Eco-profile of Aromatic Polyester Polyols (APP)

PU Europe

June 2021

1 Summary

This Eco-profile has been prepared according to **Eco-profiles program and methodology –PlasticsEurope – V3.0 (2019)**.

It provides environmental performance data representative of the average European production of 2019 for **the declared unit of 1 kg unpacked aromatic polyester polyols (APP)** from cradle-to-gate **(from crude oil extraction to liquid resin at plant, i.e. APP production site output).**

The goal was to update the existing ISO 14040/44-compliant cradle-to-gate Eco-profile for APP and the life cycle inventories published in 2016 [PU Europe 2016 APP], through compiling up-to-date and consistent high-quality average industry data and combining it with the updated data from the GaBi databases.

Please keep in mind that comparisons cannot be made on the level of the polymer material alone: it is necessary to consider the full life cycle of an application in order to compare the performance of different materials and the effects of relevant life cycle parameters. It is intended to be used by member companies, to support product-orientated environmental management; by users of plastics, as a building block of life cycle assessment (LCA) studies of individual products; and by other interested parties, as a source of life cycle information.

Meta Data

Data Owner	PU Europe aisbl
LCA Practitioner	Sphera Solutions GmbH
Programme Owner	PlasticsEurope AISBL
Reviewer	Angela Schindler, Umweltberatung, Salem
Number of plants included in data collection	6
Representativeness	75-85 % coverage in terms of production volumes in Europe
Reference year	2019
Year of data collection and calculation	2020
Expected temporal validity	2026
Cut-offs	No significant cut-offs
Data Quality	Good
Allocation method	Price allocation (for one of the products)

Description of the Product and the Production Process

Aromatic Polyester Polyols (APP) comprises a group of products which are polymers. Therefore, neither a CAS number, nor an IUPAC name, nor a chemical formula can be stated.

APP are hydroxy-terminated polymers based in ester-repeating units and containing phenylene groups. They are obtained from the polycondensation reaction between dicarboxylic acids and diols/triols. They can also contain other raw materials such as natural oils. APP structure can have a great versatility, in terms of molecular weight and functionality (with minimum 2 reactive groups per molecule), due to the broad range of different monomers that can be used in the Polycondensation reaction. In this Eco-profile, the “hydroxyl value“ is given as a range as an information on the covered APP. This is as a measure of the hydroxyl group content (in mg KOH/g of polyol). The higher the hydroxyl number of the polyol, the greater the crosslinking in polyurethane production. More crosslinking leads to harder, stiffer products with higher chemical and thermal resistance.

Polyols end-capped with 2 hydroxyl (OH) groups are named diols; with 3 OH groups they are called triols, and with 4 hydroxyl groups they are called tetrols.

The following products are considered:

- HOOPOL (Synthesia), Spain
- ISOEXTER (COIM), Italy
- LUPRAPHEN (BASF), Germany
- POLIOS (Purinova), Poland
- STEPANPOL (Stepan), Germany
- TERATE POLYOLS (Stepan), Netherlands

Polyester Polyols are important intermediate products for many production chains. APPs are used to manufacture polyisocyanurate (PIR) and polyurethane (PUR) rigid insulation foam, which finds extensive use in the automotive, construction, refrigeration and other industrial sectors. Other uses include flexible polyurethane foams, semi-rigid foams, and polyurethane coatings. A major part of the world's polyols production is shared by two groups of polyols, namely polyether and polyester polyols.

Production Process

Aromatic polyester polyols result from the polycondensation from a variety of potential input materials such as di- or trifunctional glycols, e.g. diethylene glycol and aromatic anhydrides, e.g. phthalic anhydrides. Also, the production technology can differ from producer to producer. For more details, see the long version of this Eco-profile.

The reference flow, to which all data given in this Eco-profile refer, is 1 kg of average aromatic polyester polyols (APP).

Data Sources and Allocation

The main data source is a primary data collection from European producers of APP, providing site-specific gate-to-gate production data for processes under the operational control of the participating companies: 5 producers with 6 plants / 6 products in 5 different European countries.

This covers more than 75-85 % of a total market of more than 200,000 t of the European APP production in 2019.

All relevant background data for the upstream supply chain until the precursors as well as energy and auxiliary materials are taken from the database version SP 40 GaBi 2020 (https://gabi.sphera.com) of the software system GaBi 10 [SPHERA 2020].

For one of the six products, economic allocation has been applied. This has been preferred over mass allocation since the economic value of the co-product is significantly less than of the main product APP. For the other products, no allocation has been applied as there is only one product.

Use Phase and End-of-Life Management

Due to high resistance to light and thermal aging, as well as thermal stability of polyurethane produced with APPs, the polyurethane/polyisocyanurate (PUR/PIR, in the following the common term for both PU is applied) products are used for paints, coating materials and flame-retarded rigid foams. They also may be formulated into adhesives, sealants, and elastomers.

Polyurethanes are made from polyols e.g. APPs and polyisocyanates. Typical isocyanates used include polymeric methylene diphenyl diisocyanate (PMDI) in rigid foam applications. Toluene diisocyanate (TDI) is used in flexible foam applications. Monomeric MDI is used in adhesive, coating, sealant, and elastomer applications. Flame retardants may be included in the APP batch and/or added separately during PUR production. This Eco-profile refers to APP without flame retardant additions.

Rigid polyurethane foams produced from MDI and polyester polyols have excellent thermal insulation and fire-retardancy properties and are used in building & construction and automotive applications.

When used in thermal insulation products, the use phase results in substantial energy savings of buildings / technical installations / fridges over their use phase.

Most of the production waste (and some installation off-cuts) is recycled.

Post-consumer recycling of polyurethane products is a practice which is spreading in more and more countries for applications where high volumes are available and which could include collection and sorting. A range of mechanical (regrinding, bonding, pressing, and moulding) and chemical (glycolysis, hydrolysis, pyrolysis) recycling technologies are available to produce alternative products and chemical compounds for subsequent domestic, industrial and chemical applications.

For all post-consumer polyurethane waste, for which recycling has not proven to be economically feasible due to contamination and/or complex collection and/or dismantling steps (e.g. automotive shredding), energy recovery today is still the option of choice. However, as society moves towards a circular economy in the coming decades the level of energy recovery will decrease and increasingly more sectors will initiate recycling projects for post-consumer PU waste.

Environmental Performance

The tables below show the environmental performance indicators associated with the production of 1 kg of aromatic polyester polyols (APP).

Input Parameters

Indicator	Unit	Value	Impact method ref.
Non-renewable energy resources[1)]			
• Fuel energy	MJ	35.1	Gross calorific value
• Feedstock energy[2)]	MJ	ca. 22.5	Gross calorific value
Renewable energy resources (biomass)[1)]			
• Fuel energy	MJ	2.83	Gross calorific value
• Feedstock energy	MJ	0.00	Gross calorific value
Abiotic Depletion Potential			
• Elements	kg Sb eq	6.00E-07	CML (Jan.2016)
• Fossil fuels	MJ	52.0	CML (Jan.2016)
Renewable materials (biomass)	kg	2.56E-12	n.a.
Water[3)]			
• Use	kg	686	Blue water use
• Consumption	kg	30.5	Blue water consumption

1) Calculated as upper heating value (UHV)
2) Since this value cannot be retrieved directly from the LCA model, it was assumed to be equal the upper calorific value.
3) Water use and consumption now refer to the complete cradle-to-gate system boundaries; whereas in the Eco-profile for APP from 2016 these values referred to the foreground system only.

Output Parameters

Indicator	Unit	Value	Impact method ref.
GWP	kg CO_2 eq.	1.63	CML 2016
ODP	g CFC-11 eq.	8.62E-12	CML 2016
AP	g SO_2 eq.	5.69	CML 2016
POCP	g Ethene eq.	0.71	CML 2016
EP	g PO_4^{3-} eq.	0.84	CML 2016
Dust/particulate matter[4)]	g PM10	1.45E-03	-
Total particulate matter[4)]	g	0.20	-
Waste[5)]			
• Non-hazardous	kg	1.20	-
• Hazardous	kg	3.97E-04	-

4) Including secondary PM10
5) Waste values refer to the complete cradle-to-gate system boundaries; whereas in the Eco-profile for APP from 2016 these values referred to the foreground system only.

Additional Environmental and Health Information

This part has been written under the only responsibility of the Data owner and is not part of the LCA practitioner and reviewer work.

Additional Technical Information

This part has been written under the only responsibility of the Data owner and is not part of the LCA practitioner and reviewer work.

APP are a raw material for polyurethane materials. The intrinsic product qualities of polyurethanes are lightweight; strong; durable; resistant to abrasion and corrosion and superior thermal insulation performance.

The incorporated aromatic acid provides thermal stability which allows the rigid foam to meet typical building code flammability tests. The structure of the aromatic ring also provides hydrolysis resistance to the final product.

The scope of this APP Eco-profile does not cover flame retardants which may be added to APP for their supply to customers. This is consistent with the previous approach taken for the 2016 study. As many application areas of APP require different amounts of flame retardant, the input of flame retardant (including its potential environmental burdens) can be easily added afterwards since it is physically mixed and does not require a chemical linkage.

Additional Economic Information

This part has been written under the only responsibility of the Data owner and is not part of the LCA practitioner and reviewer work.

As part of the formulation of rigid polyurethane thermal insulation products, APP enables substantial energy savings of buildings / technical installations / fridges over their use phase.

Programme Owner

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For copies of this Eco-profile, for the underlying LCI data ; and for additional information, please refer to www.pu-europe.eu or to http://www.plasticseurope.org/.

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References

PlasticsEurope: Eco-profiles and environmental declarations – LCI methodology and PCR for uncompounded polymer resins and reactive polymer precursors (version 3.0, October 2019).