possible to reach a solution in the present study. In the event, the foundries in the EEC were found to be so numerous and diverse in size and facilities that they could not be adequately inventorised in the time available. The question of capacity definition was therefore set aside, but it is an issue that will probably require attention in the future.

In respect of non-ferrous metal production plants, it was decided to include all works listed in the principal directories which are likely to emit dust and the relevant heavy metals to atmosphere, other than very small units.

c) Waste Incineration Plants

No threshold capacity is mentioned in the Directive, and it was decided to concentrate on plants with a waste treatment capacity of at least 2 tonnes per hour.

d) Heavy Metals

The term 'heavy metals' is not defined in the Directive and there does not appear to be a clear and generally accepted definition in the published literature. For study purposes it was decided to include metals considered by the World Health Organisation (WHO) to have carcinogenic potentiality, viz. arsenic, beryllium, chromium, cobalt and nickel, together with some others which, in the opinion of the Commission after taking expert advice, can present dangers to health and the environment. The complete list is as follows:

Antimony	Copper
Arsenic	Lead
Beryllium	Manganese
Cadmium	Mercury
Chromium	Nickel
Cobalt	Zinc

Special importance was attached to seeking data for cadmium, lead and mercury, on account of their high toxicity and widespread release into the environment. Beryllium is included because, although not a 'heavy' metal, it is highly toxic.

During the study, certain industry associations represented to Metra that the selection of metals was not appropriate

and that to refer to these metals as being carcinogenic or otherwise dangerous to health and the environment was to apply an unduly generalised and prejudicial description. It was also mentioned that several of the metals are essential trace elements for many life forms, and that inorganic forms of zinc are not included in some recently issued national air pollution control directives.

In response it was pointed out that the toxicity of a metal depends on the ambience; copper, for example, is certainly an essential trace element for human, animal and plant life, but can be lethal to some species of fish at concentrations as low as 0.05 ppm. For metals which are potentially dangerous in some circumstances it is therefore relevant to take account of levels of emissions to atmosphere, and the effects of the resultant fall-out and possible accumulation in the environment.

1.3 Approach to Compilation

The compilation of a stationary atmospheric emission source inventory involves the tasks of identification, description and quantification. Ideally, the inventory should contain such details as the organisation owning and operating the plant; the location; the process generating the emission, and the raw materials and products; the equipment from which the emission initially issues; the composition and physical state of the pollutants; any emission control facilities and their efficiency; the characteristics of the actual discharge to the atmosphere: altitude, volume, velocity and temperature; pollutant quantities and concentrations; time pattern of the discharge; and whether the emission is quantified by direct measurement or estimation. On many industrial plant sites there is a multiplicity of emission sources.

To compile an emission inventory ab initio in that degree of detail is a formidable undertaking, requiring substantial resources and either the power to demand information, or a high degree of voluntary cooperation from the industries concerned. The maintenance of an inventory is also a major task.

Few countries have comprehensive inventories and, in the EEC, the Netherlands appears to be the only Member State which has a national inventory - the Emissieregistratie - with the amount of detail outlined above, and accessibility other than to authorised government officials is largely limited to data aggregations, e.g. by industry sector or region.

It was recognised at the outset of the study, therefore, that with the very limited resources and time available it would be necessary to rely largely on central sources of information, although this would inevitably provide an incomplete picture and a heterogeneous format. The exercise proved instructive, however, in revealing the problems and constraints in preparing an inventory of this type, and these are reviewed in Section 2, following.

1.4 Acknowledgement

Metra Consulting is most grateful to the organisations which responded to approaches for information and advice during the course of the study, and whose cooperation proved invaluable. References are given for the sources of the information and data presented in the following sections.

2. DATA COLLECTION AND PRESENTATION

2.1 Constraints and Problems

There are some fundamental differences between the origins and character of the information available on air pollutant emissions as compared with that on air quality, and these differences have an important bearing on the tasks of collecting the two types of data.

Immission measurements to provide information on air quality outside plant perimeters are mostly undertaken or sponsored by central and local government authorities and their agencies. In the EEC this is apparent from an inspection of the data sources for the immission tables presented in a report by Lahmann* and others, on a recent survey for the Commission of information available on heavy metal concentrations in air in the EC.

Most of the results of such immission measurements are in the public domain and are presented in readily accessible published reports, or in technical and scientific journals. The collection of this information, while time consuming, seldom raises special problems. Another feature of immission data is that the concentration of a particular pollutant at a given location frequently represents contributions from a multiplicity of emission sources and activities, some of which may be far distant from the sampling point and not individually identifiable.

The compilation of industrial plant emission source inventories in terms of individual installations is less straightforward due to the following factors:

Lahmann, E. et al, 'Heavy metals: identification of air quality and environmental problems in the European Community'.

Report on EEC Study Contract No. 84-B-6642-11-016-11-N (October 1985).

a) Confidentiality

For commercial and other reasons, emission data and other details relating to individual plants are often treated as confidential by the organisations concerned and by the controlling authorities. Where national or regional emission inventories exist, confidentiality is usually preserved by only releasing aggregated data, such as total emissions in a particular area or industry sector.

b) Data not available in readily transferable form

Where information is not subject to a confidentiality embargo the details needed may not be collated in a form in which they can be issued, for example they may have to be extracted from a number of separate files. In such cases the authorities may be unwilling or very slow to respond to a request for information.

c) Problem of identifying optimum central information sources

It is often necessary to make a succession of approaches to identify the central source holding the details needed on a particular set of plants in a given territory. Sometimes no single source has all the information and it has to be assembled from several sources. Where there are no central sources it may be difficult to proceed because the numbers of plants and local authorities concerned are too numerous to canvas individually.

d) Information unreliable/out-of-date

Emission figures are often based on emission factors and operating parameters, and not on direct measurements. Such estimated figures can be very

inaccurate because of variations in plant performance, raw materials etc. Central source information is also often out-of-date by several years, a disadvantage which also applies to air quality data when obtained on a campaign basis.

2.2 Sources of Information

Information was sought from a wide range of sources including:

- Central and local government departments and agencies
- International bodies, such as the UNEP Industry and Environment Office
- National and European trade and industry associations, and bodies such as the Comité de Liaison des Industries de Métaux Non Ferreux de la Communauté Européenne ('C de L'.)
- Some companies in the relevant process industry sectors
- Plant and equipment suppliers, particularly manufacturers of waste incineration plant
- Specialist information services, such as the AERE Harwell Waste Management Information Bureau
- The general published literature: technical journals, symposium proceedings, statistical reports, trade directories etc.

As indicated in Section 2.1, some sources were of limited utility. In general, central government departments did not prove to be major data sources, while local authorities and process operating companies were too numerous to approach individually.

For plant identification the most useful sources proved to be the trade and industry associations and their publications, and specialist trade directories. For information on emission measurements and estimates the best sources proved to be symposia proceedings and reports on special investigations and reviews, which had been organised or undertaken by trade and industry bodies, research and development agencies, and international bodies such as UNEP.

2.3 Nature of Emission Source Data Available

Although specific emission data based on regular measurements are not available for most individual incineration and metallurgical plants, the majority - especially those in the higher capacity ranges - have to comply with national or local regulations setting limits for particulate emissions, and frequently for one or more heavy metals. Sometimes the limits relate to all plants in a given category, and sometimes they are determined on a case by case basis, taking account of factors such as the age and prospective remaining life of the installation, the economics of emission control and other local circumstances. Where general limits apply they are normally ascertainable, but licence conditions attaching to individual plants are not always open to public inspection.

The published literature and reports contain many accounts of emission measurements, mostly made on a campaign basis. The plants concerned are sometimes identified but are often designated as Plant A, Plant B, etc. The variability of the results shows how dependent they are on day-to-day operating conditions as well as plant design, and demonstrates the pitfalls of taking the performance of one or two plants as typical of a set. The literature also contains estimates of total pollutant emissions from particular areas and industry sectors in which the

compilers have drawn on several data sources, and exercised selective judgment as to reliability and representation.

Broadly speaking, therefore, the information collected falls into five groups:

- a) **Emission sources:** brief details of individual plants, including location, function, capacity, and process
- b) **Emissions limits,** applying to all plants in specified categories and territories, and sometimes to individual plants as licence or permit conditions.
- c) **Emission measurement data,** relating to individual identified and unidentified plants, often obtained in ad hoc campaigns to investigate a particular aspect, e.g. to compare different gas cleaning systems.
- d) **Emission estimates,** relating to individual installations but calculated from emission factors, plant design and operating parameters, throughput etc.
- e) **Aggregated data,** comprising pollutant emissions summated by territory, industry sector and time period; compiled on a regular or ad hoc basis, generally from estimates as in (d) above, but sometimes employing a substantial element of personal assessment.

2.4 Presentation

2.4.1 Plant inventories

Iron, steel and non-ferrous metal production plants are grouped firstly by principal function, (e.g. integrated iron and steel works, lead smelters), and secondly by Member State. For the aluminium, lead and zinc sectors individual plants are listed by company, site location, type and size of plant.

Waste incineration plants are grouped by Member State and listed by location. For each plant details are given, as available, of numbers of furnace units, waste treatment capacity, and type of exit gas cleaning equipment. Relevant additional detail supplied is also included, e.g. where there is a waste heat recovery facility.

As explained in Section 1.2.2 (b), foundries presented a special problem because of the large numbers, diversity of size and activity, and inhomogeneity of directory listings. It was not found practicable to compile comprehensive inventories either for individual plants or for categories, but examples of the type of information available are included.

2.4.2 Emission information

Quotable emission data is not available for the majority of individual plants and it is deemed unwise to include estimates in the inventories. The potential margins of error are too great, and estimates could be unwarrantably prejudicial to the organisations concerned.

For each main category of plant and process a brief review is provided of any recently published data on emission levels. Some recently reported aggregate national emission data is also included, together with information on national emission limits.

3. IRON AND STEEL WORKS

3.1 Statistics and Location

The most recently published comprehensive statistics relating to iron and steel production in the EC are those issued by Eurostat [3/1] and data has been extracted from this source and assembled in tables to provide an overall picture of the industry, and some recent trends. The latest figures are for year 1984 and relate to the 10 Member State Community before the accession of Spain and Portugal. Figures for some earlier years relate to the Community when it comprised 6 and 9 Member States.

Table III-1 shows crude steel production in the EC by size of plant in years 1982, 1983 and 1984, during which the total number of plants in the 10 Member States fell from 270 to 232. The rationalisation in the industry over the past 15 years is indicated in Table III-2, showing the decline in the numbers of operative blast furnaces, which totalled 341 in EUR 9 in 1973, but only 186 in EUR 10 in 1983.

Table III - 3 lists iron and steel production capacity utilisation by country in 1984, the average utilisation in that year being only 68%, despite the capacity cutbacks.

Table III-4 lists numbers of steelmaking plants by type and capacity for the years 1970, 1973, 1978 and 1983.

Steel manufacture by the open-hearth and basic Bessemer processes has now been phased out, and virtually all steel is now made in oxygen converters and electric furnaces, and the distribution of production between the two processes in 1984 is shown by country in Table III-5.

Table III-6 lists the consumption of the principal raw materials, - iron ore, sinter, coke and scrap - by application in year 1984.

Table III-7 shows the location of iron and steel plants in the 12 countries which now comprise the Community. This table has been derived from entries in a directory published by Metal Bulletin Books Ltd [3/2] in 1983, and presumably relates to year 1983 when Spain and Portugal were not EC members.

Table III - 8 lists the total numbers of iron and steel foundries in each EC country for the years 1981 and 1982, the total for 1981 being nearly 2000 enterprises. The Eurostat source also gives totals for turnover and numbers of employees but no breakdown by capacity. A directory published by the Foundry Trade Journal [3/3] lists ferrous and non-ferrous custom foundries in the UK, but it is not necessarily comprehensive. Company entries include types of metal and alloys cast, maximum casting weights, and the casting processes used. Melting equipment details which would be of interest for an emission source inventory are not included, and indeed are not relevant for the commercial purposes of the directory. The same comment applies to comparable trade directories published in other countries.

Table III - 1

Size of EC iron and steelworks : EUR 10

Crude steel production million t/year	1982		1983		1984	
	n	kt	n	kt	n	kt
< 1	239*	34,120	210*	37,268	204*	33,337
1 < 2	15	19,100	8	10,629	12	17,676
2 < 3	10	24,746	10	24,315	7	17,354
≥ 3	6	32,189	6	36,275	9	49,944
TOTAL	270*	110,155	234*	108,487	232*	118,311

Source: Eurostat

n = number

kt = kilotonnes

* Eurostat estimate

Table III - 2

Blast-furnaces by dimensions: EEC

Hearth diameter cm	1970 (EUR 6)	1973 (EUR 9)	1978 (EUR 9)	1983 (EUR 10)
< 600	151	131	90	42
600 < 900	139	170	137	94
900 < 1200	20	36	49	45
≥ 1200	-	4	5	5
TOTAL	310	341	281	186

Table III - 3 EC Crude iron and steel production plant capacity and capacity utilisation in year 1984

	Crude Iron			Crude Steel		
	Capacity kt	Actual prod. kt	Capacity utilisation %	Capacity kt	Actual prod. kt	Capacity utilisation %
D	42,172	30,203	72	51,556	39,389	76
F	24,565	15,039	61	28,829	18,827	65
I	17,152	11,667	68	37,271	24,062	65
NL	6,580	4,926	75	7,965	5,743	72
B	13,130	9,011	69	15,664	11,300	72
L	5,700	2,768	49	6,380	3,987	62
UK	14,453	9,643	67	23,991	15,214	63
IRL	-	-		345	166	48
DK	-	-		850	548	64
GR	-	-		4,417	895	20
EUR 10	123,752	83,257	67	177,268	120,131	68

Source: Eurostat

Notes: 1) Capacity = maximum possible production in normal economic conditions.

2) Crude iron includes spiegel and high-carbon ferro-manganese

3) Steel plants include independent steel foundries.

Table III - 4 Steelmaking plants by type and capacity : EC

Capacity per heat (1) (tonnes)		1970 (EUR 6)	1973 (EUR 9)	1978 (EUR 9)	1983 (EUR 10)
Oxygen converters					
<	100	36	75	88	25
100	< 200	33	44	55	42
200	< 300	9	29	32	32
	≥ 300	2	10	18	17
TOTAL		80	158	193	116
Open-hearth furnaces					
<	60	51	42	9	2
60	< 120	102	125	42	3
120	< 250	70	97	58	4
	≥ 250	17	39	14	3
TOTAL		240	303	123	12
Electric furnaces					
<	20	339	351	243	130
20	< 40	84	121	104	92
40	< 100	61	103	152	153
	≥ 100	11	23	40	43
TOTAL		495	598	539	418
Basic Bessemer converters					
<	20	33	10	-	-
20	< 40	123	60	-	-
	≥ 40	20	29	7	-
TOTAL		176	99	7	-

Source: Eurostat

(1) 1978 and 1983 : Average capacity per heat as liquid (t)

Table III - 5 EC Crude steel production by process in 1984

	Oxygen converters		Electric furnaces		Total	
	kt	%	kt	%	kt	%
D	31,731	81	7,657	19	39,389	100
F	15,279	81	3,549	19	18,827	100
I	11,350	47	12,712	53	24,062	100
NL	5,533	96	211	4	5,743	100
B	10,401	92	899	8	11,300	100
L	3,987	100	-	-	3,987	100
UK	10,295	68	4,836	32	15,131	100
IRL	-	-	166	100	166	100
DK	-	-	548	100	548	100
GR	-	-	895	100	895	100

Eur 10

Ingots

31,143	78	8,939	22	40,082	100
--------	----	-------	----	--------	-----

Continuously cast products

57,407	73	21,385	27	78,793	100
--------	----	--------	----	--------	-----

Liquid steel for casting

25	2	1,149	98	1,174	100
----	---	-------	----	-------	-----

TOTAL

88,576	74	31,473	26	120,049	100
--------	----	--------	----	---------	-----

Source: Eurostat

**Table III - 6 Consumption of iron ore, sinter, coke and scrap by department
in the EC iron and steel industry in 1984**

	1000 t
Iron ore consumption	
- sinter plants	94,333
- blast furnaces and electric smelting furnaces	32,836
- steelworks melting shops	862
	<hr/> 128,028
Sinter consumption : in blast furnaces	96,788
Coke consumption (1) (2)	
- sinter plants	5,368
- blast furnaces & electric smelting furnaces	42,970
- other	210
	<hr/> 48,548
Scrap consumption (including cast iron scrap)	
- blast furnaces, electric smelting furnaces and sinter plants	523
- steelworks (oxygen : 19,471 kt) (electric: 31,499 kt)	50,969
- rolling mills	262
- independent steel foundries	958
	<hr/> 52,712

(1) Including semi-coke and breeze

(2) Excluding consumption of independent steel foundries;
excluding steelworks coking plants.

Source: Eurostat

Table III - 7 Location of EC Iron and Steel Plants

Member State	IRON AND STEEL		
	Integrated iron & steel plants	iron-making	Steel making mostly electric arc.
Belgium	7	-	5
Denmark	-	-	1
France	12	-	28
FR Germany	16	2	26
Greece	1	-	4
Ireland	-	-	1
Italy	5	-	97
Luxembourg	4	-	1
Netherlands	1	-	1
Portugal	1		2
Spain	4	2	37
United Kingdom	4	7	27
TOTAL	55	11	230

Source: 'Iron and Steel Works of the World', Metal Bulletin Books Ltd. (1983)

Table III - 8 EC Iron and Steel Foundries: 1981 and 1982

	Number of enterprises	
	1981	1982
D	464	445
F	379	369
I	446	460
NL	44	43
B	47	n.a.
L	4	n.a.
UK	549	524
IRL	10	n.a.
DK	31	26
GR	24	n.a.
	<hr/>	
	1998	

Source: Eurostat

n.a. = figure not available

3.2 Emissions to Air from Iron and Steel Works

A comprehensive review of emission factors in the iron and steel industry was prepared by J. Raguin [3/4] for UNEP in 1985. The bibliography contains 121 references, the majority being to material published in the period 1979 - 1985. The data relates to emissions to water as well as to air and, for atmospheric pollutants, factors are quoted for emissions before and after pollution control.

Having reviewed data in the literature and eliminated values which appeared manifestly too high or too low, Raguin provides the collation given in Table III - 9 for atmospheric dust emission factors for modern integrated works when the following conditions apply.

1600 kg sinter/t pig iron
400 kg coke/t pig iron
850 kg iron/t raw steel
1100 kg raw steel/t rolled steel

Ranges are also included for a mill with electric arc furnace, continuous casting and rolling.

For airborne heavy metals Raguin affirms that direct emission factor data does not exist, although figures can be calculated on the basis of dust emission factors and averages of dust sample analyses and he quotes the dust composition figures listed in Table III-10 from a study in France reported by Jecko, [3/5]. The validity of this view is questionable, however, because the particles which escape collection in the dust removal equipment may contain higher proportions of the more volatile trace metals and their compounds, such as cadmium and cadmium oxide.

Table III - 9 Dust emission factors for iron and steel works.

Plant/process	Dust emission to atmosphere kg/tonne raw steel
<u>Integrated works</u>	
Sintering (inc. storage)	0.4 - 3.4
Coke ovens (inc. storage)	0.1 - 1.6
Blast furnace	0.2 - 2.6
Basic oxygen furnace	0.2 - 0.7
Ladle metallurgy, casting, and hot rolling	<u>0.1 - 0.9</u>
	1.0 - 9.2
<u>Mill with electric arc furnace</u>	
Electric arc furnace	0.2 - 2
Ladle metallurgy, casting and hot rolling	<u>0.1 - 0.9</u>
	0.3 - 2.9

Source: Raguin [3/4]

Table III - 10 Examples of iron and steel works dust analysis

	Zn	Pb	Cd	Cu	Ni	Cr
Blast Furnace						
Primary dust	0.9 - 1.2	0.1 - 0.4	0 - 0.002	0.001 -0.005	0.02	0.01
Secondary sludge						
- phosphorous ore	12	5	0.005	0.002	0.003	0.01
- hematite ore	5	3	0.01	0.004	0.005	0.02
Cast house dust						
(phosphorous ore or hematite ore)	0.01	0.003 -0.01	-	0.006 -0.02	0.02	0.02-0.03
Basic Oxygen Furnace						
All processes	0.9	0.2	0.004 - 0.02	0.01-0.1	0.01	0.01-
Electric Arc Furnace						
- carbon and structural steels	4 - 34	1 - 13	0.01-0.4	0.1-0.4	0.02-0.3	0.01-0.7
- alloy steels	3 - 6	0.7-1.9	0.04	0.3-0.5	2.5-3.1	11

Source: Jecko [3/5]

Prater [3/6] made a comprehensive experimental investigation of the behaviour of cadmium in the major UK iron and steelmaking plants and obtained the following emission factors:

	g Cd/t
Sinter production	0.074
Coke production	0.02
Steel (basic oxygen)	0.012
Steel (electric arc)	0.2

Hutton and Symon [3/7] have made the estimates reproduced in table III-11 below for releases to atmosphere of heavy metals from UK iron and steel production.

Table III-11 Atmospheric releases of trace elements from UK iron and steel production: 1983

	Cd	Pb	Hg	As
Iron production	0.9	n.d*	n.d.	7.5
Steel production				
- Basic oxygen	0.1	24	n.d.	0.9
- Electric arc	1.3	69	n.d.	0.6
	2.3	93	1.8	9

Source: Hutton & Symon [3/7]

n.d. = not determined

* an estimated 385 tonnes/year Pb is emitted to atmosphere from iron castings production.

In their comments on these figures, Hutton and Symon point out that although more steel is produced by the basic oxygen process in the UK than by the electric arc process (10.5 million and 4.4 million tonnes per year respectively in 1983), the latter is responsible for greater emissions of lead and cadmium because of the large quantities of steel scrap used in the electric arc process, a proportion of which contains cadmium-plated scrap together with discarded automobile exhaust systems and other lead containing materials. For the same reason there are significant emissions of lead from iron foundries which also use large amounts of steel scrap as raw material, and also because the dust emission control facilities at foundries are often relatively inefficient.

Because of the variable composition of the ores, fuels and scrap materials used in iron and steel production and conversion processes it would be unwise to apply any of the emission factors cited above to the aggregate tonnage statistics for the EC.

Further discussion of the problems of quantifying particulate and heavy metal emissions is provided with reference to non-ferrous metallurgical processes in Section 4.2, and in connection with waste incineration in Section 5.4.

3.3 Emission Limits

In general, regulatory limits for iron and steel plants relate to particulate matter. They are often decided on a local basis for individual plants but the national limits currently applied in the UK by the Industrial Air Pollution Inspectorate are listed in Table III - 12.

Table III-12 Emission limits applied to UK coke ovens and iron and steel plants

Scheduled process	Process description	Substance controlled	Limit applicable (see Note 1)
Gas and coke	Production of hard coke in vertical slot ovens, operative from 1976		
	car charging and coke handling	Particulate matter	0.23 g.m ³
	pipeline charging oven discharging coal preheating drying }	Particulate matter	0.115 g.m ³
Iron and steel	Sinter plants and ore dryers { pre-1970	Particulate matter	0.46 g.m ³
	{ 1970-	ditto	0.115 g.m ³
	Blast furnaces: all deliberate 'bleeding' to air	ditto	0.46 g.m ³
	Electric arc furnaces		
	new furnaces (1982-)		
	less than 50 te—primary systems	ditto	0.115 g.m ³
	more than 50 te—separate primary systems	ditto	0.115 g.m ³
	—separate secondary systems	ditto	0.030 g.m ³
	—combined primary and secondary systems	ditto	0.050 g.m ³
	associated processes	ditto	0.115 g.m ³
	less than 20 te and not using oxygen for refining	ditto	0.46 g.m ³
Other steel-making processes (including arc furnaces pre-1982)			
using oxygen for refining	ditto	0.115 g.m ³	
not using oxygen for refining	ditto	0.46 g.m ³	

Source : UK Health and Safety Executive, [3/8]

In the Federal Republic of Germany the current 'TA-Luft' (Technical Instructions - Air) includes some particulate emission limits specifically applying to iron and steel production and these are listed in Table III - 13. In addition, there are generally applicable limits for the emission of metals and their compounds as inorganic particulate substances and these are also listed in Table III - 13.

Table III - 13 FR Germany. Emission limits for particulates from iron and steel plants, and for metals in particulates.

Plant for melting

steel or cast iron: Particulate emission limit

Electric arc furnaces,
induction furnaces or cupolas
with top exhaust. 20 mg/m³

Cupolas with bottom exhaust 50 mg/m³

Plant for production of ferrous
alloys by electrothermal or
pyrometallurgical processes 20 mg/m³

Table III-13 FR Germany Cont'd

**General limits for metals and their
compounds in emissions of inorganic
particulates**

Limit (as the metal)

Class I

Cadmium

Mercury

Thallium

- for mass flows of 1g/h or more: 0.2 mg/m³

Class II

Arsenic

Cobalt

Nickel

Selenium

Tellurium

- for mass flows of 5g/h or more: 1 mg/m³

Class III

Antimony

Lead

Chromium

Copper

Manganese

Platinum

Palladium

Rhodium

Vanadium

Zinc

- for mass flows of 25g/h or more: 5 mg/m³

Source: TA Luft 27.2.1986

3.4 References in Section 3

- 3/1 Eurostat Iron and Steel Statistical Yearbook:
Statistical Office of the European Communities,
Brussels - Luxembourg (1985).
- 3/2 Iron and Steel Works of the World:
Metal Bulletin Books Ltd., Surrey, England (1983)
- 3/3 Foundry Yearbook and Castings Buyers Directory 1986:
Foundry Trade Journal, Redhill, Surrey, England
(1986).
- 3/4 RAGUIN, J. 'Environmental protection in the iron and
steel industry: review of emission factors and control
cost world-wide', Report for the UNEP Consultative
Committee on the Iron and Steel Industry, March 1985.
(Ref No. UNEP/WG. 124/3).
- 3/5 JECKO, G. 'Determination of the chemical composition
of iron and steel industry dust': Study for French
Environment Ministry. Open report of IRSID (Institut
de Recherches de la Sidérurgie Française), RE 1143
(November 1984).
- 3/6 PRATER, B.E., 'The Environmental Significance of
Cadmium in UK Steelmaking Operations', Environmental
Technology Letters, Vol. 3, 179-192 (1982).
- 3/7 HUTTON, M. and SYMON, C., 'The quantities of cadmium,
lead, mercury and arsenic entering the UK environment
from human activities'. In press (1986).
- 3/8 Industrial Air Pollution: Health and Safety 1985.
UK Health and Safety Executive, HM Stationery Office,
London (1986).

4. NON-FERROUS METALLURGICAL PROCESS PLANTS

4.1 Production Plants: Numbers and Locations

In tonnage terms the principal non-ferrous metals are aluminium, copper, lead and zinc. Table IV-1A lists the primary aluminium smelters in the EC by company, location and capacity, and Table IV-1B shows the numbers of secondary aluminium plants in each country.

Table IV-2 lists the various types of copper production works by country and numbers of companies. Alloy and fabrication plants are not included.

Tables IV-3 and IV-4 list primary and secondary lead plants in each country by company, location and capacity, and similar information is provided for primary zinc works in Table IV-5.

Table IV-6 lists companies by numbers and country which produce the other eight metals listed as being 'heavy metals' in Section 1.2.

Tables IV-1 to IV-6 do not include the numerous plants in which metals are only melted for alloying, or prior to casting for moulding and fabrication purposes.

TABLE IV - 1A Primary Aluminium Smelters

Source: 'Non-Ferrous Metal Works of the World'
Metal Bulletin Books (1985)

Country, company and plant location	Capacity tonnes/year
FRANCE	
Aluminium Pechiney:	
St. Jean de Maurienne	} Capacity at St. Jean de Maurienne being increased from 50 to 120 kt.
Riouperoux	
Sabart	
Noguères	
Venthon	
Lannemezan	349,000
FR GERMANY	
Alcan Aluminiumwerke: Ludwigshafen	ns
Hamburger Aluminium-Werk Hamburg-Funkenwerder	100,000
Kaiser Aluminium Europe Voerde	ns
LMG - Leichtmetall-Gesellschaft-Essen Essen	100,000
Aluminium-Hütte Rheinfelden Rheinfelden	ns
VAW - Vereinigte Aluminium Werke Lünen Stade	} Output 419,000
GREECE	
Aluminium de Grèce SA St. Nicolas (Boeotia)	150,000
ITALY	
Alumina SpA Porto Vesine, Cagliari	ns
Fusina, Venice	ns
Sava - Alluminio Veneto SpA Porto Marghera, Venice Fusina, Venice	} 62,000
NETHERLANDS	
Pechiney Nederland NV Vlissingen - Oost	90,000
SPAIN	
Alumina Espanol SA San Ciprián (Lugo)	180,000
Endasa - Empresa Nacional del Aluminio SA Söderberg	125,000
UK	
Anglesey Aluminium Ltd Holyhead	113,000
British Alcan Aluminium Highland Smelters Fort William	49,000
British Alcan Lynemouth Ashington	125,000

Table IV - 1B Secondary Aluminium Plants

Country	Number of Plants (excluding in-house melting of production scrap)
Belgium	-
Denmark	1
France	3
FR Germany	15
Greece	-
Ireland	1
Italy	12
Luxembourg	1
Portugal	1
Spain	5
United Kingdom	28

Source: As Table IV - 1A

Table IV - 2 Copper Production Works in the EC

Product	Numbers of companies											EC(12)					
	B	D	DK	E	F	GR	IRL	I	L	NL	P		UK				
Fire refined copper		3						1					1				
Blister copper	1	1		1									1				
Black copper				1	1			1					1				
Copper matte					2								1				
High grade copper cathodes	2	3		3	2			2					1			1	
Standard cathodes		1		1				1					1			2	
Copper billets-electrolytic		3		1	1			2								1	
Copper wirebars - electrolytic			2														
Copper cakes and slabs - electrolytic		1		1	1											1	
Copper powder/flake paste		4			1			2								5	
Numbers of enterprises:																	36
- all products	2	9		4	6			6					1			8	
- excluding powder, flake and paste	2	6		4	5			4					1			3	25

Source: 'Non-ferrous metal works of the world'
Metal Bulletin Books (1985)

Note: More than one product made on same sites

Table IV - 4 Secondary EC Lead Plants

Source : International Lead and Zinc Study Group

Key to table designations:

Smelter type : B - blast furnace
 Rev - stationary reverberatory furnace
 RR - rotary reverberatory furnace

Refinery type: P - pyrometallurgical; E - electrolytic

Country and Company	Plant location	Year built	Smelter type	Refinery type	Annual capacity '000t
Belgium					
Chemisch en Metallurgisch Bedrijft 'CAMPINE' NV	Beerse	1967	B	P	10
Fonderie et Manufacture de Métaux SA	Brussels	1970	RR	P	Smelter :15 Refinery :20
France					
Sté Minière et Métallurgique de Penarroya	(1) Escandoeuvres, Nord	1971	RR	P	27
	(2) Villefrande, Rhone	1974	RR	P	40
Sté de Traitements Chimique des Métaux	(1) Toulouse	1952	RR	P	18
	(2) Loiret	1964	RR	P	27
FR Germany					
Blei-und Silberhuetten Braubach GmbH	Rhineland-Palatinate	1978	RR	P	40
Dr Stauber & Simon Metalle	Bavaria	1939	Rev	P	2
Grillo-Werke AG	North Rhine-Westphalia	1952	B	P	18
Hetzel & Co GmbH	Bavaria	1940	RR	P	12
Metallhuetten AG Schumacher	North Rhine-Westphalia	1945	Rev,RR	P	10
Metallhuettenwerk Alfred Bauer GmbH	Berlin	1930	Rev,RR	P	5
Preussag AG Metall	Lower Saxony	1970	RR	P	45
Varta Batterie AG	Rhineland-Palatinate	1974	B	P	20
Ireland					
Metal Refiners Ltd.	Co. Dublin	1950	RR	P	Smelter: 13 Refinery: 19
Italy					
Italpiombo	Arcola (SP)	1980	RR	P	15
Nissometal SpA	Nissoria (EN)	1978	RR	P	5
Piombifera Bresciana di Guerini Aldo	Maclodio (BS)	1980	RR	P	10
Piomboghe	Brughevio (MI)	1973	RR	P	15
Sarpi SpA	Borgo Si Siro (PV)	1975	RR	P	15
Tonolli Grezzi SpA	Paderno Dugnano (MI)	1965	B, Rev, RR	P, E	50
Tonolli Sud Grezzi SpA	Marcianise (CE)	1968	RR	P	40

Table IV - 4 Secondary EC Lead Plants Cont'd

Country and Company	Plant location	Year built	Smelter type	Refinery type	Annual capacity '000t
Netherlands					
Hollandse Metallurgische Industrie Billiton bv	Arnhem	1981	RR	P	35
Uzimet bv	Delft	1982	RR	P	20
Portugal					
Metal Portuguesa Sarl	Castanheira do Ribatejo	1976	RR	P	7
Spain					
Acumuladores Tudor	San Esteban Gormaz, Soria	1984	RR	P	15
" "	Auda, Zaragoza	1975	-	P	16
Antonio Casas SA	Barcelona	1963	RR	-	2.5
Derivados de Minerales y Metales SA	Barcelona	1973	-	P	3.5
Ferroaleaciones Espanolas SA	Vallodolid	1980	-	P	12
Jose Ballesteros Peinado	Pulianas, Granada	1970	B	-	2.5
Metalurgica de Cubas	Ctra. de Madrid -Toledo, km 27.7	1971	-	P	3.5
Perdigones Azor SA	Espinardo Murcia	1968	RR	-	4
United Kingdom					
Associated Lead Mfrs. (Cookson Group)	Newcastle-upon-Tyne	1975	RR	→ P	50 80
" " "	Glasgow	1960s	-	P	25
Billiton (UK) Ltd.	Darley Dale, Derbyshire	1942	B,RR, Rev	P	55
(To be replaced by new plant of same capacity in 1987)					
" " "	Wandsworth, London	1976	-	P	11
" " "	St. Helens, Merseyside	1903	-	P	14
" " "	Welwyn Garden City, Herts.	1932	-	P	14
Britannia Refined Metals Ltd.	Northfleet, Kent	1977	Bergsoe, RR	P	30
Capper Pass & Son Ltd	North Ferriby, North Humberside	1938	B	E	12
Chloride Metals Ltd	Wakefield	1971	RR	P	16
Wilson & Jubb Ltd	Leeds	1968	Rev	P	10

TABLE IV - 5 Primary EC Zinc Works

Source : International Lead Zinc Study Group (1984/85)

Country and Company	Plant Location	Year built	Type of process	Annual capacity '000t
Belgium				
Metallurgie Hoboken-Overpelt SA	Overpelt, Hoboken	(1) 1934	Fire refining	25
		(2) 1974	Electrolytic	120
Société des Mines + Fonderies de Zinc de la Vieille Montagne, SA	Balen, Antwerp	1935	Electrolytic	180
France				
Asturienne - France	Auby-les-Douai, Nord	1975	Electrolytic Capacity will be raised by 100kt to 200kt in 1988, but this will be balanced by closure at Viviez	100
Sté des Mines et Fonderies de Zinc de la Vieille Montagne	Viviez, Aveyron	1922 Closing in 1988	Electrolytic	110
Sté Minière et Metallurgique de Penorroya	Noyelles-Godault Pas-de-Calais	1962	Imperial Smelting Furnace	110
FR Germany				
Berzelius Metalhutzen GmbH	Duisberg	1965	Imperial Smelting	80
Preussag AG Metall	Harlingerode	1935	Vertical retort (tonnage includes treatment of secondary materials)	70
Preussag-Weser-Zinc GmbH	Nordenham	1972	Electrolytic	145
Ruhr Zinc GmbH	Datteln	1968	Electrolytic	145
Italy				
SAMIM SpA	Porto Vesme, Sardinia	(1) 1973	Imperial Smelting	70
		(2) 1985	Electrolytic	83
Pertusola Sud SpA	Crotone	1928	Electrolytic	100
Netherlands				
Budelco BV	Budel-Dorplein	1974	Electrolytic	185
Portugal				
Quimigal-Quimica de Portugal EP	Barreiro	1980	Electrolytic	11
Spain				
Asturiana de Zinc SA	Aviles, Asturias	1960	Electrolytic	200
Espanola del Zinc SA	Cartegena, Murcia	1960	Electrolytic	60
Metal Quimica del Nervion, SA	Axpe, Bilbao	1976	Electrolytic	8
United Kingdom				
Commonwealth Smelting Ltd.	Avonmouth	1967	Imperial Smelting	100

Table IV - 6 Other EC Non-Ferrous Metal Production Plants

	B	D	DK	E	F	GR	I	IRL	L	NL	P	UK	Total
Antimony	2	1		3	2	1				1		1	11
Arsenic		1										1	2
Beryllium		1											1
Cadmium	2	4		1	3	1				1		3	15
Chromium		1			1				1			3	6
Cobalt	1	1		1	1								4
Manganese													1
Mercury	2	2		2	2							1	9
Nickel					3					1		1	5
	7	11		7	13	1	1		1	3		10	54

Source: 'Non-ferrous metal works of the world'
Metal Bulletin Books (1985)

4.2 Emissions from Non-Ferrous Metallurgical Processes

Pollutant emissions into the atmosphere may be expressed in three ways:

- as a concentration in the gases issuing from a stack or vent, usually as a weight of pollutant per unit volume of gas under standard conditions but sometimes on a volume per volume basis,
- as a mass flow rate, in weight per unit time,
- as a factor, in terms of the amount of pollutant released per unit of product or material treated, or per unit of energy input or output.

Emission limits or standards are most frequently expressed as concentrations; less often as mass flow rates; and sometimes in both terms. Published national standards for non-ferrous metallurgical processes are listed in Section 4.3.

Mass flow data in conjunction with the discharge conditions are needed for estimating the effects of emissions on air quality in the vicinity of a source. Emission factors are useful for statistical purposes such as for estimating total pollutant releases in a given territory from specific source categories.

The determination of reliable emission data for particulate and heavy metal emissions presents several major problems:

- Particulate emissions vary in size from coarse grit to sub-micron fume and great care must be exercised to ensure that a sample taken from a gas stream is representative in respect of the total particulate content and in size distribution.

- Not all particulate emissions issue under controlled conditions in which all the carrying gases are captured, channelled through dust arrestment equipment and eventually discharged through a stack. In metallurgical process plants there are often considerable fugitive emissions on account of difficulties in collection, especially at certain stages of batch type operations such as slag tapping, converter charging and in start-up periods. Although these stages may represent a small proportion of the total operating time, the majority of the total particulate emission may occur during these periods, and such uncontrolled emissions are very difficult to quantify.
- Heavy metal emissions occur largely as constituents of particles so that quantification is subject to at least the same uncertainties as the determination of particulate emissions, with the additional possibility that some emission occurs as vapour and may escape capture in the sampling apparatus.
- The heavy metal content of dust particles often varies with the size range, for example due to volatilisation and condensation processes; hence sampling efficiency can be a critical factor governing accuracy.
- In contrast to many chemical processes in which operating conditions remain sensibly constant for long periods, metallurgical plant operations are often intermittent and subject to wide variation in raw material composition, resulting in corresponding variations in emission characteristics.

These problems were considered in depth by a panel of the NATO Committee on the Challenges of Modern Society (NATO/CCMS) which was convened to study the reduction of heavy metal emission from stationary sources, and issued

its final report in December, 1983, [4/3]. The panel found that, in general, the emission factors available in the literature had not been published with pertinent operational parameters or with the heavy metal content of the feed stock, and that even with that information variable conditions occurred from time to time. It was concluded to be seldom possible to provide heavy metal emission factors which deserved to be termed 'representative', and country-related heavy metal emission estimates were considered to be 'highly risky'. Accordingly, the panel recommended that the data that had been compiled should not be applied for projecting emissions, setting standards or making cost estimates without careful study of the literature sources.

On the positive side, the NATO/CCMS panel found the overall dust collection efficiencies of the control techniques available to be quite well known, and that, 'if there is the need to reduce heavy metal emissions to a certain level, any reasonable requirement could be met on the part of control technology'.

The Chairman of the NATO/CCMS panel was Gerhard GÜthner, of the Umweltbundesamt (UBA), Federal Republic of Germany. He advised Metra that the panel's report of 1983 still represented the state of knowledge in 1986, and that on account of the difficulties in obtaining reliable data on heavy metal emissions, the UBA could not provide information on heavy metal emissions in the Federal Republic which would suffice in quality and extent for inventory purposes. Projects were in hand, however, for the evaluation of heavy metal emissions from a number of the older industrial plants and for developing proposals for reduction measures.

There would be little point in quoting a miscellany of examples from the literature of emission measurements on individual plants, but the following test results quoted

by Butler [4/5] in a paper for a UNEP workshop on environmental aspects of non-ferrous metals illustrate the variability of emission rates during a typical melting operation.

Table IV - 7

Emission tests on a 1 tonne melting furnace

Material : 60/40 brass Gas flow: 85 Nm³/min

Operation	Particulate concentration: g/Nm ³
Charging	0.62 for 15 min 18s
Rabbling	2.97 for 10 min
Skimming	0.71 for 1 min 27s
Pouring	2.74 for 1 min 39s

Source: Butler [4/5]

The USEPA has prepared estimates of atmospheric emissions of copper and its compounds in the U.S. from a number of source categories including metallurgical operations. The database comprised the published literature supplemented by EPA test results and databases, and the approach involved estimating total particulate emissions, including fugitives; determining the effect of air pollution control on emissions; and estimating the proportion of copper in the particulates. The results have been summarised by Weant [4/6] and the extracts quoted in Table IV-8 mainly serve to indicate the ranges of uncertainty.

Table IV - 8**Estimates of copper emissions in the United States**

Source	Estimated copper emissions '000 kg/year
Copper and iron ore processing	480 - 660
Primary copper smelting	43 - 6000
Iron and steel making	112 - 240
Coal and oil combustion	45 - 360
Municipal incineration	3.3 - 270
Secondary copper smelting	160
Copper sulphate production	45
Grey iron foundries	7.9
Primary lead smelting	5.5 - 65
Primary zinc smelting	24 - 340
Ferro-alloy production	1.9 - 3.2
Brass and bronze production	1.8 - 36
Carbon black production	13

Source: Weant, [4/6]

As a final example of the variability of metallurgical process emissions, some measurements made at a plant in Belgium producing antimony metal, alloys and oxides are reproduced in Table IV-9. They are taken from a case study appended to the NATO/CCMS report previously cited, [4/3], and illustrate the typical complexity of metallurgical plant operations, with several controlled and fugitive emission sources on one site. The emissions arise from three processes:

- a) The reduction of low antimony materials with coke in blast furnaces operated batchwise. Particulates in the furnace exit gases are collected in bag filters; those in the fugitive emissions during metal tapping are less effectively captured by a hood connected to the dust arrestment systems.

- b) The roasting of antimony ores and other materials in continuously operating rotary converters. The oxides evolved are collected in a train comprised of settling chambers, cyclones and baghouses. Some fugitive emission occurs during slag tapping.

- c) The production of antimony metal from impure oxides in refining furnaces, also a batch operation, with controlled and fugitive emissions and dust collection systems as in (a) and (b).

The wide ranges of the dust and antimony concentrations and emission rates listed in Table IV-9 reflect the variations which occur at different stages and events in the operating sequences, and also the fluctuations in the efficiency of the baghouses. Fugitive emissions escaping capture were estimated by a tracer release method in which the ratio of tracer to pollutant in the dispersed plume is measured.

To obtain meaningful estimates of emission factors for such processes it is clearly necessary to take numerous measurements over long time periods and to treat the results statistically. Even then it is difficult to guarantee continuing validity of the emission factors, which may radically change with variation in the raw materials, operating practice and the condition of the dust collection equipment.

The plant investigation quoted in the NATO/CCMS report was carried out by an external team of experts and involved advanced techniques such as neutron activation analysis. Such investigations are time consuming and demand expensive and relatively scarce resources, thus constituting a major obstacle to the construction and maintenance of quantified emission source inventories for the metallurgical industry sectors.

Installation	Average Gas flow Nm ³ .h ⁻¹	Average Temperature °C	Dust concentration mg.Nm ⁻³	Antimony concentration mg.Nm ⁻³	Emission rate g Sb.h ⁻¹	Number of measurements	Efficiency of dust control system
Blast furnace H ₂	27900	59	4.4 0.8/11.6	2.1 0.4/5.6	61±36 10/114	33	good
Refinery furnace R ₆	9100	105	10.2 6.6/14.3	8.0 5.2/11.3	73±17 47/103	8	good
R ₆	9300	86	445 157/1277	352 125/1013	3270±1600 790/7000	28	very bad
R ₄	11800	70	100.5 7.6/277	79.4 6/219	940±600 82/2260	37	bad
R ₇	13400	71	12.3 4.3/26.8	9.7 3.4/20.9	130±70 44/270	15	moderate
Convertor C ₃₀	11200	71	12.6 6.3/18.5	10.4 5.2/15.5	116±39 58/175	22	good
C ₃₈	11600	66	5.5 3.2/12.2	4.7 2.7/10.2	54±17 31/93	14	good
C ₂₁	19200	46	14.8 2/177	11.7 1.5/140	225±194 26/2570	47	moderate

Note : 1. the values are referred to the clean gases

2. the upper value represents the mean, the values beneath represent the range

Table 4.3 : Mean emission rates per installation

Table IV -9 Dust and antimony emissions from a metallurgical plant in Belgium

Source: NATO/CCMS [4/3]

4.3 Emission Limits for Non-Ferrous Metallurgical Processes

4.3.1 Controlling Authorities

Limits for particulate and heavy metal emissions from non-ferrous metallurgical processes in EC countries are mostly established on a plant basis by local government authorities, although in setting the standards regard may be paid to guidelines provided by central government agencies and to standards applying elsewhere.

The most extensive national regulations are those applying in the Federal Republic of Germany and the United Kingdom, although with contrasting modes of implementation. In FR Germany the regulatory standards for emissions to atmosphere are established by central government and issued as the 'TA Luft' regulations (Technische Anleitung zur Reinhaltung der Luft); but implementation of the regulations is the responsibility of the regional (Land) authorities. In the UK, the controlling authority for scheduled industrial processes is the Industrial Air Pollution Inspectorate - a central government body which sets emission limits and is also responsible for securing compliance.

In the following sub-sections, national standards are listed by the principal metals being produced or processed: in some cases there may be emission limits for other metals besides the one predominantly concerned.

For FR Germany it should be remembered that there are generally applicable limits for emissions of a number of heavy and other metals, divided into three classes, I, II and III, with limits of decreasing stringency. Details have been listed in Section 3.3.

New plants are usually required to comply with the most recently issued national standards, but existing plants may be allowed - at least temporarily - to continue working to the previously applying limits.

4.3.2 Non-ferrous metals: general limits for particulates

FR Germany, [4/1]

Plant for the extraction of non-ferrous metals:

Particulates : 20 mg/m³
" in lead works : 10 mg/m³

Melting plant for refining of non-ferrous metals and their alloys, except aluminium

Particulates : 0.2 kg/h or 20 mg/m³
except for lead and its alloys : 10 mg/m³

United Kingdom, [4/2]

Metal recovery by burning cable insulation:

Particulates : 0.46 g/m³

4.3.3 Aluminium

FR Germany, [4/1]

Plants for the production of aluminium:

Particulates in electrolysis furnace exit gases: 30mg/m³, and particulates from the electrolysis furnaces released via the furnace house: 5kg/tonne aluminium (daily average).

Aluminium melting:

Particulates in furnace exit gas: 0.5kg/h or 20mg/m³

United Kingdom, [4/2]

Secondary aluminium:

Particulates - usage of salt-flux 0.115 g/m³
- dross treatment 0.115 g/m³
- swarf degreasing 0.23 g/m³

4.3.4 Arsenic

FR Germany, [4/1]

General limit : as As, 1mg/m³

Spain, [4/3]

Arsenic extraction (limits as As₂O₃):

- gas flow < 9000 m³/h
 - new sources : 60 mg/m³
 - existing sources : 120 mg/m³
- gas flow > 9000 m³/h
 - new sources : 20 mg/m³
 - existing sources : 45 mg/m³

United Kingdom, [4/2]

Defined processes involving arsenic, limits as As₂O₃:

Volume flow up to 140m³/min : 0.115 g/m³
" " over 140m³/min : 0.046 g/m³

4.3.5 Beryllium

UK, [4/2] Defined processes: Be 2 x 10⁻⁶g/m³

4.3.6 Cadmium (also see copper 4.3.7)

FR Germany, [4/1] General limit, as Cd: 0.2 mg/m³

Spain, [4/3]

- new sources : 17 mg/m³
- existing sources: 40 mg/m³

the total emission must not exceed 13.6 kg/h weekly

UK, [4/2]

Defined processes involving cadmium:

Cd : 0.040 g/m³ and 80 g/h

4.3.7 Copper

FR Germany, [4/1] General limit, as Cu: 5 mg/m³

Re-melting of cathode copper in shaft furnaces allowing emissions of copper and its compounds, as Cu: 10 mg/m³

UK, [4/2]

Defined processes in copper alloy production or recovery

Total volume flow:

- up to 700m³/min : particulates : 0.46 g/m³
- 700 to 4000m³/min : " : 0.46-0.23 g/m³
- over 1400 m³/min : " : 0.23 g/m³

fume* as Cu : 0.115g/m³

Where other elements may

be present in emissions : Zn : 0.115g/m³

Total volume flow:

- up to 200m³/min : Cd : 0.070g/m³ and
150g/h
- 200 to 4000m³/min : " : 0.012g/m³ and
700g/h
- over 4000m³/min : " : individual limits

Total volume flow:

- up to 200m³/min : Pb : 0.115g/m³ and
300g/h
- 200 to 4000m³/min : " : 0.023g/m³ and
2700g/h
- over 4000m³/min : " : 0.012g/m³ and
5400g/h

* In this context 'fume' is that part of the particulate emission sample which is not collected by a BCURA cyclone but is collected on the backing filter of the BCURA apparatus.

4.3.8 Lead

The emission limits applying worldwide in 1985 have been collated by the International Lead and Zinc Study Group [4/4] and the situation for EC countries is shown below. For the UK, the full details of limits in relation to size of plant have been added.

- Belgium : No general standard; limits set for individual plants but typically 20 mg/m³
- France : No national regulations. Regional authorities set limits of 5-30 mg/m³ for total dust emissions
- FR Germany : 5 mg/m³ (see also 4.3.2)
- Ireland : No national regulations. Local authorities may set limits
- Italy : Variable with region. Typically, Lombardy limits are particulates 10 mg/m³, lead 3.3 mg/m³
- Netherlands : Variable. Most local authorities use best practicable means
- Spain : 10-120 mg/m³ depending on size and age of plant. Lowest level applies to plants built after 1980 and emitting more than 300 m³/minute. Ground level immission levels are also limited to 50 µg/m³ (30 minute maximum) or 10 µg/m³ (8 hour maximum).
- UK : Depends on age and size of plant as follows:
Emissions of lead dust or fume from defined processes classified by total process emission volumes:

Lead: UK Cont'd

	up to 200m ³ /min:	Pb	: 0.115g/m ³ & 270g/h
Pre-'85 plants	200-4000m ³ /min :	"	: 0.023g/m ³ & 2700g/h
	over 4000m ³ /min:	"	: 0.0115g/m ³ & 5400g/h

	up to 700 m ³ /min :	particulates	: 0.46g/m ³
Pre-'85 plants	700-1400m ³ /min :	"	: 0.46-0.23 g/m ³
	over 1400m ³ /min :	"	: 0.23 g/m ³

Plants 1985 and after:

all emissions	:	Pb	: 0.01g/m ³ *
" "	:	Pb	: 0.002g/m ³ **
" "	:	particulates	: 0.10 g/m ³

* Additionally, the mass rate of emission of lead from all sources on any new works shall not exceed 4000 g/hour.

** This limit applies in certain circumstances where it may be practicable to instal a back-up arrestment system in conjunction with a lower height of discharge.

4.3.9 Other requirements

It should be noted that, in addition to emission limits in terms of concentration or mass flow rate, conditions relating to plant construction and operation may also be applied, for example as regards chimney height and exit gas velocity. There may also be a general requirement to use 'best practicable means' for controlling emissions, and these may take local circumstances into account as well as available technology. The setting of air quality standards provides an indirect way of limiting plant emissions which automatically relates requirements to local environmental conditions.

4.4 References in Section 4

Sources of the plant inventories in Section 4.1, Tables IV-1 to IV-6, are given with the tables. References cited in Sections 4.2 and 4.3 are listed below.

- 4/1 FRG: Technische Anleitung zur Reinhaltung der Luft - TA Luft, 27.2.86 (GMBI S.95).
- 4/2 'Industrial Air Pollution - Health and Safety 1985' UK Health and Safety Executive. HM Stationery Office, London (1986).
- 4/3 'Control of Heavy Metal Emissions from Stationary Sources'. Report No.144, Committee on the Challenges of Modern Society, North Atlantic Treaty Organisation, Brussels (1983).
- 4/4 'Environmental and Health Controls on Lead', International Lead and Zinc Study Group, London (1985).
- 4/5 BUTLER, D.H. 'Copper: environmental impact in its processing, use and disposal'. Paper for UNEP Workshop on environmental aspects of non-ferrous metals, Ref. UNEP/WS/NFM.8 (1981).
- 4/6 WEANT, G.E., 'Sources of Copper Air Emissions', US EPA Project Summary EPA/600/S2-85/046, (June 1985).

5. WASTE INCINERATION PLANTS

5.1 Preface

In respect of plant identification and characterisation, coupled with the availability of recent emission measurement reports, the coverage of waste incineration emission sources in the EC is the most satisfactory of the industry sectors reviewed in the study.

This is mainly because waste incineration on the scale being inventorised, i.e. installations with a capacity of at least 2 tonnes/hour, is largely a public service industry, with a high proportion of the facilities being operated by, or on behalf of local authorities. The confidentiality barriers which impede information collection in the private manufacturing sectors are therefore often absent or much lower.

There is considerable public interest in the whole subject of waste disposal, and several specialist journals are devoted to the technology, e.g. 'Müll and Abfall' and 'Wastes Management'. There are national and international associations, in particular the International Solid Wastes and Public Cleansing Association (ISWA), which has active sections in most EC countries, and the production of waste disposal equipment has become a major industry.

There is increasing interest in the recovery of heat and energy from waste incineration and, in addition to the incorporation of energy recovery facilities in waste incineration plants, the conversion of household waste into pelletised fuel for use in steam raising, water heating and other applications has developed rapidly in recent years. This raises the interesting question as to whether an installation whose function is to raise steam but which burns refuse-derived fuel is to be regarded as a waste incineration plant. For the purposes of the present

inventory, only plants whose primary function is waste incineration are taken into account, but the air pollutant emission aspects of the increasing production and use of refuse-derived fuel (RDF) are discussed in Section 5.4

5.2 Plant Inventories

The authorities in Ireland and Portugal advised that there are no large waste incinerators in those countries, and this also appears to apply in Greece. Lists of plants in the other nine EC countries are provided in Tables V - 1 to V - 9.

These lists have been compiled from information derived from a variety of sources including government authorities, national sections of the ISWA and journals. The plants covered are essentially those which mainly treat household and general commercial waste, although some of them also treat certain categories of industrial waste, hospital wastes etc. There are, of course, many in-house industrial waste incineration plants dealing with material specifically related to the operations of the organisation concerned, for example woodworking waste, solvent residues, and organic wastes generated by the chemical and allied industries. The majority of these plants are relatively small, with capacities of less than 2 tonnes/hour, and many are treating organic materials which do not give rise to significant emissions of heavy metals.

The information supplied about individual plants varies widely in content, ranging from little more than the location and approximate daily or annual tonnage treated, to details which include furnace type and capacity; date of construction or start-up; the construction company; type of exit gas cleaning equipment; energy recovery facility; the population served; ownership and management. It was not possible, therefore, to present the information in a standardised format and details which are superfluous for

the purpose of the present inventory have been excluded.

The total numbers of plants included in the tabulations for each Member State are as follows:

Numbers of plants listed in Tables V-1 to V-9	
Belgium	26
Denmark	49
France	302
FR Germany	44
Italy	95
Luxembourg	1
Netherlands	12
Spain	9
United Kingdom	59
	<hr/>
	597
	<hr/>

It must be noted, however, that the date to which each country list relates varies, and is uncertain in some instances.

5.3 Comments on Inventories

5.3.1 Belgium (Table V - 1)

For the Northern or Flemish region of Belgium 22 incineration plants are listed as compared with only 4 in the Southern region of Wallonia. The date of the Flemish inventory is uncertain but the details supplied included tonnages treated in 1981, indicating that most of the plants were built before that year. Most of the Flemish plants are equipped with electrostatic precipitators for stack gas cleaning, but two rely on water scrubbing and

two on multicyclones. Details of the Wallonia plants were not available at the time of reporting.

5.3.2 Denmark (Table V - 2)

With 49 plants being listed in an inventory relating to year 1984, Denmark is particularly well served with waste incineration facilities although 22 of the units are relatively small with capacities in the range 1 to 3 tonnes/hour. For exit gas cleaning 24 plants are equipped with electrostatic precipitators, 15 have cyclones and one has a gas scrubber, but one has only gravity setting and 8 are listed as having no filters.

5.3.3 France (Tables V - 3A and 3B)

Comprehensive inventories of household waste treatment installations in France are compiled at intervals by the Agence Nationale pour le Récupération et l'Élimination des Déchets (ANRED) and l'Association Générale de Hygiénistes et Techniciens Municipaux (AGHTM). The fourth and most recent of these inventories is published in the AGHTM journal: 'Techniques Sciences Méthodes' No.9, 1986, and relates to the situation at 31 December 1985. All treatment methods are covered including incineration, compostage, controlled dumping, the production of refuse derived fuel, and combinations such as compostage with incineration.

In Table V - 3A the waste treatment installation in France in the years 1975, 1981 and 1985 is analysed by method of treatment in terms of numbers of units, the average tonnage of waste treated daily, and the percentage of population served.

Table V - 3B provides a full inventory of the household waste incineration plants in terms of location, furnace capacity, date of commissioning, average tonnage treated

per day and whether there is energy recovery. Plants in which compostage is supplemented by incineration have been included in this list, but in Table V - 3A these are included in the compostage category. The published inventory does not indicate the modes of exit gas cleaning treatment employed.

The territorial distributions of 'simple' incineration and of incineration with energy recovery are illustrated in Maps 5 - 1A and 1B.

From 1975 to 1985 the number of incineration plants grew from 103 to 284; the average daily tonnage treated rose by 36% and the proportion of the population served increased from 28% to 36%. The compilers of the survey point out that waste incineration units with heat recovery are situated mainly in urban and industrial areas, while plants without heat recovery in such areas are mostly over 10 years old. In other districts there is a relatively high ratio of numbers of incineration plants to the population served - especially in mountainous and tourist regions.

5.3.4 Federal Republic of Germany (Table V - 4)

This inventory is reproduced from the journal 'Der Städtetag' for June 1986, although more detailed but less recent information was supplied by the Federal Environment Agency: the Umweltbundesamt (UBA). The list covers 44 plants mainly treating household refuse and household type commercial and industrial wastes and the other details include capacity, annual throughput, waste heat utilisation and mode of exit gas cleaning. The UBA information shows that the majority of the plants were built during the 1960's and 1970's and that many of these were equipped with electrostatic gas cleaning some years later. Only two plants are indicated as not having

electrofilters, and all except three utilise waste heat in some way.

5.3.5 Italy (Table V - 5)

This list has been assembled from tables in a report on a survey of urban incineration plants in Italy by Professor Luigi Giannico and Ing. Luciano Seller of the Ministry of Health. The survey was prepared from questionnaire returns and is understood to relate to the situation in 1980 but, as is apparent, the details requested were not all supplied in many instances. The copy of the survey report was supplied to Metra by the Italian Section of ISWA.

In contrast to the situation in FR Germany, of the 95 Italian plants listed only 9 are indicated to have some form of energy recovery facility, and only 21 to employ electrofilters for stack gas cleaning. Forty nine plants have gas washers or cyclones followed by gas washers, 18 rely on cyclones only for gas cleaning and in 7 cases the mode of gas cleaning is not indicated.

For the majority of plants, figures are given for dust emission in terms of the maximum concentration in the exit gas and the maximum weight of dust emitted daily. It appears that in most cases the former is a target or permit figure, and the latter is calculated from the concentration limit and gas flow. Where electrofilters are used the maximum dust concentrations range from 50 to 150 mg/Nm³. With gas washing, maxima of up to 700 mg/Nm³ are quoted and with cyclones up to 1500 mg/Nm³, although for one plant with cyclonic cleaning the maximum is given as 5600 mg/Nm³.

Plant capacities range from 10 to 600 tonnes/day, and in 1980 the majority were operating well below capacity. It must be borne in mind that the situation disclosed by the survey may have materially changed during the past 5 years.

5.3.6 Luxembourg (Table V - 6)

The Grand Duchy of Luxembourg has one quite large 3 line incineration plant treating household and commercial wastes, including automobile tyres, and the details given in Table V - 6 were provided by the operating authority. The plant is currently operating continuously at about 70% of its total nominal capacity for the 3 furnaces of 576 tonnes/day, (3 x 8 tonnes/hour). It is equipped with electrofilters which restrict dust in the stack gases to concentrations of 50 to 100 mg/Nm³.

Measurements of heavy metal concentrations in the 'clean' gas stream from one of the furnace lines are also included in Table V - 6. The wide ranges reflect the variable composition of the input waste, but indicate significantly higher concentrations of lead, cadmium and zinc in the exit gases when tyres are included in the furnace feed.

5.3.7 The Netherlands (Table V - 7)

Details are listed for the eleven operating plants and a new installation in Nijmegen which is due to start up in 1987. Total nominal capacities range from 8 to 120 tonnes/hour. Ten plants have electrofilters and one has gas washing only, but it is of interest that the new Nijmegen plant will use fabric filters to effect the final gas cleaning.

During studies for the Dutch Ministry of Housing, Physical Planning and the Environment during 1984, Metra collected the results of dust and heavy metal concentration measurement campaigns on some of the plants, but these are not available for quotation. It can be stated, however, that recent extensions and modifications to the exit gas cleaning equipment in several installations have resulted in substantially improved performance.

5.3.8 Spain (Table V - 8)

The details tabulated for 9 waste incineration plants were provided by the Spanish Association of Public Cleansing Undertakings. Capacities range from 1.5 to 45 tonnes/hour and two plants utilise waste heat for electricity generation. Four have electrofilters for gas cleaning, two use cyclones and the other three use water washing, a settling chamber and pyrolysis respectively.

The authorised maximum level of dust emission is 150 mg/Nm³ in all cases. Actual levels are within this limit for two of the plants with electrofilters, and above it for the other two. Not surprisingly, one of the plants using cyclones runs well above the limit, and figures are not quoted for the remainder.

5.3.9 United Kingdom (Table V - 9A and 9B)

Waste disposal and treatment facilities, including incineration plants, are licensed by local authorities in the UK and a computer file of data abstracted from the licence registers has been assembled for some 5500 sites in England, Wales and Scotland by a private company, Aspinwall Data, Information and Training Limited. The information on the file includes location, operator and management, type of facility, types of waste authorised for treatment and any input limits. An example of the format is provided in Table V - 9A.

Metra arranged for the Aspinwall file to be interrogated for the data on all operating incinerator plants in Great Britain excluding any with a known capacity of less than 2 tonnes/hour. This yielded 139 records of which many related to industrial waste incineration, e.g. for waste organic chemicals, food processing wastes etc. For consistency with the other inventories, only the 57 plants recorded as burning household wastes are tabulated

here in Table V - 9. The information on year contracted, furnace capacity, and energy recovery, together with the entries for Northern Ireland and the Channel Islands have been added from another source, but no published record was found listing details such as type of gas cleaning equipment, although it is believed that most of the larger plants now employ electrofilters. The result is less satisfactory than some of the other inventories and, while a better picture could readily be obtained by approaching the individual plant managers and operators, that was beyond the scope of the survey.

Table V - 1 Waste Incineration Plants : BELGIUM

A. Flemish Region

Location	No. of ovens/ capacity t/h	Optimum annual capacity		Exit gas cleaning
		5 day/wk kt	7 day/wk kt	
Brasschat	2 x 3.5	24		ESP
Brugge	3 x 9	132	184	GW
Duerne	2 x 3.5	34		ESP
Edegem	2 x 3.3	32		ESP
Eeklo	2 x 7	68		ESP
Gent	2 x 5.5	53	75	ESP
Harelbeke	2 x 5.5	53		ESP
Heist-op-den Berg	2 x 3.2	31		ESP
Houthalen	2 x 8	under construction		GW
Izegem	2 x 3	29		Multicyclone
Knokke-Heist	2 x 2	19		ESP
Lokeren	2 x 1.8			Multicyclone
Melsele	2 x 2.2	21		ESP
Menen	2 x 4	39	54	ESP
Merksem	2 x 3.5	34		ESP
Oostende	2 x 5.6	54	76	ESP
Roeselare	2 x 3.2	31		ESP
Ronse	2 x 2.7	26		ESP
St. Niklaas	2 x 3.2	31		ESP
Stabroek	1 x 4.5	22		ESP
Willebroek	2 x 2.2	21		ESP
Wilrijk	2 x 10	97		ESP

Source: Openbare Afvalstoffenmaatschappij voor het Vlaamse Gewest (OVAM)
ESP = electrostatic precipitators GW = gas washing.

B. Wallonia Region

Summary (details of individual plants not received)

Location	Amount of waste treated kt/y
Nivelles	28
Ath	36
Charleroi	101
Namur	14

Source: 'BESWA - Revue', January 1985
(BESWA = Belgian Solid Waste Association)

Table V - 2 Waste Incineration Plants : DENMARK (1984)

District and Name of plant	Number of furnaces	Capacity t/h	Waste treated kt/y	Exit gas cleaning
(FB = Forbraending)				
Hovedstadsområdet:				
Amager FB	3	36.0	282	El
Vest FB	4	50.0	319	El
Brøndby	2	8.0	30.6	El
Albertslund	2	7.5	28.7	El
Tastrup	1	3.0	14	Cy
Helsingør	2	10.7	25	Cy
I/S Nord FB	2	6.0	37.4	El
Gerlev FB	1	1.0	4	No
Skibby FB	1	1.9	4.5	No
I/S Kara Roskilde	3	13.0	66.4	El
Solrød FB	1	2.0	6.1	El
Graested FB	1	3.0	6.4	Cy
Vestsjællands Amt:				
Korsør FB	1	2.0	8.8	Cy
Ringsted FB	1	2.0	9.9	Cy
Slagelse FB	2	7.0	28.3	El
Storstrøms Amt:				
Nykøbing F	2	7.0	42	El
Næstved FB	2	9.0	48	El
Klippinge, Magleby	1	2.0	2.5	No
Bornholms Amt:				
Klemensker FB	1	2.0	5.8	No
Paulsker FB	1	2.0	5.8	No
Fyns Amt:				
Middelfart FB	2	4.0	11.9	Cy
*Nyborg FB	2	6.2	26	Cy
Rudkøbing FB	2	1.9	4.8	Cy
*Svendborg FB	2	7.0	20.7	Cy
Sønderjyllands Amt:				
Haderslev FB	2	7.5	19.2	Cy
Sønderborg FB	2	6.0	28.7	El
Ribe Amt:				
Vestforbraend I/S Kaerup	2	5.0	12.3	Fk
Vejen FB			6	Cy
Vejle Amt:				
Horsens FB	2	10.0	32.2	El
Kolding FB 1	2	6.0	22.5	El
Kolding FB 2 (8)	2	8.0	58	El
Ringkøbing Amt:				
Herning FB	2	7.0	16.7	Cy
Holstebro FB	2	7.0	14	Cy
Struer FB	1	2.0	8.5	Cy
Videbaek FB	1	2.0	12.5	El
Århus Amt:				
Svejstrup FB (10)	2	2.2	15	Rv
Grena FB	1	2.5	7.9	El
Rosenholm FB	1	2.4	8	No
Skanderborg FB	1	4.0	23	El
Århus Nord	2	15.2	111.2	El
Viborg Amt:				
I/S Thyra Thisted	1	3.0	11.3	El
Nordjyllands Amt:				
Frederikshaven FB	2	7.0	18.2	El
Hjørring FB	2	6.5	20	Cy
Hobro FB	1	3.0	-	El
Sindal FB	1	2.0	1.6	No
I/S Reno Nord	2	16.0	83	El
Skagen FB	1	2.5	6.2	El
Hadsund FB	2	2.5	-	El
Brønderslev FB	3	3.0	4.2	No

Electrostatic precipitators will probably be installed

El = electrostatic precipitator Cy = cyclone
 Rv = scrubber Fk = gravity chamber No = without filter

Table V - 3A Household Waste Treatment Installations in FRANCE: 1975, 1981 and 1985

Method of Treatment	December 1975			December 1981			December 1985		
	No. of units per day	Average tonnage treated per day	% of population served	No. of units	Average tonnage treated per day	% of population served	No. of units	Average tonnage treated per day	% of population served
Incineration	82	4 687	9.3	184	7 337	14.5	218	7 136	13.1
Incineration with energy recovery	21	9 659	19.0	34	11 337	22.0	66	12 296	22.8
Total incineration	103	14 346	28.3	218	18 674	36.5	284	19 432	35.9
Compostage-all methods	60	3 260	6.5	94	4 671	9.4	90	4 053	8.0
Crushing and combustible derivatives	44	2 072	3.9	144	4 735	9.4	133	4 312	8.6
Controlled dumping	83	8 803	17.0	264	17 634	34.4	341	18 445	34.4
Others (pyrolysis, methanisation)	0	0	0	0	0	0	2	165	0.3
TOTAL	290	28 481	55.8	720	45 715	89.7	850	46 407	87.2
Population of France		52 655 9000			52 565 700			54 330 300	
Total population serviced		29 377 200 (55.8%)			47 150 300 (89.7%)			47 369 200 (87.2%)	

Source: 'Techniques Sciences Méthodes' No.9, 1986.

TABLE V - 3B

**Household Waste Incineration Plants in France (1985):
Locations, Capacities, Utilisation and Ages**

Key

Type of plant: I = incineration without energy recovery
IR = " " with " "

CL+I = slow compostage with incineration of refuse
CA+I = accelerated compostage with incineration of refuse

Capacity : t/h = tonnes/hour; t/d = tonnes/day

Utilisation : average tonnes/day waste actually treated

IWC = industrial waste comparable with household waste

Where tonnage varies seasonally:
t/d = daily tonnage out of season
t/d SEA = " " in season

Source: Techniques Sciences Méthodes: Genie Urbain - Genie Rural. No.9 (1986)

DEPARTMENT and Location	Type of plant	Capacity	Utilisation	Year of start-up
01 - AIN				
Belley	I	1 x 16 t/d	10 t/d	78
Chanay	I	1 x 1.5 t/h	1 t/d	82
Courmangoux	I	1 x 12 t/d	8 t/d	85
Divonne les Bains	I	1 x 1.5 t/h	5 t/d	
			10 t/d SEA	84
Echallon	I	1 x 1.5 t/h	1 t/d	82
Feillens	I	1 x 16 t/d	7 t/d	81
Genissiat "La Truyere"	I	1 x 6 t/d	1 t/d	82
Groissiat	I	2 x 2.5 t/h	50 t/d	74
Hotonnes	I	1 x 16 t/d	0.4 t/d	
			1.0 t/d	82
Jujurieux	I	1 x 12 t/d	6 t/d	82
Le Plantay	I	1 x 20 t/d	20 t/d	81
Sandrans	I	1 x 0.6 t/h	2 t/d	77
Tenay	I	1 x 16 t/d	7 t/d	82
Vieu d'Izenave	I	1 x 6 t/d	2 t/d	77
	-			
02 - AISNE				
Tergnier "Rue Hoche"	IR	1 x 1.8 t/h	26 t/d	72
Chauny "Quai Crozat"	IR	1 x 1.8 t/h	23 t/d	76
Omissy "Chemin de Morcourt"	IR	1 x 10 t/h	80 t/d	67

Cont'd ...

TABLE V - 3B

DEPARTMENT and Location	Type of plant	Capacity	Utilisation	Year of start-up
03 - ALLIER Bayet	IR	1 x 3.9 t/h	54 t/d	82
04 - ALPES-DE-HAUT-PROVENCE La Brillanne	I	1 x 0.5 t/h	0.6 t/d 1.5 t/d SEA	78
St Andre des Alpes	I	1 x 1 t/h	1.8 t/d 4.4 t/d SEA	82
St Julien du Verdon	I	1 x 0.5 t/h	1 t/d	80
Vaumeilh	I	1 x 0.2 t/h	0.1 t/d 1.3 t/d SEA	84
05 - HAUTES-ALPES Briancon "Mallefosse"	I	1 x 2 t/h	12 t/d 35 t/d SEA	74
Chateau Villevielle	I	1 x 1 t/h	1.2 t/d 9.0 t/d SEA	82
Superdevoluy	I	1 x 0.5 t/h	2 t/d SEA	82
Superdevoluy	IR	1 x 0.5 t/h	4 t/d SEA	80
06 - ALPES-MARITIMES Antibes "Font de Cine"	I	2 x 9 t/h	180 t/d 590 t/d SEA	70
Bonson	I	1 x 1.5 t/h	17 t/d	77
Isola 2000	I	1 x 2 t/h	3 t/d 16 t/d SEA	76
Moulinet	I	1 x 0.8 t/h	1.5t/d	68
St Martin Vesubie	I	1 x 1.5 t/h	1.5t/d 8 t/d SEA	68
Utelle "La Chaudan"	I	1 x 0.3 t/h	0.5t/d SEA	75
Valderoure	I	1 x 1.5 t/h	2 t/d 7 t/d SEA	78
Vallebergue	I	1 x 1.8 t/h	6 t/d	81
Nice-est (Quartier de l'Ariane)	IR	3 x 12 t/h	460 t/d 600 t/d SEA 80 t/d IWC	77
07 - ARDÈCHE Le Cheylard	I	1 x 1.5 t/h	14 t/d	83
Privas "La Fruguiere"	I	1 x 1.8 t/h	25 t/d	76
St Marcel les Annonay	I	1 x 14 t/d	4 t/d	84
Lavilledieu	CA+I	1 x 60 t/d 1 x 1.5 t/h	40 t/d 60 t/dSEA	80
09 - ARIÈGE Saint Girons "Palettes"	I	1 x 2 t/h	11 t/d 20 t/d SEA	77
Tarascon	I	1 x 1.5 t/h	12 t/d	75
Villeneuve d'Olmes	I	1 x 1.5 t/h	12 t/d	74
10 - AUBE Bernon	I	1 x 0.5 t/h	4 t/d	80
11 - AUDE Conques/Orbiel	I	1 x 1 t/h	8 t/d	82
Lezignan-Corbieres	I	1 x 0.9 t/h	16 t/d	79
Quillan	I	1 x 2 t/h	12 t/d	71

TABLE V -3B

DEPARTMENT and Location	Type of plant	Capacity	Utilisation	Year of start-up
13 - BOUCHES-DU-RHÔNE				
Arles "Zi Nord"	I	1 x 3 t/h	50 t/d	77
Chateaufrenard "Zi"	I	1 x 1.8 t/h	30 t/d	76
Ensues la Redonne	I	2 x 4 t/h	108 t/d	72
Grans "Tardagu"	I	1 x 2 t/h	45 t/d	73
Saintes Maries "Quartier des Arnelles"	I	1 x 1.5 t/h	5 t/d	
			24 t/d SEA	72
Trets	I	1 x 0.5 t/h	7 t/d	82
14 - CALVADOS				
Colombelles	I	2 x 7.5 t/h	250 t/d	72
Vendeuvres Escure sur Favieres	I	1 x 1 t/h	10 t/d	80
Lisieux "Zi de la Vallee"	IR	1 x 3.7 t/h	50 t/d	73
Tourques	IR	2 x 2.5 t/h	15 t/d	
			60 t/d SEA	74
15 - CANTAL				
Maurs	I	1 x 1 t/h	71 t/d	82
16 - CHARENTE				
La Couronne	CA+I	1 x 96 t/d	70 t/d	
		1 x 2 t/h		
17 - CHARENTE-MARITIME				
Clerac	I	1 x 0.9 t/h	15 t/d	79
St Pierre Oleron "Le Bois d'Augas"	I	1 x 2.5 t/h	10 t/d	
			45 t/d SEA	79
Jonzac	IR	1 x 3 t/h	40 t/d	81
Paille	IR	1 x 3.5 t/h	50 t/d	81
Surgeres	IR	1 x 2 t/h	35 t/d	80
19 - CORRÈZE				
St Pantaleon de l'Arche	IR	2 x 3.5 t/h	110 t/d	73
" "	IR	1 x 3.5 t/h	50 t/d	82
2B - HAUTE-CORSE	CL+I	1 x 7 t/h		
		1 x 15 t/d	50 t/d	75
21 - CÔTE D'OR				
Nogent les Montbard	I	1 x 1.5 t/h	20 t/d	81
Ruffey les Beaune	I	1 x 1.8 t/h	10 t/d	73
Saulieu	I	1 x 1.5 t/h	16 t/d	84
Chatillon sur Seine	IR	1 x 2 t/h	20 t/d	85
Dijon	IR	2 x 12 t/h	215 t/d	74
			45 t/d IWC	
Is/Tille	IR	1 x 1.5 t/h	25 t/d	83
22 - CÔTES-DU-NORD				
Route de Ploubaley Taden"	I	2 x 2 t/h	50 t/d	76
Brehat	I	2 x 0.5 t/h	0.3 t/d	
			5 t/d SEA	71
Guingamp "Plouisy"	I	1 x 3.5 t/h	32 t/d	72
Pleumeur Gautier	I	1 x 1 t/h	10 t/d	78
25 - DOUBS				
La Riviere Drugeon	I	1 x 0.9 t/h	6 t/d	82
Vercel Ville-Dieu-le-Camp "Valdahon"	I	1 x 1.5 t/h	18 t/d	82
Besancon "Planoise"	IR	2 x 2 t/h	67 t/d	
			10 t/d	71
" "	IR	1 x 3 t/h	51 t/d	
			7 t/d IWC	76
27 - EURE				
Bernay "La Petite Malouve"	I	2 x 2 t/h	37 t/d	74
Pont-Audemer "La Grande Cote"	I	1 x 2 t/h	18 t/d	72
28 - EURE-ET-LOIR				
Mainvilliers "La Mare Carbone"	I	2 x 4 t/h	100 t/d	71
Chateaudun	I	1 x 3.4 t/h	30 t/d	76
Dangeau "Hameau du Plesis"	I	1 x 2 t/h	25 t/d	73
Nogent le Rotrou "Le Padas"	I	1 x 3.2 t/h	30 t/d	76
Ouarville "Le Bois de la Follie"	I	1 x 60 t/h	30 t/d	
Dreux "ZI Nord"	CA+I	1 x 2 t/d		74

TABLE V -3B

DEPARTMENT and Location	Type of plant	Capacity	Utilisation	Year of start-up
29 - FINISTÈRE				
Menez "Gouret en Meillars"	I	1 x 3 t/h	20 t/d 40 t/d SEA	74
Plougoulm "Ty-Corn"	I	1 x 2 t/h	15 t/d 30 t/d SEA	74
30 - GARD				
Cabrieres	I	1 x 2 t/h	15 t/d	85
Mejannes le Clap	I	1 x 0.8 t/h	0.3t/d 4t/d	82
Sauve	I	1 x 1.5 t/h	9t/d	77
Sommieres	I	1 x 1 t/h	5t/d	83
St Benezet	I	2 x 1 t/h	5t/d	84
St Florent/Auzonnet "Le Gros"	I	1 x 0.9 t/h	7 t/d	76
St Martin de Valgalgues	I	1 x 3.5 t/h	84 t/d	75
31 - HAUTE GARONNE				
Cazeres "Brioulette"	I	1 x 1.5 t/h	15 t/d	75
Montgaillard de Salies	I	1 x 0.9 t/h	6 t/d	83
Villefranche de Lauragais	I	1 x 1.5 t/h	20 t/d	74
Toulouse "Zup du Mirail"	IR	3 x 8 t/h	400 t/d 47 t/dIWC	70
32 - GERS				
Pauilhac	I	1 x 0.7 t/h	15 t/d	79
33 - GIRONDE				
La Teste "ZI"	I	2 x 3.6 t/h	40 t/d 90 t/d SEA	74
Cenon "La Maregue"	IR	2 x 8 t/h	350 t/d	84
34 - HÉRAULT				
Pezenas "L'Amandier"	I	1 x 3 t/h	25 t/d	81
35 - ILLE-ET-VILAINE				
Bageur Pican	I	1 x 0.9 t/h	15 t/d	80
Cesson Sevigne	I	1 x 1 t/h	14 t/d	79
Redon	I	1 x 3 t/h	32 t/d	75
Tinteniach	I	2 x 1.5 t/h	31 t/d	84
Rennes	IR	2 x 5 t/h	220 t/d	68
36 - INDRE				
Chateauroux	I	2 x 3 t/h	55 t/d	72
Issoudun	I	1 x 2 t/h	20 t/d	79
"	I	1 x 2 t/h	20 t/d	83
Le Blanc	I	1 x 1.5 t/h	10 t/d	78
St Marcel "La Martine"	I	1 x 1.5 t/h	8 t/d	77
37 - INDRE-ET-LOIRE				
Saint Benoit la Foret	IR	1 x 3 t/h	45 t/d	83
38 - ISÈRE				
Crolles "Les Iles du Raffour"	I	1 x 1.8 t/h	25 t/d	74
Livet et Gavet	I	1 x 1.8 t/h	12 t/d 18 t/d SEA	78
Pontcharra	I	1 x 3 t/h	33 t/d	77
St Laurent du Pont	I	1 x 1.2 t/h	12 t/d 16 t/d	81
St. Marcellin	I	1 x 2.5 t/h	20 t/d	79
Vaulnavay le Haut	I	1 x 1 t/h	3 t/d	81
Villars de Lans "Fenat"	I	1 x 1.5 t/h	6 t/d 22 t/d SEA	72
La Tronche "L'Ile d'Amour"	IR	3 x 6 t/h	250 t/d 350 t/d SEA	77
Pont de Beauvoisin	IR	1 x 1.5 t/h	11 t/d	83
	IR	2 x 1 t/h	16 t/d	
Sousville	IR	2 x 1 t/h	10 t/d	85
39 - JURA				
Etival	I	1 x 0.9 t/h	4 t/d	81
Evans	I	1 x 3.2 t/h	60 t/d	74
Moirans	I	1 x 0.9 t/h	3 t/d	81
St. Laurent	I	1 x 0.9 t/h	3 t/d	81

TABLE V -3B

DEPARTMENT and Location	Type of plant	Capacity	Utilisation	Year of start-up
40 - LANDES				
Benesse Maremnes	I	1 x 3 t/h	15 t/d 30 t/d SEA	72
	I	1 x 4 t/h	20 t/d 40 t/d SEA	85
Messanges	I	1 x 3 t/h	15 t/d 30 t/d SEA	76
41 - LOIR-ET-CHER				
Nouan le Fuzelier	I	1 x 2.7 t/h	30 t/d	83
Blois	IR	2 x 3.1 t/h	90 t/d	82
42 - LOIRE				
L'Horme "Font-Rosay"	I	2 x 1.8 t/h	60 t/d	68
Luriecq - Estivareilles	I	1 x 1 t/h	9 t/d 18 t/d SEA	82
Sail Sous Couzan	I	1 x 0.8 t/h	2 t/d	83
43 - HAUTE-LOIRE				
Dunieres	I	1 x 1 t/h	1 t/d 3 t/d SEA	82
Landos	I	1 x 1 t/h	1 t/d 1.6 t/d SEA	84
45 - LOIRET				
Arrabloy "Les Gatines"	I	2 x 1.8 t/h	45 t/d 20 t/d IWC	75
Chuelles	I	1 x 1 t/h	10 t/d	79
	I	1 x 1 t/h	10 t/d	82
Pithiviers "ZI"	IR	1 x 3.5 t/h	16 t/d 54 t/d IWC	85
46 - LOT				
Figeac	I	1 x 0.9 t/h	15 t/d	81
St. Jean Lagineste	I	1 x 0.9 t/h	8 t/d	80
47 - LOT-ET-GARONNE				
Tonneins	I	1 x 1.5 t/h	12 t/d	79
Le Passage d'Agen "Montbusq"	IR	1 x 4 t/h	80 t/d	83
48 - LOZÈRE				
St. Chely d'Apcher "Rimeize"	I	1 x 1 t/h	9 t/d	82
49 - MAINE-ET-LOIRE				
Juigne sur Loire	I	1 x 1.2 t/h	16 t/d	78
Lasse	I	1 x 1.2 t/h	19 t/d	81
Saint Gemmes d'Andigne	I	1 x 1.8 t/h	25 t/d	74
Angers "La Roseraie"	IR	3 x 5 t/h	170 t/d	74
La Seguinere	IR	1 x 4 t/h	70 t/d 10 t/d IWC	83
53 - MAYENNE				
Aze "ZI"	IR	1 x 2 t/h	18 t/d	81
Pontmain "Rout de Fougères"	IR	1 x 4 t/h	50 t/d	84
54 - MEURTHE-ET-MOSELLE				
Haussonville	I	1 x 0.9 t/h	8 t/d	84
Nancy "BD Australie"	IR	2 x 6.2 t/h	230 t/d	74
55 - MEUSE				
Marville	I	1 x 0.9 t/h	12 t/d	84
Tronville en Barrois	IR	1 x 5 t/h	100 t/d	83

TABLE V -3B

DEPARTMENT and Location	Type of plant	Capacity	Utilisation	Year of start-up
57 - MOSELLE				
Forbach Marienau "Peterselk"	I	2 x 3 t/h	82 t/d	76
Nilvange	I	1 x 1 t/h	10 t/d	82
Metz-Chambiere	IR	2 x 6 t/h	220 t/d	70
58 - NIÈVRE				
Corbigny "Rennebourg"	I	1 x 0.9 t/h	8 t/d	78
Cosne "Le Tremblay"	I	1 x 2.4 t/h	22 t/d	75
La Charite sur Loire	I	1 x 1.5 t/h	12 t/d	76
Nevers "Quartier du Tonkin"	I	1 x 3 t/h	25 t/d	65
Nevers "Quartier Tonkin"	I	-	45 t/d	77
Preporche	I	1 x 1 t/h	12 t/d	82
Rouy "ZI"	I	1 x 1.5 t/h	12 t/d	82
Sichamps	I	1 x 1 t/h	8 t/d	82
59 - NORD				
Duchy les Mines	I	2 x 5 t/h	105 t/d	77
Dunkerque ZI "Petite Synth Usine I"	I	2 x 4.4 t/h	150 t/d	71
Dunkerque ZI "Petite Synth Usine II"	I	1 x 4.5 t/h	60 t/d	78
Halluin	I	2 x 5 t/h	240 t/d	67
Wasquehal	I	3 x 10 t/h	510 t/d	75
Sequedin	I	3 x 10 t/h	470 t/d	73
St. Hilaire	I	2 x 0.9 t/h	25 t/d	81
St. Saulve	I	3 x 5 t/h	230 t/d	78
Strazeele	I	3 x 1.8 t/h	80 t/d	73
Maubeuge	IR	2 x 5.5 t/h	150 t/d	81
60 - OISE				
Nogent sur Oise (Chemin Lateral SNCF)	I	2 x 4 t/h	70 t/d	70
61 - ORNE				
Caligny	I	1 x 2.5 t/h	50 t/d	73
St. Ouen S/Iton	I	1 x 2 t/h	25 t/d	73
62 - PAS-DE-CALAIS				
Henin-Beaumont "La Buisse"	I	3 x 3.5 t/h	240 t/d	73
Noyelles Sous Lens	I	2 x 6.7 t/h	320 t/d 70 t/d IWC	73
Saint-Omer	I	1 x 4.2 t/h	60 t/d	75
Sainte Austreberthe	I	1 x 1.5 t/h	12 t/d	74
Labeuvriere	IR	2 x 5 t/h	220 t/d	78
Tilloy Les Mofflaines "ZI"	IR	1 x 5 t/h	80 t/d	77
64 - PYRÉNÉES-ATLANTIQUES				
Arudy	I	1 x 1.5 t/h	10 t/d 20 t/d SEA	82
Larrau-"Iraty"	I	1 x 1.5 t/h	0 t/d 0.8 t/d SEA	75
Lescar	I	2 x 3 t/h	130 t/d 50 t/d IWC	75
St. Etienne de Baigorry	I	1 x 0.7 t/h	4 t/d 10 t/d SEA	85

TABLE V -3B

DEPARTMENT and Location	Type of plant	Capacity	Utilisation	Year of start-up
66 - PYRÉNÉES-ORIENTALES				
Argeles s/Mer	I	1 x 3 t/h	20 t/d 80 t/d SEA	75
Canet en Roussillon	I	1 x 2.5 t/h	23 t/d 140 t/d SEA	71
Mont-Louis	I	1 x 1.2 t/h	2 t/d 14 t/d SEA	71
Saillagouse	I	1 x 1 t/h	1 t/d 7 t/d SEA	68
Ur	I	1 x 1 t/h	4 t/d 10 t/d SEA	71
St. Feliu d'Avall	IR	1 x 1.5 t/h	15 t/d	81
67 - BAS-RHIN				
Strasbourg "Zone Indus"	IR	3 x 13 t/h	460 t/d 70 t/d IWC	74
	IR	1 x 11 t/h	130 t/d 30 t/d IWC	85
68 - HAUT-RHIN				
Didenheim Usackerstraeng	IR	2 x 4.5 t/h	170 t/d	73
69 - RHÔNE				
Bourg de Thizy	I	1 x 2.5 t/h	20 t/d	77
Lyon 7ème Arrondissement	IR	4 x 10 t/h	780 t/d	63
Caluire et Cuire	CA + I	1 x 40 t/d 1 x 7 t/h 1 x 1.8 t/h	50 t/d	66
Sainte Foy l'Argentiere	IR	2 x 1.5 t/h	28 t/d	85
St. Forgeux	IR	1 x 2 t/h	20 t/d	83
Villefranche	IR	1 x 4.5 t/h	70 t/d 25 t/d IWC	84
70 - HAUTE-SAÛNE				
Echenoz-la-Meline	I	2 x 1.5 t/h	22 t/d	68
Froideconche	I	1 x 1 t/h	6 t/d	84
Melisey	I	1 x 1 t/h	5 t/d	85
St. Germain	I	1 x 1 t/h	5 t/d	84
71 - SAÛNE-ET-LOIRE				
Vendennes	I	1 x 0.9 t/h	7 t/d	79
Vinzelles	I	1 x 0.8 t/h	2 t/d	81
72 - SARTHE				
La Chauviniere "Rue Angevinière"	I	2 x 10 t/h	229 t/d 50 t/d IWC	75
La Ferte-Bernard	I	1 x 1.5 t/h	10 t/d 15 t/d SEA	80

TABLE V -3B

DEPARTMENT and Location	Type of plant	Capacity	Utilisation	Year of start-up
73 - SAVOIE				
Bonneval sur Arc	I	1 x 1 t/h	1 t/d	77
Chambery (ZI Bissy)	I	2 x 5 t/h 2 x 6 t/h	160 t/d	77
Entremonts	I	1 x 6 t/d	1 t/d	79
Gilly s/Isere "Pont de Guly"	I	1 x 3 t/h	26 t/d	75
La Bathie "Ballieres"	I	1 x 12 t/d	5 t/d 6 t/d SEA	82 82
Lanslebourg	I	1 x 12 t/d	2 t/d	81
Le Chatelard	I	1 x 6 t/d	2 t/d	80
Pralognan	I	1 x 6 t/d	1 t/d	79
St. Francois	I	1 x 6 t/d	2 t/d	78
St. Jean de Couz	I	1 x 6 t/d	3 t/d	83
St. Martin de Belleville	I	1 x 1.5 t/h	2 t/d 25 t/d SEA	75
Tignes	I	2 x 1.5 t/h	4 t/d 50 t/d SEA	85
Valmorel	I	1 x 1 t/h	20 t/d SEA	82
74 - HAUTE-SAVOIE				
Bonneville	I	1 x 4 t/h	45 t/d	82
Faverges "Les Grandes Frasses"	I	1 x 1.2 t/h	11 t/d 18 t/d SEA	76
Rumilly "Chardieu"	I	1 x 2.5 t/h	25 t/d	76
Thonon "ZI"	I	1 x 2 t/h	12 t/d 20 t/d SEA	72
Thonon "ZI"	I	1 x 4 t/h	24 t/d 40 t/d SEA	76
76 - SEINE-MARITIME				
Le Havre	I	2 x 8 t/h	180 t/d	70
	IR	1 x 8 t/h	80 t/d	76
Le Treport	I	1 x 3 t/h	35 t/d	72
Lillebonne	I	2 x 1.8 t/h	35 t/d	74
	IR	1 x 8 t/h	35 t/d	84
Senneville-sur Fecamp	I	1 x 3 t/h	40 t/d	75
Villers-Ecalles	I	1 x 4 t/h	40 t/d	74
Dieppe "ZI"	IR	2 x 3 t/h	53 t/d	71
Rouen (Rive Droite)	IR	2 x 10 t/h	320 t/d	70
77 - SEINE-ET-MARNE				
Montereau	I	1 x 4.2 t/h	40 t/d	73
St. Thibault Les Vignes	IR	1 x 8 t/h	200 t/d	85
Meaux	CL + I	1 x 120 t/d 1 x 10 t/h 1 x 3 t/h	55 t/d	71
Coulommiers	CA + I	1 x 55 t/d 1 x 7 t/h 2 x 3 t/h	48 t/d	80
Samoreau	CA + I	1 x 60 t/d 1 x 20 t/h 1 x 3 t/h	80 t/d	68
78 - YVELINES				
Luchaire	I	1 x 3 t/h	20 t/d	36
"	IR	1 x 10 t/h	120 t/d	77
"	I	1 x 5 t/h	60 t/d	62
"	I	1 x 5 t/h	60 t/d	62
Thiverval "Pont Cailloux"	I	2 x 10 t/h	240 t/d	74

TABLE V -3B

DEPARTMENT and Location	Type of plant	Capacity	Utilisation	Year of start-up
79 - DEUX-SÈVRES Niort-Souche "Route de Chaban"	I	2 x 3 t/h	59 t/d	72
80 - SOMME Epeville "Chemin des Hetres"	I	1 x 2 t/h	11 t/d	72
81 - TARN Aussilon "ZI"	I	2 x 1 t/h	7 t/d 5 t/d	75
Lautrec "Le Trillou"	I	1 x 0.9 t/h	5 t/d	84
St Juery "La Besse"	I	1 x 1.5 t/h	14 t/d	76
82 - TARN-ET-GARONNE Auvillar	I	2 x 1 t/h	28 t/d	83
Molieres	I	1 x 0.7 t/h	15 t/d	80
Negrepelisse	I	2 x 0.7 t/h	9 t/d	82
83 - VAR Cavalaire/mer "Haut du Dattier"	I	2 x 2 t/h	8 t/d 41 t/d	78
Toulon "La Goubran"	IR	2 x 12 t/h	300 t/d	84
Sillans la Cascade	IR	1 x 2.5 t/h	15 t/d 40 t/d	79
84 - VAUCLUSE Carpentras	I	2 x 1.9 t/h	50 t/d	73
Gargas	I	1 x 0.5 t/h	2 t/d	83
Orange "Bonne Barbe"	I	1 x 2.8 t/h	40 t/d 65 t/dSEA	77
Vaison	I	2 x 1 t/h	13 t/d	85
Apt	IR	1 x 2.5 t/h	40 t/d	84
86 - VIENNE Poitiers	IR	2 x 4 t/h	125 t/d	84
87 - HAUTE-VIENNE Sigoure	I	1 x 1.5 t/h	6 t/d	80
Bessines	I	1 x 0.9 t/h	8 t/d	75
88 - VOSGES Contrexeville	I	1 x 0.9 t/h	15 t/d	81
Cornimont "Le Veternat"	I	1 x 7 t/h	7 t/d	83
Lepanges	I	1 x 0.6 t/h	8 t/d	73
Lerrain	I	1 x 1 t/h	15 t/d	79
Moriville	I	1 x 2.5 t/h	30 t/d	74
Vienville "Ton Oeil"	I	1 x 7 t/h	7 t/d	85
Rambervilliers	IR	2 x 4 t/h	100 t/d 30 t/dIWC	83
89 - YONNE Coutarnoux	I	1 x 0.9 t/h	5 t/d	77
Montillot	I	1 x 0.9 t/h	5 t/d	85
90 - TERRITOIRE DE BELFORT Fêche l'Eglise	I	2 x 1 t/h	26 t/d	70
Belfort	IR	2 x 4 t/h	90 t/d	74
91 - ESSONNE Villejust	IR	1 x 8 t/h	137 t/d	84
"	IR	1 x 6 t/h	28 t/d	71

DEPARTMENT and Location	Type of plant	Capacity	Utilisation	Year of start-up
92 - HAUTS-DE-SEINE Issy les Moulineaux	IR	4 x 17 t/h	1400 t/d 400 t/dIWC	65
93 - SEINE-SAINT-DENIS Saint Quen	IR	4 x 6 t/h	1150 t/d 40 t/dIWC	54
94 - VAL-DE-MARNE Ivry/Seine	IR	2 x 50 t/h	1650 t/d 500 t/dIWC	69
Rungis (Marche Interet Nation)	IR	2 x 8.5 t/h	100 t/d 280 t/dIWC	85
95 - VAL-D'OISE Argenteuil "RN 12"	IR	2 x 7.5 t/h	230 t/d	75
Sarcelles	IR	2 x 10 t/h	280 t/d	78

Table V - 4 Waste Incineration Plants: FR GERMANY

Source: 'Der Städtetag', June 1986

Standort	Feuerungssystem	Theoret. Kapazität Mg/h	Jahresdurchsatz 1000 Mg	Abfallarten	Sperrmullzerkleinerung	Wärmenutzung	Abgasreinigung
1 Bamberg	Gegenschub-Umwälzrost u. Schlamm-einblasung	2×6	86	HM, GM, SM, KS	ja	KSK, KST	EF GW
2 Berlin	Walzenrost	3×12,5 4×16	400	HM, GM, SM	ja	Abgabe an KW	EF
3 Bielefeld	Gegenlauf-überschubrost	3×18	420	HM, GM, SM, KS	ja	HW	EF + GW
4 Bonn-Bad Godesberg	Stufenrost Drehtrommel	2×5,5	29	HM, GM, IA, KH	nein	teilweise	Zyklon + EF
5 Bremen	Walzenrost	3×15 1×20	240	HM, SM, GM, IA	ja	HW	EF
6 Bremerhaven	Vorschubrost	3×10	150	HM, GM, SM	ja	HKW	EF GW
7 Darmstadt	Vorschubrost	2×8,5 1×11	136	HM, SM, GM	nein	HW	EF
8 Düsseldorf	Walzenrost	4×10 1×12,5 1×12,5	360	HM, SM, GM, IA, KH	ja	HW	TS + EF
9 Essen-Karnap	Wanderrost	5×20	355	HM, SM, GM, KS	ja	KW	EF
10 Geiselbullach (Kreis Füstefeldbruck)	Gegenschub-Umwälzrost u. Schlamm-einblasung	1×2 1×6	42	HM, SM, GM, KS, KR	ja	KST	EF
11 Göppingen	Walzenrost	2×12	104	HM, SM, GM	ja	HKW	EF
12 Frankfurt/Main	Vorschubrost	4×15	330	HM, GM	nein	HKW	EF
13 Hagen	Walzenrost	3×6	112	HM, SM, GM, AÖ	ja	BG, HW, Freibad	EF
14 Hamburg I (Billbrook)	Vorschubrost Rückschubrost	3×7,5 1×12	182	HM, SM, GM	ja	ES, HKW	EF
15 Hamburg II (Stellinger Moor)	Rückschubrost	2×19	264	HM, SM, GM	ja	ES, Abgabe an KW	TS + EF
16 Hamburg III (Stapelfeld)	Vorschubrost	2×19	260	HM, SM, GM, IA	nein	HKW	EF GW
17 Hameln	Walzenrost	1×10	70	HM, SM, GM	ja	Abgabe an KW	EF
18 Heidelberg	Vorschubrost	1×5	23	IA, GM, SM, KR	ja	KT	EF
19 Ingolstadt	Vorschubrost und Schlamm-einblasung	2×7	95	HM, SM, GM, IA, KS	ja	teilweise KST	EF GW
20 Iserlohn	Vorschubrost Wanderrost Walzenrost	1×8 1×8 1×16	157	HM, SM, IA, GM, AÖ	ja	KHW, ES	EF GW
21 Kassel	Walzenrost	2×10	115	HM, SM, GM, IA, KH	ja	Abgabe an KW	EF
22 Kempten/Allgäu	Vorschubrost	1×4 1×5	65	HM, SM, IA, GM	ja	zur Zeit Dampfkondensation	EF
23 Kiel-Süd	Walzenrost	2×5 1×10	96	HM, GM	ja	HW	EF GW
24 Krefeld	Walzenrost und Schlamm-einblasung	2×12	162 ohne KS	HM, KS, AÖ, SM, GM	ja	KST, HKW	EF GW
25 Landshut	Vorschubrost	2×3	31	HM, GM, SM, IA	ja	KW, ES	EF

Table V - 4 Waste Incineration Plants: FR GERMANY (Contd.)

Standort	Feuerungssystem	Theoret. Kapazität Mg/h	Jahresdurchsatz 1000 Mg	Abfallarten	Sperrmüllzerkleinerung	Wärmenutzung	Abgasreinigung
26 Leverkusen	Vorschubrost	2×10	130	HM, SM, GM, KH, AÖ	ja	HKW	EF
27 Ludwigshafen	Vorschubrost	2×10	90	HM, SM, GM	ja	HKW	EF
28 Mannheim	Wanderrost	2×12 1×20	172	HM, GM, SM, IA, AÖ	ja	HKW	EF
29 Markt- oberdorf	Stufen- schwenkrost und Etagenofen für KS	1×2	10 ohne KS	HM, KS, SM, GM	nein	KST	GW
30 München- Nord	Rückschubrost	2×25 1×40	223	HM, GM, SM (und Kohlenstaub)	ja	HKW	EF
31 München- Süd	Rückschubrost	1×40 1×40	265	HM, GM, IA	nein	Speise- wasservor- wärmung für KW	EF
32 Neufahrn/ Freising	Gegenschub- Umwälzrost Rückschubrost	1×3 1×3	33	HM, SM, GM	nein	HW	EF
33 Neunkirchen	Rückschubrost	1×5 1×10	100	HM, GM, AÖ, SM	ja	HW HKW	EF
34 Neustadt/ Holstein	Kipp- stufenrost	1×4,5	19	HM, GM	nein	ohne	Multi- zyklon
35 Nürnberg	Vorschubrost Rückschubrost	3×12,5 1×20	200	HM, GM, IA, SM, KH	ja	Abgabe an HKW	EF
36 Oberhausen	Walzenrost	3×22	320	HM, SM, GM	ja	Abgabe an KW	EF
37 Offenbach	Walzenrost	3×10	180	HM, GM, SM	ja	HKW	EF
38 Pinneberg	Vorschubrost	2×5	50	SM, GM, IA, KR	ja	-	TS + EF
39 Rosenheim	Walzenrost	1×4,5 1×6	40	HM, GM	nein	Abgabe an HKW	EF
40 Schwandorf	Horizontaler Gegenlauf- Überschubrost	3×18,7	355	HM, GM, SM, IA	nein	HKW, ES Industrie	TS
41 Solingen	Vorschubrost	2×10	100	HM, GM, SM, AÖ	ja	HKW	EF
42 Stuttgart	Rückschubrost Walzenrost Walzenrost	1×16 1×16 1×20	245	HM, SM, GM, IA	ja	HKW	EF
43 Wuppertal	Walzenrost	4×15	250	HM, GM, SM	ja	Abgabe an KW	EF GW
44 Zirndorf	Vorschubrost	1×4 1×4	52	HM	nein	HW	EF GW

Key **Type of waste :**
 HM - household refuse
 SM - bulk refuse
 IA - household type industrial waste
 GW - household type trade waste
 AÜ - waste oil
 KS - clarifier sludge
 KR - landwaste compost
 SK - specific hospital waste
 KH - household type hospital waste

Gas cleaning :
 EF - electrofilter
 GW - gas washing
 TS - dry extraction

Heat Utilisation :
 KW - power
 HKW - central heating and power
 HW - central heating
 ES - internal services
 KST - clarifier sludge drying
 KSK - clarifier sludge conditioning

Table V - 5 Waste Incineration Plants: ITALY (1980)

Source: Report on survey by Italian Ministry of Health, copy supplied by Italian Section of ISWA (See Section 5.3.5)
 Exit gas cleaning: E = electrofilter C = cyclone W = gas washing ni = not indicated

Location	Year of start-up	Capacity tonnes/day	Utilisation tonnes/day	Energy recovery	Exit gas cleaning	Exit gas Flow '000 Nm ³ /hr	Max. concentration, mg/Nm ³	Dust Emission Max. emitted kg/day
PIEMONTE								
Borghesio (VC)	1974	36	12	-	W	7	900	154
Domossola (NO)	1974	36	36	-	C	13	269	84
Verbania (NO)	1977	120	90	-	C+W	25	150	90
Vercelli	1977	150	65	Hot water	E	56	150	202
LOMBARDIA								
Abbiategrasso (MI)	1970	60	52	-	n.i.	10	1000	240
Albino (BG)	1976	60	43	-	E	8.8	48	10
Bergamo	1965	150	120	-	C+W	40	643	617
Busto Arsizio (VA)	1974	200	200	-	C+W	58	387	696
Calolziocorte	1967	26	12	-	W	-	-	-
Como	1967	100	97	Steam	C	27	788	510
Desio (MI)	1976	240	165	Steam	E	80	-	-
Gorle (MI)	1976	40	(28)	-	E	4	-	-
Livigno (SO)	1975	24	3	-	C	-	250	-
Merate (CO)	1971	24	22	-	W	-	-	-
Milano 1	1968	400/600	380	Electricity	E	96	100	346
Milano 2	1975	400/600	470	Electricity	E	131	50	150
Olgiate Comasco (CO)	1973	36	25	-	W	7	-	-
Pavia	1973	130	43	-	C	65	1480	2300
Prata Comportaccio (SO)	1974	25	16	-	W	1.3	100	3
Rho (MI)	1973	96	33	-	C	14	1000	336
Rovetta (BG)	1974	60	20	-	n.i.	8.8	342	82
Sesto S. Giovanni (MI)	1968	100	95	Steam	C	100	300	936
Sumirago (VA)	1968	72	50	-	C	16	150	58
Valmadrera (CO)	1980	240	160	Steam	E	76	50	91
Varese	1974	140	120	-	C+W	35	300	252
LIGURIA								
Genova	1971	600	430	Electricity	E	120	101	290
La Spezia	1971	300	(225)	-	E	60	71	102
Savona	1969	60	55	-	C	-	-	-

Table V - 5 Waste Incineration Plants: ITALY (1980) Cont'd

Location	Year of start-up	Capacity tonnes/day	Utilisation tonnes/day	Energy recovery	Exit gas cleaning	Exit gas Flow '000 Nm ³ /hr	Max. concentration, mg/Nm ³	Dust Emission Max. emitted kg/day
VENETO								
Dolo (VE)	1976	30	15	-	W	-	-	-
Eraclea (VE)	1975	30	12	-	W	-	-	-
Padova 2	1972	150	100	-	W	20	-	-
Mirano (VE)	1975	84	55	-	C+W	-	269	-
Oderzo (TV)	1972	24	12	-	W	-	-	-
Valdagno (VI)	1974	72	34	-	C	33	-	-
Venezia	1969	160	140	Steam	C+W	23	434	240
Vicenza	1971	55	(38)	-	W	-	-	-
FRIULI-VENEZIA GIULIA								
Genova (UD)	1976	10	10	-	n.i.	-	-	-
Gorizia	1971	60	45	-	W	12	500	144
Monfalcone (GD)	1972	72	46	-	W	-	-	-
Trieste	1972	400	260	-	E	64	100	154
Udine	1974	72	25	-	W	-	500	-
Villa Santina (UD)	1973	40	(28)	-	n.i.	-	-	-
EMILIA ROMAGNA								
Bologna	1973	600	438	-	E	126	138	410
Coriano (FO)	1976	300	190	-	E	98	-	-
Ferrara	1975	100	120	-	C+W	70	364	611
Forli	1976	200	89	-	E	126	150	410
Lugo (RA)	1971	65	55	-	W	-	-	-
Modena (in construction)	-	240	200	-	E	99	150	356
Parma	1975	300	216	-	E	-	98	-
Reggio Emilia	1968	200	175	-	C	70	483	811
Salsomaggiore (PR)	1975	72	33	-	W	16	377	143
TOSCANA								
Arezzo	1976	100	85	-	C+W	-	315	-
Altopascio (LU)	1975	36	32	-	W	-	-	-
Castelnuovo di Garfagnana (LU)	1977	36	12	-	W	7	700	118
Casentino:Comunità Montana del (AR)	1978	48	(33)	-	W	-	-	-
Follonica (GR) Valpiana	1975	86	30	-	W	-	-	-
Firenze	1973	450	395	-	E	110	150	396

Table V - 5 Waste Incineration Plants: ITALY (1980) Cont'd

Location	Year of start-up	Capacity tonnes/day	Utilisation tonnes/day	Energy recovery	Exit gas cleaning	Exit gas flow '000 Nm ³ /hr	Max. concentration. mg/Nm ³	Dust Emission Max. emitted kg/day
TOSCANA Cont'd								
Livorno	1973	200	150	-	C	60	-	-
Massa	1972	130	80	-	W	25	500	300
Montale (PT)	1978	120	40	-	W	25	600	360
Pisa (in construction)	-	240	(180)	-	E	185	150	660
Poggibonsi (SI)	1980	72	40	-	W	-	-	-
Pietrasanta (LU)	1974	120	60	-	W	25	162	97
Pistoia	1974	120	80	-	C	-	-	-
Pontedera (FI)	1966	72	45	-	W	-	-	-
Pontassieve (FI) Rufina	1976	35	28	-	C	-	-	-
S.Casciano Val di Pesa (FI)	1964	120	100	-	W	25	470	285
UMBRIA								
Perugia	69/75	140	85	-	W	50	-	-
Terni (in construction)	-	150	80	-	C	46	-	-
MARCHE								
Pergola (PS)	1979	29	(20)	-	W	-	-	-
LAZIO								
Frosinone	1976	120	(79)	-	W	-	-	-
Genzano (RM)	1977	23	15	-	W	-	-	-
Manziana (RM)	1977	10	6	-	n.i.	4	100	10
Roma (Roccacencia)	1967	600	(450)	-	W	210	-	-
Roma (Pontemalnome)	1964	620	(465)	-	W	210	-	-
Viterbo	1975	60	40	-	W	12	500	144
ABRUZZO								
Avezzano (AQ)	1977	30	(21)	-	C	-	-	-
Teramo	1979	72	(48)	-	E	-	150	-
CAMPANIA								
Cava dei Tirreni (SA)	1975	80	50	-	C	-	5600	-
Salerno	1977	120	80	-	W	-	-	-

Table V - 5 Waste Incineration Plants: ITALY (1980)

Location	Year of start-up	Capacity tonnes/day	Utilisation tonnes/day	Energy recovery	Exit gas cleaning	Exit gas flow '000 Nm ³ /hr	Max. concentration. mg/Nm ³	Dust Emission Max. emitted kg/day
FUGLIA								
Bari	1979	65	55	-	E	45	150	162
Brindisi	1973	36	29	-	W	-	-	-
Castellaneta	-	20	(14)	-	n.i.	-	-	-
Foggia	1972	72	60	-	C	27	500	324
Lecce	65/79	100	85	-	W	-	600	-
BASILICATA								
Potenza (in construction)	-	60	40	-	W	12	500	144
CALABRIA								
Reggio Calabria	1973	150	120	-	C+W	-	-	-
SARDEGNA								
Cagliari	68/74	200	176	-	W	80	-	-
Nuoro	1973	80	30	-	W	-	-	-
Sassari	1977	90	(59)	-	W	-	-	-
Selargius (CA)	1979	24	12	-	C	-	-	-
SICILIA								
Cefalù	1973	20	20	-	W	-	-	-
Messina 1	1976	216	150	-	E	30	500	360
Messina 2	1979	150	100	-	W	16	500	180
Siracusa	1975	60	55	-	n.i.	8.4	960	194

Table V - 7

Waste Incineration Plants : THE NETHERLANDS

Province and Location	Year of construction	Number of ovens/ capacity (t/h)	Typical annual input '000t	Exit gas cleaning	Waste heat recovery
Friesland					
Leeuwarden	1973	2 x 6	60	ESP	No
Gelderland					
Arnhem	1975	3 x 12	160	ESP	No
Nijmegen	(start-up in 1987)	1 x 9		GW + F	Yes
North Holland					
Alkmaar	1971/78	3 x 6	120	ESP	No
Amsterdam	1968	4 x 16	370	ESP	Yes
Zaanstad	1976	2 x 9	120	ESP	No
South Holland					
Den Haag	1967/74	4 x 12.5	280	C + ESP	Yes
Dordrecht	1972	3 x 7	130	GW	No
Leiden	1966/76	3 x 4	80	ESP	No
Rotterdam : 'AVR'	1972	6 x 20	750	ESP	Yes
Rotterdam : 'Roteb'	1963	4 x 13	270	ESP	Yes
North Brabant					
Roosendaal	1976	2 x 4	35	ESP	No

Sources: Plants in operation:
Provincial authorities
(Data relates to 1984)

Nijmegen plant:
K + K Ofenbau AG
(Switzerland)

C = chalk injection into ovens
ESP = electrostatic precipitators
F = cloth filter
GW = gas washing

Table V - 8 Waste Incineration Plants: SPAIN (1986)

Source: Asociacion de Empresas de Limpieza Publica (ASELIP)

Region	Andalucia		Baleares	Cataluna		Galicia	Pais Vasco	Melilla
	Ubrique (Cadiz)	Jaén	Palma Mallorca	Montcada (Barcelona)	Sant Adriá del Besos (Barna)	Vigo (Pontevedra)	Mondragón (Guipuzcoa)	
Location								
Plant capacity - No. of furnaces	2	1	1	2	3	2	2	2
- Unit capacity (t/h)	1.5	1.5	8	3	15	5	3	2.5
Treatment rate (t/h)	1.5	1	8	6	45	8	4.5	2.5
Operation (h/d) hours - days/week	24 h - 4 d	16 h - 6 d	24 h - 7 d	24 h - 7 d	24 h - 7 d	24 h - 7 d	24 h - 6 d	24 h - 6 d
Gas cleaning	Water wash	Post combustion settling chamber	Electrostatic	Electrostatic	Electrostatic	Multi-cyclones	Multi-cyclones	Pyrolytic
Dust emission level (mg/tm ³)	-	-	100	80	200	-	560	-
Max. authorised level of particulate emission (mg/Nm ³)	150	150	150	150	150	150	150	150
Energy recovery - Electricity (Mw/h)	-	-	-	0.5	12	-	-	-
- Steam (t/h)	-	-	-	6	-	-	-	-

Note: All plants treat general household waste except that at Jaén which treats waste treatment plant compost.

Table V - 9A

UNITED KINGDOM : Example of computer file record of waste disposal facility licence data
(See Section 5.3.9)

	TEXT REFERENCE & KEY Used to identify additional text which is printed at the bottom of each profile	WASTE AUTHORIZATION CODE eg: A AUTHORIZED P PROHIBITED PA PRIOR APPROVAL	WASTE TYPE DESCRIPTION	CONCENTRATION & FORM OF WASTE (where specified in licence) eg: S DRY E SLUDGE R SLURRIED K DRUMMED H LIQUID	LICENSED INPUT RATE (where specified in licence) A M: AVERAGE MAXIMUM QTY: QUANTITY UM: UNIT OF MEASUREMENT eg: T tonnes KGAL thousand gallons TM: TIME PERIOD eg: D DAY M MONTH	ACTUAL INPUT RATE (where information is not confidential) QTY: QUANTITY UM UNITS eg. KTA thousand tonnes annum
	COPYRIGHT 1985 ASPINWALL DATA, INFORMATION & TRAINING LTD		TELEPHONE (0743) 241391	PAGE : 1		
	SEQUENCE :		CLIENT NAME :	PUBLISHED 07.03.85		
SITE LOCATION & DETAILS OF LICENSED OPERATOR	TEXT REF. & KEY	SITE ADDRESS	MANAGER/OPERATOR/OP. ADDRESS	NAT GRID REF		
	03BL 0001	SPINFORD FARM WOODLEY	MR. A.N. SMITH	AB 123 456		
	03BL 0002	STAFFS	WOODLEY GRAVEL CO.			
	03BL 0003		25 MILL ROAD EAST			
	03BL 0004		WOODLEY STAFFS			
WASTE PROFILE	03BL 0006	A/P WASTE	WASTE CODE	A/M QTY UM TM	ACTUAL INP QTY UM	
	03BL 0007	A * HOUSEHOLD	* * A020	* * * * *	* * *	
	03BL 0008	A * CIVIC AMENITY	* * A040	* M * 100 * T * D * A040	* * *	
	03BL 0009	A * COMM. INC. NON HAZ	* S * A032	* M * 250 * T * D * A032	* 20 * KTA	
	03BL 0010 T	A * ASBESTOS	* E * C010	* M * 10 * T * W * *	* * *	
	03BL 0011 T	A * BENZONITE	* R * B012	* M * 5 * KGAL * M * *	* * *	
	03BL 0012 T	A * MIXED INORGANIC COMPOUNDS	* * C020	* * S02 * * * *	* * *	
	03BL 0013 T	A * ALKALI METAL OXIDES	* K * C011	* M * 0.1 * T * D * *	* * *	
	03BL 0014 T	PA * CONTAMINATED SAND	* * C030	* * * * *	* * *	
	03BL 0015	PA * TOXIC METAL COMPOUNDS	* * C031	* * * * *	* * *	
	03BL 0016	PA * HALOGENATED COMPOUNDS	* * C040	* * * * *	* * *	
	03BL 0017	PA * PERSISTENT ORGANICS	* * C070	* * * * *	* * *	
	03BL 0018	PA * CONTROLLED WASTE N.O.S	* * C011	* * * * *	* * *	
	SITE CATEGORY & LICENCE INFORMATION	03BL 9998	SITE CAT : LANDFILL		REVISION DATE : 10/81	
		03BL 9999	LICEN AUTHY : STAFFORDSHIRE		LICENCE NO. : 54/12/4/99	
ADDITIONAL TEXT LINKED TO TEXT KEY	TEXT REF.					
	03BL 0010	BAGGED ONLY				
	03BL 0010 to 0013	SHALL NOT AMOUNT TO MORE THAN 10% OF THE TOTAL INPUT PER DAY				
	03BL 0013	EX LYTHWOOD ELECTROPLATING LTD ONLY				
03BL 0014	EX ROAD SPILLAGES, TIGHTLY OILED ONLY					
		SITE CATEGORY	LICENSING AUTHORITY	DATE LICENCE ISSUED OR LAST DATE OF REVISION	AUTHORITY LICENCE NUMBER	

Source: Aspinwall Data, Information & Training Ltd

Table V - 9b Waste Incineration Plants: UNITED KINGDOM

Plants licensed by local authorities for treatment of household wastes. (Some are also licensed for general commercial and industrial wastes).

Source: 1) Aspinwall Data Information and Training (1986)
 (Search of waste disposal plant databank commissioned by Metra Consulting)
 2) T.J.K. Rolfe, 'Warmer Bulletin', June 1986. (For year contracted, furnace capacity, energy recovery)

County licensing authority and location	Year Contracted	Furnace capacity t/h	Permitted throughput (tonnes/day except where stated)	Energy recovery
ENGLAND			n.s. = not specified in licence	-
AVON Avonmouth	1968	2 x 15.2	n.s.	
CLEVELAND Newport Bridge			1000	-
DERBYSHIRE Derby	1967	2 x 7.6	460	-
DEVON Exeter	1968	1 x 8.3	45 kt/year	-
ESSEX Chigwell			n.s.	-
HAMPSHIRE Basingstoke	1968	1 x 9.1	n.s.	-
Otterbourne			n.s.	-
Portsmouth			n.s.	-
HEREFORD AND WORCESTER Hanley Swan			70	-
KENT Folkestone	1971	2 x 10.2	n.s.	
LEICESTERSHIRE Whetstone			n.s.	-
Sileby			n.s.	-
GREATER LONDON Dagenham			100	
Edmonton	1967	5 x 14.2	2000	Electricity generation
Morden, Surrey			100	
Royal Albert Dock			2 t/h	

Table V - 9b Waste Incineration Plants: UNITED KINGDOM(Contd.)

County licensing authority and location	Year contracted	Furnace capacity t/h	Permitted throughput (tonnes/day except where stated)	Energy Recovery
ENGLAND				
MERSEYSIDE				
Bidstone			n.s.	
Prescot			10	
Knowsley			400	
GREATER MANCHESTER				
Altrincham	1971	2 x 4.6	n.s.	
Rochdale	1972	1 x 1.8	n.s.	
Salford	1971	2 x 6.6	n.s.	
Middleton	1966	1 x 1.8	n.s.	
Bolton	1969	1 x 16.2	n.s.	
Stretford			n.s.	
Oldham			n.s.	
Bury			50	
NOTTINGHAMSHIRE				
Mansfield	1969	1 x 5.5	5.5 t/h	District heating
Cossall			10	
STAFFORDSHIRE				
Burntwood			100	
Stoke-on-Trent	1973	2 x 10.2	500	-
TYNE AND WEAR				
Sunderland	1969	2 x 10.2	500	-
Gateshead	1969	2 x 10.2	500	-
South Shields	1969	2 x 10.2	500	-
North Shields			500	
WEST MIDLANDS				
Perry Barr, Birmingham	1967	2 x 12.2	n.s.	-
Stirchley, Birmingham			n.s.	-
Tyseley	1974	2 x 15	n.s.	-
Wolverhampton	1970	2 x 10.2	n.s.	-
Coventry	1970	3 x 12.2	n.s.	Hot water to factory
Dudley	1966	2 x 6.3	n.s.	-
Sutton Coldfield	1967	1 x 10.2		-
WILTSHIRE				
Swindon	1971	1 x 12.2	n.s.	-
Westbury			n.s.	
NORTH YORKSHIRE				
York	1967	1 x 8.3	n.s.	-
SOUTH YORKSHIRE				
Sheffield	1973	2 x 10.2	480	District heating

TABLE V - 9b Waste Incineration Plants: UNITED KINGDOM (contd.)

County licensing authority and location	Year contracted	Furnace capacity t/h	Permitted throughput (tonnes/day except where stated)	Energy Recovery
WEST YORKSHIRE Huddersfield Meltham Otley, Leeds Pudsey Wakefield	1972 1971	2 x 6 1 x 4.1	n.s. n.s. n.s. n.s. n.s.	- - - -
WALES				
RHONDDA D.C. Porth, Rhondda	1971	1 x 9.1	30 kt/year	-
SCOTLAND				
INVERCLYDE D.C. Port Glasgow			n.s.	
GLASGOW D.C. Dawholm, Glasgow Polmadie Rd, Glasgow	1968	2 x 12.2	n.s. n.s.	
DUNDEE D.C. Baldovie Dundee Harefield Rd, Dundee	1975	2 x 7	14/h n.s.	- -
NORTHERN IRELAND Belfast	1973	1 x 4.1		
CHANNEL ISLANDS Jersey	1977	2 x 5		Electricity generation

5.4 Particulate and Heavy Metal Emissions from Waste Incineration

5.4.1 Household waste incineration emissions

It is perhaps self-evident that the levels of atmospheric emissions of dust and heavy metals will depend upon:

- the nature and composition of the raw waste, including the physico-chemical properties of the metallic constituents,
- the treatment of the waste prior to incineration, e.g. sorting to remove non-combustible and reclaimable materials such as glass and metallic items, shredding, compaction etc.,
- type of furnace and the operating conditions including residence time, temperature, amount of excess air, addition of supplementary fuel,
- throughput, i.e. the utilisation of design capacity,
- the type and efficiency of the furnace exit gas cleaning train, which may include gravity settling, cyclonic separation, water scrubbing, electrostatic precipitation and fabric filtration.

The metallic elements present in the furnace feed, since they cannot be destroyed, must all eventually report in furnace residues, gas washing liquors and sludges, cyclone and precipitator dusts, and the stack gas stream. Metals with relatively low boiling points such as mercury and cadmium present special collection problems because they may pass through the system as vapour, which may condense or interact with the combustion gases to form very fine particles.

Comprehensive determinations of particulate and heavy metal concentrations in stack gases are technically exacting procedures and are generally performed as special investigations by experts rather than as a matter of routine. Because of concern about emissions of heavy metals (and of certain organic substances) from waste incineration, a number of studies have been undertaken in recent years to ascertain prevailing release levels, and to investigate the efficiency of different gas cleaning systems, the influence of waste composition and various plant design and operating factors. Because of the variety of factors which influence emission levels, including the composition of the raw waste which may vary from hour to hour, and because each plant provides a unique combination of these factors, it is not surprising that the measurement data quoted in the literature varies over very wide ranges and that it is not easy to draw comparisons in respect of a single variable.

Schulte-Schrepping [5.1] quotes ranges for the composition of household refuse arising in various industrialised countries, and of the cadmium contents mentioned in the literature for the different components: Table V - 10. The highest figures for cadmium are found in the non-ferrous metal components, and also in plastics which may contain cadmium pigments and stabilisers. In the same paper the author reviews the results of dust emission measurements cited in the literature for waste incineration, and concludes that with present technology it is possible to reduce dust concentrations in the outlet gas to less than 100 mg/m^3 but that a representative figure using wet scrubbing is 700 mg/m^3 . The latter figure may be somewhat pessimistic but there is no doubt that electrostatic precipitation is capable of much higher collection efficiencies than wet scrubbing and cyclonic separators alone, because it is more effective in capturing the lower size fractions of the particles.

Table V - 10**Sorting analysis and cadmium contents of household refuse**

Material	Range of content in refuse weight %	Cadmium content of material mg/kg
Fine material	4.3 - 22	0.3 - 1.1
Paper & cardboard	13 - 38	0.03 - 0.4
Food residues	15 - 50	0.5 - 0.7
Textiles	2 - 8	0.14 - 0.53
Rubber, leather, wood	1 - 6	9.5 - 17.2
Ferrous metals	4.5 - 8.5	0.08 - 2.8
Non-ferrous metals	0.4 - 1.5	0.05 - 500
Glass	2 - 13	0.3 - 3
Plastics	1.5 - 13	64 - 151
Remainder	3 - 11	4 - 16

Source: Schulte - Schrepping, [5.1]

Most household waste incineration plants constructed in the EC in recent years employ electrostatic precipitation (ESP) for the final gas cleaning stage although some have fabric filters (bag filters) instead of, or in addition to ESP. Bag filters are also very efficient collectors of fine particles, although they entail a higher pressure differential than ESP and therefore consume more energy. Some plants originally only equipped with cyclones or gas washers have subsequently been equipped with ESP or bag filters.

A limit for dust emission from waste incineration of 100 mg/Nm³ is now being widely applied in the EC and elsewhere, and limits as low as 50 mg/Nm³ are being discussed and applied in some cases. But although ESP technology is capable of dust collection efficiencies above 99%, this potential may not be attainable in many existing installations, especially those built before 1980. For example, Clayton [5/2] reports on investigations by the Warren Spring Laboratory on eight municipal incinerators in the UK in which ESP dust collection efficiency measurements on five of the plants ranged from 95% down to 87%.

The Warren Spring Laboratory studies included measurements of emissions to atmosphere of sulphur dioxide, hydrogen chloride, heavy metals, benzene, toluene and a number of polynuclear aromatic compounds. Lead emission factors based on incinerator throughput ranged from 3 to 95mg/kg refuse burned, and cadmium emissions from 0.3 to 4.4 mg/kg refuse. The majority of the input cadmium and lead reported in the furnace ash and ESP fly ash, and up to 5% of the lead and up to 29% of the cadmium were emitted to atmosphere. The results for cadmium were reported in more detail in a paper by Arthurs and Wallin [5/3], and the distribution in the feedstock and incinerator outputs in tests on 5 plants is shown in Table V-11 below.

Table V - 11 Cadmium distribution in municipal incinerator feedstock and outputs

Incinerator	Cd in feed mg/kg	% distribution of feedstock Cd			
		Furnace ash (%)	ESP ash (%)	Emission to atmsp. (%)	Cd/kg feed
A	15.7	49.0	44.7	6.3	1.0
B	13.5	56.4	41.0	2.6	0.4
C	15.0	6.7	64.1	29.2	4.4
D	40.6	46.1	50.9	3.0	1.2
E	18	76.0	20.0	4.0	0.7

Source: Arthurs and Wallin [5/3]

- Notes:**
1. No cadmium detected in quench and cooling water
 2. Cadmium in feedstock calculated from incinerator outputs.

Knorn [5/4] reported studies of cadmium emissions from five Bavarian domestic refuse incineration plants, all equipped with ESP. Emission factors ranged from 0.002 to 0.610 g Cd/tonne refuse with a mean of 0.231. Analysis of the heavy metal contents of different particle size fractions in the purified gas showed increasing cadmium concentration with decreasing grain size, and similar trends were found for lead and zinc. Knorn's proposed explanation is that cadmium and cadmium compounds such as the oxide and chloride leave the furnace as vapours which, on cooling, tend to condense preferentially on fine particles of other non-volatile substances already present in the gas stream.

Among the most recent papers in this field are those presented at a seminar on incinerator emissions of heavy metals and particulates held in Copenhagen in September 1985, and subsequently published, [5/5]. In one of the papers, Carlsson [5/6] compares gas cleaning systems and claims that dry injection of hydrated lime followed by fabric filters give outstanding performance for dust and heavy metal removal, including mercury.

A number of the papers in the Copenhagen symposium are particularly concerned with the problem of mercury emissions. Vogg et al [5/7] have investigated the behaviour of mercury in incineration and flue gas purification systems to provide guidance on the optimum conditions for removal. They found that more than 80% of the mercury in the feedstock is released into the gas phase and on leaving the waste heat boiler is present mainly as mercury (II)-chloride which at temperatures well below 200°C will condense and be adsorbed on fly ash particles, whereby it can be removed by filtration. They found that cadmium is also mostly volatilised as the chloride during waste incineration and that virtually all of it condenses on fly ash particles.

Gounon and Milhau [5/8] report on the pollutant concentrations in the emissions from the three refuse incineration plants which serve the city of Paris, two of which - at Ivry and Issy-les-Moulineaux are equipped with high efficiency ESP. The third, at Saint-Ouen, is a much older plant and only equipped with cyclone and 'rudimentary' water scrubbing. The Saint-Ouen plant has been reconstructed, but it is of interest to list some results obtained before reconstruction in comparison with those at the Issy plant: Table V-12.

Table V-12

Concentrations of heavy metals in particulates emitted from city of Paris incineration plants.

Plant	Issy		Saint-Ouen	
Sampling point:	ESP outlet		Scrubber outlet	
			Stack 12	Stack 34
Date	:17.10.84	18.10.84	? 1984	
Concentrations in mg/m ³				
Ag	0.015	0.018	0.16	0.25
Cd	0.10	0.06	1.50	1.23
Co	0.007	0.007	0.02	0.02
Cr	0.28	0.09	0.58	0.74
Cu	0.13	0.13	5.20	3.14
Ni	0.02	0.01	0.25	0.26
Ba	0.086	0.055	2.04	2.29
Hg	0.006	0.008	0.32	0.74
Pb	1.68	1.94	56.17	50.03
Zn	2.07	2.27	54.33	42.80
As	n.d.	n.d.	0.07	0.09
Be	n.d.	n.d.	<0.01	<0.01
Total particles	below 100		677	797

Source: Gounon & Milhau, [5/8]

5.5 Refuse Derived Fuel (RDF)

There are various ways in which the energy content of refuse can be recovered and utilised, and one which is finding increasing favour is the initial separation of materials which can be recycled, such as glass, metals and paper.

When refuse is incinerated, heat can be recovered from the combustion chamber outlet gases by means of waste heat boiler systems, and utilised to provide hot water for domestic purposes including space heating, or steam for process uses and electricity generation.

Alternatives to direct incineration which ultimately involve combustion to release thermal energy include:

- The production of solid fuel, generally in the form of pellets or briquettes, which can be transported elsewhere for use in the ordinary range of industrial combustion installations for steam raising etc., often in conjunction with other fuels such as coal.
- The recovery or production of biogas, for example by collection from landfills, and by anaerobic fermentation under controlled conditions. Biogas is generally used near the site of production, e.g. for running gas engines for power generation, or for use in district heating plants.
- Pyrolysis, ie heating under oxygen starved conditions to temperatures of 800°C+ to decompose organic matter and produce combustible gases and carbonaceous chars which can also be burnt.

The Commission's Directorate-General for Science, Research and Development, DG XII, is currently sponsoring a range of demonstration programmes on the treatment of refuse to produce solid fuel, biogas and pyrolysis products.

These means of obtaining energy from waste other than by direct incineration obviously have important implications in respect of atmospheric emissions. Where combustible gases are produced and purified, emissions of particulates and heavy metals are virtually eliminated from the combustion process. When solid fuels are produced, their heavy metal content will be lower than that of the raw waste because of the elimination of a high proportion of the non-combustible material.

Fuel made from waste is commonly designated 'refuse derived fuel' or RDF, and there are equivalents in other languages, such as BraM in German (Brennstoff aus Müll) and CDD in French (combustibles dérivés de déchets).

RDF production technology development and plant construction have accelerated during the past decade, and progress is regularly reported in the 'Warmer Bulletin', a newspaper published by The Warmer Campaign, an organisation for promoting the recycling of warmth and energy from rubbish, and funded by The World Resource Foundation.

RDF manufacturing processes are designed to optimise the separation of organic material, and they include the magnetic removal of ferrous metals and a variety of crushing, shredding, screening and air classification steps to concentrate and extract non-combustible material which may be discarded for landfill.

In an account of a recently constructed plant in the Ruhr [5/9] it is stated that 1000 kg municipal refuse yields about 450 kg of fuel pellets, and the following reduction in heavy metal content is quoted:

	g/tonne untreated refuse	g/0.45 tonne RDF pellets	Percent reduction compared with untreated refuse
Pb	600 - 2000	40	93 - 98
Cd	3 - 12	0.5	83 - 96
Zn	440 - 2300	90	80 - 96

A series of combustion trials with various RDF products from European and USA sources, and different boiler types, was recently reported by Bünsow and Dobberstein [5/10].

In Table V - 13 the pollutant contents of the wastes and refuse derived fuels investigated are compared with those of brown and hard coals. In the combustion trials the heavy metal contents of the furnace ash and fly ash were also analysed, and a very large volume of data is reported which cannot be summarised here.

Table V - 13 Pollutant contents of wastes, refuse derived fuels and coals.

Parameter	Raw waste	Refuse derived fuel	Brown coal	Hard coal
Calorific value kJ/kg	8500	~16500	16000-2100	28000-32000
Water content mg/kg	290000-340000	57000-150000	200000-300000	15000-50000
Ash content mg/kg	480000-530000	70000-304000	25000-150000	10000-15000
Sulphur mg/kg	600-850	990-5900	4000-10000	10000-15000
Chlorine mg/kg	3370-4200	5500-18200	10000-20000	2000-8000
Fluorine mg/kg	8,9-15,3	12-79	30-370	100-600
Zinc mg/kg	460-610	400-1200	20-150	500-5000
Copper mg/kg	180-300	100-2200	n.s.	11,5
Cadmium mg/kg	3-5	0,3-9,0	1-10	5-100
Lead mg/kg	180-640	110-400	5-500	250-5000
Chromium mg/kg	n.s.	36-160	n.s.	94
Mercury mg/kg	0,4-1,1	0,21-2,8	0,1-2,0	1-40
n.s. = not stated				

Source: Bunsow and Dobberstein [5/10]

The concentration ranges quoted in Table V - 13 are so wide that it is difficult to make meaningful comparisons, and there are anomalies which indicate the problem of obtaining representative samples of waste materials which are so variable and heterogeneous in composition.

5.6 Chemical and Other Industrial Wastes

The inventories presented in Tables V-1 to V-9 related mainly to incineration plants dealing largely with general domestic and commercial refuse. Manufacturing concerns, hospitals and other organisations producing special categories of waste frequently have in-house incineration facilities, but these are mostly of relatively low (less than 2 tonnes/hour) capacity, and are generally not identifiable from central sources. There are also some municipal and private sector facilities which treat industrial wastes on a contract basis, and these may be specially equipped to deal with specific pollutants, such as by having alkali scrubbers to remove the hydrochloric acid generated in the combustion of chlorinated solvents.

In the United Kingdom the control of air pollution from certain industrial processes is administered by a central authority, the Industrial Air Pollution Inspectorate, and this authority deals with chemical incineration works which are defined as plants for the incineration of wastes produced in the organic chemical processes for making materials for the fabrication of plastics and fibres, and of chemical wastes containing combined chlorine, fluorine, nitrogen, phosphorus or sulphur. Such plants must be registered with the inspectorate, and must employ 'best practicable means' for preventing emissions of 'noxious and offensive gases' which includes particulates.

The inspectorate provided Metra with a list of 65 plants registered as chemical incineration works in England and Wales, but confidentiality restrictions precluded the

provision of any details beyond the name of the operating company and the location of the plant, which illustrates the problems of inventorisation discussed in Section 2. However, one of the companies operating a number of the in-house plants supplied information indicating that none of them were of interest in the present study because they were not treating materials containing significant amounts of heavy metals or other non-combustible substances. Another UK company approached was Re-Chem International Limited, which specialises in the safe disposal of hazardous wastes produced by industry. Hazardous chemical wastes arising in a number of countries are exported to the UK for treatment in Re-Chem incineration plants and the operations have aroused some much publicised disquiet about their safety, mainly because of fears about the possible emissions of highly toxic substances such as PCBs and dioxins.

Re-Chem provided a copy of a report [5/11] summarising results to date of a monitoring programme in which monthly samples of soil and foliage were taken from sites located within a 3km radius of each of Re-Chem's three operating plants. The samples were all analysed for copper, lead, zinc, cadmium, selenium, arsenic, antimony, mercury and molybdenum, and also for PCBs. Some samples were analysed in addition for dioxins and dibenzofurans. For comparison, samples taken from areas remote from the Re-Chem sites were also analysed, and the overall conclusion from the results was that in all cases the average values for all the metals and compounds in samples from the vicinity of the plants were well within the background levels.

5.7 Emission Standards for Waste Incineration

In the majority of EC countries the regulation of atmospheric emissions from domestic waste incineration is a matter for local authorities, not central government, and where limits are imposed they are generally in respect

of acid gases (HCl and HF) and particulates, but not specifically for heavy metals.

Belgium has a set of national regulations for domestic incineration plants issued in April 1982, which includes limits for HCl, HF, CO and dust, depending on plant capacity. For plants with a capacity of 0.4 to 0.75 tonnes/hour of waste the limit for dust is 100 mg/Nm³ at 17% oxygen by volume; for plants above 0.75 tonnes/hour capacity the dust limit is 100 mg/Nm³ at 11% oxygen.

In FR Germany, the implementation of air pollution control measures is the responsibility of the regional authorities (the Länder), but they are required to comply with the technical instructions for air quality (Technische Anleitung, zur Reinhaltung der Luft - 'TA Luft' issued under the Federal immission control law (Bundes-Immissionsschutzgesetz: 'BImSchG').

New TA Luft limits for waste incineration were introduced in 1986 which are much more stringent than those previously obtaining, as shown in Table V-14, and the implications have been discussed by Matthes [5/12].

Table V - 14**FR Germany: emission limits applicable to waste incineration**

Limits for exit gas with 11% O₂
(mg.m³ except where other units given)

Particulates	TA Luft '83 100	TA Luft '86 30
Particulate inorganic substances including heavy metals:		
Class I (Cd, Hg, Tl)	20	0.2
Class II (As, Co, Ni, Se, Te)	50	1
Class III (Sb, Pb, Cr, Cu, Mn, Pt, Pa, Rh, V, Zn)	75	5
also:		
Chloride (HCl)	100	50
Fluoride (HF)	5	5
Cyanide (CN)	nsl	5
	(= no stated limit)	
CO	1000	100
Organic substances (as C)	nsl	20
SO ₂	nsl	100
Organic chlorine compounds (HCl)	nsl	50
" fluorine " (HF)	nsl	2
Nitrogen oxides (as NO ₂)	as low as possible	500

In Italy responsibility for industrial plant air pollutant emission control is vested in the commune authorities, which must comply with national framework decrees and ensure that appropriate abatement technology is employed. In particular, Decree DPR No. 322 of 1971 limits the contribution which an industrial plant may make to pollutant levels in the vicinity in respect of a number of specified pollutants including lead compounds and inert suspended particulates. Inspection of the

dust emission limits for the individual incineration plants listed in Table V-5 indicates that (in 1980) most facilities equipped with ESP were working to limits of 50 to 150mg/Nm³.

For the domestic waste incineration plant in **Luxembourg** the dust emission limit is an average of 75 mg/Nm³, with actual levels being maintained in the range 50 to 100 mg/Nm³.

The official dust emission limit for waste incineration in **Spain** is given as 150 mg/Nm³, but some of the installations are not yet in compliance.

In the **United Kingdom** there are no national standards for domestic waste incineration plants, which are controlled by the district authorities, but it is understood that dust emission limits do not exceed 460 mg/Nm³ and that many plants operate well below this level, typically in the range 100 to 250 mg/Nm³. For plants categorised as chemical incineration works (see Section 5.6), the Industrial Air Pollution Inspectorate applies the following limits:

HCl	460 mg/m ³
H ₂ S	5 ppmv/v

Particulate matter:

unspecified general wastes:	115 mg/m ³
specified materials	: up to 460 mg/m ³

The other three countries inventorised: **Denmark, France,** and the **Netherlands**, also do not have national emission standards for waste incineration. Limits are set by local authorities, generally on a plant basis, but figures were not quoted in the inventory data obtained. Probably most plants in these countries are working to dust emission limits no higher than 500 mg/Nm³, with limits of 100 mg/Nm³, applying in many cases and becoming more common.

5.8 References in Section 5.

The following references relate to citations in the text of sub-sections 5.4 to 5.7. The sources from which the incineration plant inventories in Tables V-1 to V-9 were compiled are given with each table.

- 5/1 SCHULTE-SCHREPPING, K.H., 'Emission of cadmium from refuse incineration plants', Report on seminar: Cadmium in Plastics, Brussels, 1982, p.36
Cadmium Association, London (1982).
- 5/2 CLAYTON, P., 'The Incineration of Municipal Refuse' Warren Spring Laboratory Report No. LR 498 (AP)M, (1984).
- 5/3 ARTHURS, J. AND WALLIN, S.C., 'Cadmium in emissions from incineration of waste at local authority disposal sites in the United Kingdom', Proceedings of Fourth International Cadmium Conference, Munich, 1983. p.70
Cadmium Association, London.
- 5/4 KNORN, C., *ibid.* p.76
- 5/5 Incinerator Emissions of Heavy Metals and Particulates: Specialized Seminar, Copenhagen, September 1985. Waste Management & Research, Vol.4, No.1, (1986).
- 5/6 CARLSSON, K. 'Heavy metals from "energy from waste" plants - comparison of gas cleaning systems', *ibid.* p.15.
- 5/7 VOGG, H. et al., 'The specific role of cadmium and mercury in municipal solid waste incineration', *ibid.*, p.65.
- 5/8 GOUNON, J. and MILHAU, A., 'Analysis of inorganic pollutants emitted by the City of Paris garbage incineration plants' *ibid.*, p.95.

- 5/9 Warmer Bulletin, vol. 1, No.4, p.3 (1984).
- 5/10 Bünsow, W. and Dobberstein, J., 'Investigation of the possibilities to use RDF in power stations for energy-gaining reasons - Phase I - combustion trials', Report (in German):
Reference No. 143 01 99, Technische Universität Berlin, (December 1984).
- 5/11 Re-chem International Ltd., Report: 'Environmental Monitoring Review', (April 1986).
- 5/12 MATTHES, T., 'Die Verbrennung von Hausmüll - Stand 1986 - (I)', Der Städtetag, No.6 (1986) p.421.

European Communities — Commission

EUR 11086 — Identification and quantification of atmospheric emission sources of heavy metals and dust from metallurgical processes and waste incineration

Christopher F.P. Bevington

Luxembourg: Office for Official Publications of the European Communities

1987 — XVIII, 106 pp., 39 tab., 2 fig. — 21.0 × 29.7 cm

Environment and quality of life series

EN

ISBN 92-825-7478-4

Catalogue number: CD-NA-11086-EN-C

Price (excluding VAT) in Luxembourg

ECU 12.80 BFR 550 IRL 10 UKL 9.10 USD 14.50

In connection with a Council Directive (84/360/EEC) on the combating of air pollution from industrial plants, a survey was made of atmospheric emission sources of heavy metals and dust from iron, steel and non-ferrous metallurgical processes, and from waste incineration plants in the European Community.

The problems of assembling industrial emission inventories are reviewed; they include confidentiality barriers, the absence of reliable data in many cases, and the scarcity of accessible central sources of information.

Tabulations are provided of individual primary aluminium, primary and secondary lead and primary zinc plants. For the other non-ferrous metals and for the iron and steel sectors the tables relate to types and numbers of production plants in each Member State.

Lists are provided with details of most of the domestic waste incineration plants in the Community with a capacity of at least two tonnes per hour.

The quality of the available emission data for the industry sectors concerned is discussed and examples are given which illustrate the variation of emission factors with the type of plant, raw material composition, operating conditions, etc. Published national emission standards are also included.

**Venta y suscripciones · Salg og abonnement · Verkauf und Abonnement · Πωλήσεις και συνδρομές
Sales and subscriptions · Vente et abonnements · Vendita e abbonamenti
Verkoop en abonnementen · Venda e assinaturas**

BELGIQUE / BELGIË

Moniteur belge / Belgisch Staatsblad
Rue de Louvain 40-42 / Leuvensestraat 40-42
1000 Bruxelles / 1000 Brussel
Tél. 5 12 00 26
CCP / Postrekening 000-2005502-27

Sous-dépôts / Agentschappen:

**Librairie européenne /
Europese Boekhandel**

Rue de la Loi 244 / Wetstraat 244
1040 Bruxelles / 1040 Brussel

CREDOC

Rue de la Montagne 34 / Bergstraat 34
Bte 11 / Bus 11
1000 Bruxelles / 1000 Brussel

DANMARK

Schultz EF-publikationer

Møntergade 19
1116 København K
Tlf: (01) 14 11 95
Telecopier: (01) 32 75 11

BR DEUTSCHLAND

Bundesanzeiger Verlag

Breite Straße
Postfach 10 80 06
5000 Köln 1
Tel. (02 21) 20 29-0
Fernschreiber: ANZEIGER BONN 8 882 595
Telecopierer: 20 29 278

GREECE

G.C. Eleftheroudakis SA

International Bookstore
4 Nikis Street
105 63 Athens
Tel. 322 22 55
Telex 219410 ELEF

Sub-agent for Northern Greece:

Molho's Bookstore

The Business Bookshop
10 Tsimiski Street
Thessaloniki
Tel. 275 271
Telex 412885 LIMO

ESPAÑA

Boletín Oficial del Estado

Trafalgar 27
28010 Madrid
Tel. (91) 446 60 00

Mundi-Prensa Libros, S.A.

Castelló 37
28001 Madrid
Tel. (91) 431 33 99 (Libros)
431 32 22 (Suscripciones)
435 36 37 (Dirección)
Télex 49370-MPLI-E

FRANCE

Journal officiel
**Service des publications
des Communautés européennes**
26, rue Desaix
75727 Paris Cedex 15
Tél. (1) 45 78 61 39

IRELAND

Government Publications Sales Office

Sun Alliance House
Molesworth Street
Dublin 2
Tel. 71 03 09

or by post

**Government Stationery Office
Publications Section**

6th floor
Bishop Street
Dublin 8
Tel. 78 16 66

ITALIA

Licosa Spa

Via Lamarmora, 45
Casella postale 552
50 121 Firenze
Tel. 57 97 51
Telex 570466 LICOSA I
CCP 343 509

Subagenti:

Libreria scientifica Lucio de Biasio - AEIOU

Via Meravigli, 16
20 123 Milano
Tel. 80 76 79

Libreria Tassi

Via A. Farnese, 28
00 192 Roma
Tel. 31 05 90

Libreria giuridica

Via 12 Ottobre, 172/R
16 121 Genova
Tel. 59 56 93

**GRAND-DUCHÉ DE LUXEMBOURG
et autres pays / and other countries**

**Office des publications officielles
des Communautés européennes**

2, rue Mercier
L-2985 Luxembourg
Tél. 49 92 81
Télex PUBOF LU 1324 b
CCP 19190-81
CC bancaire BIL 8-109/6003/200

Abonnements / Subscriptions

Messageries Paul Kraus

11, rue Christophe Plantin
L-2339 Luxembourg
Tél. 49 98 888
Télex 25 15
CCP 49242-63

NEDERLAND

Staatsdrukkerij- en uitgeverijbedrijf

Christoffel Plantijnstraat
Postbus 20014
2500 EA 's-Gravenhage
Tel. (070) 78 98 80 (bestellingen)

PORTUGAL

**Imprensa Nacional
Casa da Moeda, E. P.**

Rua D. Francisco Manuel de Melo, 5
1092 Lisboa Codex
Tel. 69 34 14
Telex 15328 INCM

Distribuidora Livros Bertrand Lda.

Grupo Bertrand, SARL

Rua das Terras dos Vales, 4-A
Apart. 37
2700 Amadora CODEX
Tel. 493 90 50 - 494 87 88
Telex 15798 BERDIS

UNITED KINGDOM

HM Stationery Office

HMSO Publications Centre
51 Nine Elms Lane
London SW8 5DR
Tel. (01) 211 56 56

Sub-agent:

Alan Armstrong & Associates Ltd

72 Park Road
London NW1 4SH
Tel. (01) 723 39 02
Telex 297635 AAALTD G

UNITED STATES OF AMERICA

**European Community Information
Service**

2100 M Street, NW
Suite 707
Washington, DC 20037
Tel. (202) 862 9500

CANADA

Renouf Publishing Co., Ltd

61 Sparks Street
Ottawa
Ontario K1P 5R1
Tel. Toll Free 1 (800) 267 4164
Ottawa Region (613) 238 8985-6
Telex 053-4936

JAPAN

Kinokuniya Company Ltd

17-7 Shinjuku 3-Chome
Shinjuku-ku
Tokyo 160-91
Tel. (03) 354 0131

Journal Department

PO Box 55 Chitose
Tokyo 156
Tel. (03) 439 0124

NOTICE TO THE READER

All scientific and technical reports published by the Commission of the European Communities are announced in the monthly periodical '**euro abstracts**'. For subscription (1 year: BFR 3 300) please write to the address below.

Price (excluding VAT) in Luxembourg
ECU 12.80 BFR 550 IRL 10 UKL 9.10 USD 14.50



OFFICE FOR OFFICIAL PUBLICATIONS
OF THE EUROPEAN COMMUNITIES

L — 2985 Luxembourg

ISBN 92-825-7478-4



9 789282 574782