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THIRD PARTY REPORT

Comparative Life Cycle Assessment of PP versus ductile iron pipe systems for soil and waste removal

Final Third Party Report

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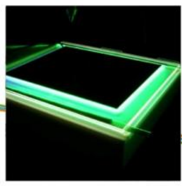

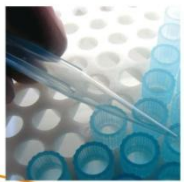

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CHAPTER 1 INTRODUCTION

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 this project is to carry out cradle to grave life cycle assessments of different plastic pipe systems. Another objective of the project is to get a better view on the advantages and disadvantages (from an environmental point of view) of a pipe system in plastic compared to its main competing (non-plastic) material. The result of these additional analyses allow TEPPFA and its member companies and National Associations to distinct (for the pipe systems considered) for which phases of the total life cycle the differences between the competing materials are most significant, and which input or output material (or stream) is responsible for the difference in environmental impact.

This document is a summary of the comparative LCA study of a PP pipe system for soil and waste removal versus a ductile iron pipe system, which has been performed on request of TEPPFA and serves as a 'Third Party Report' which is aimed at a broad public. VITO is the author of the underlying comparative LCA study. The LCA study has been critically reviewed by denkstatt (see Chapter 6). For the PP pipe system results have been taken from the study 'Life Cycle Assessment of a PP pipe system for soil and waste removal in the building (according to EN 1451)' (Spirinckx et al., 2011 – Ref. 2010/TEM/R/232).

The methodology used to determine the environmental aspects of the PP pipe system for soil and waste removal and the ductile iron pipe system for soil and waste removal follows the principles of ISO standards 14040 and 14044 (ISO, 2006). According to these ISO standards, the 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 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 prEN 15804 (CEN TC 350 framework documents 2008-2009)).

CHAPTER 2 GOAL AND SCOPE DEFINITION

2.1. DEFINITION OF THE GOAL OF THE STUDY

The goal of this comparative LCA study is twofold.

A first goal of the study is to gain insight in the position of the PP soil and waste pipe system compared to commonly applied alternatives for what regards the environmental aspects. Therefore TEPPFA wants a comparative LCA, consistent with ISO 14040 series LCA standards, which compares the environmental performance of the TEPPFA PP soil and waste pipe system with an alternative ductile iron system.

A second objective is the communication of the results to a broad public. The results will be disclosed to the public by all means including online and printed documents. This Third party report will be made available to interested parties on request and previous approval of TEPPFA management. Because TEPPFA has the intention to make the results of this comparative LCA publicly available, the LCA study has been critically reviewed by denkstatt (Chapter 6 shows the review statement).

2.2. DEFINITION OF THE 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 pipe systems for soil and waste removal 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 Buildings the definition of the function and the functional unit of the pipe systems for soil and waste removal was discussed. The basic assumption was that the definition of the functional unit should represent the function of the pipe system for soil and waste removal 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 pipes and fittings.

The functional unit of the 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 and its alternative a ductile Iron Soil and Waste gravity drainage system installed into a 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*".

Basic conditions concerning the building to define the functional unit are: 100 m² of a typical residential single family apartment in a 5-storeyed building with all the facilities clearly positioned, like bath, shower, etc. For more specific design parameters, we refer to Figure 1.

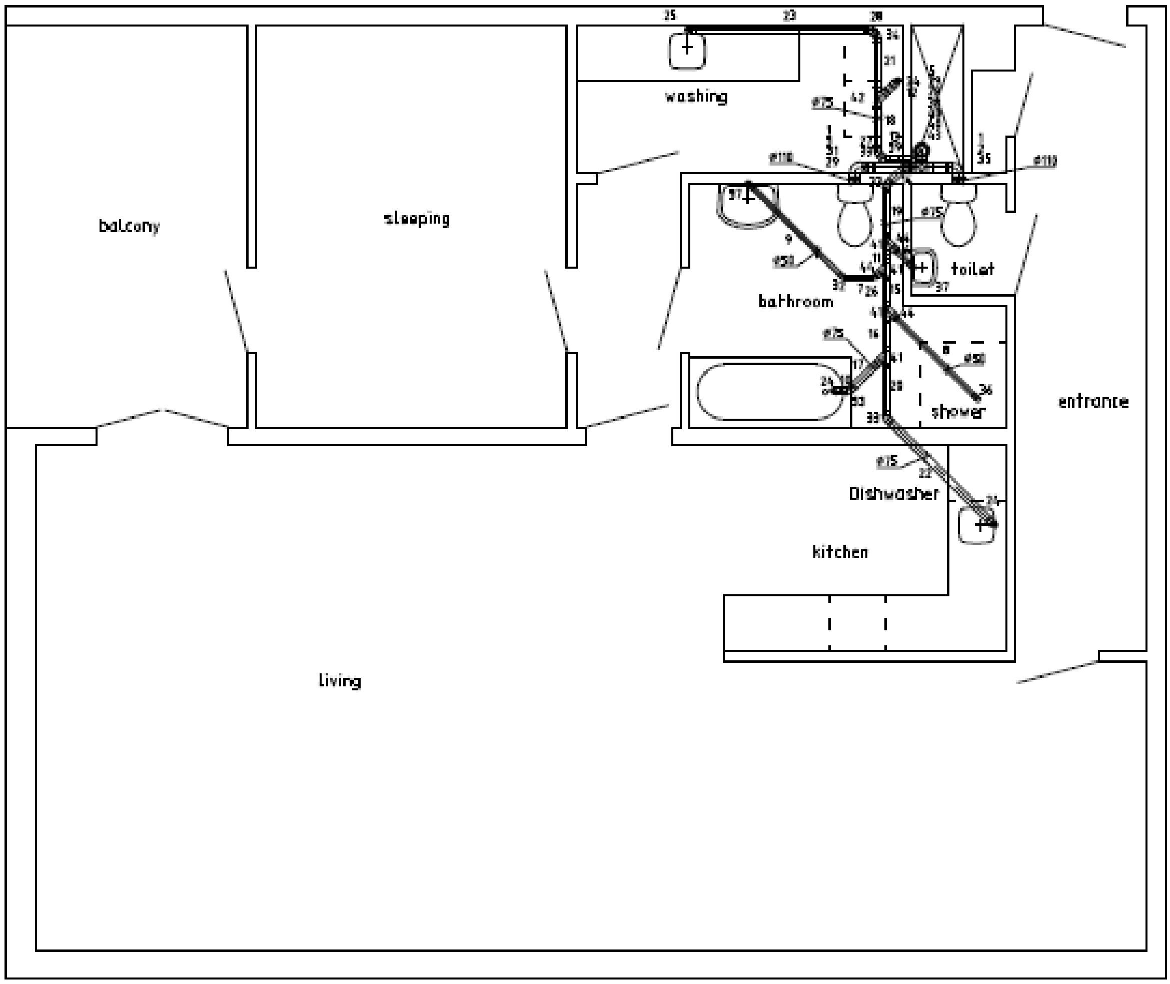

Figure 1: Design of 100 m² apartment (representative for the soil and waste pipe system)

The design of the PP pipe system for soil & waste removal related to the functional unit includes the following:

- 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 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 and fittings);
- Service life time of PP Soil & Waste pipe system is considered to be 50 year (= service life time of the apartment).

The design of the ductile iron pipe system for soil & waste removal related to the functional unit includes the following (publicly available data):

- The complete ductile iron Soil & Waste pipe system is considered;
- The pipe material consists of ductile iron;
- The above ground pipes have a nominal diameter of 50 mm (outside diameter of 60 mm and inside diameter of about 47,5 mm), 70 mm (outside diameter of 80 mm and inside diameter of about 68,25 mm) and 100 mm (outside diameter of 112 mm and inside diameter of about 97,5 mm) (as representatives for the typical pipe diameters for inside building soil and waste removal);
- The below ground pipes have a nominal diameter of 100 mm (outside diameter of 112 mm and inside diameter of about 97,5 mm) (as representative for the typical pipe diameters for below ground soil and waste removal);
- The above ground pipes have an internal coating made of two-part epoxy (thickness 0,13 mm) and an external coating made of acrylic paint (thickness 0,04 mm);
- The below ground pipes have an internal coating made of two-part epoxy (thickness 0,25 mm) and an external coating made of zinc (130 g/m²) and acrylic paint (thickness 0,04 mm);
- Ductile iron fittings are considered in the LCA. The popularity of fittings in the "average" pipe system of functional unit has been calculated in line with the PP pipe system (same type and number of fittings are used);
- Connections to 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 100 mm and fittings);

The reference service life time of the ductile iron pipe system is considered to be 50 year (same as the reference service life time of the PP).

As TEPPFA is well-aware of all design parameters related to the PP pipe system, the specifications of this design are detailed and experience-based. The design of the ductile iron pipe system for soil & waste removal is based on readily available data from literature and from internet.

Both pipe systems for soil and waste removal are analysed over their complete life cycle, from the cradle to the grave. The life cycle is divided in the life cycle phases listed in Table 1.

Table 1: Summary of life cycle phases for both pipe systems from cradle-to-grave

PP pipe system	Ductile iron pipe system
Production of raw materials for PP **pipes**	Production of raw materials for ductile iron **pipes***
Transportation of PP pipe raw materials to converter	Transportation of ductile iron pipe raw materials to converter
Converting process for PP pipes (extrusion)	Converting process for ductile iron pipes (centrifugal casting)*
Production of raw materials for PP **fittings**	Production of raw materials for ductile iron **fittings**
Transportation of PP fittings raw materials to converter	Transportation of ductile iron fittings raw materials to converter
Converting process for PP fittings (injection moulding)	Converting process for ductile iron fittings (casting)
Production of **SBR rubber rings**	Production of **EPDM gaskets**
Transportation of complete soil and waste pipe system to the apartment	
Installation of complete soil and waste pipe system at the apartment	
Use and maintenance of complete pipe system for soil and waste removal during 50 years of reference service life time	
Disassembly of the complete pipe system for soil and waste removal after 50 years of reference service life time	
Transportation of complete pipe system for soil and waste removal after 50 years of reference service life time to end-of-life treatment	
End-of-life waste treatment of complete soil and waste pipe system after 50 years of reference service life time of the apartment	

* The production of ductile iron pipes and the converting process for ductile iron pipes are presented in an aggregated form in the environmental profiles in Chapter 4.

The following underlying principles are adopted when <u>system boundaries</u> 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 specific pipes and fittings. For all other processes (production of basic materials, production of ductile iron parts, additives, energy, transport, etc.) the impact of capital goods is included in the analysis. For example the impact of the pipelines for natural gas is 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 mechanical 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 different pipe system for soil and waste removal 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.

In order to support efficient calculation procedures, some inputs and outputs have been excluded from the LCA. prEN 15804 (CEN TC 350, 2008-2009) describes criteria for the exclusion of inputs and outputs (cut-off rules). In this study, only for some processes there was a need to use the cut-off criteria, namely for exclusion of inputs lower than 1% on mass basis:

- Transportation of the different packaging waste flows to the respective treatment facilities;
- The production of the packaging materials to pack the raw materials for pipes and 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 prEN 15804 (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 do not make the basic data of a study more reliable, but allow assessing the effect of a change in inventory data on the results and conclusions of the study.

In this study the following sensitivity analysis is performed:

- Variation in the recycled content of ductile iron pipes.

CHAPTER 3 LIFE CYCLE INVENTORY

3.1. DATA REQUIREMENTS

The objective is to compose datasets representative and relevant for an average European PP pipe system for soil and waste removal and an average European ductile iron pipe system for soil and waste removal. The data that are used in this LCA study are not case-specific, but reflect the average European representative situation. 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.

The used data are consistently reported in the background report (Spirinckx et al., 2012 – Ref. 2011/TEM/R/115), so that they can be easily reproduced and are critically reviewed. 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.

3.2. LIFE CYCLE INVENTORY OF THE PP PIPE SYSTEM FOR SOIL AND WASTE REMOVAL

Details on the life cycle inventory of the PP pipe system for soil and waste removal are described in the Third party report of the life cycle assessment of a PP pipe system for soil and waste removal in the building (according to EN 1451) (Spirinckx et al., 2011 – Ref. 2010/TEM/R/232). This report is available on the website of TEPPFA (http://www.teppfa.com/). The data are based on European averages established through PlasticsEurope (PP raw materials for pipes and fittings) and 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).

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 Application Group Building. They are based and calculated on the 100 m² of apartment with its specific design (see Table 2).

Table 2: PP soil and 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		

3.3. LIFE CYCLE INVENTORY OF THE DUCTILE IRON PIPE SYSTEM FOR SOIL AND WASTE REMOVAL

Data for the ductile iron pipe system were taken from publicly available data sources. Data gathering is coordinated by VITO and is performed by both TEPPFA and VITO:

- TEPPFA:
  - Data related to the design of the ductile iron Soil & Waste pipe system (amounts of pipes, fittings and other components);
  - Amounts of inputs and outputs related to the application-specific phases.
- VITO:
  - Data related to production processes (from cradle to factory gate) for the entire soil and waste removal pipe system;
  - Background LCI data.

All data are collected in terms of the functional unit and the environmental burdens are calculated in relation to the functional unit, which resulted for the ductile iron pipe system in the following basic pipe system components:

- Ductile iron pipes;
- Ductile iron fittings;
- EPDM gaskets.

The system consists of ductile iron pipe material, for above and below ground application. The above ground pipes have a nominal diameter of 50 mm, 70 mm and 100 mm, an internal coating made of two-part epoxy (thickness 0,13 mm) and an external coating made of acrylic paint (thickness 0,04 mm). The below ground pipes have a nominal diameter of 100 mm, an internal coating made of two-part epoxy (thickness 0,25 mm) and an external coating made of zinc (130 g/m²) and acrylic paint. For the 100 m² apartment 117,74 kg of DI Soil & Waste pipes are needed. The total weight of fittings is 75,90 kg.

Calculations related to the design of the ductile iron pipe system (amounts of ductile iron pipes, ductile iron fittings and rubber gaskets) needed per 100 m² apartment are based on either the design of the PP pipe system and on information from literature and websites of ductile iron pipe producers. Data are summarized in Table 3.

Table 3: Ductile iron soil and waste pipe system in relation to the functional unit

ductile iron 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 pipe left over during installation (2%) (kg/F.U)
Ductile iron pipe	117,740	2,355	2,402	0,047
Ductile iron fittings	75,900	1,518		
Rubber gaskets	1,999	0,040		

CHAPTER 4 LIFE CYCLE IMPACT ASSESSMENT

4.1. METHODOLOGY

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 functional unit 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 and its alternative a ductile Iron Soil and Waste gravity drainage system installed into a 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*".

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 (kg Sb equivalences);
- 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).

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 and the ductile iron pipe system for soil and waste removal in the building.

In discussing the results of the individual profiles of the pipe systems for soil and waste removal 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 Annex B of ISO 14044 the importance of contributions can be classified in terms of percentages. The ranking criteria 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. ENVIRONMENTAL PROFILE OF THE PP PIPE SYSTEM FOR SOIL AND WASTE REMOVAL

Table 4 and Figure 2 present the environmental profile for the PP pipe system for soil and waste removal from the cradle to the grave (expressed per functional unit). The environmental profile shows the contribution of the various steps in the life cycle per environmental impact category. In Figure 2, for each environmental impact category, the total contribution of the pipe system is always set at 100% and the relative contributions of the various sub-processes are visible.

Table 4: Environmental profile of the PP pipe system for soil and waste removal (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	0,00002
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	0,00002
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

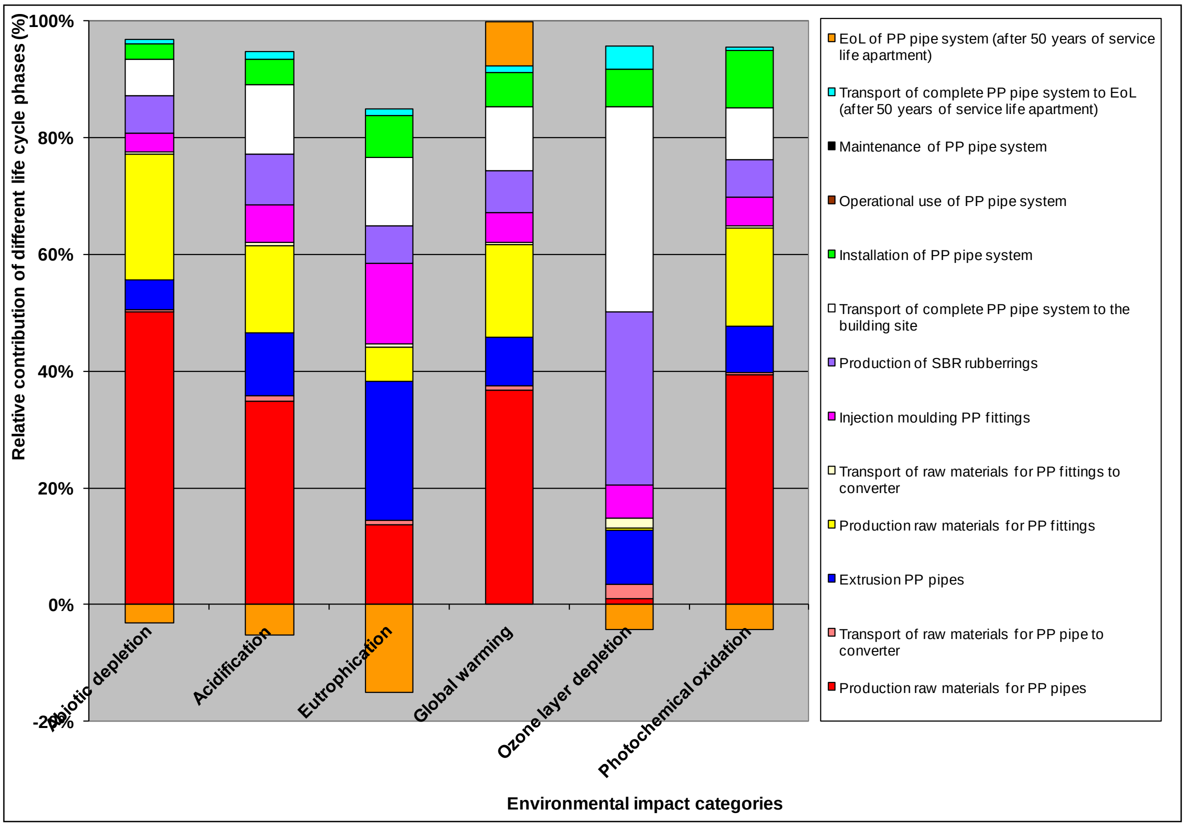

Figure 2: Environmental profile of the PP soil and waste pipe system from cradle-to-grave

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**. 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.

Transportation of the complete PP Soil & Waste pipe system to the apartment accounts for an 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%).

A 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

A more detailed analysis of the environmental profile of the PP pipe system for soil and waste removal in the building can be found in the Third party report on the life cycle assessment of the PP pipe system for soil and waste removal (Spirinckx et al., 2011 – Ref. 2010/TEM/R/231) available on the TEPPFA website.

4.3. ENVIRONMENTAL PROFILE OF THE DUCTILE IRON PIPE SYSTEM FOR SOIL AND WASTE REMOVAL

Table 5 and Figure 3 present the environmental profile for the ductile iron pipe system from the cradle to the grave. The environmental profile shows the contribution of the various steps in the life cycle per environmental impact category. In Figure 3, for each environmental impact category, the total contribution of the pipe system is always set at 100% and the relative contributions of the various sub-processes are visible.

Table 5: Environmental profile of the ductile iron pipe system for soil and waste removal (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 of ductile iron pipes	0,03333	0,01392	0,00757	3,67514	0,000000122	0,00210
Transport of all raw materials for DI pipes to pipe producers	0,00132	0,00070	0,00019	0,17739	0,000000029	0,00002
Production of ductile iron fittings	0,02103	0,00876	0,00477	2,31943	0,000000077	0,00132
Transport of all raw materials for DI fittings to fittings producers	0,00083	0,00044	0,00012	0,11197	0,000000018	0,00001
Production of EPDM gaskets	0,00159	0,00039	0,00014	0,11224	0,000000043	0,00002
Construction process stage						
Transport of complete DI pipe system to the building site (apartment)	0,00438	0,00205	0,00060	0,62444	0,000000095	0,00013
Installation of DI pipe system (in apartment)	0,00038	0,00020	0,00009	0,06744	0,000000004	0,00002
Use stage						
Operational use of DI pipe system	0	0	0	0	0	0
Maintenance of DI pipe system	0	0	0	0	0	0
End of life stage						
Transport of DI pipe system to EoL (after 50 years of service life time apartment)	0,00772	0,00397	0,00110	1,09806	0,000000166	0,00014
EoL of DI pipe system (after 50 years of service life time of apartment)	0	0	0	0	0	0
Total	**0,07058**	**0,03043**	**0,01458**	**8,18612**	**0,00000055**	**0,00378**

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

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

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

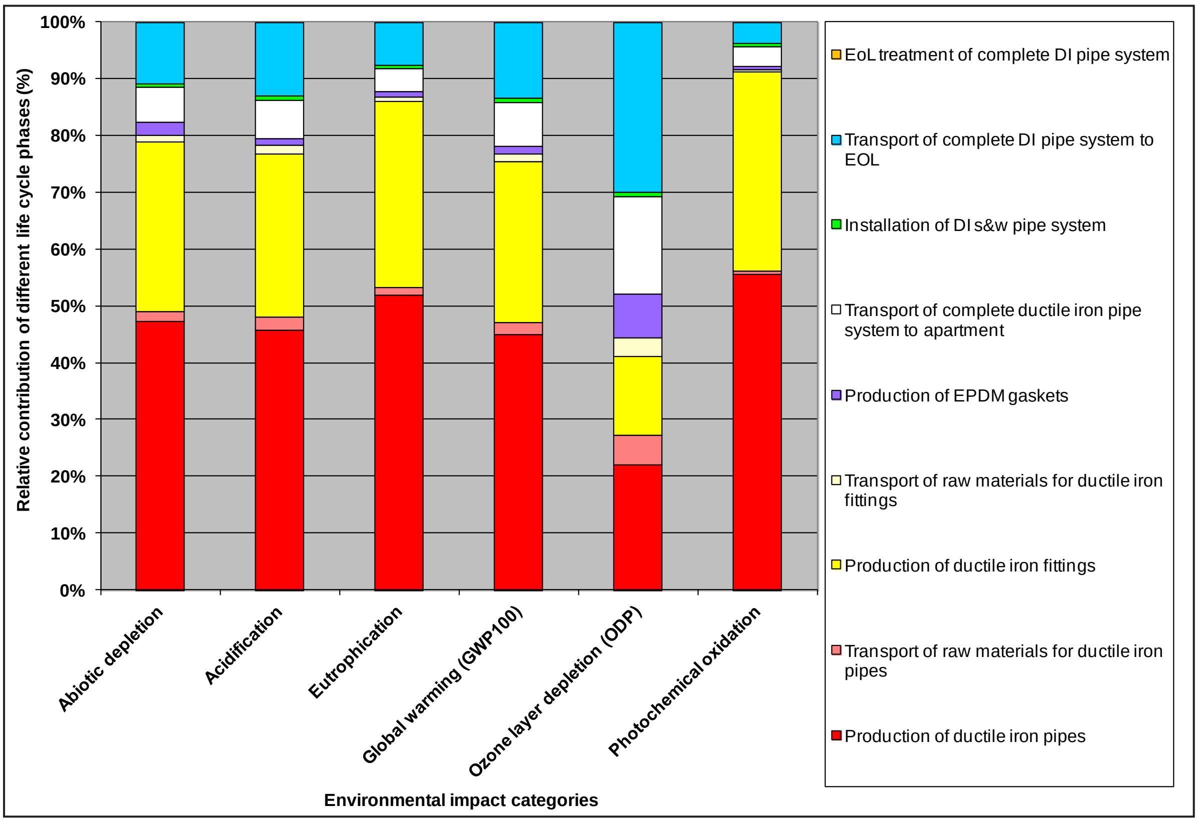

Figure 3: Environmental profile of the ductile iron pipe system in relation to the functional unit

The environmental profile of the ductile iron pipe system for soil and waste removal is dominated by the contribution of the **production of the raw materials and ductile iron pipes** (contributions vary depending on the impact categories from 22% to 56%). It is important to note that this phase includes both production of raw materials and production of pipes.

Other important categories are the **production of the raw materials and ductile iron fittings** (14% to 35%) and the **transport of the ductile iron pipe system to end-of-life treatment** (7% to 30%).

The contribution of the **transportation of the complete ductile iron pipe system to the apartment** is fairly important for the impact category Ozone layer depletion, where this life cycle phase represents 17%.

The other life cycle phases of the ductile iron pipe system for soil and waste removal have a minor or negligible influence on the total environmental impact from the cradle to the grave, in the 6 categories considered in this study.

4.4. Comparative environmental profile of the PP versus the ductile iron pipe system for soil and waste removal.

Figure 4 compares the environmental impacts of the PP with the ductile iron pipe system for soil and waste removal. The system with the highest impact is always set at 100%.

One conclusion that follows directly from this comparative profile is that the ductile iron pipe system contributes significantly more to all 6 environmental impact categories than the PP pipe system, looking at the cradle to the grave life cycle. The difference is mainly due to the higher impact of the production of the ductile iron pipes and fittings.

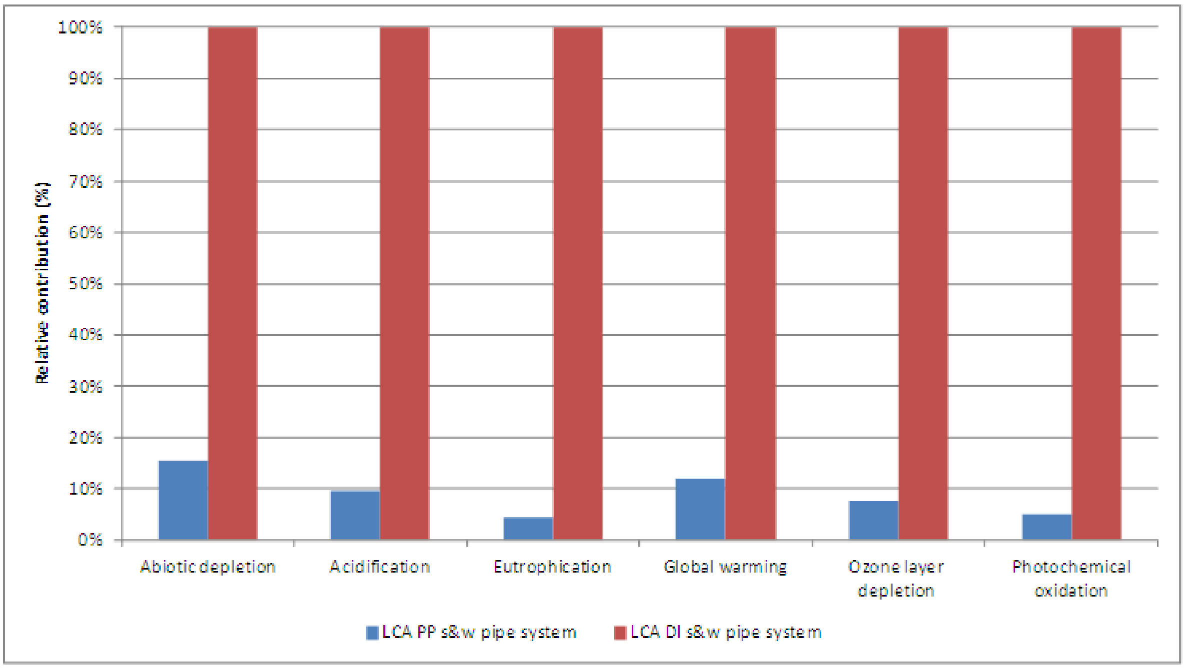

Figure 4: Comparative environmental profile from cradle-to-grave between ductile iron and PP pipe system for soil and waste removal (related to FU)

Sensitivity assessment: Recycled content of the ductile iron pipe system for soil and waste removal

Because the production of the ductile iron pipes and raw materials dominates the environmental profile of ductile iron pipe system for soil and waste removal, it was decided to increase the recycled content from 35% up till 50% and 80%. By doing so, it is possible to see if a change in the amount of recycled raw materials for the ductile iron pipes and fittings has an influence on the results of the comparison. All other parameters and life cycle inventory data for the plastic pipe system remain the same.

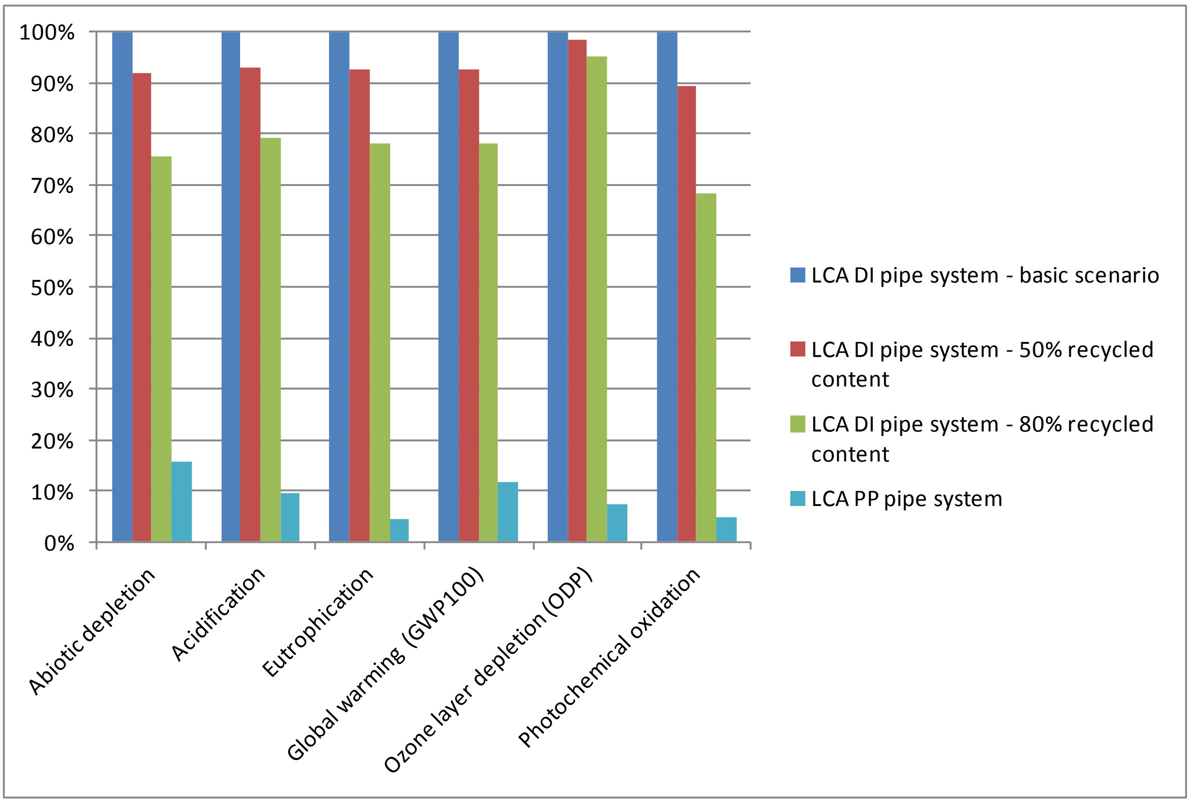

Figure 5: Comparative environmental profile of ductile iron(DI) versus PP including sensitivity analyses on the recycled content of ductile iron

Compared to the basic scenario for the ductile iron pipe system for soil and waste removal the scenarios with an increased recycled content (from 35% in the basic scenario to 50 and 80% in a sensitivity analyses) lead to a reduction of the environmental impact from 1% to 32%. The overall conclusion however, remains the same.

CHAPTER 5 FINAL CONCLUSIONS

The conclusions of the study concern the LCA-results for the comparison of the PP with the ductile iron pipe system for soil and waste removal, from the cradle to the grave: from the primary extraction of raw materials, up till the final disassembling and end-of-life treatment of both pipe systems at the end of their service life (50 years).

Analysis of the environmental profile of the ductile iron pipe system for soil and waste removal reveals that the environmental impact primarily originates from the production of the ductile iron pipes and fittings and the necessary raw materials (contribution between 22% and 56%, depending on the impact category). This contribution is mainly coming from the production of raw materials (mainly pig iron) for the ductile iron pipes and fittings, in combination with the casting processes to produce pipes and fittings. For Ozone layer depletion the impact of the production of the pipes is also determined by the transportation of the disassembled ductile iron soil and waste pipe system to an end-of-life treatment facility after 50 years of service life (30%).

The other life cycle phases of the ductile iron pipe system have a minor or negligible influence on the total environmental impact from the cradle to the grave, in the 6 impact categories considered in this study.

The environmental profile of the ductile iron pipe system for soil and waste removal was compared to the environmental profile of the PP pipe system for soil and waste removal. The ductile iron pipe system for soil and waste removal contributes significantly more to all 6 environmental impact categories than the PP pipe system, looking from the cradle to the grave life cycle. The difference is mainly due to the higher impact of the production of ductile iron pipes and fittings in comparison to the production of PP soil and waste pipes and fittings.

The obvious reason for the impact of the production of the ductile iron pipes and fittings being higher is the heavy weight of the ductile iron pipe system in comparison with the PP pipe system for soil and waste removal in the building.

A sensitivity analysis on the recycled content was performed. Because the production of the ductile iron pipes and raw materials for pipes dominates the environmental profile of ductile iron pipe system for soil and waste removal, it was decided to increase the recycled content from 35% up to 50% and 80%. Compared to the basic scenario for the ductile iron pipe system for soil and waste removal the scenarios with an increased recycled content lead to a reduction of the environmental impacts from 1% to 32%. When comparing to the PP pipe system, environmental impacts of the ductile iron system with 80% recycled content are still significantly higher.

CHAPTER 6 CRITICAL REVIEW STATEMENT

Author: Bernd Brandt (denkstatt)

6.1. 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 commissioned a project which was carried out by the Flemish Institute for Technological Research (VITO) in Belgium.

The aim of the first phase of the project was to carry out a "cradle to grave" 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 this LCA-project phase 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);

One of the systems that was studied in the first phase was the PP pipe system for soil and waste removal in the building. 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 were analysed by means of an LCA assessment. The life cycle assessment of the PP pipe system for soil and waste removal has been described in a background report [Spirinckx et al., 2011a] and a third party report [Spirinckx et al., 2011b].

To get a better view on the advantages and disadvantages (from an environmental point of view) of a pipe system in plastic compared to its main competing (non-plastic) material, TEPPFA additionally commissioned comparative LCAs, which fol-low with ISO LCA standards series [ISO 14040, 2006] and [ISO 14044, 2006], to compare the environmental performance of the following applications and materials:

- **PE** versus **ductile iron** pipe systems for water distribution (pressure)
- **PEX** Hot & Cold versus **copper** Hot & Cold water pipe systems
- **PVC-U** solid wall versus **concrete** sewer pipe systems
- **PP** versus **ductile iron** pipe systems for soil and waste removal

The result of the additional project allows TEPPFA and its member companies to distinct (for the pipe systems considered) for which phases of the total life cycle the difference between the competing materials is most significant, and even more specific, which input or output material (or stream) is responsible for the difference in environmental impact. Based on these results TEPPFA is able to highlight the environmental advantages of plastic pipe systems compared to their main competing materials.

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. Different to ISO requirements for comparative LCA studies TEPPFA did not install a review panel, but commissioned a single critical review. This critical review was performed by denkstatt GmbH.

6.2. Review Process

The critical review process of the 4 comparative LCA-studies described in section 1 was commissioned by The European Plastic Pipes and Fittings Association (TEPPFA). It was established in the timeframe of May 2011 to June 2012.

After the receipt of the 4 draft background reports reports from VITO (May/July 2011) 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 im-provements of the studies were included. VITO and denkstatt then discussed the issues raised in the comments as well as suggestions made by denkstatt. Based on the results of these discussions VITO 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 the draft final background report, dated December 2011 as well as the draft third party report, dated June 2012. The critical review statement will be included in the final version of the 4 final third party reports.

6.3. Scientific Background

The herein described critical review statement covers the study "Comparative Life Cycle Assessment of PP versus ductile iron pipe systems for soil and waste removal". 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.
- Additionally for comparative studies the following requirements are defined according to [ISO 14044, 2006]:
- Scope of the study shall be defined in a way that the systems under investigation are comparable
- Systems shall be compared using the same functional unit and equivalent methodological considerations
- Any differences between systems shall be identified and reported.

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 both the draft final back-ground and third party report as well as the discussions with the authors of the study and TEPPFA.

6.4. Critical Review Findings

This particular LCA-study aims to examine and compare pipe systems for soil and waste removal made of both PP and ductile iron, to gather and assess comprehen-sive and reliable information regarding the environmental performance of these pipe systems, generated over its entire life cycle.

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 as well as the ductile iron 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 both the PP and ductile iron pipe components.

The functional unit for this comparative LCA for pipe systems for soil and waste removal has been defined as: "The yearly impact of a soil and waste gravity drain-age system installation into a 100 m^2 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)".

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 comparative LCA-study and thus the study is scientifically and technically adequate. The authors of the study at VITO put a lot of effort into design-ing the system and gathering respective data to be able to give a thorough picture of the pipe systems under investigation over its entire life cycle. The overall system was defined in a way that the competing pipe systems under investigation are comparable.
- Quality of required data and data sources as well as data collection proce-dures 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 justi-fications are given, whenever necessary, especially when certain negligible issues were not considered in the calculations. Any differences between the systems were well reported.
- Sensitivity analyses were made in the framework of this study using a higher recycled content for the ductile iron pipes when comparing with the plastic pipes.
- 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 the reviewer questioned assumptions made by VITO in cooperation with TEPPFA ex-perts. These cases were discussed between VITO, TEPPFA and the reviewer. Finally solutions could be found, which were acceptable for the reviewer. For

example, an important issue was to clarify which processing steps are already included in the dataset for "cast iron", and if any additional processing steps should be included additionally.

- The "recycling content approach" was selected for the calculation. In this particular comparative LCA-study this is not a conservative approach from the plastic pipe system's perspective, because this particular approach increases the environmental burden of ductile iron pipes compared to other allocation options. Other allocation approaches for recycling like the "open loop" approach influence the results, but do not change the order of results (in the case of an "open loop" allocation).
- The calculation of transport activities was intensively discussed between VITO and denkstatt. Finally the calculation of VITO was accepted by the reviewer, as any changes won't change the overall results significantly.
- 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. 5 Conclusion

This study is a comparative 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 and ductile iron pipe systems 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.

For communication of the results to external parties and the public, the reviewer recommends using the results of the sensitivity analysis (higher recycling content of ductile iron pipes) – which are more conservative from the plastic pipe system's perspective – with the same prominence as the main results.

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