

# LEAD INDUSTRY PROFILE

## LEAD PRODUCTION

About 60% of lead produced world-wide is derived from ore. Lead ore is mined in many countries around the world, though three quarters of world output comes from only six countries: China, Australia, USA, Peru, Canada and Mexico. Small amounts are mined in several countries in Europe, with the biggest producer being Sweden. Total production has been at a similar level since the 1970s; new mines open or are expanded to replace old mines. (Note: all these mines contain at least two metals (also zinc, sometimes silver, gold and copper) so lead extraction is not the only reason for the mining.)

The production of refined metallic lead from minerals dug out of the ground involves a number of steps which are outlined below.

**Mineral extraction** - mining and separation of the lead-rich mineral (ore) from the other extracted materials to produce a lead concentrate.

**Primary production** - production of metallic lead from lead ore concentrates involves the following process steps:

**Smelting** - reacting the lead rich mineral with other ingredients, to yield impure metallic lead. This is traditionally done in two stages:

- roasting in air, turning the lead concentrate (usually lead sulphide) into lead oxide;
- heating the lead oxide in a blast furnace with coke to yield metallic lead.

Alternative single stage methods offer many potential advantages in terms of overall efficiency, energy consumption and lower emissions (e.g. QSL, Kivcet, Isasmelt, TBRC).

**Refining** - the removal of impurities and other metals from the crude lead (S, Cu, Ni, As, Sb, Bi, Ag, Au, etc.). The refining process is applied in several steps in kettles with addition of specific agents, or alternatively, smaller quantities are processed by electrolytic refining.

Total production of refined lead (from all sources) has a different pattern, with the highest production rates being in the more industrialised countries. North America and Western Europe produce over half the world's refined lead, and the trend is for slowly rising production. The world-wide trend is for a slow increase in production, though there have been short-term falls in production in the 1970s and 1980s, as a result of oil crises and economic recession.

**Alloying** - of refined lead with other metals to give the desired composition.

**Secondary production** - the production of refined metal by processing lead scrap. It is often possible to simply re-melt scrap lead, with very little extra processing. However, compounds of lead (such as battery pastes) require smelting. Refining is often needed to remove any unwanted contamination and alloying additions in the feed material. The procedures are similar to those outlined for primary processing, but in general, fewer operations are required.

The proportion of lead produced from secondary sources (i.e. scrap metal), which represents about 60% of total world-wide production, is also higher in the more industrialised countries. North America produces 70% of its lead from secondary sources, and Western Europe 60%. In contrast, Chinese production is almost entirely from ore.

In Western Europe the lead producing industry consists of:

- Primary production - eight smelters in five countries with a total capacity of 600,000 tonnes and a labour force of 2,000.
- Secondary production - 30 smelters in 12 countries with a total capacity of 750,000 tonnes and a labour force of approximately 3,000.

Secondary production requires much less energy (less than half) than producing lead from ore. (Primary production 7,000-20,000 MJ/t lead, secondary production 5,000-10,000 MJ/t lead).

## TRADE IN LEAD

Lead is bought and sold by many countries on the world market, in the forms of ore, impure metal and refined metal, as well as final products. The USA, South East Asia, and Western Europe are the largest importers of lead in its various forms, though many of these countries also export refined metal. The main exporters of lead are the countries which mine large amounts of lead ore.

## CONSUMPTION OF LEAD

Lead is used by all industrialised nations. The USA is by far the biggest consumer, with some countries in Asia (China, Japan, Korea) and Europe (UK, Germany, France and Italy) also using large amounts. Most of the lead is used for

batteries, an application which has grown enormously in importance. The use of lead pipe has declined, as it is no longer used for potable water supplies, though lead sheet is used in roofing and other applications, particularly in the UK. The use of lead in chemicals remains at about 10% of European consumption; much of this is used in glass for TV screens and stabilisers in PVC. Lead cable sheathing, shot and alloys are minor uses of lead. The addition of lead compounds to petrol was at one time a significant market, but this has already been phased out in the USA and most of Europe, and is declining in many other countries. It now represents a minor market segment with less than 1 percent of total consumption worldwide\*.

## **ECONOMIC VALUE OF LEAD**

It is impossible to calculate this accurately. The battery market is chosen as an example as the major lead-based product sold world-wide. Data for 1999 suggest that the automotive battery market had a turnover of \$6-10 billion, and batteries for back up power supplies \$2.85 billion, with the latter expected to expand rapidly.

### **Employment in lead and related industries**

Though there are no precise figures, estimates by the lead industry suggest that between 70,000 and 90,000 people are employed in lead mining, smelting and refining, and over 2,000 more in lead oxide manufacture. Battery manufacture is estimated to employ about 60-70,000 people. Many more work in industries which use small amounts of lead in their products.

*\*In countries which are members of the ILZSG, including: Australia, Austria, Belgium, Canada, Finland, France, Germany, India, Italy, Japan, Republic of Korea, Mexico, Netherlands, New Zealand, Scandinavia, South Africa, South East Asia, Spain, Switzerland, United Kingdom, United States.*

## 4.1 THE TECHNOLOGY OF LEAD PRODUCTION

### 4.1.1 PRODUCTION OF LEAD MINERAL FROM MINES

Lead has been mined in much of Europe for centuries, and even in the last century lead production in Britain, Germany and Spain was significant (Pulsifer, 1888). However, in most of the region, economic reserves have been exhausted. At present, the main lead mining countries are: China, Australia, USA, Peru, Canada, Mexico, and Sweden. Smaller quantities of lead are extracted from several countries in Africa, Asia, other Latin American countries and Europe. Lead extraction from the Russian Federation and Commonwealth of Independent States has greatly declined following economic change (ILZSG, Lead and Zinc Statistics, 2001).

It is extremely rare that lead is found in its native form as lead metal; as with most metals, it almost always occurs as a mineral, chemically combined with other elements, such as sulphur and oxygen. Although there are a host of different naturally occurring minerals which contain lead, the most important ore (mineral suitable for the extraction of the metal) is galena (lead sulphide,  $PbS$ ); other ores include cerrusite (lead carbonate,  $PbCO_3$ ) and anglesite (lead sulphate,  $PbSO_4$ ), which are generally found in small amounts nearer the surface of sulphide deposits. Lead-rich minerals frequently occur together with other metals, particularly silver, zinc, copper and sometimes gold. Thus lead is also a co-product of zinc, copper and silver production making the extraction of lead more economic than if it occurred in isolation.

#### Ore Concentration

The lead-rich ore, with a typical concentration range of 3-8% lead, must first be separated from other material (the gangue). The principle of using flowing water to wash away the lighter gangue particles, leaving the denser ore behind, has also been used since ancient times (e.g. Laurium, Greece, 5th century BC. Healy, 1978, cited in Blaskett and Boxall, 1990). More sophisticated methods which utilise differences in densities of the materials include jigging devices and rotating and shaking tables. These methods were in use by the end of the last century.

The modern method of ore concentration is froth flotation which allows much higher extraction efficiencies to be achieved. Also, both lead and zinc can be separated. The ore mixture is ground to very fine particles, preferably less than a quarter of a millimetre in size. The ground material is made into a suspension or pulp by adding water and other chemicals. Air is blown into the suspension and the addition of frothing agents allows a stable froth to form on the surface. Other additions can make mineral components become attached to the froth (for example, non-wetting agents), or sink to the bottom (termed depressants) as the process requires.

In the case of lead-zinc ores, the metals are usually separated in a two-stage process. First the zinc sulphide is depressed while the lead sulphide is floated off and removed. In a separate stage further additions are made to activate the zinc ore, and it is floated off. The froths are then broken down by water sprays and the mineral suspensions filtered to remove the water. A number of chemical reagents can be used in this process. They include zinc sulphate, sodium cyanide or sodium sulphite to depress the zinc, and copper sulphate to activate it.

## 4.1.2 PRIMARY PRODUCTION

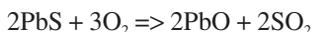
### 4.1.2.1 Production of Metallic Lead - Smelting

The next stage is to convert the lead ore into lead metal. The general name given to this type of process is smelting.

Historical accounts of lead smelting are described in the Annex - *Historical production and uses of lead*. Old lead workings are a current source of lead in the environment, and will be discussed in Chapter 6. Some of these early slags have proved to be a profitable raw material for lead extraction by more modern methods.

#### Traditional two-stage process

The first stage is to remove the sulphur from the lead ore by roasting the ore in air. The lead mineral is converted to lead oxide, and sulphur dioxide gas is released:



This is performed in a Dwight Lloyd Sintering Machine which allows continuous processing of ore. A mixture of finely divided ore concentrates and flux (the flux is required later), diluted with returned sinter fines or blast furnace slag, are placed on a moving grate and ignited. As the grate moves the charge forward, air is forced through the charge either from above, or in more modern plants, from below. The reaction is exothermic (i.e. heat is released). The lead sulphide is mostly converted to lumps of the oxide as shown above. The exhaust gases used to be vented to air but now they are routed to gas cleaning equipment to remove metallic fume and sulphur dioxide. The metallic dusts are returned to be re-processed. The sulphur dioxide generated can be used in the manufacture of sulphuric acid.

The second stage is to reduce the lead oxide to metallic lead using carbon (coke) as both the reducing agent and heat source. The lead oxide rich sinter from the first stage is placed in a blast furnace along with coke and limestone or some other flux (such as silica or iron oxide). A series of reactions take place in the blast furnace, but overall the effect is:



The lead is molten at blast furnace temperatures and is tapped off from the bottom of the furnace. The fluxes form a molten slag of metal oxides / silicates which floats on top of the liquid metal. The composition of this slag is chosen to enable it to collect most of the impurities from the lead. The slag generally contains a small amount of lead (around 2 or 3%, according to Blaskett and Boxall, 1990), and most of any zinc present (zinc containing slag can be processed to extract metallic zinc).

The lead obtained from the blast furnace contains small amounts of some metallic impurities also contained in the ore. These can include the metals: copper, arsenic, antimony, bismuth, tin, silver and gold. This lead is called lead bullion because of the presence of precious metals (molten lead has been used to extract silver and gold from other metals, such as copper, since ancient times). Separate refining operations are required to remove these metals from the lead, which are described later.

Besides processing ore, modern plants add small amounts of flue dusts (obtained from dust extraction systems treating exhaust air) and other lead-containing residues from their works and from other industries which produce dusts containing lead.

A variation of the traditional blast furnace is the **Imperial Smelting Process**. This operates in a similar way, but allows lead and zinc to be removed simultaneously, the lead in liquid form, and the zinc distilled off as a vapour. Lead and zinc usually occur together in ore bodies (and also some flue dusts), and this type of furnace has the advantage that it extracts these metals effectively, without the need for separation processes to be performed on the ore.

### **Alternatives to the two-stage process**

Although the above processes are effective in producing lead, they have some major drawbacks:

- there is much opportunity for pollution to occur during the operations and therefore extensive gas cleaning equipment is necessary;
- operating these two separate stages is inefficient in terms of energy consumption and plant required.

For these reasons, much research has been devoted to developing methods of extracting lead directly from its ore, without a separate intermediate stage. The main difficulty is that, if extraction is performed in a single vessel, either the metal obtained will have an undesirably high sulphur content, or the slag has a high lead content. (Some processes produce a slag rich in lead oxide, into which coke is added to reduce it to the metal, which is then returned to the furnace.)

However, a number of direct smelting processes are in operation or under development, including the Isasmelt, Kivcet, QSL, and Outokumpu processes. They employ differing furnace designs, methods of heat input and process control. In general emissions from such processes are much lower because:

- there are fewer handling stages of lead-containing material (during which dusts can escape)
- the smelting processes themselves are carried out within closed furnaces. In some cases the furnaces are maintained at pressures slightly below atmospheric pressure to limit dust and gas egress
- some processes use oxygen gas or air enriched with oxygen, rather than air, which reduces the volumes of gases that need to be handled and also increases the sulphur dioxide content of waste gases, enabling more economic production of sulphuric acid.

Most of the new processes can also process secondary materials such as lead sulphates, lead ashes etc.

Although these direct smelting processes all have advantages compared to the conventional sinter - blast furnace route, they still only account for about 20% of primary lead production (ILZSG World Directory of Primary and Secondary Lead Plants, 1997). However, this has increased from about 10% in 1992 (LDA Technical Notes, 1992) and is likely to increase further. The Imperial Smelting Process accounts for another 12% of primary production (ILZSG, 1997).

**Hydrometallurgical Processes** (which include **electrolytic processes**) are an alternative approach to obtaining and purifying metallic lead. These offer the advantage that, unlike traditional smelting operations, harmful lead fume and sulphur-containing gases are not evolved (although in modern plants, pollution control systems can reduce emissions to low levels. Industrial emissions are discussed in Chapter 8.) Hydrometallurgical processes always produce waste solutions that are rich in metal salts, which could be regarded as a useful resource for the recovery of metals, or as a problematic waste.

Hydrometallurgical methods are generally regarded by the industry as a much cleaner approach than pyrometallurgy, and may become important in the future (LDA Technical Notes 1992). (For comparison, copper is now produced and refined by hydrometallurgical methods, rather than pyrometallurgical.)

The principle for all such methods is that anodes of impure lead are dissolved into an electrolyte (a suitable solution or liquid which allows the passage of electrical current) and pure lead is deposited on the cathode. At present, this approach is not economical for primary production, except possibly in rare cases where there is a very cheap source of electricity (LDA Technical notes 1992; A. Bush, LDA, private communication, 1999). Electrolytic methods are sometimes used to refine lead which contains relatively small amounts of impurities, as described later.

#### 4.1.2.2 Lead Refining

##### Pyrometallurgical Refining

Refining involves the removal of metallic impurities from lead to yield a pure product. Lead often contains traces of several different metals, and separate stages are needed to remove these.

##### 1. *Copper*

The bullion is heated to just above its melting point and held at that temperature. Solid copper and copper sulphide, possibly mixed with sulphides of lead and other metals, rise to the surface of the melt and can be skimmed off. Sometimes sulphur is added to allow more effective removal of the copper. This impure copper is sent to be purified or is used to make copper-lead bearing material.

##### 2. *Arsenic, Antimony and Tin*

These elements are more chemically reactive than lead and can be removed by preferential oxidation. There are two methods available:

###### *The softening process*

Lead is melted and stirred with an air blast. The impurities are preferentially oxidised (along with some of the lead) and form a molten slag, which is skimmed off. "Softening" derives its name from the fact that these impurities harden the lead.

###### *The Harris process*

The molten lead is churned with an oxidising agent such as molten sodium hydroxide or sodium nitrate. After several hours the impurities have left the lead and are suspended in the flux as sodium arsenate, antimonate and stannate (tin); any zinc is removed as zinc oxide. The flux and lead are separated and impurities may be extracted from the flux. The major product, sodium antimonate, is refined. The tin is also refined and the arsenic is landfilled.

##### 3. *Silver and Gold*

Separation of silver from lead was performed in ancient times by the process of cupellation, which was effective but extremely inefficient. Cupellation is used primarily to produce silver. The lead metal was heated and stirred in air, eventually turning it completely to lead oxide, leaving behind metallic silver (and any gold present). If the lead itself was required, the oxide would have had to be re-smelted.

However, modern methods (the Parkes process or the more recent Port Pirie process) extract these precious metals with molten zinc. The lead is melted and

mixed with zinc; the precious metals form an alloy with zinc, which floats to the top and can be removed as liquid or cooled to allow the zinc to solidify. The zinc is removed from the precious metals by heating it under reduced pressure, which makes the zinc evaporate (vacuum distillation). The zinc is condensed and re-used; the silver is refined and sold.

#### 4. *Zinc*

The lead is now free from precious metals, but contains traces of zinc which must be removed. The usual method is, again, vacuum distillation. The lead is heated for several hours in a large kettle under vacuum and the zinc evaporates under the combined effects of temperature and low pressure. The zinc then condenses on a cooled lid.

#### 5. *Bismuth*

The only impurity likely to be left in the lead is bismuth, although this is not always present in the first place. Bismuth cannot be removed by selective oxidation as it, like silver and gold, is less reactive than lead. For years, it could only be effectively removed by electrolytic means (described below). As a result, ores rich in bismuth (particularly those found in Canada) have usually been refined using these methods. Electrolytic processes, such as the Betts process (described below), still remain the best way to obtain lead of very high purity. Alternatively bismuth can be removed by the production of stoichiometric  $\text{CaMg}_2\text{Bi}_2$  compound by adding calcium and magnesium as an alloy or as individual metals. Crystals form which can then be skimmed off.

The degree of purity finally aimed for is a balance between customer demand (i.e. added value of high purity lead, as traces of bismuth are acceptable for some applications) and the additional costs of removing further traces of this impurity.

### **Electrolytic refining**

This is an alternative to the refining stages described above and can be performed after copper removal and softening. Successful electrolytic refining has been possible since the Betts process was developed at the beginning of the 20th century.

**The Betts Process** uses large cast anodes (positive terminals about  $1\text{m}^2$  in area) of lead bullion (from which copper has already been removed), and thin starter sheets of high purity lead used for cathodes, (or negative terminal) onto which the new lead is deposited. The electrolyte used is a fluosilicate acid; (solutions of simpler electrolytes, including nitrate and acetate, did not allow successful deposition of lead.) When an electrical current is switched on, the lead anode slowly dissolves and purified lead is deposited upon the cathode.

A more recent variation on the above (developed in Italy in the 1950s) uses a sulphamate electrolyte which is easier to prepare and works equally well.

The main advantages of the electrolytic route are:

- any bismuth present is effectively removed (this process was favoured in Canada, where lead ores contained bismuth)
- higher levels of purity are possible
- dust and fume are not evolved as high temperatures are not needed.

However, drawbacks include:

- a separate treatment is needed to remove all of the tin
- extracting the mineral contaminants from the residues can be complex and difficult
- disposal of the solutions, which are rich in metals, can present environmental problems (though arguably less than the problems of fume)
- it is more expensive than pyrometallurgical methods.

#### 4.1.3 SECONDARY PRODUCTION

Secondary production - the production of lead from scrap, rather than ore - is distinct from primary production. There are many plants which are dedicated to production of only secondary lead, while other plants are designed to produce primary lead. However, the processes involved are very similar, and a number of primary production plants now take some scrap as part of their feed material, i.e. produce part secondary lead, a trend which is likely to increase. Secondary lead can be indistinguishable from primary lead provided it is subjected to sufficient refining steps.

In Europe at present, approximately 50% of the lead produced is secondary lead. Most of this comes from scrap lead-acid batteries; lead pipe, sheet and cable sheathing are also significant sources. Scrap lead from the building trade is usually fairly clean and is re-melted without the need for smelting, though some refining operations may be necessary.

Of course, it is necessary to collect the waste materials, sort and remove other components and contaminants and prepare it in a form suitable for further processing. These operations are described in more detail in Chapter 5. Production of lead from secondary sources requires far less energy than producing lead metal from ore. It is estimated to use less than half of the energy used in primary production (LDA). A description of the smelting and refining processes follows.

##### 4.1.3.1 Secondary smelting

Only compounds of lead or very crude lead mixtures (such as pastes from batteries, or oxidised lead dust and dross obtained from other operations) need to be smelted. Smelting is not required for clean scrap lead.

Smelting was traditionally performed in a **blast furnace** in a similar way to the extraction of primary lead. The furnace is charged with lead-rich feed, metallurgical coke and possibly hard rubber battery casing. The lead bullion produced is usually high in antimony and requires subsequent refining steps.

In Europe, smelting is now generally conducted in smaller **rotary furnaces**. The principle is the same, but a greater degree of process control is possible. Adjustment of the charge can allow production of a “hard” (high antimony) crude lead, or a two stage process which yields a “soft” (more pure) lead product. In addition, greater flexibility in operation allows for better treatment of occasional batches of unusual composition. High throughputs of material are not necessary for economic operation, unlike blast furnace operation.

As with primary smelting, large volumes of gases are produced consisting mainly of air enriched with carbon dioxide, sulphur dioxide from contaminated feed (and also any sulphur present in the fuel), small amounts of other gases (depending upon the charge material used) and dusts. Dust filtering to a very low outflow concentration (less than 5mg Pb/m<sup>3</sup>) is now common practice in modern plants in the EU. The dusts are returned to the smelter. For the SO<sub>2</sub> reduction, iron can be added to the charge, or sometimes soda (with the disadvantage that it forms a slag with soluble components). Other solutions to reduce SO<sub>2</sub> emissions are leaching or alkaline scrubbing of the flue gases.

An example of a more modern approach to secondary smelting is the **Isasmelt process** (which can also be used for primary production). This process can deal with charge in any form including slurry, powder and wet or dry agglomerates making the process suitable for treating residues from batteries. The battery paste (a mixture of lead oxides and lead sulphate) is treated, for example with an alkaline solution, to remove most of the sulphate, yielding a lead rich paste which is low in sulphur. This paste is charged to the furnace and oxygen and fuel are injected through a lance causing heating and stirring which facilitates rapid chemical reaction. The furnace is continually charged with wet paste and coal and tapped every 3 hours to produce soft lead. After a suitable length of time (18-36 hours) the feed stops and reduction of the slag yields antimonial lead. There are difficulties in marketing the sodium sulphate so the choice of the sulphur removal process is site-specific (Note, the same opportunities for processing secondary materials are offered by some other modern smelting technologies such as the QSL). Off-gases are cooled and passed to a baghouse to remove dust and fume, which are returned to the furnace.

This process claims a number of advantages over traditional rotary furnaces: higher thermal efficiency; lower operating costs; direct production of both soft and antimonial lead alloy, which allows for blending to suit some applications; slags of low lead content, which reduce disposal problems; and good process hygiene. However, in reality some of these advantages can be very difficult to achieve.

All these processes are still in use. All have some advantages and disadvantages and it is not possible to place them in an order of preference.

#### **4.1.3.2 Secondary Refining**

The lead is either cast into blocks and re-melted in refining kettles or, in more modern plants, refining is performed on the hot lead bullion immediately after production.

Copper is removed in a similar manner to that already described (i.e. it is allowed to float to the surface of molten lead and is skimmed off.) A variation on this is to add iron pyrites and sulphur; this works at higher temperatures and also removes any nickel present. Other elements are removed by a modified Harris process using a flux of molten sodium hydroxide and nitrate to oxidise antimony, arsenic and tin. Bismuth and silver levels are normally very low and the metals rarely need to be removed.

## **4.2 LEAD PRODUCTION, TRADE AND CONSUMPTION: CURRENT STATUS AND TRENDS**

(All figures are for 2000, source ILZSG statistics, (2001), unless otherwise stated.)

### **4.2.1 LEAD PRODUCTION**

#### **4.2.1.1 Production from Mines**

The main producers of lead mineral are: China, Australia, USA, Peru, Canada and Mexico. These six countries produce three quarters of world output. However, smaller reserves of lead are exploited elsewhere, as shown below, and in Figure 4.1.

Mine production in Western Europe accounts for a small proportion (8%) of global mineral production. The largest producer by far is Sweden (109,000t). Smaller amounts are extracted in Ireland (57,000t), Spain (51,000t), Greece (18,000t) and Italy (7,000t).

#### **4.2.1.2 Total Production of Refined Lead**

Total production includes both lead from ore (primary lead) and secondary lead, produced from scrap batteries and other lead-containing products.

Refined production is performed in more countries than mineral extraction. Countries not endowed with mineral deposits import ore or impure lead metal, scrap lead or produce lead from their own scrap. Some countries, such as Denmark, do not produce any of their own lead. The largest outputs of refined lead are in highly industrialised countries, which have a high demand for this commodity (see Figure 4.2).

**TABLE 4.1** World-wide Production of Lead Ore by Region

	Mine production in 2000 (lead content, in thousand tonnes)
Western Europe	242
Central and Eastern Europe	121
Africa	181
North America	607
Central and South America	446
China	560
Rest of Asia	135
Australia	650
<b>TOTAL</b>	<b>2942</b>

In Western Europe, in 2000, 12 countries produced refined lead and two others have produced small amounts earlier this decade. However, production by four of these countries, UK (394,000t), Germany (388,000t), France (262,000t) and Italy (228,000t), together account for over three-quarters of production (see Figures 4.3 and 4.4).

**TABLE 4.2** World-wide Production of Refined Lead Metal by Region

	Mine production in 2000 (lead content, in thousand tonnes)
Western Europe	1578
Eastern Europe	309
Africa	135
North America	1705
Central and South America	478
China	1051
Rest of Asia	1017
Australia and New Zealand	261
<b>TOTAL</b>	<b>6532</b>

#### 4.2.1.3 Secondary Production

World-wide, production of refined lead from scrap and other secondary sources now accounts for approximately 60% of total lead production.

Rates of secondary production are again higher in the more highly industrialised countries. In North America, processing of lead scrap accounts for the bulk (just over 70%) of metal output. In Western Europe secondary production accounts for 60% of lead output, in Africa 50%, in Latin America a

little under 50% and in Asia less than 30%. The Asian figure is dominated by Chinese production which is entirely primary.

In addition, some scrap is simply re-melted and used without further treatment. This is not included in any of the above figures, but world-wide is estimated at just under 400,000t per year. In comparison to total world output, this is a very small figure (less than 7% of total metal output). Even adding this to production figures, the world-wide proportion of lead produced from secondary sources, with or without refining, is 48% (1999 figures).

In Western Europe, the lead produced by each of the four major lead producers (UK, Germany, France and Italy) is between 50 and 75% secondary. Some other countries, namely Austria, Ireland, the Netherlands, Spain and Portugal, produce only secondary lead. Belgium was the only country to produce most of its lead from ore until 1998, but has recently made alterations to its plant and now produces most of its lead from secondary sources (G. Deckers, U.M. Hoboken, personal communication). (See Figure 4.3.)

It is likely that the proportion of secondary lead produced will continue to increase as patterns of lead use change. The phasing out of the major diffuse applications of lead (particularly in paints and petrol additives) from which lead is virtually impossible to recover, began in the 1950s and is still continuing. Applications which lend themselves to recycling (in particular batteries) are increasing.

**TABLE 4.3** Production of Secondary Lead in Western Europe in 2000

	Production (thousand tonnes)	% of total refined production
Austria	24	100
Belgium	108	92
France	139	53
Germany	213	55
Greece	5	83
Ireland	10	100
Italy	171	75
Netherlands	21	100
Portugal	5	100
Spain	97	100
Sweden	47	61
Switzerland	9	90
UK	179	54
<b>TOTAL</b>	<b>1028</b>	<b>65</b>

(ILZSG, 2001)

**TABLE 4.4** Location of Lead Smelters in the EU

	Primary	Secondary
Austria	0	4
Belgium	1	3
France	1	6
Germany	3	6
Greece	0	1
Ireland	0	1
Italy	0	6
Netherlands	0	1
Spain	0	5
Sweden	1	1
UK	1	6
<b>TOTAL</b>	<b>7</b>	<b>40</b>

Plants for production of primary lead are usually larger than secondary plants.

*Note:* figures separating primary and secondary production should be treated with some caution, as many primary facilities increasingly use secondary raw materials as part of their feedstock.

## 4.2.2 WORLD TRADE IN LEAD

### 4.2.2.1 Overview

Lead is mined in many countries, in every continent around the world, though the bulk is in China, Australia and the Americas.

Some countries have mineral reserves and produce lead entirely or largely from this source, in particular China, Australia, Mexico, Iran, Turkey. However relatively few countries are self-sufficient in lead, and many large consumers of this metal have few mineral reserves. These countries must import lead metal or ore, or use their own scrap to add to any mineral reserves they have. The largest producers in this category are the USA, most of Western Europe, Japan, Republic of Korea; there are also many other such smaller producers of lead world-wide.

There are a number of stages between mineral extraction and production of refined metal ready for use. These processing steps can be carried out:

- in the producer country (such as in China, which refines almost all of its lead) for overseas markets after domestic demand has been met,
- in a consumer country primarily for its own needs (such as in Japan, Austria), or
- in a country which imports ore, impure metal or scrap, refines the metal, then exports a higher value commodity (performed in many countries in Europe, including Belgium, France, UK).

Thus there is a large international trade in lead: as mineral, smelted but unrefined metal, refined metal ready for use, scrap metal, and lead products.

A detailed breakdown of imports and exports of the different grades of metal is not easily available. It is also complicated by the fact that many countries import from, and export to, up to a dozen or more other countries; also many states both import and export lead metal, and some even lead ore. However, figures for imports and exports of lead ore and metal provide information given below. All figures refer to 1999 imports and exports, unless otherwise stated, because information about 2000 flows is incomplete.

#### **4.2.2.2 Trade in lead ore**

##### **Exporters of lead ore**

The largest exporters in 1999 were Peru (147,000t), Australia (256,000t), followed by South Africa (66,000t), Canada (49,000t), Sweden (71,000t), Ireland (40,000t), the USA (93,000t), Poland (46,000t), Morocco (26,000t) and Spain (23,000t).

##### **Importers of lead ore**

The most recent figures (for 1999) show that the largest importers are France (115,000t) and Japan (122,000t), with significant imports being made into China (102,000t), Republic of Korea (90,000t), Canada (56,000t), Germany (111,000t), the UK (37,000t), Bulgaria (115,000t), Italy (110,000t) and Belgium (58,000t).

#### **4.2.2.3 Trade in lead metal**

The world-wide trade in lead metal is much larger than the trade in lead ore.

##### **Exporters of lead metal**

The largest exporters of lead metal are nations which mine large quantities of lead ore: China, Australia and Canada. In 1999 they exported 450,000t, 255,000t and 166,000t respectively.

Significant exports also occur from Europe, in particular from the UK (81,000t), Belgium (71,000t), France (76,000t), Germany (80,000t), Sweden (57,000t) and Italy (23,000t).

World-wide, other important exporters are Mexico, the USA, Peru, Morocco and South East Asia.

##### **Importers of lead metal**

The largest importer of lead metal is the USA, at 311,000t in 1999. However, this is a small quantity compared to the country's total production. Asia and Western Europe import very large quantities of lead with the largest importers being

Korea (117,000t), Taiwan (121,000t), Malaysia (117,000t), Singapore (90,000t), Italy (91,000t), Germany (87,000t), France (67,000t) and Spain (100,000t). The quantities of lead imports are generally rising slowly in the western world, and very rapidly in eastern Asia.

A summary of the main imports and exports of lead ore and metal is given in Table 4.5. This is derived from the above statistics for imports and exports from individual countries and is intended for use as a guide, as the information is not entirely complete.

It should be noted that there will be some other omissions, for example some countries; such as New Zealand, produce lead metal, but there is no record of their import of lead mineral or metal, or mine production. However, it is expected that such inaccuracies are relatively minor compared to total metal flows.

**TABLE 4.5** Worldwide Trade in Lead Ore and Metal in 1999

	Lead ore and concentrates (thousand tonnes)		Lead Metal (thousand tonnes)	
	Imports	Exports	Imports	Exports
Western Europe	430	195	477	394
Central and Eastern Europe	46	46	20	85
Africa	12*	94	15	57
North America	68	142	322	189
Central and South America	Not known	170	62	128
Asia	314	20	552	529
Australia	0	256	0	255
<b>TOTAL</b>	<b>870</b>	<b>923</b>	<b>1448</b>	<b>1337</b>

\* Data for 1998

#### 4.2.2.4 Lead stocks

Many countries have very small stocks of lead. There is an estimated global total of 471,000t held by producers, consumers and the London Metal Exchange (1999 figures). This is equivalent to 4 weeks of consumption. The only country with significant stocks is the USA, which had a strategic stockpile of 252,000t in 1999.

### 4.2.3 LEAD CONSUMPTION

#### 4.2.3.1 Global consumption of lead

Lead consumption world-wide has grown since the 1960s, and is currently at an all-time high of over 6 million tonnes (ILZSG 2001). This is almost double the consumption in the early 1960s. This growth in lead use has not been smooth. Drops in world demand followed the oil crises in 1973/4 and 1979, and again in 1989 to the early 1990s following the end of the Cold War and economic collapse in the former Soviet Union. However, the overall trend in consumption is slowly rising in spite of the phasing out of lead in paint, petrol additives and water pipes.

The largest growth in consumption has been in Eastern Asia due to increases in automobile production and use. There have also been small increases in demand in the USA and, to a lesser extent, in parts of Eastern Europe and Latin America.

All industrialised nations use lead. The USA is by far the greatest consumer, most of it being used for batteries. Other major consumers are: China, UK, Germany, Japan, Republic of Korea, France and Italy. Spain, Mexico and Brazil use less, but still more than 100,000t of lead each in a year. Smaller amounts of lead are used in most other countries around the world. (See Figure 4.2.)

**TABLE 4.6** Consumption of Refined Lead by Region

	Consumption of Refined Lead 1999 (in thousand tonnes)
Western Europe	1699
Central and Eastern Europe	300
Africa	127
North America	1859
Central and South America	392
China	524
Rest of Asia	1286
Australia and New Zealand	64
<b>TOTAL</b>	<b>6251</b>

#### 4.2.3.2 Lead consumption in Western Europe

The largest consumers are: UK (19%), Germany (22%), France, Italy and Spain. These countries consume 84% of all the lead in Western Europe (ILZSG, 2001). The consumption of lead in Eastern Europe is much smaller, in total less than the UK consumption.

#### 4.2.3.3 Breakdown of end uses of lead

The applications and uses of lead metal and lead compounds are detailed in Chapter 3 of this volume.

## **4.3 ECONOMIC VALUE OF LEAD**

### **4.3.1 LEAD PRODUCTION AND TRANSFORMATION**

Lead ore is currently produced at a rate of over 4 million tonnes a year of concentrate, having a lead content of 3.1 million tonnes. This has a market value of \$2.2 billion (1998 figures). In 1998, 6 million tonnes of refined lead were produced, which was worth almost \$4 billion. Consumption of 6 million tonnes of lead in this year was estimated to have a total market value of \$4.5 billion. It has been estimated that all mining, smelting and refining operations world-wide are worth around \$15 billion per year (ILZSG, 1999b).

### **4.3.2 LEAD-CONSUMING INDUSTRIES**

#### **Batteries**

Automotive SLI lead-acid batteries are the largest use of lead. Available data suggests that in 1999, approximately 270 million SLI batteries were produced, which had a market value of between \$7 and \$10 billion. There are currently 500 manufacturers of lead-acid batteries world-wide. Currently, 41% of the market is in the USA, 27% in Europe, 16% in Japan and the rest of the world uses the remaining 16%.

#### **Lead compounds**

Half a million tonnes of lead compounds were sold in 1996. The majority of this total was lead oxide with sales of \$650-680 million. Most were used in the manufacture of cathode ray tubes and PVC additives. Sales of lead oxide to cathode ray tube manufacturers are worth around \$250 million a year. In 1995, 127 million television sets and 57 million monitors were sold, each of which incorporated a cathode ray tube, accounting for sales worth around \$70 million. The market for leaded PVC is worth approximately \$4 billion a year.

## **4.4 EMPLOYMENT IN THE LEAD AND RELATED INDUSTRIES**

It is estimated that world-wide employment provided by lead mining, smelting and refining, is around 72,000 - 89,000, with a further 2,400 employed in lead oxide production. Many more people are employed in industries which use lead as a component in manufactured products. The lead-acid battery industry provides employment for about 60,000-70,000 people world-wide.

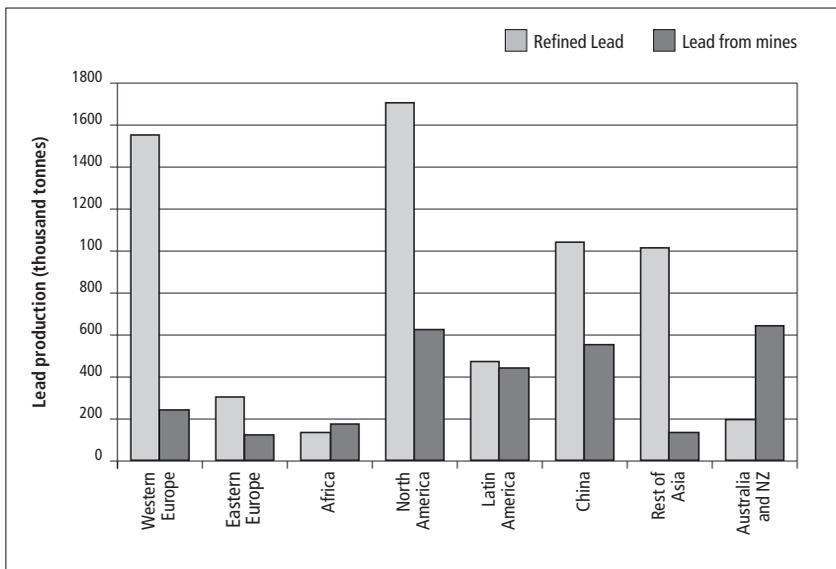


Figure 4.1 Lead Production by Region in 2000

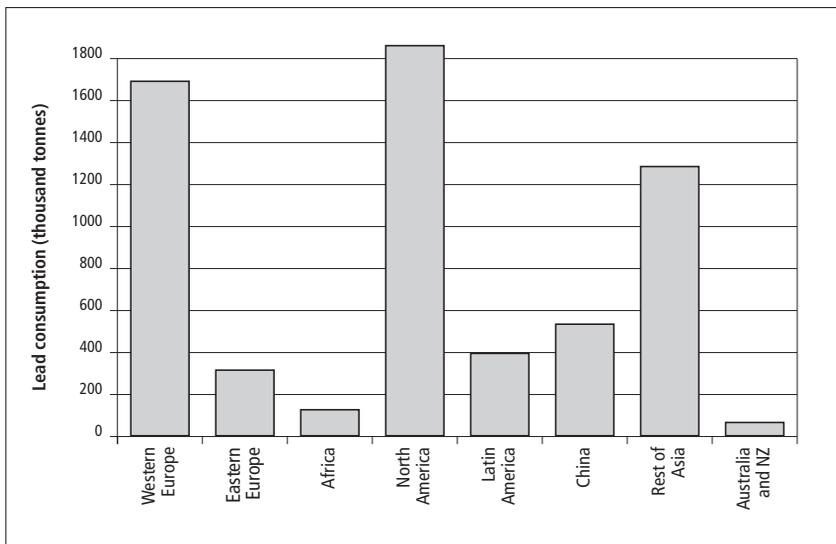
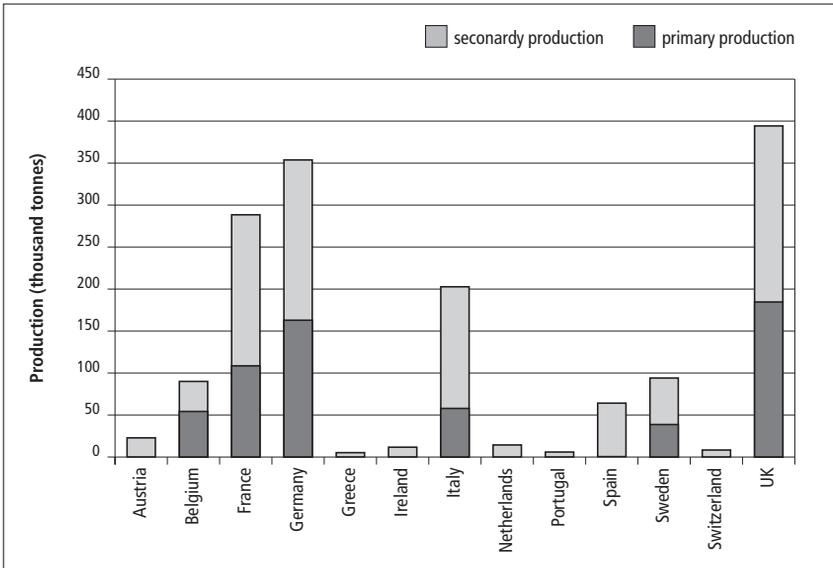
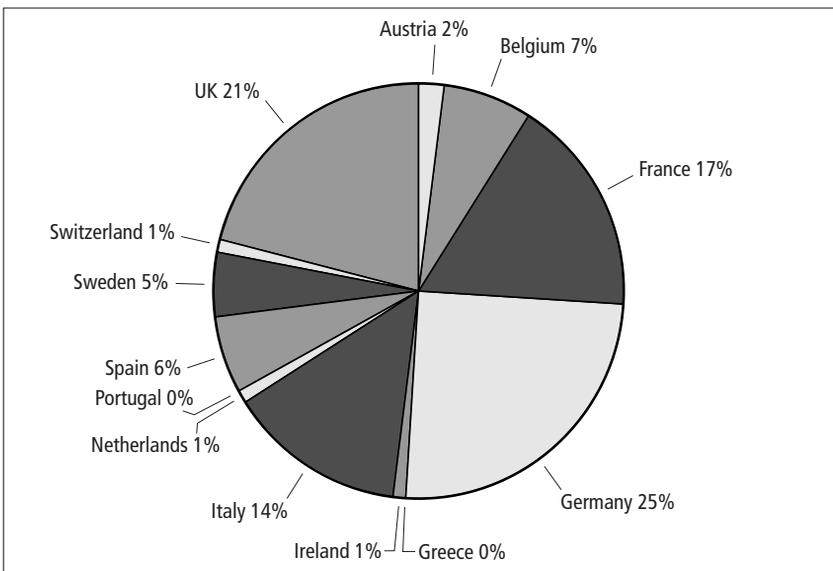


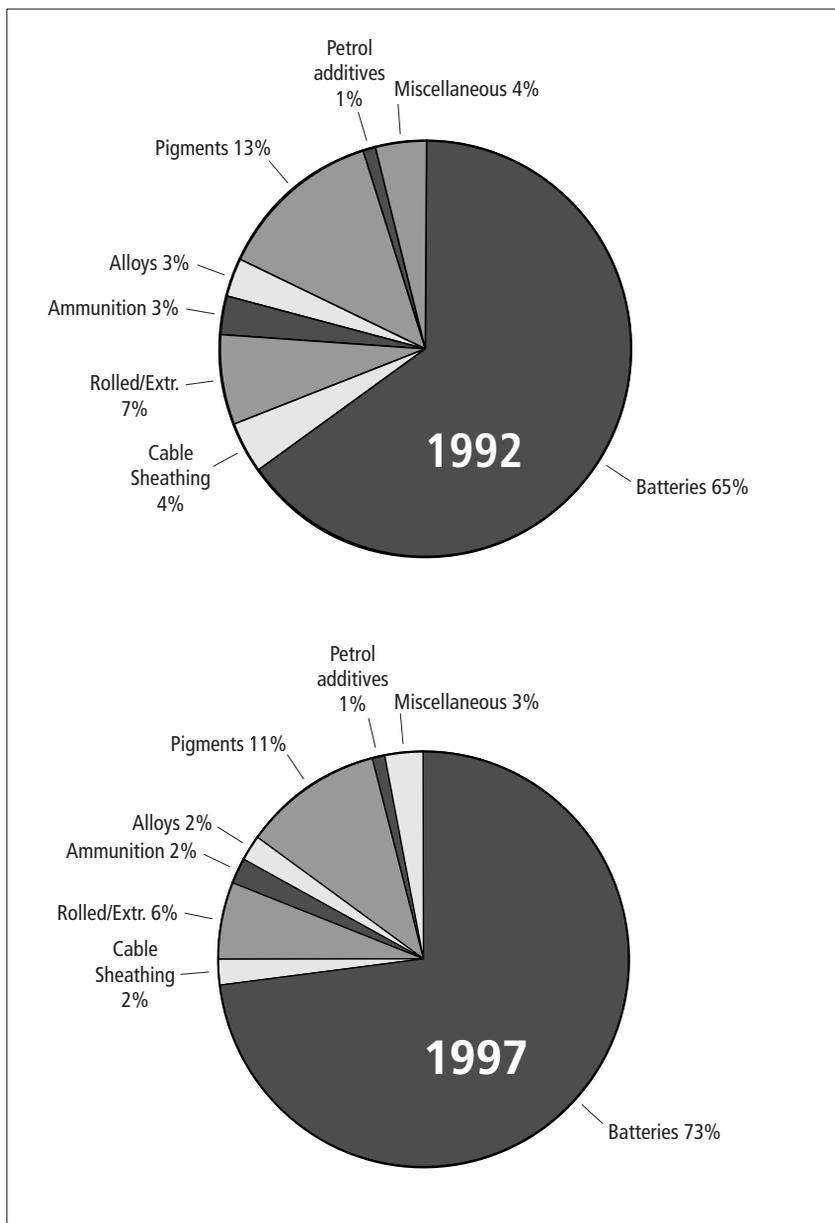
Figure 4.2 Lead Consumption by Region in 1999



**Figure 4.3** Primary and Secondary Production of Refined Lead in Western Europe in 1998

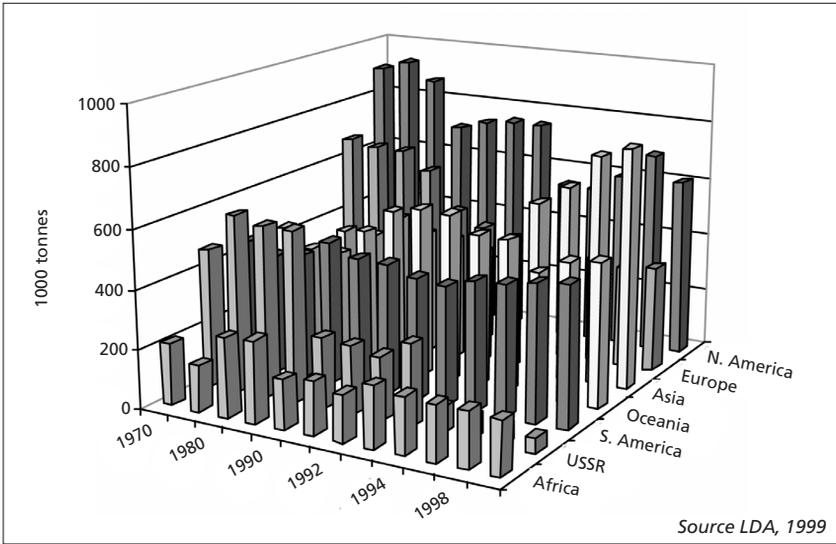


**Figure 4.4** Refined Lead Production in Western Europe in 2000

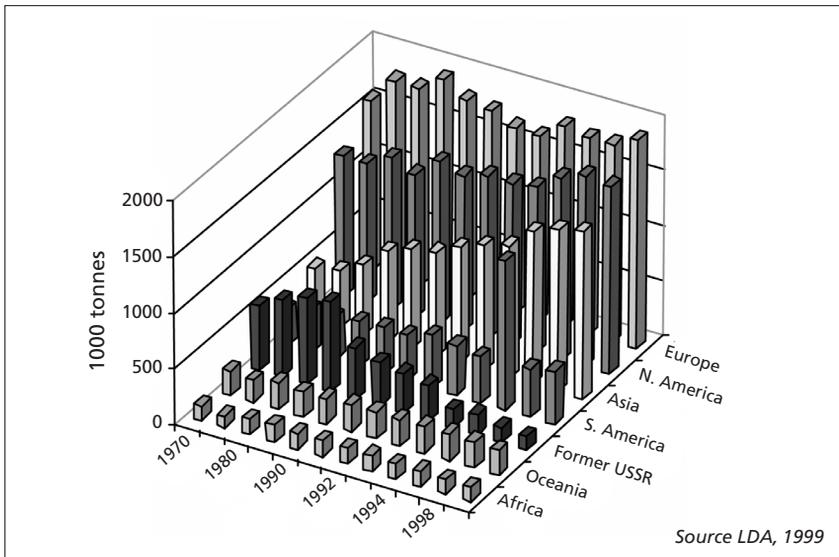


**Figure 4.5** Comparative Uses of Lead in 1992 and 1997

This data refers to the total use of lead in countries which are members of the ILZSG, together accounting for over 80% of the total global consumption of lead.



**Figure 4.6** World Lead Mine Production 1970-1998



**Figure 4.7** World Refined Lead Production by Principal Producers, 1970-1998

