Contract 081827)

THIRD PARTY REPORT

Life Cycle Assessment of a PP pipe system for soil and waste removal in the building (according to EN 1451)

Final Third Party Report

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Study accomplished under the authority of The European Plastic Pipes and Fittings Association - TEPPFA
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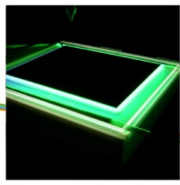

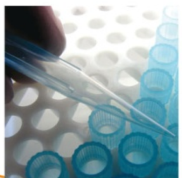

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CHAPTER 1 INTRODUCTION

The European Plastics Pipes and Fittings Association (TEPPFA) deems it important to have an insight into the integral environmental impacts that are 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 this project is to carry out a life cycle assessment (LCA) from cradle to grave of 4 specific applications of pipe systems. This analysis outlines the various environmental aspects which accompany the 4 pipe systems, from the primary extraction of raw materials up to and including the end of life (EoL) treatment after their service life time. With the present document the Flemish Institute for Technological Research (VITO) is reporting on the life cycle assessment (LCA) of one specific plastic pipe system performed on request of the European Plastic Pipes and Fittings Association (TEPPFA) with the final aim to establish an environmental product declaration (EPD). The EPD has been made according to the CEN framework (CEN TC 350 draft framework documents, 2008 - 2009). This PP LCA is part of a larger project where other 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) 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 draft framework documents, 2008 – 2009);
- to focus improvement activities on the most important impact-generating process phases;
- ...

VITO is the author of this comprehensive LCA study which has been carried out under assignment from TEPPFA. The study was started in early 2009 and was completed in April 2010. The LCA study has been critically reviewed by Denkstatt (see Chapter 6).

The methodology used to determine the environmental aspects of the PP pipe system for soil and waste in the building conforms 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 draft documents prepared within the technical committee CEN TC 350 "Sustainability of construction works" are used (CEN TC 350 draft framework documents, 2008 – 2009). An overview of these categories can be found in the clean version of the prEN15804 (Sustainability of construction works – Environmental Product Declarations – Core rules for the product category of construction products).

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 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 pipe system, generated 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 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 documents, 2008-2009) is used for this project.

The intended audience of the LCA-study of the PP pipe system is the TEPPFA member companies and its National Associations in the first place and external stakeholders (like governments, professionals, installers) at the second stage. For the latter, 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 and 3rd party report are performed. This critical review is performed by Denkstatt.

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 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 (for the PP case) the definition of the function and the functional unit of the PP pipe system was discussed. The basic assumption was that the definition of the functional unit should represent the function of the PP 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 pipes and fittings. The functional unit of the PP 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 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".

In order to define the design of the PP pipe system in terms of the functional unit the following considerations have been made:

- the complete PP Soil & Waste pipe system is considered;
- the PP 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-systems, pipes and fittings, are in accordance with EN 1451 "Plastics piping systems for soil and waste discharge (low and high temperature) part 1: Specifications for pipes and fittings and the system" (unfilled - without flame retardants - solid wall - single layer PP pipe - grey);
- the PP Soil & Waste pipe system is designed in class S20 within the building structure (B-application);
- Connections to the several sanitary appliances (siphons, ...) are not considered; risers will be included in the design;
- Brackets are included at the installation phase in the apartment;
- for the connection to the public sewer extra pipe work has been considered (length 1,5 m diameter 110 mm and fittings);
- service life time of PP 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 Soil & Waste case as well as for modelling the PEX Hot & Cold plumbing case. As such the work is harmonized within the larger LCA-project and a consistent approach is generated over the two building application cases. For more specific design parameters, we refer to Figure 1.

The life cycle of the PP pipe system has been divided in the following different life cycle phases:

- Production of raw materials for PP pipes;
- Transport of PP pipe raw materials to converter;
- Converting process for PP pipes (extrusion);
- Production raw materials for PP fittings;
- Transport of PP fitting raw materials to converter;
- Converting process for PP fittings (injection moulding);
- Production of SBR rubber rings (raw materials + converting process) as one of the other components of the PP pipe system;
- Transport of complete PP pipe system to the apartment;
- Installation of complete PP pipe system in the apartment;
- Use and maintenance of the complete PP pipe system during 50 years of reference service life time of apartment;
- Disassembly of complete PP pipe system after 50 years reference service life time of the apartment;
- Transport of complete PP pipe system after 50 years reference service life time of the apartment to an end-of-life treatment;
- End-of-life waste treatment of complete PP pipe system after 50 years reference service life time of the apartment.

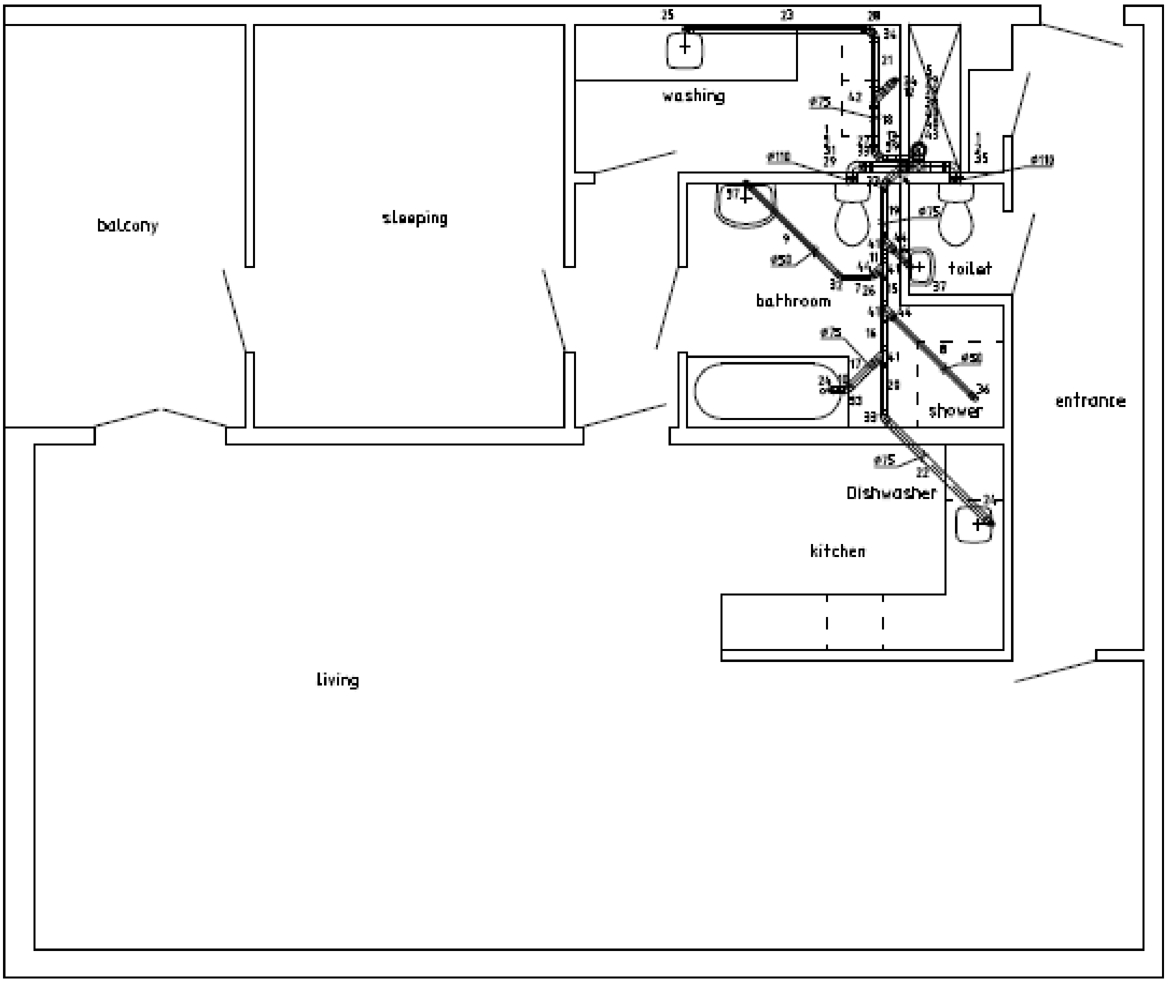

Figure 1: Design of 100 m² of apartment (representative for the PP Soil & Waste pipe system)

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 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 pipe system for soil and waste removal in the building LCA). 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 that 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 PP pipes and PP 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 draft documents prepared by Technical Committee CEN TC 350 (Sustainability of construction works – Environmental Product Declarations – Core rules for the product category of construction products – presented in the draft prEN15804 (CEN TC 350 framework documents, 2008-2009).

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 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 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 raw materials - mainly caused by the PP 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 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 standardised norms and equipment and thus they are very similar across Europe. Since the LCA study on the PP pipe system is performed for an anticipated European average, European manufacturer data are used. The TEPPFA member companies represent more than 50% of the European market for extruded plastic pipes.

All data relates 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 pipes, PP fittings and 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 of apartment with its specific design as presented in Figure 1 (see Table 1).

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

PP pipe system	Average (kg/100 m² apartment) - life time 50 yr	Average (kg/F.U and excl. pipe left over)	Average (kg/F.U and incl. pipe left over)	Average PP pipe left over during installation (5%) (kg/F.U)
PP Pipe	8,612	0,17224	0,180852	0,008612
PP fittings	3,873	0,07746		
SBR sealing rings	0,7021	0,014042		

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

Data on the raw materials for PP 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 the environmental inputs and outputs related to the extrusion of PP pipes and injection moulding of PP fittings. 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 fittings injection moulding and PP pipe extrusion. The revised datasets have been used within this LCA study. 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 pipe system).

Application specific data are dealing with all life cycle phases from the transportation of the packed PP pipe system to the customer to the final EoL treatment scenario. In this framework VITO prepared an application-specific questionnaire in close consultation with the TEPPFA experts. 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 waste 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 Soil and Waste gravity drainage system installation into the 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 draft documents prepared by Technical Committee CEN TC350 (CEN TC 350 draft framework documents, 2008 - 2009):

- Abiotic depletion;
- Acidification;
- Eutrophication;
- Global warming;
- Ozone layer depletion;
- Photochemical oxidation.

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 pipe system for soil and waste removal in the building (apartment).

In discussing the results of the individual profile of the PP 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 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 pipe system is always set at 100% and the relative contributions of the various subprocesses are visible.

Table 2 and Figure 3 present **the environmental profile for the PP 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 pipe system is always set at 100% and the relative contributions of the various life cycle phases are visible.

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

Impact category	Abiotic depletion	Acidification	Eutrophication	Global warming	Ozone layer depletion	Photochemical oxidation
Life cycle phases	**kg Sb eq**	**kg SO2 eq**	**kg PO4--- eq**	**kg CO2 eq**	**kg CFC-11 eq**	**kg C2H4 eq**
Product stage						
Production raw materials for PP pipes	0,00589	0,00114	0,00013	0,35713	0,0000000004	0,00008
Transport of raw materials for PP pipe to converter	0,00005	0,00003	0,00001	0,00685	0,000000001	0,000001
Extrusion PP pipes	0,00060	0,00035	0,00022	0,08054	0,000000004	0,000016
Production raw materials for PP fittings	0,00253	0,00049	0,00005	0,15334	0,0000000002	0,00003
Transport of raw materials for PP fittings to converter	0,00004	0,00002	0,000005	0,00484	0,000000001	0,0000006
Injection moulding PP fittings	0,00038	0,00021	0,00013	0,04954	0,000000003	0,00001
Production of SBR rubberrings	0,00075	0,00028	0,00006	0,06915	0,00000001	0,00001
Construction process stage						
Transport of complete PP pipe system to the building site (apartment)	0,00075	0,00039	0,00011	0,10643	0,00000002	0,0000179
Installation of PP pipe system (in apartment)	0,00031	0,00014	0,00007	0,05641	0,000000003	0,00002
Use stage						
Operational use of PP pipe system	0	0	0	0	0	0
Maintenance of PP pipe system	0	0	0	0	0	0
End of life stage						
Transport of PP pipe system to EoL (after 50 years of service life time apartment)	0,00008	0,00004	0,00001	0,01140	0,000000002	0,000001
EoL of PP pipe system (after 50 years of service life time of apartment)	-0,00037	-0,00017	-0,000141	0,07448	-0,000000002	-0,00001
Total	**0,01100**	**0,00291**	**0,00066**	**0,97011**	**0,00000004**	**0,00018**

A: contribution > 50 %: most important, significant influence

B: 25 % < contribution ≤ 50 %: very important, relevant influence

C: 10 % < contribution ≤ 25 %: fairly important, some influence

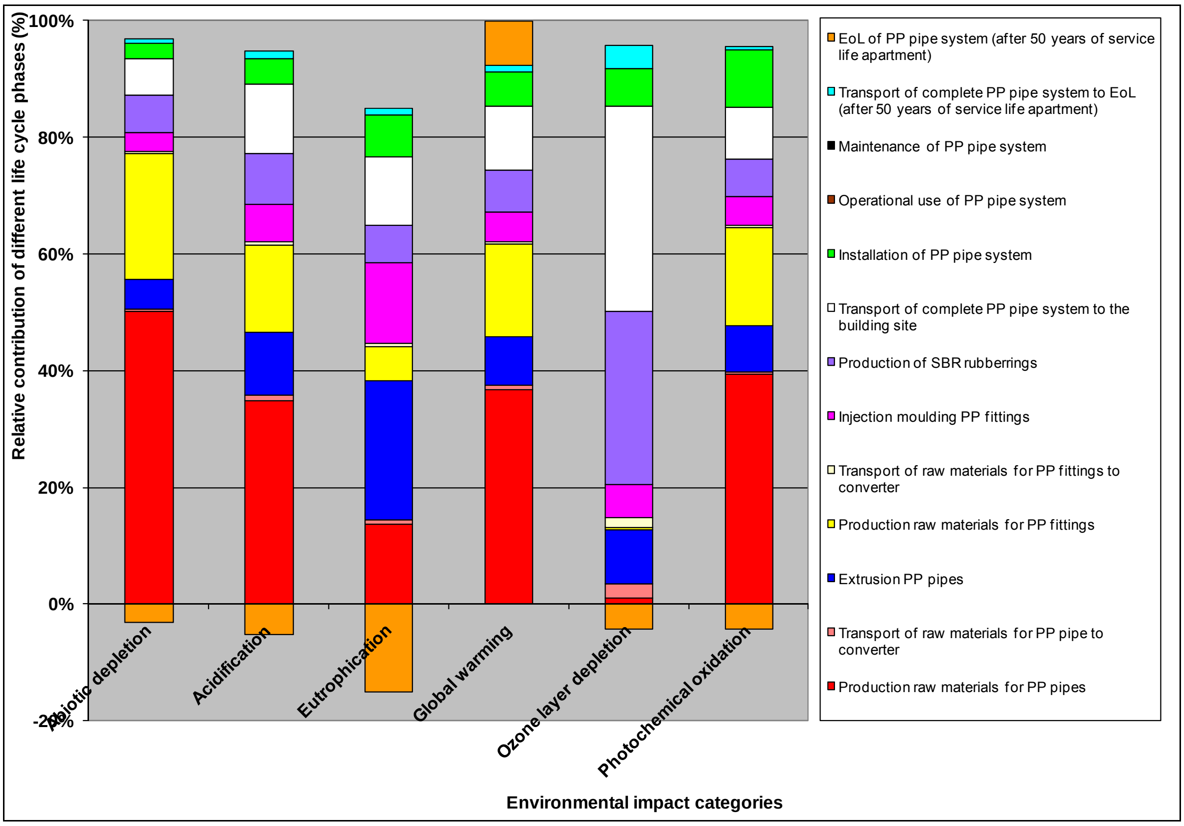

Figure 2: Environmental profile of the PP pipe system for soil and waste removal (building) from the cradle-to-the grave (per functional unit)

For the PP Soil & Waste pipe system it appears that the profile is primarily determined by the production of the **raw materials for the PP pipes and fittings**. It accounts for at least 52% in most impact categories. Only for 2 categories (ozone layer depletion and eutrophication) other phases of the life cycle have a higher impact than the production of raw materials. For the depletion of the ozone layer, transportation of the PP Soil & Waste pipe system to the apartment and the production of the SBR sealing rings become relatively more important. For eutrophication, the extrusion process of the PP pipes is the most important phase. A more detailed analysis of the production of the raw materials for the PP pipes and fittings shows that production of PP resins makes the greatest contribution. However, for ozone layer depletion, the contribution of PP raw materials for pipes and fittings is primarily derived from the production of the stabilisers and the titanium dioxide pigments.

The **transportation of the PP raw materials for pipes and fittings** from raw material producers to the converters has an insignificant impact on the environmental profile of the PP Soil & Waste pipe system for soil or waste removal in the apartment. The contribution is for all impact categories lower than 3% (negligible influence).

The impact from the **production of the SBR sealing rings** is relatively low for most environmental impact categories, with the exception of ozone layer depletion, which is dominated by the transportation of the PP pipes system to the apartment and the production of SBR sealing rings (contribution of 32% which can be considered to be of relevant importance). 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 for the production of the carbon black, one of the raw materials for the production of the SBR rings.

Analysis of the environmental profile of the PP Soil & Waste pipe system shows that the **extrusion of PP pipes** accounts for a percentage between 5% and maximum 12% for 5 of the environmental impact categories considered in this study. According to Annex B of the ISO 14044 guidelines a contribution between 2,5 % and 10 % is of little importance or has a minor influence in the total environmental profile. An exception is the category eutrophication, where the impact of the extrusion of the pipes accounts for 34% (relevant influence).

The impact from the **injection moulding process of PP fittings** is also relatively low for most environmental impact categories: the contribution only amounts between 3% and 8%. According to Annex B of the ISO 14044 guidelines a contribution between 2,5 % and 10 % is of little importance or has a minor influence in the total environmental profile. Only for eutrophication this phase is fairly important (20% on the total environmental impact in this impact category).

Furthermore analysis of the environmental profile of the PP Soil & Waste pipe system shows that the contribution of the **transportation of the complete PP Soil & Waste pipe system to the apartment** accounts for a environmental burden for most environmental impact categories between 6% and 17%, with exception of the contribution to the depletion of the ozone layer, where the transportation of the pipe system to the apartment leads to an important contribution (38%).

The influence of the **installation phase** of the PP Soil & Waste pipe system in the apartment is relatively low for most environmental impact categories (between 2,5% and 11% on the total impact per environmental impact category). The contribution of this phase of the life cycle of the PP Soil & Waste pipe system is little important for most categories.

The contribution of the **transportation of the disassembled 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).

Another general observation with regard to the environmental profile of the PP Soil & Waste pipe system is the fact that for some environmental impact categories the **EoL treatment of the PP Soil & Waste pipe system** leads to environmental benefits or credits. After 50 years of service life time the PP Soil & Waste pipe system is disassembled: 80% of the pipe system is considered to go to a landfill, 15% goes to incineration and 5% is treated by means of mechanical recycling. The benefits in the environmental profile of the PP Soil & Waste pipe system are entirely ascribed to the incineration of the PP Soil & Waste pipe system after 50 years of service life. Incineration of the PP waste in an incinerator with energy recovery leads to energy that can be employed elsewhere as energy source, which helps to realise savings in the production of primary energy that is produced traditionally. These avoided impacts have been incorporated as 'credits' in the study. Landfill will not lead to environmental credits and for mechanical recycling is approached by means of the "recycled content approach". This means that the impacts of the recycling process and the avoided production of virgin materials are considered as soon as the recyclates that are produced during recycling are actually used as substitutes of virgin raw materials.

CHAPTER 5 FINAL CONCLUSIONS

The conclusions of the study concern the LCA-results for the PP 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 PP resin, up till the final disassembling and EoL treatment of the PP Soil & Waste pipe system at the end of its service life (being the life time of the apartment, 50 years).

The environmental profile 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 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 Soil & Waste pipe system from the apartment primarily originates from the production of the raw materials for the PP pipes and the production of the raw materials for the PP fittings. Together, they account for at least 52% in most impact categories. Only for 2 categories (ozone layer depletion and eutrophication) other phases of the life cycle have a higher impact than the production of raw materials. For the depletion of the ozone layer, transportation of the PP Soil & Waste pipe system to the apartment and the production of the SBR sealing rings become relatively more important. For eutrophication, the extrusion process of the PP pipes is the most important phase. A more detailed analysis of the production of these raw materials shows that production of PP resins makes the greatest contribution in the production stage. The contribution accounts for most impact categories for more than 50% (except eutrophication -26%- and ozone layer depletion – less than 2,5%-) of the total environmental impact. For ozone layer depletion, the contribution of PP raw materials for pipes and fittings is primarily derived from the production of the stabilisers and the titanium dioxide pigments.

Analysis of the environmental profile of the PP Soil & Waste pipe system also shows that the converting processes (core business of the TEPPFA member companies) only has a minor influence on the total environmental profile, except for the category eutrophication.

The other life cycle phases are little important, some have even a negligible influence on the total contribution to most environmental impact categories. And a last general observation with regard to the environmental profile of the PP Soil & Waste pipe system is the fact that for some environmental impact categories the EoL treatment of the PP Soil & Waste pipe system leads to environmental benefits or credits. This is mainly related to the incineration of the PP Soil & Waste pipe system with energy recovery. Incineration of the PP waste in an incinerator with energy recovery leads to energy that can be employed elsewhere as energy source, which helps to realise savings in the production of primary energy that is produced traditionally. These avoided impacts have been incorporated as 'credits' in the study.

It can finally be concluded that the environmental profile of the PP Soil & Waste pipe system from the apartment is mainly determined by the amount of raw materials (PP resins) that is needed to produce the PP pipes and fittings. Hence the largest potential for optimisation to raise the environmental performances of the PP Soil & Waste pipe system is to be further developed in the further reduction of the mass or to reduce the amount of virgin resins and to think about applying recyclates.

For global warming (carbon footprint) the contribution of the PP Soil & Waste pipe system (expressed per functional unit, being a soil and waste removal PP Soil & Waste pipe system installed in a 100 m² of apartment over its entire life cycle, calculated per year), is comparable to the impact to global warming related to the driving of a passenger car over a distance of 5 kilometers (Ecoinvent datarecord: 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 the 4 selected TEPPFA 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 can not 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 a later stage and when relevant, the environmental profiles of TEPPFA products can be compared with other competing pipe systems.

The 4 pipe systems for which the integral environmental impacts were calculated by means of an LCA are:

- a PE pipe system for water distribution (utilities);
- a PEX pipe system for hot and cold water (building);
- a PP pipe system for soil and waste removal (building);
- a PVC solid wall sewer pipe system (civils).

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 1 was ommissioned by The European Plastic Pipes and Fittings Association (TEPPFA). It was established in the timeframe of December 2009 to September 2010.
TEPPFA preferred to start the critical review of the study as soon as the first results of the life cycle impact assessment (LCIA) were ready to be able to influence the further development of the whole study from that moment on. After denkstatt had received the

first 2 draft LCA background reports (on PP and PVC pipe systems) from VITO (December 2009) TEPPFA organised a common meeting (16th of December 2009), which enabled all parties (TEPPFA, VITO and denkstatt) to discuss preliminary results and if necessary to adjust possible aspects before finalising the reports. Based on the discussions at the meeting VITO improved all 4 draft LCA background reports and delivered them to denkstatt. Based on those reports denkstatt prepared a detailed list of draft review comments on special issues on various assumptions and data, and a list of general questions to support comprehensibility of the report, accompanied by specific recommendations for improvements of the studies. VITO then had the time to consider suggestions made in the comments and compiled 4 draft final LCA background reports as well as 4 draft final third party reports.
denkstatt's critical review statement summarises the findings of the critical review and is based on those draft final LCA background reports, dated August 2010. The critical review statement will be included in the final version of the 4 LCA background reports as well as the 4 third party reports.

6.3 Scientific Background

The herein described critical review statement covers the study "Life Cycle Assessment of a PP pipe system for soil and waste removal in the building (according to EN 1451)". 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;
- reports are 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) reports and the discussions with the authors of the study and TEPPFA.

6.4 Critical Review Findings

This particular LCA-study aims to examine the PP pipe system for soil and waste removal in the building, to gather and assess comprehensive and reliable information regarding the environmental performance of this pipe system, generated over its 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 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 pipes and fittings. The functional unit of the PP 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 soil and waste gravity drainage system installation into the 100 m^2 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".

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 system and gathering respective data to be able to give a thorough picture of the pipe system under investigation over its 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 were taken from up-to-date literature and databases representing European conditions or directly from the respective industries.
- Within the study no sensitivity analyses were made, as according to the authors they would not have much added value. Keeping the goal and scope of the study in mind, the given arguments are reasonable.
- 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. In some cases assumptions made by VITO in cooperation with the specific TEPPFA application group were discussed between VITO and the reviewer (e.g. regarding plausibility and representativeness within the given system boundaries). The reviewer accepts the chosen assumptions as the result of expert judgement achieved in several workshops.
- Additionally the authors compiled a third party report, where the results are summarised in a very clear and focused manner. This allows an interested party to get an overview of all results without reading the comprehensive background report, which due to its extensive size has rather to be considered as specific reference document for all the aspects examined.

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 system under investigation over its total life cycle from the cradle to the grave. The complete study has been established in a transparent, consistent and logical way.

The third party report as the main document for the communication of the findings of this study presents the results in a clear, logical form, thus making it easy to understand. I explicitly recommend that this information should be communicated to the TEPPFA member companies and its National Associations as well as external stakeholders.

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