

*Eco-profiles of the  
European Plastics Industry*

HIGH DENSITY POLYETHYLENE  
(HDPE)

*A report by*

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*for*

PlasticsEurope

*Data last calculated*

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## IMPORTANT NOTE

Before using the data contained in this report, you are strongly recommended to look at the following documents:

### 1. Methodology

This provides information about the analysis technique used and gives advice on the meaning of the results.

### 2. Data sources

This gives information about the number of plants examined, the date when the data were collected and information about up-stream operations.

In addition, you can also download data sets for most of the upstream operations used in this report. All of these documents can be found at: [www.plasticseurope.org](http://www.plasticseurope.org).

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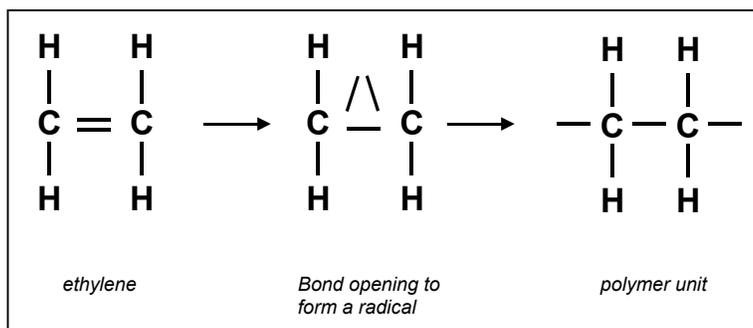
## OLEFIN POLYMERS

High density polyethylene (HDPE) is one of the olefin polymers and it is useful to examine briefly the four major olefin polymers because it highlights the differences between them and indicates why these different polymers are produced. The polymers are shown in Table 1.

*Table 1*  
*Large tonnage polyolefins produced in Europe in 1999.*

Polymer	Acronym	Production ('000 tonne) <sup>1</sup>
Low density polyethylene	LDPE	4793
High density polyethylene	HDPE	4308
Linear low density polyethylene	LLDPE	1934
Polypropylene	PP	7395

The polyolefins are chemically the simplest of all polymer structures. They can be produced commercially from olefin (alkene) monomers because the olefins contain a reactive double bond. Schematically the process of converting monomer to polymer is illustrated in Figure 1 for ethylene. Essentially the double bond in the ethylene molecule is opened to form a reactive *radical*, which then attaches itself to another radical. The process repeats itself to produce a long chain molecule or polymer terminating only when the propagating radical attaches itself to an unreactive species.<sup>2</sup> The starting material, ethylene, is called the *monomer* and the final compound consisting of many thousands of ethylene units is called the *polymer*.<sup>3</sup>



*Figure 1*  
*Schematic diagram of the formation of polyethylene.*

<sup>1</sup> APME Annual Report 2001.

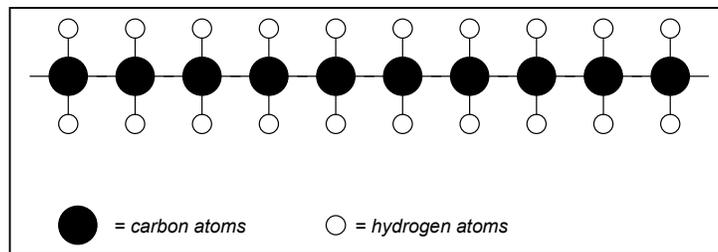
<sup>2</sup> The actual polymerisation process is somewhat more complex than this but the concept of opening the double bond is a useful way to think of addition polymerisation.

<sup>3</sup> The terms *monomer* and *polymer* are due to Berzelius (1830) from the Greek: poly = many; meros = part; mono = single or alone

Such polymers are often referred to as *addition polymers* because they are formed by continually adding further monomer units to the growing polymer chain and the polymerisation mechanism is known as *free radical polymerisation*.<sup>4</sup>

## CHARACTERISTICS OF OLEFIN POLYMERS

All olefin polymers have an unbroken carbon backbone and in its simplest form the structure of polyethylene is schematically of the form shown in Figure 2. (Polyethylene with this highly linear structure is often referred to as polymethylene).



*Figure 2*  
*Schematic structure of linear polyethylene*

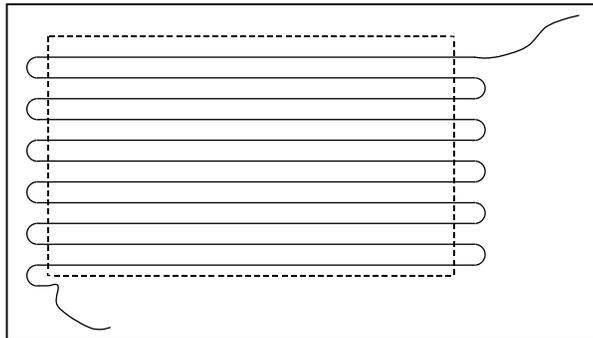
When a highly regular polymer such as that shown in Figure 2 is cooled from the melt, the polymer chains do not remain as a random tangle. Instead they tend to fold and lie alongside each other as shown in Figure 3.

These ordered regions inside polymer solids behave as crystalline regions. However, unlike atomic crystals, the whole of the long molecules cannot be incorporated into these ordered regions and so there will always be regions where the molecules are randomly arranged. These are amorphous regions. Because of the closer packing in the crystalline regions, their density is higher ( $\sim 1000 \text{ kg m}^{-3}$ ) than the amorphous regions ( $\sim 850 \text{ kg m}^{-3}$ ). Thus the higher the density of a specified polymer type, the greater the crystallinity.

The amount of crystallinity in a polymer directly affects the properties because the crystalline regions exhibit superior mechanical properties and for most applications the higher the crystallinity the better.

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<sup>4</sup> All addition polymers rely on the opening of a double bond to form the polymer backbone and this concept presents a useful way of determining polymer structures once the structural formula of the monomer is known.



*Figure 3*  
*Chain folding in regular polymers. The region inside the broken line is regarded as a polymer crystal.*

A critical factor in promoting the formation of crystalline regions in polymers is the regularity of the polymer chains. In practice, when ethylene is polymerised it does not form a simple linear chain of the type shown in Figure 2. Instead, it grows side branches. These side branches may be short (up to 8 carbon atoms) or very long (up to several thousand carbon atoms). Short, irregularly positioned side branches of different length tend to inhibit crystal formation but long side branches can usually be incorporated into the crystalline regions. The production technology determines the number, positioning and length of the side branches.

## HISTORICAL BACKGROUND

The first record of polyolefin production was in 1898 when von Pechmann in Germany produced the first polymethylene structure in the laboratory. It was not, however, until 1935 that Perrin at ICI showed that it was possible to produce large quantities of low density polyethylene by subjecting ethylene to pressures up to 350 MPa and temperatures up to 350°C. This process was developed commercially and production of LDPE started in 1938 in the UK.

In 1950, Hogan and Bank at Phillips Petroleum Co invented a catalyst containing chromium oxide on silica that allowed polymerisation at lower pressures (3 – 4 MPa) and temperatures (70 - 100°C). These Phillips catalysts were used to produce the first HDPE.

In 1953, Ziegler in Germany developed catalysts containing titanium halides and alkylaluminium which promoted polymerisation at atmospheric pressure and temperatures of 50 - 100°C. By adjusting the precise composition of the catalyst, he found that it was possible to obtain a wide range of polyethylenes that could be used in different applications. In 1954, Natta at Montecatini

modified the Ziegler catalysts to produce isotactic polypropylene and commercial production of polypropylene started in 1957.

During the period 1956-1976 considerable research by Phillips, Solvay, Montedison and Mitsui Petrochemical went into different catalyst systems with the aim of obtaining high yield isotactic polypropylene.

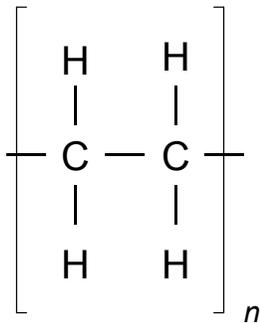
In 1976, Kaminsky and Sunn developed a new family of catalysts which allowed the production of ethylene polymers and copolymers and controlled the regularity of the chain branching. These were the catalysts that allowed the first commercial production of LLDPE.

As this brief history shows, most of the research in this area has been concerned with catalysts which achieve two main factors: obtaining more benign production conditions and producing polymers with more controlled structures.

## POLYETHYLENE

### *Low density polyethylene*

The repeat unit of polyethylene is:



Low density polyethylene (LDPE) has traditionally been defined as polyethylene with a density less than  $940 \text{ kg m}^{-3}$ . It is produced by a high pressure process and so is often referred to as high pressure polyethylene. The polymer contains both long and short chain side branching with the number of branches being from 2 and 50 per 1000 carbon atoms on the carbon backbone. LDPE can be produced with chain lengths ranging from 50,000 to 100,000 repeat units, with crystallinities in the range 35 to 75% and with densities in the range  $915$  to  $940 \text{ kg m}^{-3}$ .

## High density polyethylene

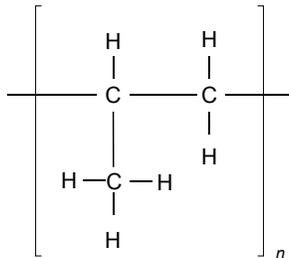
High density polyethylene (HDPE) has the same repeat unit as LDPE and is usually regarded as polyethylene with a density greater than  $940 \text{ kg m}^{-3}$ . It is produced in low pressure reactors and so is often referred to as low pressure polyethylene. It differs from LDPE in that it contains fewer side branches at 5 to 10 per 1000 carbon atoms on the backbone. Most of the side branches are short with long side branches being rare. Molecular weights are similar to low density polyethylene but crystallinities are usually high (50 – 85%) and densities range from 940 to  $960 \text{ kg m}^{-3}$ .

## Linear low density polyethylene

Linear low density polyethylene (LLDPE) is a copolymer of ethylene with another short chain olefin. The most common co-monomers are 1-butene, 1-hexene, 4-methyl-1-pentene and 1-octene. The comonomer is usually present in concentrations of 2.5 to 3.5% and this results in densities in the range  $915$  to  $925 \text{ kg m}^{-3}$  with crystallinities of 30 to 45%. The range of molecular weights of LLDPE are considerably narrower than for LDPE and HDPE; typically they lie in the range 50,000 to 200,000.

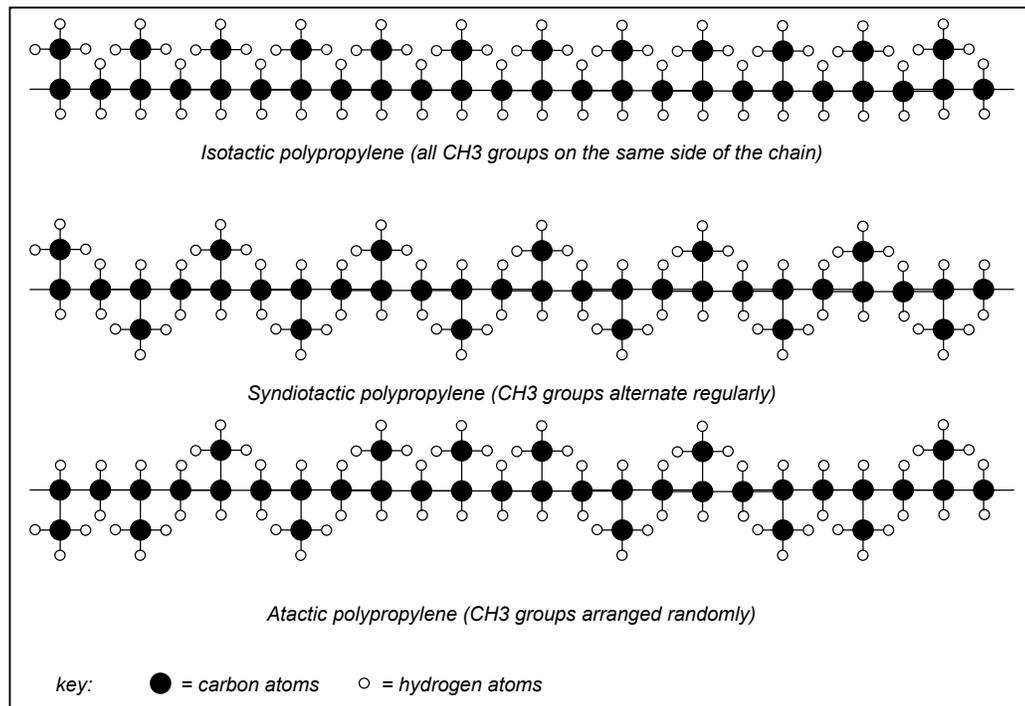
## POLYPROPYLENE

The repeat unit for polypropylene is:



The  $\text{CH}_3$  side group can be arranged in three different ways in polypropylene and the three possibilities are shown in Figure 4. In *isotactic polypropylene*, the methyl side groups all lie on the same side of the polymer chain. In three dimensions, the polymer chain forms a helix and can fold to form crystalline regions similar to Figure 3. These crystalline regions have a density of  $936 \text{ kg m}^{-3}$ . In *syndiotactic polypropylene*, the methyl side groups are arranged regularly on alternate side of the polymer chain. In three dimensions, syndiotactic polypropylene also forms a helical structure although it is more open than the isotactic form and so, although it too can fold to form crystalline regions, the crystal density is lower at  $910 \text{ kg m}^{-3}$ . In *atactic polypropylene*, the

methyl side groups are randomly arranged on either side of the chain. The resultant structure is amorphous. Of the three forms, isotactic has the most superior properties and so manufacture aims to maximise this form. Some atactic polymer is invariably produced in small quantities and this is often used as a waterproof mastic.



*Figure 4*  
*Different types of polypropylene depending on the arrangement of the methyl side group.*

## PRODUCTION PROCESSES

Three main techniques are employed in the production of polyolefins: high pressure technology, solution or slurry processes and gas phase polymerisation.

### *High pressure technology*

When monomer is held at high pressures and temperatures above the polymer melting point, the monomer/polymer mixture can act as a polymerisation medium. Initiators and catalysts can be added to this medium. This technology

is used only for LDPE and employs pressures up to 300 MPa<sup>5</sup> and temperatures up to 300°C.

There are two major problems with this type of technology. The first is the obvious one of handling materials under such high pressures and the second is that of temperature control. Two types of reactor are used to solve these problems. The *stirred autoclave* is essentially a cylindrical, thick-walled reaction vessel stirred by paddles. Because of the very thick walls needed to withstand the pressure, external heat extraction is not possible and temperature is controlled using the monomer as a heat sink. The residence time is usually less than a minute and the conversion per pass is usually less than 20%. Unreacted monomer is cooled and reused. In the *tubular reactor*, the monomer is passed along the inner of a pair of concentric tubes. Coolant passes between the inner and outer tubes. Conversion rates per pass are up to 35% and again, unreacted monomer is recovered for reuse.

### ***Solution/slurry polymerisation***

Many low molecular weight, saturated hydrocarbons will dissolve polyolefins. If the temperature is higher than the melting point of the polymer and the concentration of the polymer is low, the polymer will remain as a true solution. However, at lower temperatures and higher concentrations, the polymer will form a suspension or mobile slurry. Using solutions or slurries as the polymerisation medium requires relatively low temperatures (70 - 110°C) and relatively low pressures (1 – 5 MPa).

Reaction vessels can be either stirred tank reactors using solvents such as hexane or closed loop, cooled pipe reactors using solvents such as isopentane. In slurry reactors, the slurry concentration is usually maintained at ~25% and settling chambers at the base of the reactor allow polymer to be removed continuously. The recovered solvent is reused and conversions can be as high as 98%.

### ***Gas phase polymerisation***

A gas phase reactor is essentially a fluidised bed of dry polymer particles maintained either by stirring or by passing gas at high speeds through it. Pressures are usually relatively low at ~2MPa and temperatures are usually in the range 70 - 110°C. A variety of different configurations are used mainly to obtain an acceptable particle size and shape in the final product. Gas phase polymerisation is used for HDPE, PP and LLDPE.

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<sup>5</sup> To put these pressures in perspective, 1 atmosphere pressure is approximately 0.101MPa

## ECO-PROFILE OF HIGH DENSITY POLYETHYLENE

Data have been obtained for the production of 3.87 million tonnes of HDPE. This represents 89.7% of all West European production. The average gross energy required to produce 1 kg of high density polyethylene is 76 MJ with a range extending from 56 MJ to 91 MJ. Table 2 shows the breakdown of this gross energy and Table 3 gives these same data expressed in terms of primary fuels. Table 4 shows the energy data expressed as masses of fuels. Table 5 shows the raw materials requirements and Table 6 shows the demand for water. Table 7 shows the gross air emissions and Table 8 shows the corresponding carbon dioxide equivalents of these air emissions. Table 9 gives the emissions to water. Table 10 shows the gross solid waste generated and Table 11 gives this solid waste in EU format.

*Table 2*

*Gross energy required to produce 1 kg of high density polyethylene. (Totals may not agree because of rounding)*

Fuel type	Fuel prod'n & delivery energy (MJ)	Energy content of delivered fuel (MJ)	Energy use in transport (MJ)	Feedstock energy (MJ)	Total energy (MJ)
Electricity	5.96	2.45	0.58	-	8.98
Oil fuels	0.24	7.39	0.11	32.09	39.82
Other fuels	0.26	5.39	0.02	22.23	27.91
Totals	6.47	15.22	0.70	54.32	76.71

*Table 3*

*Gross primary fuels required to produce 1 kg of high density polyethylene.  
(Totals may not agree because of rounding)*

Fuel type	Fuel prod'n & delivery energy (MJ)	Energy content of delivered fuel (MJ)	Fuel use in transport (MJ)	Feedstock energy (MJ)	Total energy (MJ)
Coal	1.48	1.24	0.19	<0.01	2.90
Oil	0.88	7.66	0.20	32.09	40.83
Gas	1.52	6.46	0.17	22.23	30.39
Hydro	0.33	0.25	<0.01	-	0.58
Nuclear	2.07	0.93	0.13	-	3.13
Lignite	<0.01	<0.01	<0.01	-	<0.01
Wood	<0.01	<0.01	<0.01	<0.01	<0.01
Sulphur	<0.01	<0.01	<0.01	<0.01	<0.01
Biomass (solid)	0.05	0.03	<0.01	<0.01	0.09
Hydrogen	<0.01	<0.01	<0.01	-	<0.01
Recovered energy	<0.01	-1.40	<0.01	-	-1.40
Unspecified	<0.01	<0.01	<0.01	-	<0.01
Peat	0.01	0.01	<0.01	-	0.02
Geothermal	0.02	0.01	<0.01	-	0.03
Solar	<0.01	<0.01	<0.01	-	<0.01
Wave/tidal	<0.01	<0.01	<0.01	-	<0.01
Biomass (liquid/gas)	0.03	0.01	0.01	-	0.05
Industrial waste	0.02	0.01	<0.01	-	0.03
Municipal Waste	0.04	0.02	<0.01	-	0.06
Wind	0.01	0.01	<0.01	-	0.02
Totals	6.47	15.22	0.70	54.32	76.71

*Table 4*

*Gross primary fuels used to  
produce 1 kg of high density  
polyethylene expressed as mass.*

Fuel type	Input in mg
Crude oil	910000
Gas/condensate	580000
Coal	100000
Metallurgical coal	70
Lignite	3
Peat	1900
Wood	2

*Table 5  
Gross raw materials required to produce 1 kg of  
high density polyethylene.*

Raw material	Input in mg
Air	260000
Animal matter	<1
Barytes	<1
Bauxite	5
Bentonite	33
Biomass (including water)	16000
Calcium sulphate (CaSO <sub>4</sub> )	3
Chalk (CaCO <sub>3</sub> )	<1
Clay	<1
Cr	<1
Cu	<1
Dolomite	2
Fe	170
Feldspar	<1
Ferromanganese	<1
Fluorspar	<1
Granite	<1
Gravel	1
Hg	<1
Limestone (CaCO <sub>3</sub> )	130
Mg	<1
N <sub>2</sub>	170000
Ni	<1
O <sub>2</sub>	3
Olivine	2
Pb	1
Phosphate as P <sub>2</sub> O <sub>5</sub>	<1
Potassium chloride (KCl)	<1
Quartz (SiO <sub>2</sub> )	<1
Rutile	<1
S (bonded)	<1
S (elemental)	52
Sand (SiO <sub>2</sub> )	84
Shale	9
Sodium chloride (NaCl)	350
Sodium nitrate (NaNO <sub>3</sub> )	<1
Talc	<1
Unspecified	<1
Zn	15

*Table 6  
Gross water consumption required for the production of 1 kg  
of high density polyethylene. (Totals may not agree because  
of rounding)*

Source	Use for processing (mg)	Use for cooling (mg)	Totals (mg)
Public supply	1800000	160000	1900000
River canal	970000	59000	1000000
Sea	130000	11000000	11000000
Well	95000	<1	95000
Unspecified	430000	17000000	18000000
Totals	3400000	29000000	32000000

Table 7

Gross air emissions associated with the production of 1 kg of high density polyethylene. (Totals may not agree because of rounding)

Emission	From fuel prod'n (mg)	From fuel use (mg)	From transport (mg)	From process (mg)	From biomass (mg)	From fugitive (mg)	Totals (mg)
dust (PM10)	310	74	2	250	-	-	640
CO	1300	11000	21	490	-	-	12000
CO2	420000	950000	8800	190000	-2	-	1600000
SOX as SO2	2100	1400	140	510	-	-	4100
H2S	<1	-	<1	<1	-	-	<1
mercaptan	<1	<1	<1	<1	-	-	<1
NOX as NO2	1500	1500	56	170	-	-	3200
NH3	<1	-	<1	<1	-	-	<1
Cl2	<1	<1	<1	<1	-	-	<1
HCl	42	20	<1	<1	-	-	62
F2	<1	<1	<1	<1	-	-	<1
HF	2	<1	<1	<1	-	-	2
hydrocarbons not specified	740	83	17	3300	-	<1	4100
aldehyde (-CHO)	<1	-	<1	<1	-	-	<1
organics	<1	<1	<1	60	-	-	60
Pb+compounds as Pb	<1	<1	<1	<1	-	-	<1
Hg+compounds as Hg	<1	-	<1	<1	-	-	<1
metals not specified elsewhere	<1	1	<1	1	-	-	2
H2SO4	<1	-	<1	<1	-	-	<1
N2O	<1	<1	<1	<1	-	-	<1
H2	40	<1	<1	2	-	-	41
dichloroethane (DCE) C2H4Cl2	<1	-	<1	<1	-	<1	<1
vinyl chloride monomer (VCM)	<1	-	<1	<1	-	<1	<1
CFC/HCFC/HFC not specified	<1	-	<1	1	-	-	1
organo-chlorine not specified	<1	-	<1	<1	-	-	<1
HCN	<1	-	<1	<1	-	-	<1
CH4	9900	240	<1	4100	-	<1	14000
aromatic HC not specified elsewhere	<1	-	<1	85	-	<1	86
polycyclic hydrocarbons (PAH)	<1	<1	<1	<1	-	-	<1
NMVOC	<1	-	<1	150	-	-	150
CS2	<1	-	<1	<1	-	-	<1
methylene chloride CH2Cl2	<1	-	<1	<1	-	-	<1
Cu+compounds as Cu	<1	<1	<1	<1	-	-	<1
As+compounds as As	-	-	-	<1	-	-	<1
Cd+compounds as Cd	<1	-	<1	<1	-	-	<1
Ag+compounds as Ag	-	-	-	<1	-	-	<1
Zn+compounds as Zn	<1	-	<1	<1	-	-	<1
Cr+compounds as Cr	<1	<1	<1	<1	-	-	<1
Se+compounds as Se	-	-	-	<1	-	-	<1
Ni+compounds as Ni	<1	<1	<1	<1	-	-	<1
Sb+compounds as Sb	-	-	<1	<1	-	-	<1
ethylene C2H4	-	-	<1	2	-	-	2
oxygen	-	-	-	<1	-	-	<1
asbestos	-	-	-	<1	-	-	<1
dioxin/furan as Teq	-	-	-	<1	-	-	<1
benzene C6H6	-	-	-	<1	-	<1	<1
toluene C7H8	-	-	-	<1	-	<1	<1
xylenes C8H10	-	-	-	<1	-	<1	<1
ethylbenzene C8H10	-	-	-	<1	-	<1	<1
styrene	-	-	-	<1	-	<1	<1
propylene	-	-	-	1	-	-	1

*Table 8  
Carbon dioxide equivalents corresponding to the gross air emissions for the production of 1 kg of high density polyethylene. (Totals may not agree because of rounding)*

Type	From fuel prod'n (mg)	From fuel use (mg)	From transport (mg)	From process (mg)	From biomass (mg)	From fugitive (mg)	Totals (mg)
20 year equiv	1000000	990000	8900	450000	-2	<1	2500000
100 year equiv	650000	980000	8900	290000	-2	<1	1900000
500 year equiv	490000	970000	8900	230000	-2	<1	1700000

Table 9

Gross emissions to water arising from the production of 1 kg of high density polyethylene. (Totals may not agree because of rounding).

Emission	From fuel prod'n (mg)	From fuel use (mg)	From transport (mg)	From process (mg)	Totals (mg)
COD	1	-	<1	190	190
BOD	<1	-	<1	21	21
Pb+compounds as Pb	<1	-	<1	<1	<1
Fe+compounds as Fe	<1	-	<1	<1	<1
Na+compounds as Na acid as H+	<1	-	<1	77	77
NO3-	1	-	<1	1	2
Hg+compounds as Hg	<1	-	<1	2	2
metals not specified elsewhere	<1	-	<1	<1	<1
ammonium compounds as NH4+	<1	-	<1	7	7
Cl-	1	-	<1	2	3
CN-	<1	-	<1	160	160
F-	<1	-	<1	<1	<1
S+sulphides as S	<1	-	<1	<1	<1
dissolved organics (non-suspended solids)	<1	-	<1	10	10
detergent/oil	26	-	3	170	200
hydrocarbons not specified	<1	-	<1	6	6
organo-chlorine not specified	4	<1	<1	<1	4
dissolved chlorine	<1	-	<1	<1	<1
phenols	<1	-	<1	2	2
dissolved solids not specified	<1	-	<1	21	21
P+compounds as P	<1	-	<1	<1	<1
other nitrogen as N	<1	-	<1	1	1
other organics not specified	<1	-	<1	<1	<1
SO4--	<1	-	<1	830	830
dichloroethane (DCE)	<1	-	<1	<1	<1
vinyl chloride monomer (VCM)	<1	-	<1	<1	<1
K+compounds as K	<1	-	<1	1	1
Ca+compounds as Ca	<1	-	<1	3	3
Mg+compounds as Mg	<1	-	<1	<1	<1
Cr+compounds as Cr	<1	-	<1	<1	<1
ClO3--	<1	-	<1	<1	<1
BrO3--	<1	-	<1	<1	<1
TOC	<1	-	<1	11	11
AOX	<1	-	<1	<1	<1
Al+compounds as Al	<1	-	<1	1	1
Zn+compounds as Zn	<1	-	<1	<1	<1
Cu+compounds as Cu	<1	-	<1	<1	<1
Ni+compounds as Ni	<1	-	<1	<1	<1
CO3--	-	-	<1	29	29
As+compounds as As	-	-	<1	<1	<1
Cd+compounds as Cd	-	-	<1	<1	<1
Mn+compounds as Mn	-	-	<1	<1	<1
organo-tin as Sn	-	-	<1	<1	<1
Sr+compounds as Sr	-	-	<1	<1	<1
organo-silicon	-	-	-	<1	<1
benzene	-	-	-	<1	<1
dioxin/furan as Teq	-	-	<1	<1	<1

Table 10

Gross solid waste associated with the production of 1 kg of high density polyethylene. (Totals may not agree because of rounding)

Emission	From fuel prod'n (mg)	From fuel use (mg)	From transport (mg)	From process (mg)	Totals (mg)
Plastic containers	<1	-	<1	<1	<1
Paper	<1	-	<1	<1	<1
Plastics	<1	-	<1	630	630
Metals	<1	-	<1	<1	<1
Putrescibles	<1	-	<1	<1	<1
Unspecified refuse	990	-	<1	<1	990
Mineral waste	24	-	33	140	190
Slags & ash	7600	850	13	840	9400
Mixed industrial	-270	-	1	1100	860
Regulated chemicals	1200	-	<1	820	2000
Unregulated chemicals	910	-	<1	2000	2900
Construction waste	<1	-	<1	<1	<1
Waste to incinerator	<1	-	<1	870	870
Inert chemical	<1	-	<1	720	720
Wood waste	<1	-	<1	<1	<1
Wooden pallets	<1	-	<1	<1	<1
Waste to recycling	<1	-	<1	4500	4500
Waste returned to mine	20000	-	1	51	20000
Tailings	1	-	1	60	62
Municipal solid waste	-5500	-	-	<1	-5500
Note: Negative values correspond to consumption of waste e.g. recycling or use in electricity generation.					

Table 11

Gross solid waste in EU format associated with the production of 1 kg of high density polyethylene. Entries marked with an asterisk (\*) are considered hazardous as defined by EU Directive 91/689/EEC

Emission	Totals (mg)
010101 metallic min'l excav'n waste	140
010102 non-metal min'l excav'n waste	20000
010306 non-010304/010305 tailings	2
010308 non-010307 powdery wastes	2
010399 unspecified met. min'l wastes	1
010408 non-010407 gravel/crushed rock	<1
010410 non-010407 powdery wastes	<1
010411 non-010407 potash/rock salt	1
010499 unsp'd non-met. waste	<1
010505*oil-bearing drilling mud/waste	1200
010508 non-010504/010505 chloride mud	910
010599 unspecified drilling mud/waste	990
020107 wastes from forestry	<1
050106*oil ind. oily maint'e sludges	3
050107*oil industry acid tars	210
050199 unspecified oil industry waste	190
050699 coal pyrolysis unsp'd waste	16
060101*H2SO4/H2SO3 MFSU waste	<1
060102*HCl MFSU waste	<1
060106*other acidic MFSU waste	<1
060199 unsp'd acid MFSU waste	<1
060204*NaOH/KOH MFSU waste	<1
060299 unsp'd base MFSU waste	<1
060313*h. metal salt/sol'n MFSU waste	1
060314 other salt/sol'n MFSU waste	<1
060399 unsp'd salt/sol'n MFSU waste	3
060404*Hg MFSU waste	<1
060405*other h. metal MFSU waste	<1
060499 unsp'd metallic MFSU waste	<1
060602*dangerous sulphide MFSU waste	<1
060603 non-060602 sulphide MFSU waste	<1
060701*halogen electrol. asbestos waste	<1
060702*Cl pr. activated C waste	<1
060703*BaSO4 sludge with Hg	<1
060704*halogen pr. acids and sol'ns	<1
060799 unsp'd halogen pr. waste	<1
061002*N ind. dangerous sub. waste	<1
061099 unsp'd N industry waste	<1
070101*organic chem. aqueous washes	<1
070103*org. halogenated solv'ts/washes	<1
070107*hal'd still bottoms/residues	<1
070108*other still bottoms/residues	7
070111*org. chem. dan. eff. sludge	<1
070112 non-070111 effluent sludge	<1
070199 unsp'd organic chem. waste	13
070204*polymer ind. other washes	<1

continued over .....

Table 11 - continued

Gross solid waste in EU format associated with the production of 1 kg of high density polyethylene. Entries marked with an asterisk (\*) are considered hazardous as defined by EU Directive 91/689/EEC

070207*polymer ind. hal'd still waste	<1
070208*polymer ind. other still waste	3000
070209*polymer ind. hal'd fil. cakes	<1
070213 polymer ind. waste plastic	3800
070214*polymer ind. dan. additives	1400
070215 non-0702130 additive waste	130
070216 polymer ind. silicone wastes	<1
070299 unsp'd polymer ind. waste	1200
080199 unspecified paint/varnish waste	<1
100101 non-100104 ash, slag & dust	8200
100102 coal fly ash	1000
100104*oil fly ash and boiler dust	<1
100105 FGD Ca-based reac. solid waste	<1
100113*emulsified hydrocarbon fly ash	<1
100114*dangerous co-incin'n ash/slag	46
100115 non-100115 co-incin'n ash/slag	3
100116*dangerous co-incin'n fly ash	<1
100199 unsp'd thermal process waste	<1
100202 unprocessed iron/steel slag	52
100210 iron/steel mill scales	4
100399 unspecified aluminium waste	<1
100501 primary/secondary zinc slags	<1
100504 zinc pr. other dust	<1
100511 non-100511 Zn pr. skimmings	<1
101304 lime calcin'n/hydration waste	5
130208*other engine/gear/lub. oil	<1
150101 paper and cardboard packaging	<1
150102 plastic packaging	<1
150103 wooden packaging	<1
150106 mixed packaging	<1
170107 non-170106 con'e/brick/tile mix	<1
170904 non-170901/2/3 con./dem'n waste	<1
190199 unspecified incin'n/pyro waste	<1
190905 sat./spent ion exchange resins	720
200101 paper and cardboard	<1
200108 biodeg. kitchen/canteen waste	<1
200138 non-200137 wood	<1
200139 plastics	<1
200140 metals	<1
200199 other separately coll. frac'ns	-1300
200301 mixed municipal waste	1
200399 unspecified municipal wastes	-4400
Note: Negative values correspond to consumption of waste e.g. recycling or use in electricity generation.	