Eco-profiles of the
European Plastics Industry

POLYVINYLIDENE CHLORIDE (PVdC)

A report by

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for

Plastics*Europe*

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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.

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POLYVINYLIDENE CHLORIDE

Polyvinylidene chloride (PVdC) is a semi-crystalline thermoplastic with the structural formula shown in Figure 1. As can be seen, the structure is similar to that of polyethylene except that alternate carbon atoms have two chlorine atoms attached instead of hydrogen atoms.

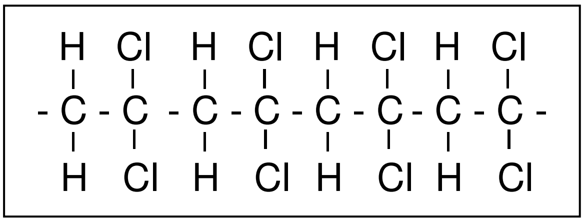

Figure 1
Structural formula of polyvinylidene chloride.

The most valuable property of PVdC is its very low permeability to gases, water vapour, aromas and fats under both wet and dry conditions. It is therefore widely used as a barrier layer in many packaging applications, especially in the food and beverage industries; about 85% of all PVdC is used in food packaging.

The polymer is commonly produced as a co-polymer with monomers such as vinyl chloride, methyl acrylate, methyl methacrylate and acrylonitrile. In general, the higher the vinylidene chloride content of the co-polymer, the higher the barrier properties.

The polymer is produced as an aqueous dispersion, as a solid resin for use in solvents, as a lacquer and as an extrudable granulate. Aqueous dispersions are used to coat paper, board, polyethylene terephthalate (PET) films and bottles, and oriented polypropylene film (OPP). Lacquers are employed as heat sealable barrier coatings on cellophane and other plastics films, while the extrudable resin can be converted into barrier films or co-extruded with other polymers into barrier films and sheets.

PRODUCTION OF PVdC

Vinylidene chloride monomer is produced by reacting vinyl chloride with further chlorine. The monomer is readily polymerised with the polymerisation conditions being governed by the form of the final polymer.

ECO-PROFILE OF PVdC

Table 1 shows the gross or cumulative energy to produce 1 kg of polyvinylidene chloride (PVdC) and Table 2 gives this same data expressed in terms of primary fuels. Table 3 shows the energy data expressed as masses of fuels. Table 4 shows the raw materials requirements and Table 5 shows the demand for water. Table 6 shows the gross air emissions and Table 7 shows the corresponding carbon dioxide equivalents of these air emissions. Table 8 shows the emissions to water. Table 9 shows the solid waste generated and Table 10 gives the solid waste in EU format.

Table 1
Gross energy required to produce 1 kg of polyvinylidene chloride (PVdC). (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	15.26	7.25	0.45	-	22.97
Oil fuels	0.78	8.42	0.28	11.90	21.38
Other fuels	1.33	25.13	0.18	9.61	36.26
Totals	17.38	40.80	0.92	21.51	80.60

Table 2
Gross primary fuels required to produce 1 kg of polyvinylidene chloride (PVdC). (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	4.63	7.39	0.12	1.29	13.43
Oil	1.64	8.96	0.59	11.90	23.09
Gas	3.53	20.80	0.11	8.30	32.74
Hydro	0.84	0.63	<0.01	-	1.47
Nuclear	6.32	3.00	0.08	-	9.41
Lignite	0.04	0.02	<0.01	-	0.06
Wood	<0.01	<0.01	<0.01	0.03	0.03
Sulphur	<0.01	<0.01	<0.01	-0.01	-0.01
Biomass (solid)	0.05	0.03	<0.01	<0.01	0.08
Hydrogen	<0.01	1.00	<0.01	-	1.00
Recovered energy	<0.01	-1.18	<0.01	-	-1.18
Unspecified	<0.01	<0.01	<0.01	-	<0.01
Peat	<0.01	<0.01	<0.01	-	<0.01
Geothermal	0.09	0.04	<0.01	-	0.13
Solar	<0.01	<0.01	<0.01	-	<0.01
Wave/tidal	<0.01	<0.01	<0.01	-	<0.01
Biomass (liquid/gas)	0.05	0.02	<0.01	-	0.07
Industrial waste	0.05	0.02	<0.01	-	0.07
Municipal Waste	0.09	0.04	<0.01	-	0.14
Wind	0.04	0.02	<0.01	-	0.06
Totals	17.38	40.80	0.92	21.51	80.60

Table 3
Gross primary fuels used to produce 1 kg of polyvinylidene chloride (PVdC) expressed as mass.

Fuel type	Input in mg
Crude oil	510000
Gas/condensate	630000
Coal	470000
Metallurgical coal	210
Lignite	4100
Peat	260
Wood	3500

Table 4
Gross raw materials required to produce 1 kg of polyvinylidene chloride (PVdC).

Raw material	Input in mg
Air	360000
Animal matter	<1
Barytes	1200
Bauxite	5
Bentonite	17
Biomass (including water)	18000
Calcium sulphate (CaSO4)	2
Chalk (CaCO3)	<1
Clay	14
Cr	<1
Cu	55
Dolomite	6
Fe	530
Feldspar	<1
Ferromanganese	<1
Fluorspar	9
Granite	<1
Gravel	2
Hg	8
Limestone (CaCO3)	690000
Mg	<1
N2	57000
Ni	<1
O2	53000
Olivine	5
Pb	4
Phosphate as P2O5	1
Potassium chloride (KCl)	8200
Quartz (SiO2)	<1
Rutile	<1
S (bonded)	<1
S (elemental)	-780
Sand (SiO2)	2400
Shale	5
Sodium chloride (NaCl)	1500000
Sodium nitrate (NaNO3)	<1
Talc	<1
Unspecified	<1
Zn	<1

Table 5
Gross water consumption required for the production of 1 kg of polyvinylidene chloride (PVdC). (Totals may not agree because of rounding)

Source	Use for processing (mg)	Use for cooling (mg)	Totals (mg)
Public supply	9500000	-	9500000
River canal	240000	23000000	23000000
Sea	75000	6700000	6800000
Well	44000	43000	88000
Unspecified	17000000	99000000	116000000
Totals	27000000	128000000	155000000

Table 6
Gross air emissions associated with the production of 1 kg of polyvinylidene chloride (PVdC). (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)	1300	520	18	6900	-	-	8700
CO	2100	1000	200	6600	-	-	9900
CO2	1100000	2300000	33000	360000	-3200	-	3800000
SOX as SO2	7200	10000	300	330	-	-	18000
H2S	<1	-	<1	<1	-	-	<1
mercaptan	<1	<1	<1	<1	-	-	<1
NOX as NO2	3300	5400	290	250	-	-	9200
NH3	<1	-	<1	2	-	-	2
Cl2	<1	<1	<1	980	-	-	980
HCl	130	97	<1	28	-	-	250
F2	<1	<1	<1	<1	-	-	<1
HF	5	4	<1	<1	-	-	8
hydrocarbons not specified	1600	670	81	510	-	<1	2800
aldehyde (-CHO)	<1	-	<1	<1	-	-	<1
organics	<1	<1	<1	810	-	-	810
Pb+compounds as Pb	<1	<1	<1	<1	-	-	<1
Hg+compounds as Hg	<1	-	<1	1	-	-	1
metals not specified elsewhere	2	5	<1	<1	-	-	7
H2SO4	<1	-	<1	<1	-	-	<1
N2O	<1	<1	<1	<1	-	-	<1
H2	70	<1	<1	4300	-	-	4400
dichloroethane (DCE) C2H4Cl2	<1	-	<1	29	-	6	35
vinyl chloride monomer (VCM)	<1	-	<1	15	-	2	17
CFC/HCFC/HFC not specified	<1	-	<1	18	-	-	18
organo-chlorine not specified	<1	-	<1	7800	-	-	7800
HCN	<1	-	<1	<1	-	-	<1
CH4	24000	1200	<1	1400	-	<1	27000
aromatic HC not specified elsewhere	<1	-	1	13	-	<1	14
polycyclic hydrocarbons (PAH)	<1	<1	<1	<1	-	-	<1
NMVOC	<1	-	<1	24	-	-	25
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	11	-	-	11
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 7
Carbon dioxide equivalents corresponding to the gross air emissions for the production of 1 kg of polyvinylidene chloride (PVdC). (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	2600000	2400000	33000	470000	-3200	<1	5500000
100 year equiv	1600000	2300000	33000	410000	-3200	<1	4400000
500 year equiv	1300000	2300000	33000	390000	-3200	<1	4000000

Table 8

Gross emissions to water arising from the production of 1 kg of polyvinylidene chloride (PVdC). (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	7	-	<1	2400	2400
BOD	1	-	<1	58	58
Pb+compounds as Pb	<1	-	<1	<1	<1
Fe+compounds as Fe	<1	-	<1	1	1
Na+compounds as Na	<1	-	<1	52000	52000
acid as H+	8	-	<1	44	52
NO3-	<1	-	<1	1	1
Hg+compounds as Hg	<1	-	<1	<1	<1
metals not specified elsewhere	2	-	<1	150	160
ammonium compounds as NH4+	7	-	<1	3	11
Cl-	1	-	<1	440000	440000
CN-	<1	-	<1	<1	<1
F-	<1	-	<1	<1	<1
S+sulphides as S	<1	-	<1	<1	<1
dissolved organics (non-	1	-	<1	52	53
suspended solids	120	-	32	70000	70000
detergent/oil	<1	-	<1	3	3
hydrocarbons not specified	2	<1	<1	<1	2
organo-chlorine not specified	<1	-	<1	9000	9000
dissolved chlorine	<1	-	<1	4	4
phenols	<1	-	<1	1	1
dissolved solids not specified	<1	-	<1	30000	30000
P+compounds as P	<1	-	<1	4	4
other nitrogen as N	2	-	<1	7	9
other organics not specified	<1	-	<1	1100	1100
SO4--	<1	-	<1	8100	8100
dichloroethane (DCE)	<1	-	<1	1	1
vinyl chloride monomer (VCM)	<1	-	<1	75	75
K+compounds as K	<1	-	<1	260	260
Ca+compounds as Ca	<1	-	<1	210000	210000
Mg+compounds as Mg	<1	-	<1	7	7
Cr+compounds as Cr	<1	-	<1	<1	<1
ClO3--	<1	-	<1	500	500
BrO3--	<1	-	<1	1	1
TOC	<1	-	<1	42	42
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	1700	1700
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 9
Gross solid waste associated with the production of 1 kg of polyvinylidene chloride (PVdC). (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	20000	20000
Metals	<1	-	<1	<1	<1
Putrescibles	<1	-	<1	<1	<1
Unspecified refuse	2300	-	<1	<1	2300
Mineral waste	1000	-	320	71000	72000
Slags & ash	22000	110000	120	9200	140000
Mixed industrial	-1300	-	13	3800	2600
Regulated chemicals	2900	-	<1	90000	93000
Unregulated chemicals	2200	-	<1	53000	55000
Construction waste	<1	-	<1	75	75
Waste to incinerator	<1	-	<1	2300	2300
Inert chemical	35	-	<1	19000	19000
Wood waste	<1	-	<1	69	69
Wooden pallets	<1	-	<1	<1	<1
Waste to recycling	<1	-	<1	460	460
Waste returned to mine	91000	-	12	4400	95000
Tailings	2	-	11	2200	2200
Municipal solid waste	-13000	-	-	<1	-13000
Note: Negative values correspond to consumption of waste e.g. recycling or use in electricity generation.					

Table 10
Gross solid waste in EU format associated with the production of 1 kg of polyvinylidene chloride (PVdC). 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	1300
010102 non-metal min'l excav'n waste	150000
010306 non 010304/010305 tailings	16
010308 non-010307 powdery wastes	12
010399 unspecified met. min'l wastes	300
010408 non-010407 gravel/crushed rock	57
010410 non-010407 powdery wastes	<1
010411 non-010407 potash/rock salt	9400
010499 unsp'd non-met. waste	2
010505*oil-bearing drilling mud/waste	2800
010508 non-010504/010505 chloride mud	2200
010599 unspecified drilling mud/waste	2300
020107 wastes from forestry	69
050106*oil ind. oily maint'e sludges	2
050107*oil industry acid tars	79
050199 unspecified oil industry waste	150
050699 coal pyrolysis unsp'd waste	170
060101*H2SO4/H2SO3 MFSU waste	15
060102*HCl MFSU waste	6
060106*other acidic MFSU waste	<1
060199 unsp'd acid MFSU waste	<1
060201*Ca(OH)2 MFSU waste	100000
060204*NaOH/KOH MFSU waste	<1
060299 unsp'd base MFSU waste	980
060313*h. metal salt/sol'n MFSU waste	9200
060314 other salt/sol'n MFSU waste	1100
060399 unsp'd salt/sol'n MFSU waste	740
060404*Hg MSFU waste	410
060405*other h. metal MFSU waste	1800
060499 unsp'd metallic MFSU waste	3100
060602*dangerous sulphide MFSU waste	<1
060603 non-060602 sulphide MFSU waste	-2
060701*halogen electrol. asbestos waste	250
060702*Cl pr. activated C waste	<1
060703*BaSO4 sludge with Hg	46
060704*halogen pr. acids and sol'ns	240
060799 unsp'd halogen pr. waste	3300
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	88000
070108*other still bottoms/residues	27
070111*org. chem. dan. eff. sludge	13
070112 non-070111 effluent sludge	<1
070199 unsp'd organic chem. waste	46000
070203*polymer ind. org. hal'd washes	35
070204*polymer ind. other washes	<1
070207*polymer ind. hal'd still waste	1100

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Table 10 - continued
Gross solid waste in EU format associated with the production of 1 kg of polyvinylidene chloride (PVdC). Entries marked with an asterisk (*) are considered hazardous as defined by EU Directive 91/689/EEC

070208*polymer ind. other still waste	480
070209*polymer ind. hal'd fil. cakes	<1
070213 polymer ind. waste plastic	<1
070214*polymer ind. dan. additives	150
070216 polymer ind. silicone wastes	<1
070299 unsp'd polymer ind. waste	19000
080199 unspecified paint/varnish waste	<1
100101 non-100104 ash, slag & dust	29000
100102 coal fly ash	190
100104*oil fly ash and boiler dust	<1
100105 FGD Ca-based reac. solid waste	35
100113*emulsified hyrdocarbon fly ash	<1
100114*dangerous co-incin'n ash/slag	260
100115 non-100115 co-incin'n ash/slag	2900
100116*dangerous co-incin'n fly ash	13
100199 unsp'd themal process waste	120
100202 unprocessed iron/steel slag	160
100210 iron/steel mill scales	12
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	2
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	19000
200101 paper and cardboard	<1
200108 biodeg. kitchen/canteen waste	<1
200138 non-200137 wood	<1
200139 plastics	460
200140 metals	<1
200199 other separately coll. frac'ns	-3600
200301 mixed municipal waste	2
200399 unspecified municipal wastes	-11000
Note: Negative values correspond to consumption of waste e.g. recycling or use in electricity generation.	

PVdC IN USE

It was noted earlier that PVdC is most commonly used as a barrier layer applied to packaging films made from other polymers. This application is quite different from the use of most other polymers, which are fabricated into the final component. As a consequence, the contribution that PVdC makes to the overall environmental burden in any application is significantly less than these other polymers because of the relatively small quantities used in the final application.

For example, oriented polypropylene film, which is typically 20 to 50 μm thick, can be coated with PVdC to a thickness between 1.8 and 3.3 μm although the thickness usually applied is in the range 2.0 to 2.5 μm.

The benefits of applying a PVdC coating are best put into perspective by considering the properties that the barrier layer imparts to the film. The permeability of coated polypropylene film to oxygen obviously depends on the thickness of the PVdC coating but in the typical thicknesses currently applied commercially (2.0 to 2.5 μm) the permeability of the film to oxygen is reduced by a factor of 50. Thus an uncoated film would need to have its thickness increased by a factor of 50 to produce an equivalent effect (i.e. 1.0 to 2.5 mm). Such an uncoated film would have a gross production energy of the order of 3700 MJ compared with 96 MJ for a coated film with equivalent permeability properties. Quite apart from the energy difference it is also clear that the thickness of the uncoated film is such that it would be unsuitable for many, if not most, applications.