SUSTAINABILITY ASPECTS OF PLASTIC PIPE SYSTEMS

The environmental pillar of the polyvinylchloride (PVC-U) solid wall sewer pipe system

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Abstract

The paper describes the importance that the European Plastic Pipes and Fittings Association (TEPPFA) attaches to sustainability aspects that are related to their business and products and focuses on a recently performed life cycle assessment (LCA) and environmental product declaration (EPD) project. First the incentives of TEPPFA to apply the concept of life cycle thinking to modern business practice, with the aim to manage the total life cycle of their products and services towards a more "sustainable" construction and housing are described. The LCA and EPD project started with the analysis of 4 basic cases from the cradle-to-the-grave: the polyethylene (PE) pipe systems for water distribution (utilities), he polyvinylchloride (PVC) sewer pipe systems, the crosslinked polyethylene (PEX) pipe systems for hot an cold water in the building and the polypropylene (PP) pipe systems for soil and waste removal from the building. In this paper we will focus on one of the systems: more specifically the PVC solid wall sewer pipe system. Overall the paper highlights the importance of life cycle thinking and managing for the European plastics pipes and fittings sector, the sector approach, the procedures for data collection, the importance of stakeholder involvement, the LCA results for the PVC solid wall sewer pipe system, and the next steps in the project.

Keywords

Plastic pipe systems, Life cycle assessment (LCA), Environmental product declaration (EPD), European sector approach, sustainable construction and housing.

1. Introduction

The European Plastic 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 the cradle to the 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.

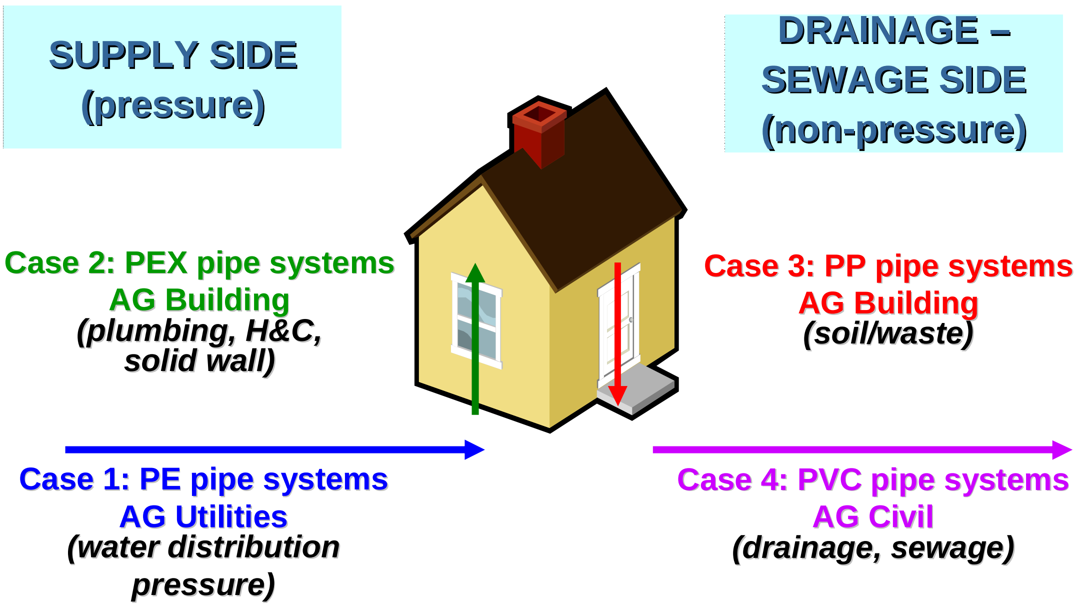

Figure 1: Overview of the 4 plastic pipe system applications that are analyzed within the larger LCA-project

With the present paper VITO is reporting on the LCA of one specific plastic pipe system performed on request of 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 PVC study is part of a larger project where other plastic pipe systems within different application areas are analyzed by means of an

LCA. This paper is a summary of the results of the polyvinylchloride (PVC) solid wall sewer pipe system aimed at a broad public. TEPPFA is planning to 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 in the CEN documents (CEN TC 350 draft framework documents, 2008 – 2009);
- to focus improvement activities on the most important impact-generating process phases;
- to consider in new product developments;
- ...

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 August 2010. The LCA study has been critically reviewed by Denkstatt (Austrian LCA experts).

2. Approach and methodology

LCA is a suitable method to analyze the environmental impacts of products, processes and/or systems, from an entire life cycle perspective. LCA quantifies the potential environmental effects of a product over its entire life cycle, meaning that the extraction of raw materials, the production of materials and the product, the use and the end-of-life treatment are taken into account.

The methodology used to determine the environmental aspects of the PVC solid wall sewer pipe system conforms to the 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.

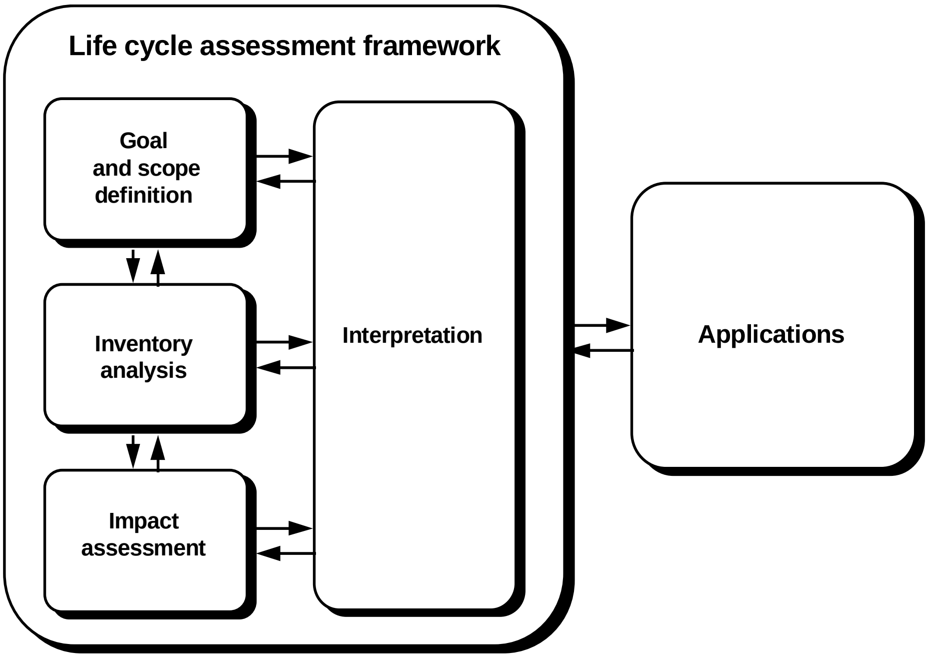

Figure 2: The methodological framework of the LCA (ISO, 2006)

For this project the different environmental impact categories presented in the draft documents prepared within the technical committee CEN TC350 “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).

Since TEPPFA plans to make the results of the LCA study available for the general public, according to ISO 14040 and ISO14044 (ISO, 2006) this requires a critical review of the LCA study. This critical review is performed by Denkstatt (Austrian LCA experts).

In order to actively involve different European TEPPFA member companies in the project, we organized different interactive series of workshops. In these workshops the application group Civils of TEPPFA, representative organizations of the raw materials (e.g. PVC4Pipes), suppliers, etc. were actively involved.

3. Goal and scope

In the first phase of an LCA, the intended use of the LCA (the goal) and the breadth and depth of the study (the scope) have to be clearly defined. The scope definition has to be consistent with the goal of the study. It is important to agree on the objective, the reference basis and the intended use of the study.

The goal and scope of the LCA of the PVC solid wall sewer pipe system for TEPPFA is defined by VITO in close consultation with TEPPFA, the Application Group Civils and the steering committee. In this framework VITO organized a first series of workshops, devoted to the discussion on goal and scope.

TEPPFA wants a cradle to grave LCA consistent with ISO 14040 series LCA standards (ISO, 2006) to assess the environmental performance of TEPPFA plastic piping systems. This LCA-study aims to examine the PVC solid wall sewer piping application, to gather and assess comprehensive and reliable information regarding the environmental performance of this application, generated over its entire life cycle. In the same time, this study helps to provide a reliable database for the development of ISO 14025 Type III Environmental Product Declarations (EPDs) on the European level.

Summarized the objective of the LCA for the PVC solid wall sewer pipe system for TEPPFA is:

- to analyze the environmental impacts of the PVC solid wall sewer pipe system;
- to investigate the relative performance of the PVC solid wall sewer pipe system 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 study of PVC solid wall sewer pipe system for business-to-business communication (via an EPD format);
- in a later stage and when relevant, the environmental profile of the PVC solid wall sewer pipe system can be compared with other competing pipe systems.

The intended audience of the LCA study of the of PVC solid wall sewer pipe system are the TEPPFA member companies, the National associations in the first place and external stakeholders (like governments, professionals, builders) at the second stage (by means of so-called third party reports and via EPD communication formats). 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 within the building and construction sector. Finally, TEPPFA intends to use results for comparisons with other traditional competing pipe systems.

The functional unit in the LCA study encompasses the function of the of PVC solid wall sewer pipe system. The functional unit must be defined in a way that different pipes systems made out of competing materials can be implemented in the same application. The function of the PVC solid wall sewer pipe system is to transport (gravity discharge) a certain amount of sewage from the entrance of a public sewer system to the entrance of the waste water treatment plant. In consultation with TEPPFA, its steering committee and the Application Group Civils the definition of the function and the functional unit of the PVC solid wall sewer pipe system was discussed. The basic assumption was that the definition of the functional unit should represent the function of the PVC solid wall sewer 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 PVC pipes and fittings. The functional unit of the PVC solid wall sewer pipe system has been defined as: "the below ground gravity transportation of sewage over a distance of 100 m by a typical public European PVC solid wall sewer pipe system (Ø 250mm) from the entrance of a public sewer system to the entrance of the waste water treatment plant, over its complete service life cycle of 100 years, calculated per year".

In order to define the design of the PVC solid wall sewer pipe system in terms of the functional unit the following considerations have been made:

- Pipes: Diameter 250 mm, 5 m length, socketed, solid wall, virgin material, red brown, SN 4 (representative for the average pipe diameter from the entrance of a public sewer system to the entrance of the waste water treatment plant);
- Manhole every 45 meters (SMP) 630 mm shaft, exclusive the manhole covers;
- Service life time 100 years (Source: TNO report, 2008, Quality of PVC sewage pipes in the Netherlands);
- Volume of fittings including seals (approximately 5%) calculated based on actual sales data;
- Reference length 100m;
- Slope 1/200 -> Capacity in L/S -> Volume of sewage transported;
- Filling rate 100% -> number of households connected.

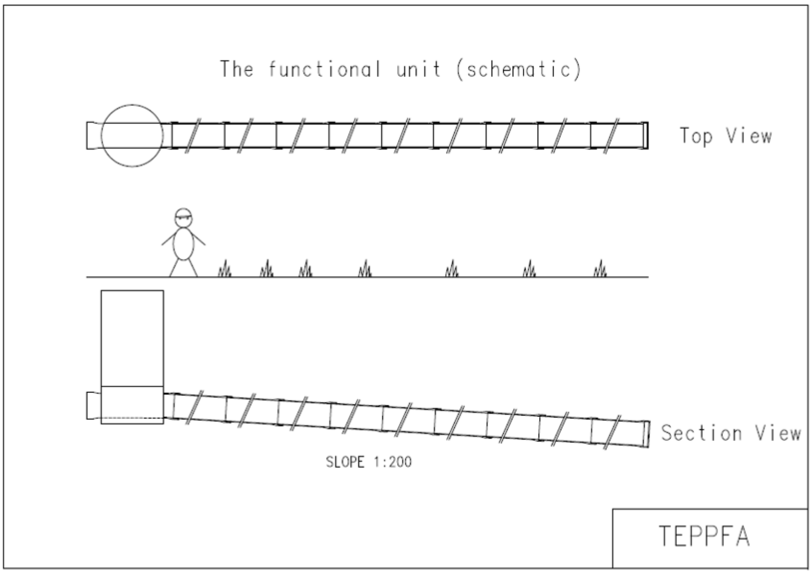

Figure 3: The design of the PVC solid wall sewer pipe system according to the functional unit

The life cycle of the PVC solid wall sewer pipe system has been divided in the following different life cycle phases:

- Production of raw materials for PVC pipes;
- Transport of PVC pipe raw materials to converter;
- Converting process for PVC pipes (extrusion);
- Production raw materials for PVC fittings;
- Transport of PVC fitting raw materials to converter;
- Converting process for PVC fittings (injection moulding);
- Production raw materials for polypropylene (PP) manholes;
- Transport of PP manholes raw materials to converter;
- Converting process for PP manholes (injection moulding);
- Production raw materials for styrene butadiene rubber (SBR) rings;
- Transport of SBR raw materials to converter;
- Converting process for SBR rings;
- Transport of complete PVC solid wall sewer pipe system to the trench;
- Installation of complete PVC solid wall sewer pipe system in the trench;
- Use and maintenance of the complete PVC solid wall sewer pipe system during 100 years of reference service life time;
- Disassembly of complete PVC solid wall sewer pipe system after 100 years of reference service life time;

- Transport of complete PVC solid wall sewer pipe system after 100 years of reference service life time;
- End-of-life waste treatment of complete PVC solid wall sewer pipe system after 100 years of reference service life time.

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 PVC 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 PVC solid wall sewer pipe system 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.

4. Life cycle inventory phase

4.1 Data requirements

The objective is to compose a dataset that is representative and relevant for average European PVC solid wall sewer pipe system. The data that are used in the LCA study are not case-specific, but reflect the average European representative situation. The production processes run according to European standardized norms and equipment and thus they are very similar across Europe. Since the LCA study on the PVC solid wall sewer 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 PVC pipes, PVC fittings, PP manholes and SBR rings (needed per 100 m of an average European sewage pipe system) are based on a consensus within the Application Group Civils of TEPPFA They are based and calculated on the 100 m of pipe system (see Table 1).

Table 1: PVC solid wall sewer pipe system in relation to the functional unit

PVC solid wall sewer pipe system	**Average (kg/100 m) - life time 100 yr**	**Average (kg/F.U and incl. pipe left over)**
PVC pipes	701,42	7,15
PVC fittings	35,07	0,35
SBR sealing rings	4,05	0,04
PP manholes	115,31	1,15

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

Data on the raw materials for PVC pipes and fittings are coming from PlasticsEurope (the association of plastics manufacturers) and the PVC4Pipes association (recipe of raw materials to produce PVC pipes). 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 (the association of plastics manufacturers). In this framework TNO collected the environmental inputs and outputs related to the extrusion of PVC pipes and injection moulding of PVC 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 PVC fittings injection moulding and PVC pipe extrusion. The datasets also included transport of raw materials to converters and packaging of produced products (pipes and fittings). The revised datasets have been used within this LCA study and have also been accepted and applied by TNO for the PlasticsEurope project.

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 PVC solid wall sewer pipe system).

Application specific data are dealing with all life cycle phases from the transportation of the packed PVC solid wall sewer 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, demolition process and the EoL treatment. The use phase is only related to the maintenance of the PVC solid wall sewer pipe system (jetting). The operational use is not relevant and thus not considered in the LCA.

4.1 Data collection procedures

Wherever possible, data collection is based on data derived from members of TEPPFA, TEPPFA experts, representative organizations 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 trench, installation, and demolition after 100 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.

Summarized, the data inventory collection process appealed to:

- inquiries (based on specific questionnaires) of relevant actors being the representative organizations 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.

5. Life cycle impact assessment

5.1 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 below ground gravity transportation of sewage over a distance of 100 m by a typical public European PVC solid wall sewer pipe system (Ø 250mm) from the entrance of a public sewer system to the entrance of the waste water treatment plant, over its complete service life cycle of 100 years, 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).

The optional declaration on ionizing radiation is not being considered in this study. An LCA calculates the potential contribution of the pipe systems 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 7.1.8” for performing the life cycle impact assessment (LCIA) and generating the environmental profile of the PVC solid wall sewer pipe system.

In discussing the results of the individual profile of the PVC solid wall sewer pipe system 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.

5.2 The environmental profile of the PVC solid wall sewer pipe system

Figure 4 presents the environmental profile for the PVC solid wall sewer pipe system from the cradle to the grave (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 PVC solid wall sewer pipe system is always set at 100% and the relative contributions of the various life cycle phases are visible.

Analysis of the environmental profile of the PVC pipe system learns that for most environmental impact categories the *production of the raw materials for the PVC pipes* has an average contribution of about 50%. Only for the depletion of the ozone layer, the installation phase becomes relatively more important. A more detailed analysis of the production of the raw materials for the PVC pipes shows that production of the polyvinylchloride (PVC) makes the greatest contribution. However, for ozone layer depletion, the contribution of PVC raw materials for pipes is primarily derived from the production of the stabilizers and lubricants, and the production of the coloring pigment.

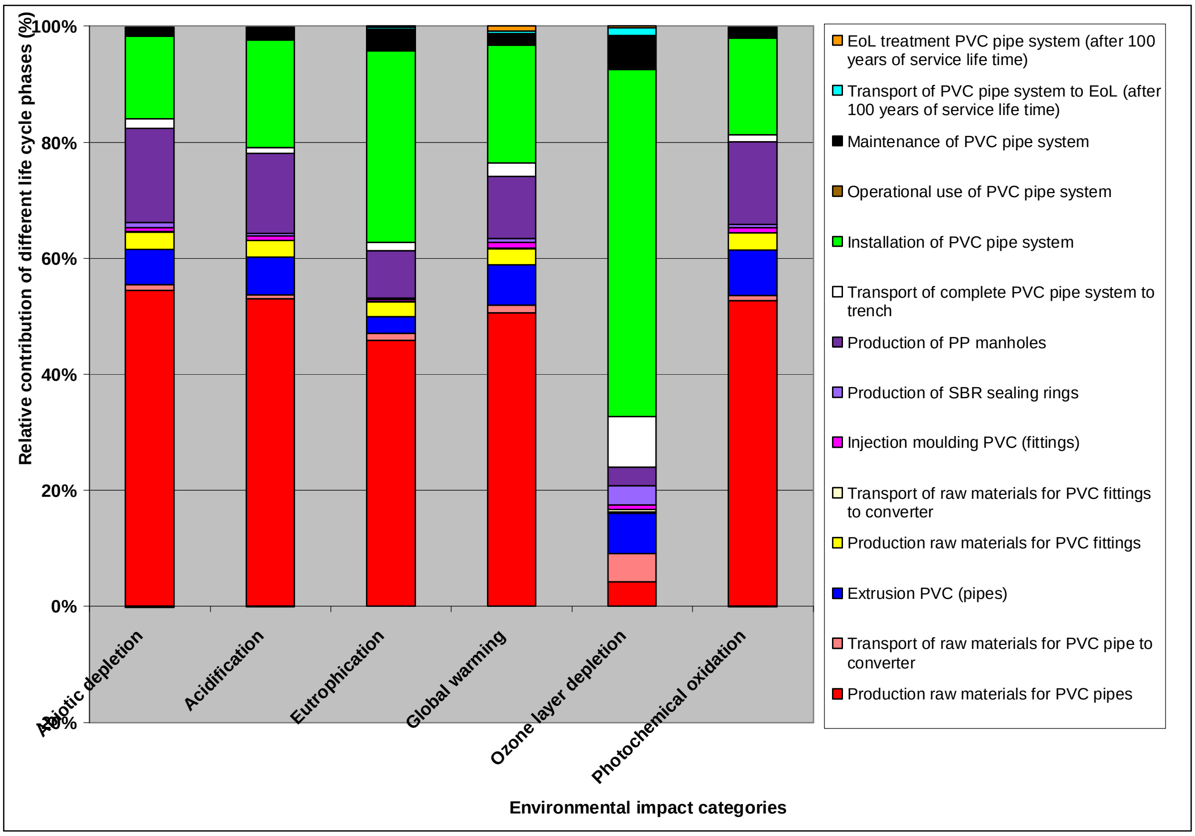

Figure 4: The environmental profile of the PVC solid wall sewer pipe system from the cradle to the grave and expressed per functional unit

The influence of the *production of the raw materials for the PVC fittings* is for most impact categories not important (contribution lower than 2,5% on the total impact per environmental impact category) or little important (about 3% of total impact per environmental impact category).

The *transportation of the PVC raw materials for pipes and fittings* from raw material producer to the converters has an insignificant impact on the environmental profile of the PVC solid wall sewer pipe system (see Figure 9). The contribution is for all impact categories lower than 2,5% (negligible influence), except for the category ozone layer depletion where the transportation of the PVC raw materials for pipes accounts for 5 % of the total contribution (minor influence).

The contribution of the *production of the SBR sealing rings* is insignificant (since contribution is lower than 2,5% for all environmental impact categories, with exception of the category ozone layer depletion).

Analysis of the environmental profile of the PVC pipe system shows that the *production of the PP manholes* results in a fairly important contribution to abiotic depletion, acidification and photochemical oxidation. For the euthrophication and global warming it accounts for respectively 8% and 10%, which is little important. The contribution of the production of the PP manholes to ozone layer depletion is negligible (3%).

Extrusion of PVC pipes accounts for a percentage between 3% and maximum 8% for most environmental impact categories considered in this study. According to Annex B of the ISO 14044 guidelines (ISO, 2006) a contribution between 2,5 % and 10 % is of little importance or has a minor influence in the total environmental profile.

The impact from the *injection moulding process of PVC fittings* is not important since the contribution is always lower than 1% for all environmental impact categories considered.

Furthermore analysis of the environmental profile of the PVC solid wall sewer pipe system shows that the contribution of the *transportation of the complete PVC pipe system to the trench* accounts for an environmental burden for most environmental impact categories between 1% and 9% (which is considered to be of minor influence).

The influence of the *installation phase of the PVC pipe system at the trench* is most important for the ozone layer depletion category (contribution of 60%) and very important for the category euthrophication (contribution of 33%). For the other impact categories, the installation phase results in a contribution between 14% and 20% which is considered to be fairly important.

Maintenance of the PVC pipe system (jetting operations) has only a minor influence for the categories eutrophication (contribution of 4%) and ozone layer depletion (contribution of 6%) and a negligible influence for the other environmental impact categories (since contribution is lower than 2 %).

The contribution of the *transportation of the disassembled PVC pipe system to an EoL treatment* facility after 100 years of service life time (in case the PVC sewer pipe does not stay in the ground) is not important since its contribution is for all environmental impact categories lower than 1,5% (negligible influence).

The contribution of the *EoL treatment of the PVC pipe system* (incineration or recycling in case the PVC pipe system does not stay in the ground after 100 years of service life time) is not important since its contribution is for all environmental impact categories lower than 1% (negligible influence).

5.3 Sensitivity analysis

For the LCA of the PVC solid wall sewer pipe system the sensitivity analysis looks at the influence of applying recyclates as a partly replacement of the virgin PVC raw materials. In that case we are talking about a multilayer sewer pipe system instead of solid wall pipe system. We expect that two important factors will influence the environmental profile: the lower weight of PVC multilayer sewer pipes (compared to solid wall PVC sewer pipes) and the application of recyclates as a partly replacement of virgin PVC raw materials. The multilayer PVC pipes are produced by means of a multilayer extrusion lines, whereas the PVC solid wall pipes can be produced by means of single layer extrusion line, which needs relatively less energy per kg of pipes produced. In this sensitivity analysis the environmental impacts related to the complete life cycle of the multilayer PVC sewer pipe system are compared to the environmental profile of the PVC solid wall sewer pipe system. The sensitivity analysis looks at the influence of including the recycling process of PVC waste into PVC recyclates that can be applied into the PVC multilayer pipe system and considers a lower weights. Since the recycled content approach has been considered within this LCA project, this means that the avoided production of virgin PVC raw materials has been taken into account in the sensitivity analysis.

Calculations of the amounts of PVC multilayer pipes, PVC fittings, PP manholes and SBR rings (needed per 100 m of an average European multilayer sewage pipe system) are based on a consensus within the Application Group Civils of TEPPFA They are based and calculated on the 100 m of pipe system and on a average yearly base (see Table 2). The functional unit is identical to the PVC-U solid wall sewer pipe system. The amount of PVC fittings, SBR sealing rings and PP manholes are the same as defined for the PVC solid wall sewer pipe system (compare Table 1 and 2).

Table 2: PVC multilayer sewer pipe system in relation to the functional unit

PVC multilayer sewer pipe system	**Average (kg/100 m) - life time 100 yr**	**Average (kg/F.U and incl. pipe left over)**
PVC pipes	547,67	5,58
PVC fittings	35,07	0,35
SBR sealing rings	4,05	0,04
PP manholes	115,31	1,15

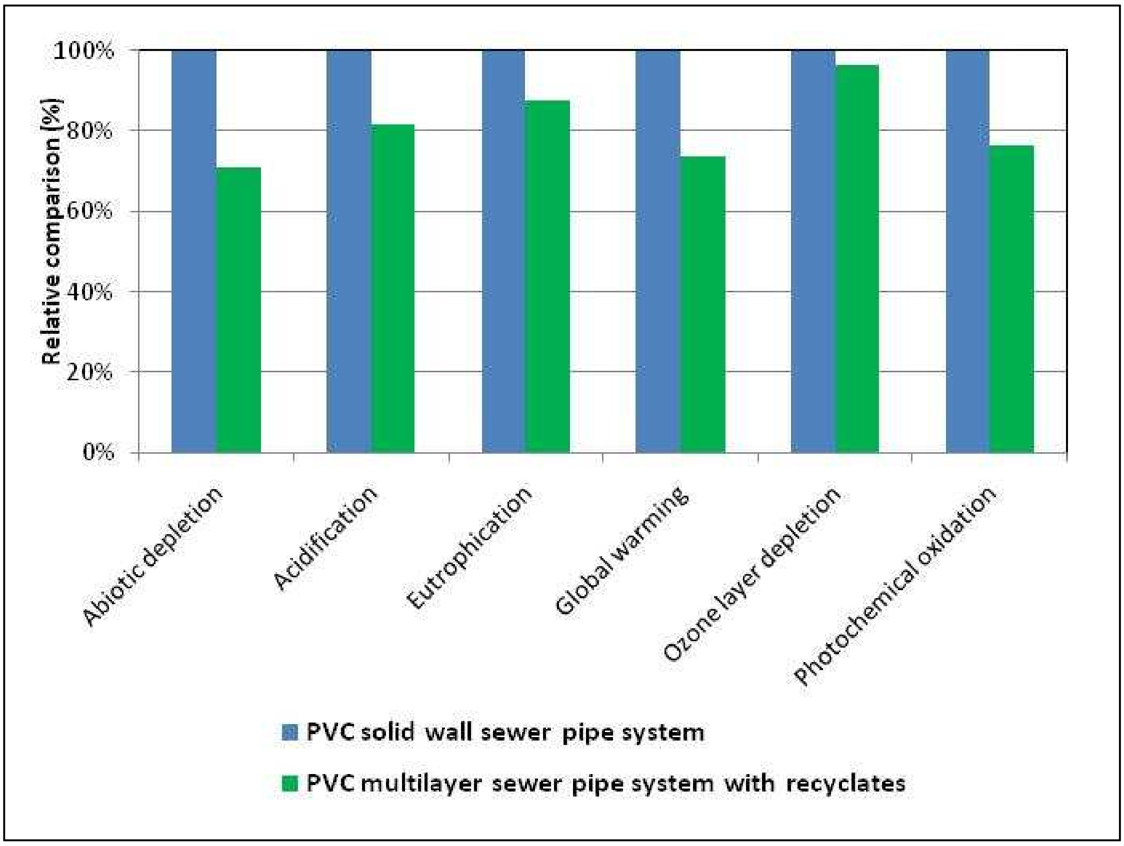

Figure 5: The environmental profile of the PVC multilayer sewer pipe system from the cradle to the grave and expressed per functional unit

The reduction of the weight and the application of recyclates have a significant influence on the total environmental impact of the PVC solid wall pipe system. It differs between the impact categories, but on average the environmental impact from cradle-to-grave is reduced by 25% when recyclates are used and when the weight of the pipes are reduced. This sensitivity analysis shows that the environmental performance of the PVC solid wall sewer pipe system can be improved when recyclates are applied and by reducing the waste of the pipes. Hence the largest potential for optimization to raise the environmental performances of the PVC solid wall sewer pipe system is to be further developed in the further reduction of the mass of the pipes and to reduce the amount of virgin PVC resins and to think about applying recyclates.

6. Conclusions

The conclusions of the study concern the LCA-results for the PVC solid wall sewer pipe system, from the cradle to the grave: from the primary extraction of raw materials to produce the vinylchloride monomers, up till the final disassembling and EoL treatment of the PVC pipe system at the end of its service life (100 years).

The environmental profile consists of various environmental impact categories. They relate to the functional unit which has been selected for this study.

The environmental impact of the PVC solid wall sewer pipe system primarily originates from the production of the raw materials for the PVC pipes and the installation of the PVC pipe system at the trench. A more detailed analysis of the production of the PVC raw materials for the pipes shows that production of PVC resins makes the greatest contribution. The contribution accounts for most impact categories for about 45% of the total environmental impact. An accurate analysis of the installation phase of the PVC pipe system at the trench learns that the contribution of the installation phase is mainly caused by the excavating processes: digging up soil and backfilling soil and sand. Analysis of the environmental profile of the PVC pipe system also shows that the converting processes (core business of the TEPPFA member companies) and transportation issues only have a minor influence on the total environmental profile. The other life cycle phases also are little important, some have even a negligible influence on the total contribution to most environmental impact categories.

A sensitivity analysis shows that the environmental performance of the PVC solid wall sewer pipe system can be improved when recyclates are applied. Hence the largest potential for optimization to raise the environmental performances of the PVC solid wall sewer pipe system is to be further developed in the further reduction of the mass of the pipes, to reduce the amount of virgin PVC resins and to think about applying recyclates. In addition the environmental profile can be optimized by reducing the amount of soil that needs to be digged up and backfilled again at the trench during installation.

For global warming (carbon footprint) the contribution of the PVC solid wall sewer pipe system (expressed per functional unit, being the 100 meter of pipe system 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 160 kilometers (Ecoinvent datarecord: transport, passenger car, petrol, fleet average/person.km – RER).

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