(Contract 121235)

THIRD PARTY REPORT

Life Cycle Assessment of a PP multilayer low noise pipe system for soil and waste removal in the building (according to EN 12056-2)

Final Third Party Report

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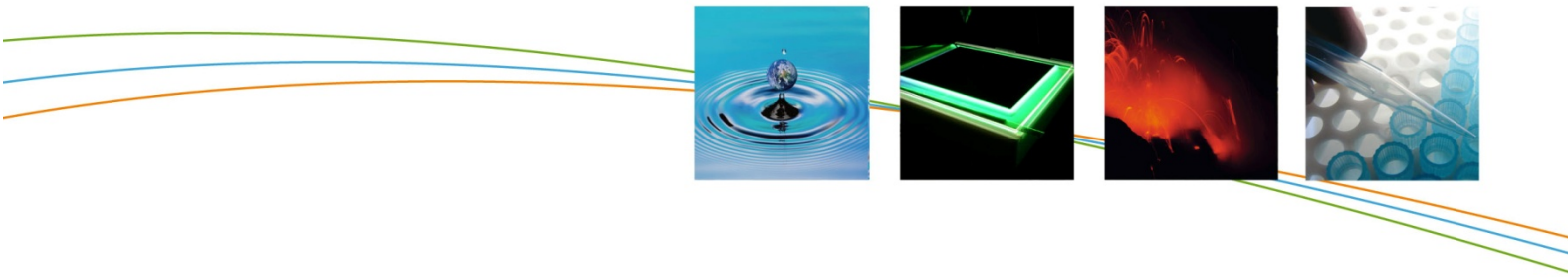

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CHAPTER 1 INTRODUCTION

The European Plastics Pipes and Fittings Association (TEPPFA) deems it important to have an insight into the integral environmental burdens encountered during the life-span of particular pipe system applications. With this framework in mind, TEPPFA has set up a project with the Flemish Institute for Technological Research (VITO). The aim of the first TEPPFA project frame was to carry out a life cycle assessment (LCA) from cradle to grave of 4 specific applications of plastic pipe systems. One of the systems studied in the first phase was the PP soil and waste removal pipe system. This report presents the results of the LCA of another soil and waste removal system, more specifically the PP multilayer low noise soil and waste removal pipe system.

The Flemish Institute for technological Research (VITO) has analysed the various environmental aspects which accompany this pipe system, from the primary extraction of raw materials up to and including the end of life (EoL) treatment after the pipe's reference service life time by means of an LCA assessment. The final aim of the study is to establish an environmental product declaration (EPD). The EPD has been made according to the CEN framework (CEN TC 350 framework document, 2012). This PP multilayer low noise soil and waste removal pipe system is therefore part of a larger project where other plastic pipe systems within different application areas are analysed by means of an LCA.

This document is a summary of the LCA study of the polypropylene (PP) low noise multilayer pipe system for soil and waste removal at the building and serves as a 'Third Party Report' which is aimed at a broad public. TEPPFA can also use the results of this LCA study for the following purposes:

- to support policy concerning sustainable construction;
- to anticipate future legislation regarding environment and certification (product development);
- for communication with various stakeholders;
- to apply for an EPD (Environmental Product Declaration), as described in ISO TR 14025 (ISO, 2006) and at the European level (CEN TC 350 framework document, 2012);
- to focus improvement activities on the most important impact-generating process phases;
- to consider new product developments;
- …

VITO is the author of this comprehensive LCA study which has been carried out under assignment from TEPPFA. The study started early in 2012 and was completed in June 2013. The LCA study has been critically reviewed by Denkstatt (see Chapter 6).

The methodology used to determine the environmental aspects of the PP multilayer low noise pipe system for soil and waste in the building is conform to LCA methodology, as prescribed in ISO standards 14040 and 14044 (ISO, 2006). According to these ISO standards, an LCA is carried out in 4 phases:

1. Goal and scope definition of the study;
2. Life cycle data inventory (LCI);
3. Determining the environmental impacts by means of a life cycle impact assessment (LCIA);
4. Interpretation.

For this project the different environmental impact categories presented in the EN15804 prepared within the technical committee CEN TC 350 "Sustainability of construction works" is used (CEN TC 350 framework document, 2012). An overview of these categories can be found in EN 15804.

The design of this third-party report complies with these 4 phases of the LCA, whereby the various chapters describe each phase of the LCA. All relevant ISO guidelines were implemented when compiling this 'Third Party Report' (ISO 14044, paragraph 5.2).

CHAPTER 2 GOAL AND SCOPE DEFINITION

2.1 Definition of goal of the study

TEPPFA wants a cradle to grave LCA consistent with ISO 14040 and ISO 14044 series of standards to assess the environmental performance of TEPPFA plastic piping systems. This LCA-study aims to examine the PP multilayer low noise pipe system for soil and waste removal in the building, to gather and assess comprehensive and reliable information regarding the environmental performance of this PP multilayer low noise Soil & Waste pipe system over its entire life cycle. In the same time, this study helps to provide a reliable database for the development of an ISO 14025 Type III Environmental Product Declarations (EPDs) on the European level for the PP multilayer low noise pipe system for soil and waste removal in the building. The CEN framework (TC 350 – Sustainability of Construction works) and more specifically the work performed within the technical committee TC 350 (CEN TC 350 framework document, 2012) is used for this project.

The intended audience of this LCA-study of the PP multilayer low noise pipe system are the TEPPFA member companies and its National Associations in the first place and external stakeholders (like governments, professionals, installers) at the second stage. TEPPFA expects to use the information from this study in aggregated manner for public communications, to develop marketing materials for customers and to provide data to customers for the purpose of developing LCIs and EPDs within the building and construction sector.

Since TEPPFA wishes to publicly communicate the results of the LCAs a critical review has been performed by Denkstatt and a 3rd party report has been compiled.

2.2 Definition of scope of the study

The scope of the study is defined in the functional unit. The functional unit is closely related to the function(s) fulfilled by the to-be-investigated product. The function of the PP multilayer low noise Soil & Waste pipe system is to remove and transport (gravity discharge) soil and waste from a typical residential single family apartment in a 5-storeyed building to the entrance of a public sewer system. In consultation with TEPPFA, its steering committee and the Application Group Building the definition of the function and the functional unit of the PP multilayer low noise pipe system were discussed. The basic assumption was that the definition of the functional unit should represent the function of the PP multilayer low noise pipe system over its entire life cycle: raw material extraction, material production, production of the pipes and fittings, the construction phase, the use phase and the processing of the waste at the end of life of the PP multilayer low noise Soil & Waste pipe system. The functional unit of the PP multilayer low noise Soil & Waste pipe system has been defined as: "the gravity discharge and transport of soil and waste, from a well-defined apartment to the entrance of a public sewer system, and this by means of a PP multilayer low noise Soil and Waste gravity drainage system installation into the typical 100 m² apartment, incorporating a bathroom, separate WC, kitchen and washroom (considering the service

life time of the pipe system to be aligned with the 50 year life of the apartment), calculated per year".

In order to define the design of the PP multilayer low noise Soil & Waste pipe system in terms of the functional unit the following considerations have been made:

- The complete PP multilayer low noise Soil & Waste pipe system is considered;
- The PP multilayer low noise Soil & Waste system is designed according to EN 12056-2 "Gravity drainage systems inside buildings – part 2: Sanitary pipe work, layout and calculation;
- The components of the PP low noise system, pipes and fittings, are in accordance with different National or Company specifications;
- The PP multilayer low noise Soil & Waste pipe system are designed for application area "B" within the building structure (B-application);
- The several sanitary appliances (siphons, ...) are not considered; risers are included in the design;
- Brackets are included at the installation phase in the apartment;
- For the connection to the public sewer we have calculated extra pipe work (length 1,5 m diameter 110 mm);
- Service life time of the PP multilayer low noise Soil & Waste pipe system is considered to be 50 year (= service life time of building system: apartment). Building system: 100 m² of a typical residential single family apartment in a 5-storeyed building with all the facilities clearly positioned, like bath, shower, etc. The building design will be used for modelling the PP multilayer low noise Soil & Waste pipe system and all other applications on the building level. As such the work is harmonized within the larger LCA-project and a consistent approach is generated over the building application cases. For more specific design parameters, we refer to Figure 1.

The life cycle of the PP multilayer low noise Soil & Waste pipe system has been divided in the following different life cycle phases:

- Production of raw materials for PP multilayer low noise Soil & Waste pipes;
- Transport of PP pipe raw materials to converter;
- Converting process for PP multilayer low noise Soil & Waste pipes (extrusion);
- Production raw materials for PP multilayer low noise Soil & Waste fittings;
- Transport of PP fitting raw materials to converter;
- Converting process for PP multilayer low noise Soil & Waste fittings (injection moulding);
- Production of SBR sealing rings (raw materials + converting process);
- Transport of complete PP multilayer low noise Soil & Waste pipe system to the apartment;
- Installation of complete PP multilayer low noise Soil & Waste pipe system;
- Operational use of the complete PP multilayer low noise Soil & Waste pipe system during 50 years of reference service life time of the apartment;
- Maintenance of the complete PP multilayer low noise Soil & Waste pipe system during 50 years of reference service life time of the apartment;
- Disassembly of complete PP multilayer low noise Soil & Waste pipe system after 50 years reference service life time of the apartment;
- Transport of complete PP multilayer low noise Soil & Waste pipe system after 50 years reference service life time of the apartment to an end-of-life treatment;
- End-of-life treatment of complete PP multilayer low noise Soil & Waste pipe system after 50 years reference service life time of the apartment.

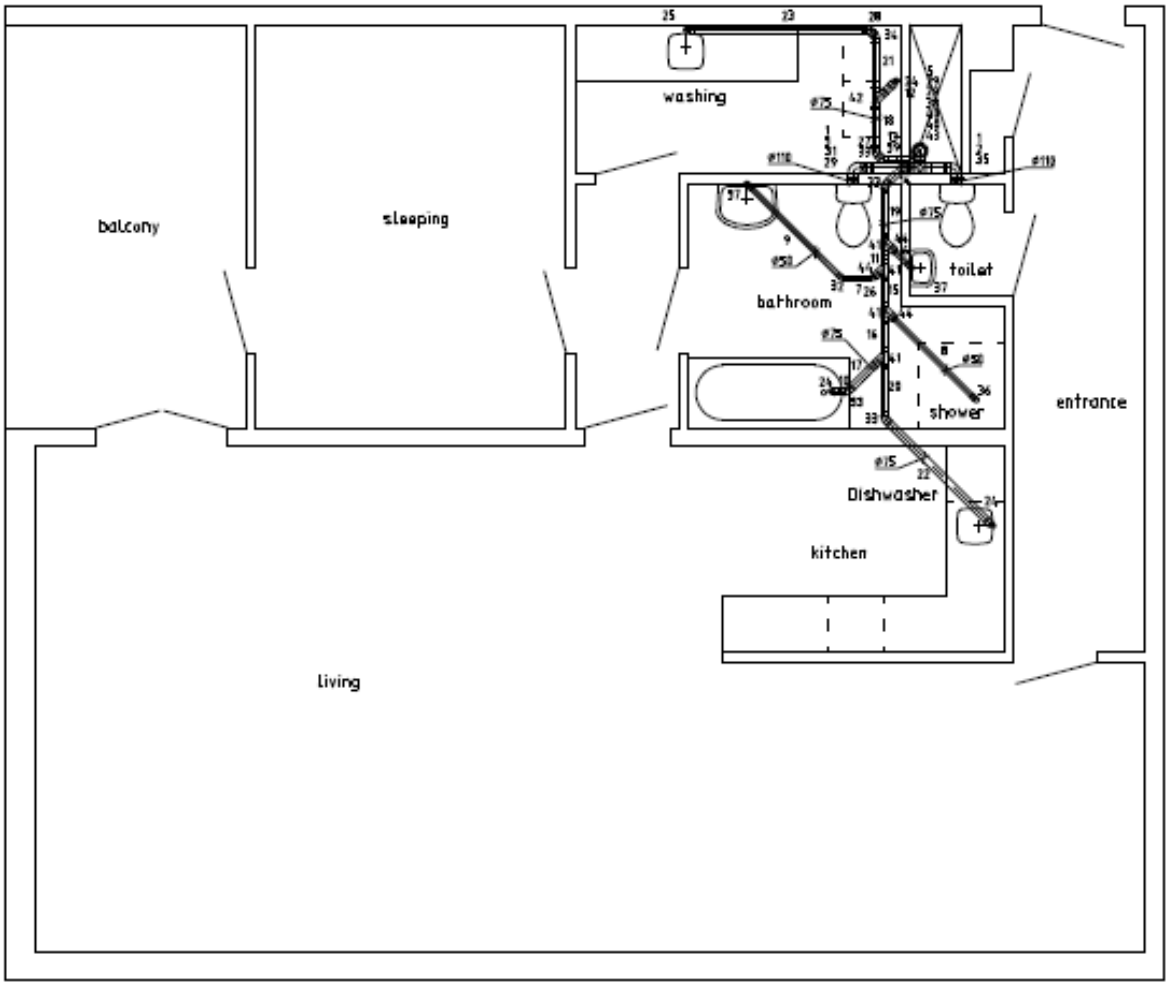

Figure 1: Design of 100 m² of apartment (representative for the PP multilayer low noise Soil & Waste pipe system)

The following underlying principles are adopted when system boundaries are established:

- The infrastructure (production of capital goods like buildings, equipment) is not considered in this study for what concerns the converting plants of the PP multilayer low noise Soil & Waste pipes and fittings. For all other processes (production of basic materials, additives, energy, transport, etc.) the impact of capital goods is included in the analysis. For example the impact of the pipelines for natural gas are considered, as well as the impact of the production of transport modes (e.g. trucks) and transport infrastructure (e.g. roads).
- Accidental pollution is not considered in this LCA;
- Environmental impacts which are caused by the personnel of production units are disregarded. This, for example, concerns waste originating from canteens and sanitary installations. Environmental measures relating to waste processing processes (combustion kilns, for example) are taken into consideration in the LCA study. Greater focus is placed on the final processing, and thus the end destination of generated waste flows.
- To model different waste treatment processes during the LCA-project we used the end of life (EoL) approach for incineration and landfill; and the recycled content approach for recycling:

- For incineration and landfill this means that the impacts (as well as the benefits: for example the energy recovery during waste incineration) of the amount of waste that is treated by waste treatment facilities, is assigned to the producing process (this means the process that causes the waste, so the PP multilayer low noise pipe system for soil and waste removal in the building). Waste that is incinerated with energy recovery is considered as part of the system under study. This means that emissions and energy consumption related to waste treatment are included in the LCA. For waste incineration the avoided electricity production due to energy recovery of waste incineration is taken into account.
- For waste recycling the credits of recyclates (secondary raw materials that can be used as input materials, so less virgin raw materials needed) are considered as soon as they are actually used (assigned to the product life cycle that uses the recyclates). This means that transport to the recycling plant is included. The recycling process itself and the fact that fewer raw materials are needed when the produced recyclates (product of the recycling process) are used as secondary raw materials are allocated to the life cycle where the recyclates are used.

Only for some processes there was a need to use so-called 'cut-off' rule where the input on mass basis is lower than 1%:

- Transportation of the different packaging waste flows to the respective treatment facilities;
- The production of the packaging materials to pack the raw materials for Soil & Waste PP multilayer low noise pipes and PP multilayer low noise fittings in order to be able to easily transport them from the producers to the converters.

For the TEPPFA project VITO uses the different environmental impact categories presented in the EN15804 document prepared by Technical Committee CEN TC 350 (EN 15804 Sustainability of construction works – Environmental Product Declarations – Core rules for the product category of construction products) (CEN TC 350 framework document, 2012).

The results of an LCA depend on different factors. Sensitivity analyses assess the influence of the most relevant and most uncertain factors on the results of the study. The results of these sensitivity analyses are compared to the basic scenarios. Sensitivity analyses don't make the basic data of a study more reliable, but allow to assess the effect of a change in inventory data on the results and conclusions of the study.

For this project we decided not to put a lot of effort in sensitivity analyses, since it appears from the life cycle impact assessment of the PP multilayer low noise pipe system for soil and waste removal in the building that the data and the uncertainty on the data for the most important life cycle phases (raw materials for PP multilayer low noise pipes and transportation of these raw materials to converters) are thoroughly discussed during the workshops. These data are based on European averages established through PlasticsEurope (PP multilayer low noise raw materials - mainly caused by the PP multilayer low noise resin production) or based on company-specific knowledge on the way the raw materials are transported to the TEPPFA member companies (averages of different individual datasets from different TEPPFA member companies). To put a lot of efforts into sensitivity analyses on other life cycle phases having a less important contribution to the overall environmental profile was not efficient to our opinion. For this project additional sensitivity analyses will not have much added value.

CHAPTER 3 LIFE CYCLE INVENTORY

3.1 Data requirements

The objective is to compose a dataset that is representative and relevant for a typical European PP multilayer low noise pipe system for soil and waste removal in the building. The data that are used in this LCA study are not case-specific, but reflect the average European representative situation. The production processes run according to European norms and the equipments are very similar across Europe. Since the LCA study on the PP multilayer low noise pipe system is performed for an anticipated European average, European manufacturers' data are used. The TEPPFA member companies represent more than 50% of the European market for extruded plastic pipes.

All data relate to the existing situation in Europe, using existing production techniques. Data are as much as possible representative for the modern state-of-technology. As such Europe in the period 2000-2008 is considered as the geographical and time coverage for these data.

The used data are consistently reported and critically reviewed, so that they can be easily reproduced. If in this document is referred to "a pipe system", this means the pipe system representing the average at the European level, and not one specific pipe system. Calculations of the amounts of PP multilayer low noise pipes, PP multilayer low noise fittings, SBR rubber rings(needed per 100 m² of apartment) are based on a consensus within the AG Building. They are based and calculated on the 100 m² apartment with its specific design as presented in Figure 1 (see Table 1).

Table 1: PP multilayer low noise Soil & Waste pipe system in relation to the functional unit

PP low noise Soil & Waste pipe system	Average in kg / 100 m^2 apartment	Average in kg / FU (excl. left over)	Average in kg / FU (incl. left over of 5 %)
PP pipes	18,005	0,3601	0,3781
PP fittings	7,440	0,1488	
SBR sealing rings	0,5078	0,0102	

For each life cycle phase an overview is generated of all environmental flows which concern the functional unit:

Data on the raw materials (resin) for PP multilayer low noise Soil & Waste pipes and fittings are coming from PlasticsEurope (the association of plastics manufacturers). PlasticsEurope represent the European plastics manufacturing chain.

Data on extrusion and injection moulding processes are collected within the framework of a project that has been carried out by TNO in commission of PlasticsEurope. In this framework TNO collected some of the environmental inputs and outputs related to the extrusion of PP multilayer low noise pipes and injection moulding of PP multilayer low noise fittings. Additional environmental input and output data are coming from the respective TEPPFA member companies. The TEPPFA and VITO experts critically reviewed the proposed datasets for the two converting processes and formulated questions and remarks to TNO. Then TEPPFA and VITO experts prepared a revised version for European average datasets for PP multilayer low noise fittings injection moulding and PP multilayer low noise pipe extrusion. The revised datasets have been used within this LCA study in combination with company specific data collected from the respective TEPPFA member companies. The datasets also included transport of raw materials to converters and packaging of produced products (pipes and fittings).

Data on other pipe system components are coming from the TEPPFA experts (amounts that are needed for the functional unit) and from publicly available LCA databases (LCI data per kg of component that is part of the PP multilayer low noise pipe system).

Application specific data are dealing with all life cycle phases from the transportation of the packed PP multilayer low noise pipe system to the customer to the final EoL treatment scenario. In this framework TEPPFA prepared an application-specific questionnaire. The collection of application specific data encompasses the identification of different kind of scenarios for transport to construction site, construction process and demolition process and the EoL treatment.

3.2 Data collection procedures

Wherever possible, data collection is based on data derived from members of TEPPFA, TEPPFA experts, representative organisations for the raw material producers, data derived from suppliers and data from public LCA databases. TEPPFA supplied, with logistical support from VITO, all environment-related data for processes, which take place within the converting factories and during the application itself (transport to apartment, installation, demolition after 50 years of service life time, transport to EoL treatment, and EoL treatment itself). The data collection process was discussed during several workshops with the TEPPFA member companies.

Summarised, the data inventory collection process appealed to:

- inquiries (based on specific questionnaires) of relevant actors being the representative organisations of the raw material producers, the different member companies of TEPPFA and their suppliers;
- simultaneously literature sources that discuss similar issues are consulted;
- if needed, specific data supplied by the TEPPFA member companies and relevant for Europe are used;
- for the background processes, generic data from literature and publicly available databases are used (more general data, representative for Europe);
- for aspects where no specific or literature data are found an assumption is made, based on well-founded arguments.

CHAPTER 4 LIFE CYCLE IMPACT ASSESSMENT

4.1 Method

During impact assessment, the emission- and consumption-data of the inventory phase are aggregated into environmental impact categories. The use of raw materials, energy consumption, emissions and wastes are converted into a contribution to environmental impact categories. The result of the impact assessment is a figure or table in which the environmental themes (environmental impact categories) are presented, describing the environmental profile of the selected functional unit "the gravity discharge and transport of soil and waste, from a well-defined apartment to the entrance of a public sewer system, and this by means of a PP multilayer low noise Soil and Waste gravity drainage system installation into the typical 100 m² apartment, incorporating a bathroom, separate WC, kitchen and washroom (considering the lifetime of the pipe system to be aligned with the 50 year life of the apartment), calculated per year".

For this project VITO uses the different life cycle impact categories presented in the document prepared by Technical Committee CEN TC 350 (CEN TC 350 framework document, 2012):

- Abiotic depletion (kg Sb equivalences);
- Abiotic depletion (MJ, calorific value);
- Acidification (kg SO_2 equivalences);
- Eutrophication (kg PO_4^{3-} equivalences);
- Global warming (kg CO_2 equivalences);
- Ozone layer depletion (kg CFC-11 equivalences);
- Photochemical oxidation (kg C_2H_4 equivalences).

The optional declaration on ionising radiation is not being considered in this study. An LCA calculates the potential contribution of the pipe system's life cycle to the different environmental impact categories. Radiation often relates to electricity consumption, but meanwhile we know that the contribution of electricity production to radiation is negligible. For this reason we do not consider radiation as an environmental impact category in this LCA study.

For performing the life cycle impact assessment (LCIA) VITO uses the LCA software package "SimaPro 7.3.0." for performing the life cycle impact assessment (LCIA) and generating the environmental profile of the PP multilayer low noise pipe system for soil and waste removal in the building (apartment).

In discussing the results of the individual profile of the PP multilayer low noise pipe system for soil and waste (building application) it is important to know whether or not a process has a significant contribution to an environmental impact category. For that the ISO framework (ISO 14044 - Annex B) is used. According to the ISO 14044 Annex B the importance of contributions can classified in terms of percentage. The ranking criterias are:

A: contribution > 50 %: most important, significant influence;
B: 25 % < contribution ≤ 50 %: very important, relevant influence;
C: 10 % < contribution ≤ 25 %: fairly important, some influence;

D: 2,5 % < contribution ≤ 10 %: little important, minor influence;
E: contribution < 2,5 %: not important, negligible influence.

4.2 The environmental profile of the PP multilayer low noise pipe system for soil and waste removal in the building

The environmental profile shows the contribution of the various steps in the life cycle per environmental impact category. For each environmental impact category, the total contribution of the PP multilayer low noise Soil & Waste pipe system is always set at 100% and the relative contributions of the various subprocesses are visible.

Table 2 and Figure 2 present **the environmental profile for the PP multilayer low noise pipe system from the cradle to the grave** for soil and waste removal in a 100 m² of apartment (expressed per functional unit). This environmental profile shows the contribution of the various steps in the life cycle, per environmental impact category. For each category, the total contribution of the PP multilayer low noise pipe system is always set at 100% and the relative contributions of the various life cycle phases are visible.

We have to remark here that some datarecords in Ecoinvent underestimate the ozone depleting emissions significantly, while other datasets (like energy carriers) do consider these emissions. The reason for this data inconsistency is the incomplete accounting within the PlasticsEurope data. This is the reason why in Table 2 and Figure 2 there is an underestimation of the relative contribution of the raw materials production in the category ozone layer depletion.

For the PP multilayer low noise Soil & Waste pipe system it appears that the profile is primarily determined by the production of the **raw materials for the PP pipes**. They have a relevant influence in most impact categories, except for eutrophication (13% - some influence), ozone layer depletion (5% - minor influence) and abiotic depletion fossils (51% -significant influence).
For abiotic depletion fossils is mainly determined by the virgin PP raw materials that are needed to produce the core layer, the inner and the outer layer. The core layer is most important due to a relatively higher weight due to the higher filler content.
For the depletion of the ozone layer, the life cycle stages transportation of the PP multilayer low noise Soil & Waste pipe system to the apartment, the production processes (extrusion and injection moulding) and the production of the SBR sealing rings become relatively more important. However we have to remember that there is an incomplete accounting of emissions related to ozone layer depletion in the PlasticsEurope data (2006). For eutrophication, the extrusion and injection moulding process of the PP pipes and fittings are the most important phases.
For eutrophication it is mainly determined by emissions of NOx (nitrogen oxides) to the air and phosphate emissions to water that are mainly released during the production of the PP resins (65%) and the production of titanium doxide (18%).
We can conclude also that the impacts from the raw materials for the pipes and fittings is not exceeding 50% of the total impacts per impact category (with one exception for abiotic depletion fossils where the contribution is 51%).

Table 2: Environmental profile of the PP multilayer low noise pipe system for soil and waste (cradle-to-grave) in absolute figures per functional unit

Impact category	Abiotic depletion - non fossils	Abiotic depletion - fossil	Acidification	Eutrophication	Climate change	Ozone depletion	Photochemical oxidation
Life cycle phases	**kg Sb eq**	**MJ, net cal**	**kg SO2 eq**	**kg PO4--- eq**	**kg CO2 eq**	**kg CFC-11 eq**	**kg C2H4**
Product stage							
Production recipe for PP low noise s&w pipes	3,30E-06	1,71E+01	1,49E-03	2,25E-04	4,93E-01	3,94E-09	1,12E-04
Transportation of recipe for PP pipe to converter	1,52E-07	4,36E-01	1,10E-04	2,88E-05	2,70E-02	4,45E-09	3,57E-06
Extrusion of PP low noise pipes	5,66E-07	2,88E+00	9,03E-04	6,49E-04	2,23E-01	1,10E-08	4,23E-05
Production recipe for PP fittings	2,19E-06	6,53E+00	6,23E-04	1,07E-04	1,95E-01	4,00E-09	4,49E-05
Transportation of recipe for PP fittings to converter	8,21E-08	2,35E-01	5,93E-05	1,55E-05	1,46E-02	2,40E-09	1,92E-06
Injection moulding PP fittings	5,46E-07	2,60E+00	8,27E-04	6,01E-04	2,08E-01	1,13E-08	3,84E-05
Production of SBR sealing rings	3,50E-08	1,15E+00	1,84E-04	4,27E-05	5,05E-02	1,21E-08	9,34E-06
Construction process stage							
Transportation of complete PP pipe system to the building	1,49E-06	3,00E+00	7,30E-04	2,06E-04	1,98E-01	2,98E-08	3,26E-05
Installation of PP low noise pipes in the building	8,97E-08	5,00E-01	1,24E-04	5,44E-05	5,79E-02	3,35E-09	1,91E-05
Use stage							
Operational use of the PP low noise pipe system	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Maintenance of PP low noise pipe system	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
End of life stage							
Disassembly of PP low noise pipe system	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00	0,00E+00
Transportation of complete PP low noise pipe system to EOL	1,82E-07	3,42E-01	8,25E-05	2,25E-05	2,25E-02	3,42E-09	2,85E-06
EOL treatment PP low noise pipe system	-2,63E-07	-1,20E+00	-2,73E-04	-2,77E-04	1,46E-01	-4,36E-09	-1,73E-05
Total	**8,38E-06**	**3,35E+01**	**4,86E-03**	**1,68E-03**	**1,64E+00**	**8,14E-08**	**2,90E-04**

A: contribution > 50 %: most important, significant influence
B: 25 % < contribution ≤ 50 %: very important, relevant influence
C: 10 % < contribution ≤ 25 %: fairly important, some influence

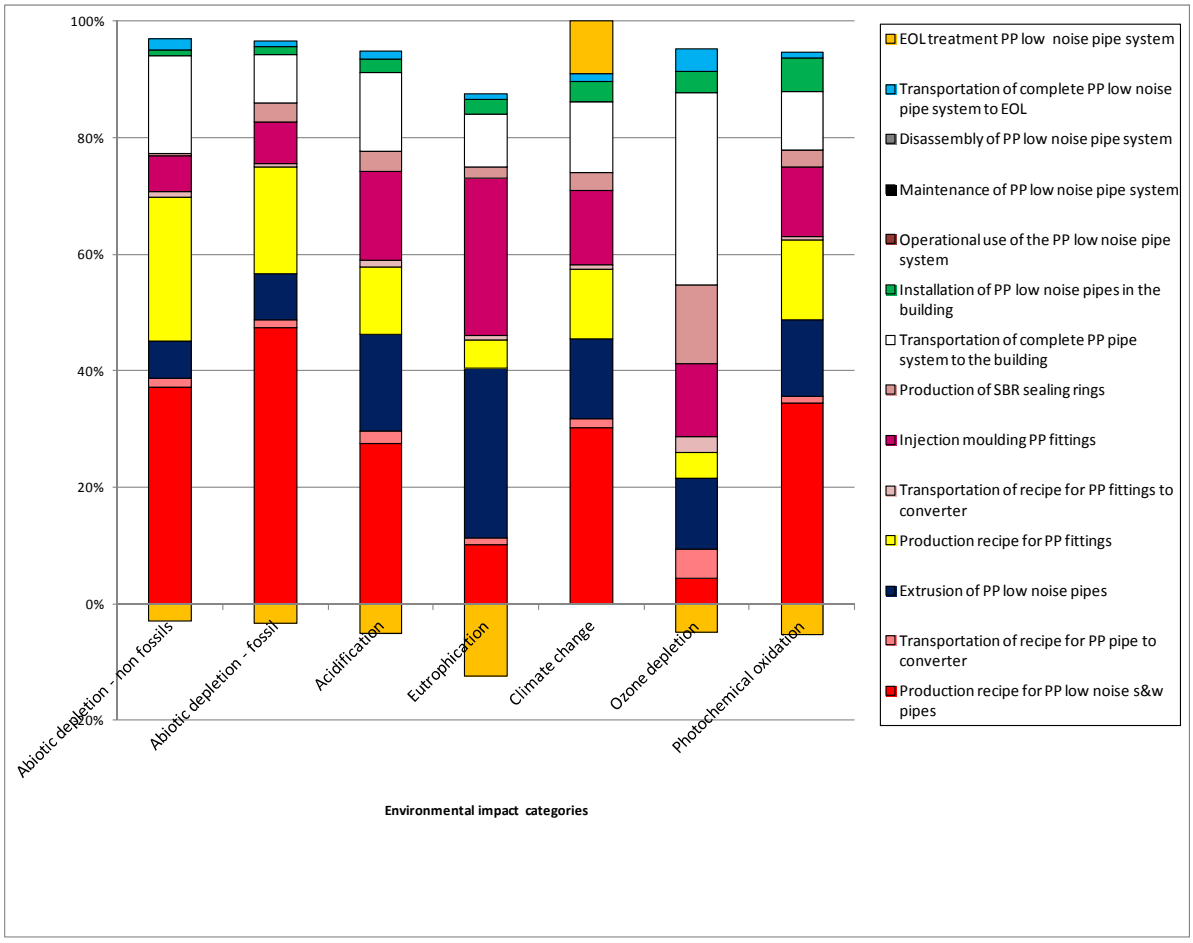

Figure 2: Environmental profile of the PP multilayer low noise pipe system for soil and waste removal (building) from the cradle-to-the grave (per functional unit)

The **production of the raw materials for the PP fittings** has some influence on the environmental profile of the PP multilayer low noise Soil & Waste pipe system in the apartment. The contribution is for all impact categories between 12% and 26%, except for eutrophication (6%) and ozone layer depletion (5%). However for ozone layer depletion we have to mention that there is an incomplete accounting of emissions related to ozone layer depletion in the PlasticsEurope data (2006).

The **transportation of the PP raw materials for pipes and fittings** from raw material producers to the converters has a minor or negligible influence on the environmental profile of the PP multilayer low noise Soil & Waste pipe system for soil or waste removal in the apartment. The contribution is for all impact categories lower than 5% (for ozone layer depletion it is 5%).

Analysis of the environmental profile of the PP multilayer low noise Soil & Waste pipe system shows that the **extrusion of PP pipes** accounts for a percentage between 7% and maximum 19% for 6 of the environmental impact categories considered in this study. An exception is the category eutrophication, where the impact of the extrusion of the pipes accounts for 39% (very important).

The impact from the **injection moulding process of PP fittings** is also very important in the category eutrophication (36%). It is fairly important in the impact categories acidification, global warming, ozone layer depletion and photochemical

oxidation. It is of minor influence in the categories abiotic depletion fossil and non-fossil resources.

The impact from the **production of the SBR sealing rings** is little or not important for most environmental impact categories, with the exception of ozone layer depletion, where the production of SBR sealing rings has a contribution of 15% (some influence). For the rubber rings this is mainly caused by the organic solvents that are used for the injection moulding process and the production of the crude oil necessary for the production of the carbon black, one of the raw materials for the production of the SBR rings.

Furthermore analysis of the environmental profile of the PP multilayer low noise Soil & Waste pipe system shows that the contribution of the **transportation of the complete PP multilayer low noise Soil & Waste pipe system to the apartment** accounts for a environmental burden for most environmental impact categories between 11% and 18% (fairly important influence), with exception of the contribution to the depletion of the ozone layer, where the transportation of the pipe system to the apartment leads to a very important contribution (37%) and the contribution to abiotic depletion-fossil fuels, where the contribution of transportation to the building is little important (9%).

The influence of the **installation phase** of the PP multilayer low noise Soil & Waste pipe system in the apartment is relatively low for most environmental impact categories (between 1% and 7% on the total impact per environmental impact category).

The contribution of the **transportation of the disassembled low noise PP Soil & Waste pipe system** after 50 years of service life (service life of apartment) **to an EoL treatment facility** is not important since it is for most environmental impact categories lower than 2,5% (negligible influence), with the exception for ozone layer depletion, where this life cycle phase represents 4% (minor influence).

The contribution of **the EoL treatment of the PP multilayer low noise Soil & Waste pipe system** is not important since its contribution is for all environmental impact categories lower than 2,5%. For most environmental impact categories, the EOL treatment of the PP multilayer low noise Soil & Waste pipe sytems has a negative value (environmental credit), with exception for climate change (CO_2 avoided emissions due to recovered energy) is not compensated by the CO_2 emissions during incineration (contribution of 9%). For eutrophication the credits have some influence (-17%) whereas for the other environmental impact categories, the credits have minor importance. For euthrophication the credits are mainly because of avoided phosphate emissions to water released during the production of electricity (in this case: avoided production of electricity).

CHAPTER 5 FINAL CONCLUSIONS

The conclusions of the study concern the LCA-results for the PP multilayer low noise Soil & Waste pipe system (building application), from the cradle to the grave: from the primary extraction of crude oil and natural gas to produce the resin for the PP multilayer low noise pipes and fittings, up till the final disassembling and EoL treatment of the PP multilayer low noise Soil & Waste pipe system at the end of its service life (being the life time of the apartment until the first refurbishment, 50 years).

The environmental profiles consist of various environmental impact categories. They relate to the functional unit which has been selected for this study, namely "the gravity discharge and transport of soil and waste, from a well-defined apartment to the entrance of a public sewer system, and this by means of a PP multilayer low noise Soil and Waste gravity drainage system installation into the 100 m² apartment, incorporating a bathroom, separate WC, kitchen and washroom (considering the service life time of the pipe system to be aligned with the 50 year life of the apartment), calculated per year".

The environmental impact of the **PP multilayer low noise Soil & Waste pipe system** in the apartment primarily originates from the production of the raw materials for the PP multilayer low noise Soil & Waste pipes. They have a relevant influence in most impact categories, except for eutrophication (some influence), ozone layer depletion (minor influence) and abiotic depletion fossils (significant influence).
For abiotic depletion fossils is mainly determined by the virgin PP raw materials that are needed to produce the core layer, the inner and the outer layer. The core layer is most important due to a relatively higher weight and differing material composition.
For the depletion of the ozone layer, the life cycle stages transportation of the PP multilayer low noise Soil & Waste pipe system to the apartment, the production processes (extrusion and injection moulding) and the production of the SBR sealing rings become relatively more important. However we have to mention that there is an incomplete accounting of emissions related to ozone layer depletion in the PlasticsEurope data (2006) for the PP raw material production. For eutrophication, the extrusion and injection moulding process of the PP pipes and fittings are the most important phases.
For eutrophication it is mainly determined by emissions of NOx (nitrogen oxides) to the air and phosphate emissions to water that are mainly released during the production of the PP resins (and the production of titanium doxide that is used as one of the colorants raw materials.
We can conclude also that the impacts from the raw materials for the pipes and fittings is not exceeding 50% of the total impacts per impact category (with one exception for abiotic depletion fossils where the contribution is 51%).

Analysis of the environmental profile of the PP multilayer low noise Soil & Waste pipe system also shows that the converting processes (core business of the TEPPFA member companies) have some or relevant influence on the total environmental profile, depending on the impact category (especially relevant for the category eutrophication). Converting processes are little important in the categories abiotic depletion non-fossils and abiotic depletion fossils.

Transportation of the complete pipe system to the apartment is of fairly important in the category ozone layer depletion. It is little or not important in the other categories.

The other life cycle phases are little important, some have even a negligible influence on the total contribution to most environmental impact categories. A last general observation with regard to the environmental profile of the PP multilayer low noise Soil & Waste pipe system is the fact that for some environmental impact categories the EoL treatment of the PP multilayer low noise Soil & Waste pipe system leads to environmental benefits or credits. This is related to the incineration of the PP part of the PP multilayer low noise Soil & Waste pipe system with energy recovery.

For global warming (carbon footprint) the contribution of the PP multilayer low noise Soil & Waste pipe system ((expressed per functional unit, being a soil and waste removal PP multilayer low noise Soil & Waste pipe system installed in a 100 m² of apartment over its entire life cycle (50 years), calculated per year)), is comparable to the impact to global warming related to the driving of a passenger car over a distance of 9 kilometres (Ecoinvent data record: transport, passenger car, petrol, fleet average/personkm – RER).

CHAPTER 6 CRITICAL REVIEW STATEMENT

6.1 Introduction

The European Plastics Pipes and Fittings Association (TEPPFA) deems it important to have an insight into the integral environmental aspects encountered during the life-span of particular applications of plastic pipes. With this framework in mind, TEPPFA commissioned a project which was carried out by the Flemish Institute for Technological Research (VITO) in Belgium.

The aim of this project was to carry out a life cycle assessment (LCA) consistent with [ISO 14040, 2006] and [ISO 14044, 2006] to analyse the environmental aspects which are associated with different plastic pipe systems.

Summarised the objectives of the overall LCA-project for TEPPFA were:

- to analyse the environmental impacts of different applications of plastic pipe systems in selected application groups;
- to investigate the relative performance of various plastic pipe systems at the system level in order to show that material choices cannot be made at the production level only;
- to use the results of the LCA-studies of the plastic pipe systems for business-to-business communication (via an EPD format).

In previous phases the integral environmental impacts of 10 pipe systems were calculated by means of an LCA.

TEPPFA decided to further extend these LCA-studies by considering 4 additional pipe systems:

- **PE pipe system for combustible gas distribution**
- **Smooth walled PP mono- and multilayer sewer pipe systems**
- **Polypropylene random copolymer (PP-R) pipe system for hot and cold water distribution in the building**
- **PP and a PVC low noise pipe system for soil and waste removal in the building**

Since TEPPFA plans to make the results of the LCA studies available for the general public, according to [ISO 14040, 2006] and [ISO 14044, 2006] a critical review of the LCA study is required. This critical review was performed by denkstatt GmbH.

6.2 Review Process

The critical review process of the 4 LCA studies described in section 6.1 was commissioned by The European Plastic Pipes and Fittings Association (TEPPFA). It was established in the timeframe of November 2012 to June 2013.

After the receipt of the draft LCA background report from VITO (March 2013) denkstatt prepared a detailed list with review comments on methodological issues, assumptions made and data used.

Furthermore general questions to support the comprehensibility of the report and specific recommendations for improvements of the studies were included. VITO then had the time to consider suggestions made in the comments and compiled a draft final LCA background report.

denkstatt's critical review statement summarises the findings of the critical review and is based on the draft final LCA background report, dated April 2013. The critical review statement will be included in the final version of the LCA background report as well as the third party report, which will be compiled by VITO.

6.3 Scientific Background

The herein described critical review statement covers the study "Life cycle assessment of a PP multilayer low noise pipe system for soil and waste removal in the building". It is based on the main guiding principles defined in the international standard series [ISO 14040, 2006] and [ISO 14044, 2006]. Thus, it should be noted that it is not the role of this critical review to endorse or dispute the goal of the study and the related conclusions. The aim was rather to examine that the:

- methods used are scientifically and technically valid for the given goal and scope of the study;
- data used are appropriate, sufficient and reasonable in respect to the goal and scope of the study;
- conclusions drawn reflect the goal and scope of the study and the limitations identified;
- report is transparent and consistent.

Therefore, the findings of this review are discussed in accordance to the above mentioned guiding principles.

The critical review did not involve a review of the calculations made in the study so that all the findings presented here are based solely on the draft (final) background report and the discussions with the authors of the study and TEPPFA.

6.4 Critical Review Findings

This particular LCA-study aims to examine a PP multilayer low noise pipe system for soil and waste removal in the building, to gather and assess comprehensive and reliable information regarding the environmental performance of these pipe systems, generated over their entire life cycle. At the same time, this study helps to provide a reliable database for the development of a Type III Environmental Product Declaration [ISO 14025, 2006] on the European level for the particular pipe system.

The scope of the study was defined by the functional unit. The basic assumption was that the definition of the functional unit should represent the function of the PP and PVC pipe systems over their entire life cycle: raw material extraction, material production, production of the pipes and fittings, the construction phase, the use phase and the processing of the waste at the end of life of the PP and PVC pipes and fittings. The functional unit of the PP multilayer low noise pipe system for soil and waste removal in the building has been defined as: "The gravity discharge and transport of soil and waste, from a well-defined apartment to the entrance of a public sewer system, and this by means of a low noise Soil and Waste gravity drainage system installation into the 100 m² apartment, incorporating a bathroom, separate WC, kitchen and washroom (considering the

service life time of the pipe systems to be aligned with the 50 year life of the apartment), calculated per year".

Based on this goal and scope of the project the following conclusions can be drawn from the review process:

- The widely accepted state-of-the-art methodology was adopted in this comprehensive LCA study and thus the study is scientifically and technically adequate. The authors of the study at VITO put a lot of effort into designing the systems and gathering respective data to be able to give a thorough picture of the pipe systems under investigation over their entire life cycle.
- Quality of required data and data sources as well as data collection procedures are appropriate, sufficient and reasonable. They are in accordance with the goal and scope of the study. Life cycle information of the different materials used was taken from up-to-date literature and databases representing European conditions or directly from the respective industries.
- The background report is presented in a very detailed, well-structured and also very transparent, consistent and logical manner. All assumptions, limitations and constraints are well described. Detailed explanations and justifications are given, whenever necessary, especially when certain negligible issues were not considered in the calculations.
- Most of the reviewer's comments and recommendations to improve the study and to raise the clarity, transparency and consistency of the background report were considered by the authors.
- It is recommended not to include ODP results in publications as these re-sults do not reflect reality properly due to incomplete and inconsistent da-ta. The reason for this data inconsistency is the incomplete accounting of ozone depleting substances (mainly related to oil production) within the PlasticsEurope ecoprofile data, while at the same time data for other mate-rials using oil does include respective ozone depleting emissions. This sub-ject is also mentioned several times in the background report.

6.5 Conclusion

This study is an LCA according to ISO standards series [ISO 14040, 2006] and [ISO 14044, 2006] and has fulfilled all necessary steps in an adequate and highly sufficient manner within the given goal of the study. All methodological steps reported are in accordance with this state-of-the-art approach.

It can be concluded that this is a competent study, which gives a thorough picture about the environmental aspects of the plastic pipe systems under investigation over their total life cycle from the cradle to the grave. The complete study has been established in a transparent, consistent and logical way.

6.6 References

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