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LCA OF LIQUID EPOXY RESIN PRODUCED BASED ON PROPYLENE AND ON GLYCERINE

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Abstract: This study compares environmental impacts of production of liquid epoxy resin (LER) produced from epichlorohydrin based on propylene with LER from epichlorohydrin based on glycerin. Environmental impacts are compared based on life cycle assessment (LCA) of both products. System boundary is defined as cradle to gate, including raw material acquisition, production, transportation, use, recycling/disposal and energy and ancillary material supply operations. Elementary flows constitute the whole input and output of a product system, i.e. material or energy which is drawn from the environment or which is discarded to the environment without subsequent human transformation. The end-of-life phase of LER was not evaluated as the study is oriented on the production and use-phase scenarios of and LER are numerous with substantial differences. LCI modeling includes system extension to ancillary processes so that LCI datasets are mainly composed of elementary flows. Glycerin based LER express lower environmental impact in all assessed impact categories. Carbon footprint (global warming potential – GWP) of LER-P production is 8693 kg CO_2 – Equiv./1000 kg of LER and GWP of LER-G production is 4630 kg CO_2 – Equiv./ 1000 kg of LER. Environmental benefits of LER-G production in compare to LER-P production are of similar extend in other impact categories.

Keywords: *liquid epoxy resin, LCA, life cycle assessment, carbon footprint, LCA of chemicals production, EPD, environmental product declaration*

INTRODUCTION

The epoxy resins are used in a wide variety of applications. Through its properties as toughness, adhesion, chemical resistance, heat resistance and electrical resistance they are used for protective coating, flooring, tooling, embedding, casting and molding, producing of laminates, adhesives and composites, in civil engineering and automotive industry. Final resin based compositions are used in building, electrotechnical and consumer goods industry. Synthetic resins are used for the manufacture of coating compositions, in building industry (masonry primers, insulation and coating compositions, poured resin floorings, polymer concrete and polymer mortars, jointing compounds, putty coats, and joint cements), in electrotechnical, consumer goods, and in other industries. This publication shortly reports results of life cycle assessment (LCA) of two different synthesis technologies of LER production: LER-P based on propylene (conventional) and LER-G based on glycerin (SPOLCHEMIE new patented technology).

A production of liquid LER is based on epichlorohydrin (ECH). The preparation of ECH is realized in own reactors from propylene and since 2007 from parallel processes from glycerin. Both processes are now operated in parallel where ancillary output HCl from one system are used in the second one (Fig. 1).

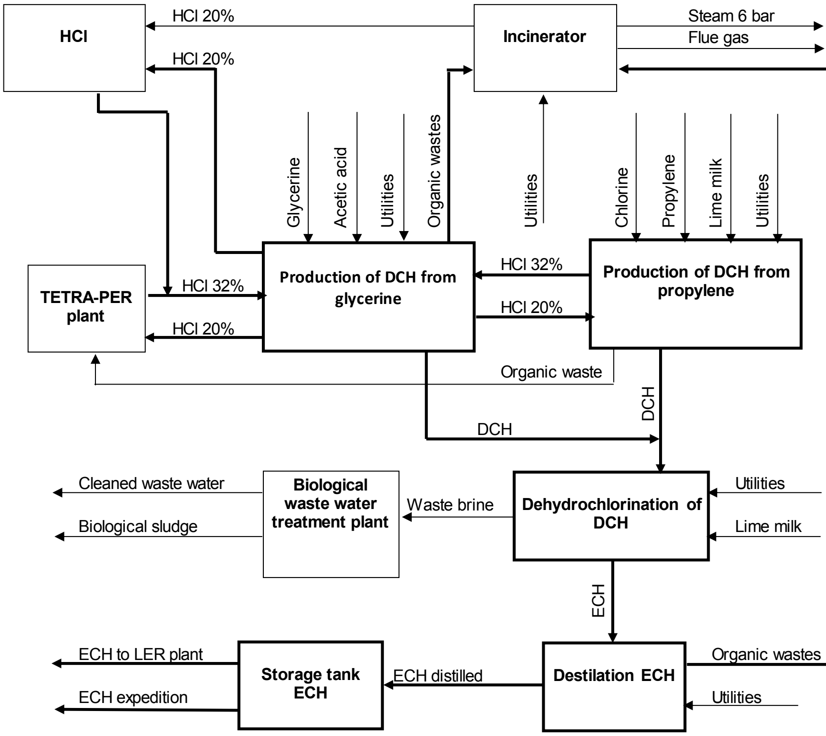

Fig. 1: Schema of epichlorohydrin production

Epichlorohydrin is transferred from a storage tank via a pipeline into reactor. Bisphenol A (BPA) is transferred from big-bags or silo-trucks via feed hopper into reactor. Bisphenol A and epichlorohydrin are mixed in reactor. The mixture is heated to specific temperature and 50% NaOH is added to start the etherification. The mixture is cooled to keep specified temperature and after the reaction is completed the reaction product is sent into second reactor. After heating and evacuating, 50% NaOH is added continuously to start the first dehydrochlorination. The by-produced water is azeotropically evaporated with epichlorohydrin, condensed and sent to the separator. Separated epichlorohydrin is recycled into reactor. Water is sent to epichlorohydrin recovery system, where epichlorohydrin is azeotropically distilled with water. Recovered epichlorohydrin is reused in first reactor for a new batch; water is collected and sent to the wastewater treatment. After completion of the first dehydrochlorination process, unreacted epichlorohydrin is withdrawn under vacuum distillation and steam distillation from and is prepared for new batch. The crude epoxy resin containing NaCl is transferred into subsequent reactor. After feeding hot water and toluene, the crude epoxy resins are sent into reactor and are mixed to extract NaCl. Saturated salty water is separated and sent to a waste water pit. Water, 50% NaOH and TEBACl (benzyltriethylamonium chloride) are added to start the second dehydrochlorination. After the reaction toluene is added to make toluene solution of the resin. The mixture is separated by the gravity to two phases (toluene and water phase). The bottom water phase containing NaCl is withdrawn and sent to the wastewater pit, and then the first part of gel phase is separated and sent to gel machine, where gels are separated and the rest is reused in next batch. The toluene phase containing resin is sent into neutralization and washing reactor. The resin solution in toluene is mixed and is neutralized by NaH_2PO_4. Hot water is fed to remove remaining salt and impurities from solution. After separation the bottom water phase is withdrawn and is sent to the wastewater pit, the interlayer is processed in gel machine and the toluene phase containing resin is transferred into concentrate drum. The solution is gradually heated to evaporate toluene and remaining water firstly by normal pressure and then by vacuum. After that the solution is steam distilled to lower toluene content and afterwards is nitrogen purged to minimize of the water content. The distillate is separated, water part is sent to the wastewater pit and toluene part is reused. Concentrated LER is ready for cleaning and filtered on pre-coat filter to remove gels and impurities to reach required quality. The product is analyzed and after that is transferred into the storage tanks.

METHODOLOGY

The study is principally performed to obtain data of carbon footprint, i.e. global warming potential (GWP) of liquid epoxy resin product together with results of other impact category indicators needed for EPD® certification. The life cycle assessment was conducted based on ISO guidelines (ISO14040 2006; ISO14044 2006).

The functional unit for this LCA study is production of 1000 kg of liquid epoxy resin (LER) produced both based on propylene (LER-P) and based on glycerin (LER-G) (Fig. 2).

The upstream processes include the following inflow of raw materials and energy wares needed for the production of the product: extraction of resources, transport of resources to refinement, refinement of resources, the production processes of energy wares used in the extraction, refinement and manufacturing, production of auxiliary products used such as detergents for cleaning etc. The core processes include: production of epichlorohydrin from glycerin and/or propylene, production of the liquid epoxy resin, treatment of organic liquid and gaseous waste streams of epichlorohydrin from glycerin and/or propylene plant, treatment of waste water of epichlorohydrin from glycerin and/or propylene plant, industrial biological wastewater treatment of wastewater results from production in chemical plants, external transportation to the core process, treatment of wastewater in communal wastewater treatment plant, transport and disposal of commercial waste in communal landfill and incineration, recycling of hydrochloric acid produced as by-product. No packaging of final product is realized as transport to costumers in tanks is realized. For this reason downstream processes as defined in GPI for EPD® (GPI 2008) are not relevant for this study.

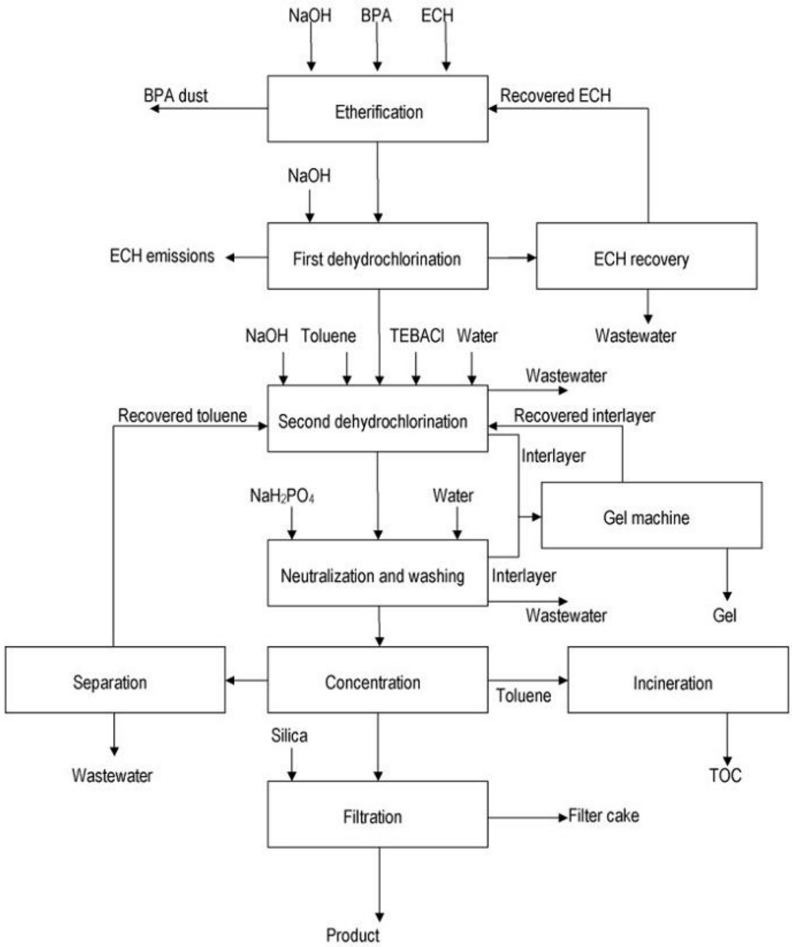

Fig. 2: Schema of liquid epoxy resin production

RESULTS

There is main energetic resources consumption for LER-P and LER-G production summarized in Tab. 1. For each LCI dataset, indicators have been calculated and reported for a pre-defined set of impact categories. As highlighted in ISO 14040 and 14044, only the environmental aspects of a product system or a service in a life cycle perspective, i.e. from cradle to grave or from cradle to recycling, is environmentally sound. Following Tab. 2 presents calculated results of impact category indicators, where actualized CML 2001 (HEIJUNGS, GUINEE et al. 1992) characterization factors were used.

Tab. 1: Resource consumption of different LER production technologies

kg / 1000 kg of LER	LER-G	LER-P
Crude oil	1113	1467
Hard coal	577	1040
Lignite	640	1495
Natural gas	757	912
Uranium	0,014	0,031

Tab. 2: Results of impact category indicators of different LER production technologies

Indicator result	LER-G	LER-P
Abiotic Depletion (ADP elements) [kg Sb-Equiv. / 1000 kg of LER]	0,009	0,021
Abiotic Depletion (ADP fossil) [MJ/ 1000 kg of LER]	102788	146313
Acidification Potential (AP) [kg SO2-Equiv. / 1000 kg of LER]	27,6	38,4
Eutrophication Potential (EP) [kg Phosphate-Equiv. / 1000 kg of LER]	7,6	5,5
Freshwater Aquatic Ecotoxicity Pot. (FAETP inf.) [kg DCB-Equiv. / 1000 kg of LER]	68,2	16,6
Global Warming Potential (GWP 100 years) [kg CO2-Equiv. / 1000 kg of LER]	4632	8654
Human Toxicity Potential (HTP inf.) [kg DCB-Equiv. / 1000 kg of LER]	566	276
Ozone Layer Depletion Potential (ODP, steady state) [kg R11-Equiv. / 1000 kg of LER]	0,0002	0,0005
Photochem. Ozone Creation Potential (POCP) [kg Ethene-Equiv. / 1000 kg of LER]	2,083	2,958
Terrestric Ecotoxicity Potential (TETP inf.) [kg DCB-Equiv. / 1000 kg of LER]	232	10,9

DISCUSSION

Comparison of glycerin and propylene based LER production from the point of view of LCA shows that in almost all applied impact categories the LER-G is more environmentally considerate in compare to LER-P (Tab. 3). The main reason is in environmentally effective way of glycerin production. Glycerin used for ECH production is a side-product from biodiesel production, so substantial part of its environmental impacts is allocated away from glycerin. Although LER-G produces almost half of GWP in compare to LER-P, its human toxicity and ecotoxicity is higher. This is because of pesticide application during oil-seed plantation for biodiesel production. General comparison of LER-G and LER-P is realized using LCIA result normalization (HUIJBREGTS, BREEDVELD et al. 2003). In this study CML 2001 normalization reference impact category results for EU 27 were used.

Tab. 3: Normalised results of impact category indicators

Normalized results / 1000 kg of LER	LER - G	LER - P
Abiotic Depletion	1,41E-09	3,53E-09
Abiotic Depletion	2,93E-09	4,17E-09
Acidification Potential	1,64E-09	2,28E-09
Eutrophication Potential	4,10E-10	2,98E-10
Freshwater Aquatic Ecotoxicity	1,33E-10	3,25E-11
Global Warming Potential	8,89E-10	1,66E-09
Human Toxicity Potential	5,60E-11	2,74E-11
Ozone Layer Depletion Potential	2,25E-11	4,93E-11
Photochem. Ozone Creation Potential	7,84E-10	1,11E-09
Terrestric Ecotoxicity Potential	2,00E-09	9,36E-11
Suma	**1,03E-08**	**1,33E-08**

CONCLUSION

Glycerin based production of LER is generally less environmentally serious in compare to propylene based production.

ACKNOWLEDGEMENT

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