(Contract 101631)

THIRD PARTY REPORT

Life Cycle Assessment a PVC-O (bi-oriented, MRS 31,5 MPa) pipe system for water distribution (according to ISO 16422)

Final Third Party Report

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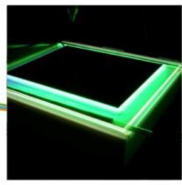
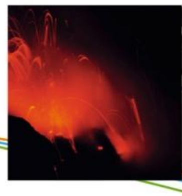
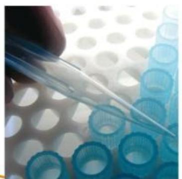

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CHAPTER 1 INTRODUCTION

The European Plastics Pipes and Fittings Association (TEPPFA) deems it important to have an insight into the integral environmental burdens encountered during the life-span of particular pipe system applications. With this framework in mind, TEPPFA has set up a project with the Flemish Institute for Technological Research (VITO). The aim of the first TEPPFA project frame was to carry out a life cycle assessment (LCA) from cradle to grave of different specific applications of plastic pipe systems. One of the systems studied in the first phase of the project was the PE pipe system for water distribution (pressure). This report presents the results of the LCA of a PVC-O (bi-oriented – MRS 31,5 MPa) pressure pipe system for water distribution.

The Flemish Institute for technological Research (VITO) has analysed the various environmental aspects, which accompany this pressure 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 are analysed by means of an LCA assessment. The final aim of the study is to establish an environmental product declaration (EPD). The EPD has been made according to the CEN framework (CEN TC 350 draft framework documents, 2008 - 2009).

This document is a summary of the LCA study of the PVC-O (bi-oriented – MRS 31,5 MPa) pipe system for water distribution (according to ISO 16422) 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 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 new product developments;
- ...

VITO is the author of this comprehensive LCA study which has been carried out under assignment from TEPPFA. The study started early in 2011 and was completed in December 2011. The LCA study has been critically reviewed by denkstatt (see Chapter 6).

The methodology used to determine the environmental aspects of the PVC-O (bi-oriented – MRS 31,5 MPa) pipe system for water distribution is conform 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.

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 PVC-O (bi-oriented – MRS 31,5 MPa) pipe system for water distribution (according to ISO 16422), to gather and assess comprehensive and reliable information regarding the environmental performance of this PVC-O pressure pipe system over its entire life cycle. In the same time, this study helps to provide a reliable database for the development of an ISO 14025 Type III Environmental Product Declarations (EPDs) on the European level for the PVC pressure pipe system. 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) was used for this project.

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

Since TEPPFA wishes to publicly communicate the results of this LCA, a critical review has been performed by denkstatt and 3rd party report has been compiled.

2.2 Definition of scope of the study

The scope of the study is defined in the functional unit. The functional unit is closely related to the function(s) fulfilled by the to-be-investigated product. The function of the PVC-O (bi-oriented – MRS 31,5 MPa) pressure pipe system for water distribution is to transport (supply) a certain amount of water from the exit of the water plant to the water meter of the building. In consultation with TEPPFA, its steering committee and the Application Group (AG) Utilities the definition of the function and the functional unit of the PVC-O pressure pipe system for water distribution was discussed. The basic assumption was that the definition of the functional unit should represent the function of the PVC-O pressure pipe system for water distribution over their entire life cycle: raw material extraction, material production, production of the pipes and fittings, the construction phase, the use phase and the processing of the waste at the end of life of the PVC-O pressure pipe system. The functional unit of the water distribution pipe system has been defined as: "*the below ground transportation of drinking water, over a distance of 100 m (from the exit of the water plant to the water meter of the building), by a typical public European PVC-O (bi-oriented – MRS 31,5 MPa) pipe system for water distribution (Ø 110mm) over its complete life cycle of 100 years, calculated per year*".

In order to define the design of the PVC-O pressure pipe system for water distribution in terms of the functional unit the following considerations have been made:

- Pipe material: PVC-O (bi-oriented) type 1: dark grey unplasticized polyvinylchloride MRS 31,5 MPa – wall thickness 2,7 mm - meter weight of pipes: 1,3614 kg;
- Pipe diameter: ø 110 mm (as a representative for the average pipe diameter from the exit of the water plant to the water meter of the building);
- 110 mm pipe calculated as average weight per metre calculated from actual sales across a market in sizes 20 mm to 1000 mm;
- SDR 41;
- Service life time of 100 years (Schulte and Hessel, 2006);
- 2 types of fittings: PVC fittings and ductile iron fittings;
- The popularity of fittings in “average” pipe of functional unit is calculated from actual sales data. The weight of fittings is calculated from company weight / piece data;
- Galvanised steel for bolt, nut, washer and rings has been taken into consideration in the product system, as well as the cutter (which become part of the system) and EPDM gaskets;
- Water use will include:
    - Agriculture – 42%;
    - Industry – 23%;
    - Urban – 18%;
    - Energy – 18%.
- Activity area (typical): 6720 inhabitants;
- Direct usage per person 150 l/day: 6,25 litre/hour;
- Speed: 1,5 meter/second;
- Hydraulic gradient of 1,65 m/100m;
- Considered flow capacity of a 110 mm SDR 26, PVC-U pipe of average roughness at a flow speed of 1,5 m per second (EN 805 advises that “in practice it will be desirable to avoid unduly high or low velocities. The range 0,5 m/s to 2,0 m/s may be considered appropriate) were taken into account;
- Most common components (other than pipe) used in functional unit:
    - Tapping Tee;
    - Coupler;
    - Flange (inc. nuts, bolts, washes and gaskets);
    - 45 elbow;
    - 90 elbow;
    - Retaining rig.

The life cycle of the PVC-O pressure pipe system for water distribution has been divided in the following different life cycle phases:

- Production of raw materials for PVC-O (MRS 31,5 MPa) pipes;
- Transport of PVC pipe raw materials to converter;
- Converting process for PVC-O (MRS 31,5 MPa) pipes (extrusion);
- Production raw materials for PVC-U fittings;
- Transport of PVC-U fitting raw materials to converter;
- Converting process for PVC-U fittings (injection moulding);
- Production of ductile iron fittings (raw materials, transport and production process) being part of the PVC-O pipe system;
- Production of galvanised steel components (raw materials + converting process) being part of the PVC-O pipe system;
- Production of steel cutter, being part of the PVC-O pipe system;
- Production of EPDM gaskets (raw materials + converting process), being part of the PVC-O pipe system;
- Transport of complete PVC pressure pipe system to the trench;
- Installation of complete PVC pressure pipe system at the trench;

- Use and maintenance of the complete PVC pressure pipe system during 100 years of reference service life time;
- Disassembly of complete PVC pressure pipe system after 100 years reference service life time;
- Transport of complete PVC pressure pipe system after 100 years reference service life time to an end-of-life treatment (in case the PVC pressure pipe system does not stay in the ground);
- End-of-life waste treatment of complete PVC pressure pipe system after 100 years reference service life time (in case the PVC pressure pipe system does not stay in the ground).

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 pressure pipe system). 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 PVC-O pressure pipes and PVC-U fittings in order to be able to easily transport them from the producers to the converters.

- The production of the packaging materials to pack the ductile iron fittings, the steel components and the EPDM gaskets in order to be able to easily transport them from the producers to the trench.

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 do not 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 PVC-O pressure pipe system for water distribution that the data and the uncertainty on the data for the most important life cycle phases (installation phase and raw materials for PVC-O pipes) are thoroughly discussed during the workshops. These data are based on European averages established through PlasticsEurope (PVC raw materials for pipes) or based on company-specific knowledge on the way the pipes are installed at the trench (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 an average European PVC-O (bi-oriented – MRS 31,5 MPa) pipe system for water distribution (according to ISO 16422). The data that are used in this LCA study are not case-specific, but reflect the typical European representative situation. The production processes run according to European standards and equipments are very similar across Europe. Since the LCA study on the PVC-O (bi-oriented – MRS 31,5 MPa) pipe system for water distribution 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 relate to the existing situation in Europe, using existing production techniques. Data are as much as possible representative for the modern state-of-technology. As such Europe in the period 2000-2008 is considered as the geographical and time coverage for these data.

The used data are consistently reported and critically reviewed, so that they can be easily reproduced. If in this document is referred to "a pipe system", this means the pipe system representing the average at the European level, and not one specific pipe system. Calculations of the amounts of PVC-O pressure pipes, PVC-U fittings, ductile iron fittings, steel components and EPDM gaskets (needed per 100 m of an average European pressure pipe system for water distribution) are based on a consensus within the AG Utilities. They are based and calculated on the 100 m of pipe system (see Table 1).

Table 1: PVC-O pressure pipe system (MRS 31,5 MPa) for water distribution in relation to the functional unit

PVC-O pressure pipe system (MRS 31,5 Mpa)	Average (kg/100 m)	Average (kg/F.U - excl. left over)	Average (kg/F.U - incl. left over)
PVC pipe	136,1	1,361	1,385
PVC fittings	19,485	0,195	
DI fittings	29	0,290	
Galvanised steel, bolts, ring, washers, nuts	5,704	0,057	
Steel cutter	0,913	0,009	
EPDM gaskets	1,579	0,016	
Total, incl. left over			1,952

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 pressure pipes and fittings are coming from PlasticsEurope and PVC4pipes association. 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 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 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). The datasets were originally based on the PVC sewer pipe system (Spirinckx et al., 2011). They are revised by TEPPFA and VITO for the PVC pressure pipe system (based on additional questionnaire, filled out by 5 TEPPFA member companies).

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 pressure pipe system for water distribution.

Application specific data are dealing with all life cycle phases from the transportation of the packed PVC pressure pipe system to the customer to the final EoL treatment scenario. In this framework TEPPFA prepared an application-specific questionnaire. The collection of application specific data encompasses the identification of different kind of scenarios for transport to construction site, construction process, demolition process and the EoL treatment. The operational use is not relevant and thus not considered in the LCA.

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 trench, installation, 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.

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 below ground transportation of drinking water, over a distance of 100 m (from the exit of the water plant to the water meter of the building), by a typical public European PVC-O (bi-oriented – MRS 31,5 MPa) pipe system for water distribution (Ø 110mm) over its complete 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 TC 350 (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 ionising 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 7.3.0.” for performing the life cycle impact assessment (LCIA) and generating the environmental profile of the PVC-O (bi-oriented – MRS 31,5 MPa) pressure pipe system for water distribution.

In discussing the results of the individual profile of the PVC-O (bi-oriented – MRS 31,5 MPa) pressure pipe system for water distribution 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 be classified in terms of percentage. 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 The environmental profile of the PVC-O (MRS 31,5 MPa) pressure pipe system for water distribution

Table 2 and Figure 1 present **the environmental profile for the PVC-O (MRS 31,5 MPa) pressure pipe system for water distribution 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-O pressure pipe system is always set at 100% and the relative contributions of the various life cycle phases are visible.
We have to remark here that some datarecords in Ecoinvent underestimate the ozone depleting emissions significantly, while other datasets (like energy carriers) do consider these emissions. The reason for this data inconsistency is the incomplete accounting within the PlasticsEurope data. As a consequence in Table 2 and Figure 1 there is an underestimation of the relative contribution of the raw materials production in the category ozone layer depletion.

Table 2: Environmental profile of the PVC-O pressure (MRS 31,5 MPa) pipe system for water distribution (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 raw materials for PVC pipes	0,03046	0,00697	0,00117	2,59090	5,97E-09	0,000424
Transport of raw materials for PVC pipe to converter	0,00045	0,00024	0,00006	0,06025	9,91E-09	0,000008
Extrusion PVC (pipe)	0,00377	0,00236	0,00155	0,51092	2,23E-08	0,000098
Production of raw materials for PVC fittings	0,00434	0,00098	0,00016	0,36621	4,12E-10	0,000061
Transport of raw materials for PVC fittings to converter	0,00010	0,00005	0,00001	0,01332	2,17E-09	0,000002
Injection moulding PVC (fittings)	0,00104	0,00063	0,00042	0,14028	6,09E-09	0,000026
Production of ductile iron fittings	0,00418	0,00176	0,00093	0,46450	1,82E-08	0,000256
Production of galvanised steel for bolt, rings, washer, nut	0,00110	0,00048	0,00029	0,13475	5,85E-09	0,000063
Production of cutter of steel	0,00018	0,00008	0,00005	0,02159	9,37E-10	0,000010
Production of EPDM gaskets	0,00063	0,00015	0,00005	0,04431	1,68E-08	0,000008
Construction process stage						
Transport of complete PVC pipe system to trench	0,00211	0,00109	0,00030	0,30091	4,56E-08	0,000038
Installation of PVC pipe system	0,01711	0,01635	0,00422	2,47016	3,17E-07	0,000492
Use stage						
Operational use of PVC pipe system	0	0	0	0	0	0
Maintenance of PVC pipe system	0	0	0	0	0	0
End of life stage						
Transport of complete PVC pipe system to EoL (after 100 years of service life time)	0,00010	0,00005	0,00001	0,01397	2,12E-09	0,000002
EoL of PVC pipe system (after 100 years of service life time)	-0,00008	-0,00002	-0,00004	0,04395	4,98E-10	-0,000001
Total	**0,06548**	**0,03116**	**0,00920**	**7,17602**	**0,00000045**	**0,001487**

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

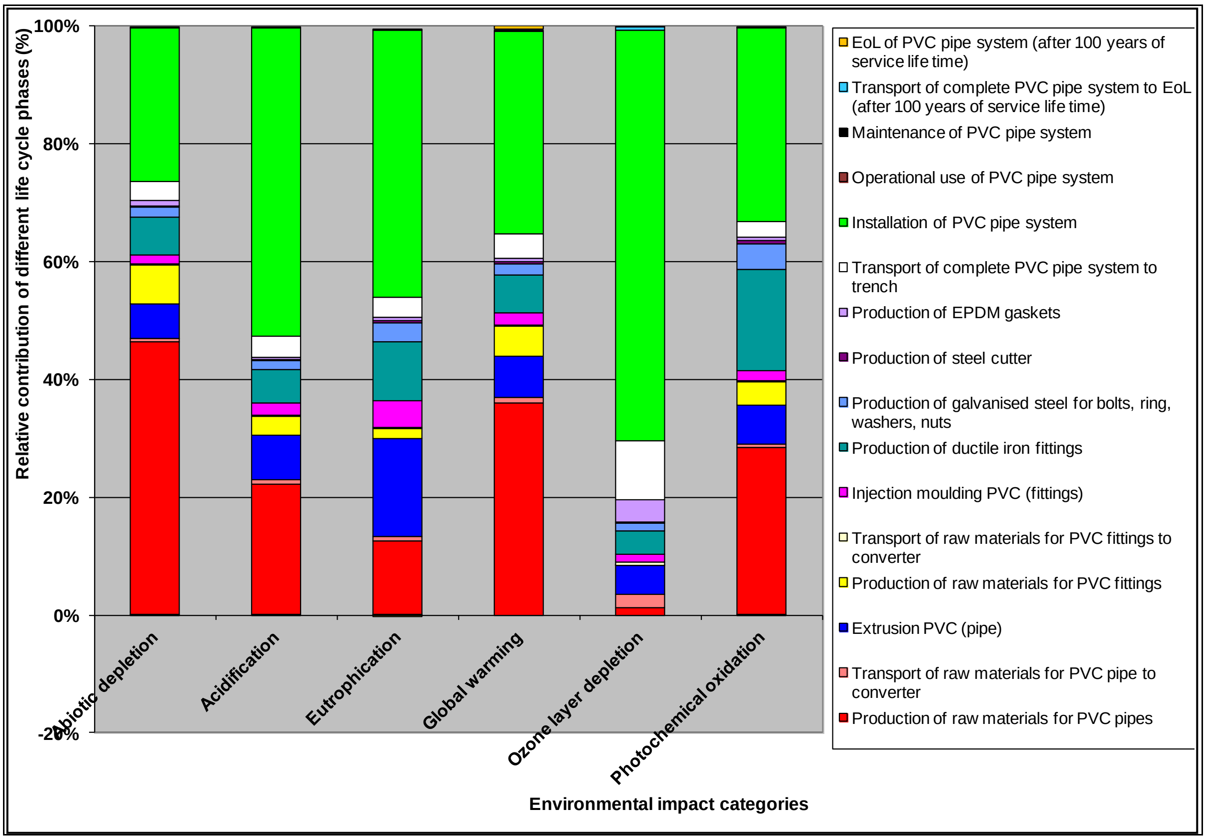

Figure 1 Environmental profile of the PVC-O pressure (MRS 31,5 MPa) pipe system for water distribution from cradle-to-grave

Analysis of the environmental profile of the PVC-O pressure (MRS 31,5 MPa) pipe system learns that for all environmental impact categories the **production of the raw materials for the PVC-O pressure (MRS 31,5 MPa) pipes** and **the installation of the PVC-O pressure (MRS 31,5 MPa) pipe system at the trench** have the highest contribution to the environmental profile of the PVC-O pressure (31,5 MPa) pipe system for water distribution.

For all environmental impact categories the **production of the raw materials for the PVC-O pressure (MRS 31,5 MPa) pipes** has a contribution between 13% and 47% depending on the impact category considered (with exception for the category ozone layer depletion where the impact only represents 1,3%).

The influence of the **installation phase** of the PVC-O pressure (MRS 31,5 MPa) pipe system **at the trench** is most important for the categories ozone layer depletion (contribution of 70%) and acidification (contribution of 53%). We have to repeat here that there is an incomplete accounting of the ozone layer depletion emissions in the PlasticsEurope data. Therefore the impact of other life cycle phases on ozone layer depletion might be overestimated. The installation phase has a very important impact in the categories eutrophication (contribution of 46%), global warming (contribution of 34%), photochemical oxidation (contribution of 33%) and abiotic depletion (26%).

The other life cycle process phases have a less significant contribution:

The influence of the **production of the raw materials for the PVC-U fittings** is for most impact categories little important or even negligible (contribution between 0,1% and 6,6% of the 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-O pressure (MRS 31,5 MPa) pipe system. The contribution is for all impact categories lower than 2,5% (negligible influence).

Extrusion of PVC-O pressure (MRS 31,5 MPa) pipes accounts for a percentage between 5% (ozone layer depletion) and maximum 17% (eutrophication) for all environmental impact categories considered in this study.

The impact from the **injection moulding process of PVC-U fittings** is not very important since the contribution is lower than 2,5% for all environmental impact categories but one. It accounts for 4,5% of the impact in the category eutrophication (minor influence).

The contribution of the **production of the ductile iron fittings** is of minor influence for the impact categories abiotic depletion (6%), acidification (6%), global warming (7%) and ozone layer depletion (4%). The contribution is fairly important in the impact categories eutrophication (10%) and photochemical oxidation (17%).

The contribution of the **production of the galvanised steel components** is insignificant (since contribution is lower than 2,5% for all environmental impact categories), with exception for photochemical oxidation and eutrophication where the contribution of the production of the galvanised steel components amounts to respectively 4,3% and 3,1% of the total impact.

The contribution of the **production of the steel cutter** is insignificant (since contribution is lower than 2,5% for all environmental impact categories).

The contribution of the **production of the EPDM gaskets** is insignificant (since contribution is lower than 2,5% for all environmental impact categories), with exception for ozone layer depletion where the contribution of the production of the EPDM gaskets amounts to 3,7% of the total impact.

Furthermore analysis of the environmental profile of the PVC-O pressure (MRS 31,5 MPa) pipe system shows that the contribution of the **transportation of the complete PVC-O pressure (MRS 31,5 MPa) pipe system to the trench** accounts for an environmental burden for most environmental impact categories between 3% and 4%, which is of little importance. In the category ozone layer depletion, the impact is 10%, which is a fairly important impact.

The contribution of the **transportation of the disassembled PVC-O pressure (MRS 31,5 MPa) pipe system to an EoL treatment facility** after 100 years of service life time (in case the PVC-O pressure (MRS 31,5 MPa) pipe system does not stay in the ground) is not important since its contribution is for all environmental impact categories lower than 0,5% (negligible influence).

The contribution of **the EoL treatment of the PVC-O pressure (MRS 31,5 MPa) pipe system** is not important since its contribution is for all environmental impact categories lower than 0,6% (negligible influence). For some impact categories the contribution results in an overall credit (very small, from -0,1% to -0,3%). This is due to the energy recovery during incineration of pipe waste in an incinerator.

CHAPTER 5 FINAL CONCLUSIONS

The conclusions of the study concern the LCA-results for a PVC-O (bi-oriented, MRS 31,5 MPa) pressure pipe system for water distribution, from the cradle to the grave: from the primary extraction of raw materials to produce the vinyl chloride monomers, up till the final disassembling and EoL treatment of the PVC-O pressure pipe system at the end of its service life (100 years). The analysed system concerns a PVC-O (bi-oriented) pressure pipe system (MRS 31,5 MPa) for water distribution.

The environmental profile consists of various environmental impact categories. They relate to the functional unit, which has been selected for this study: "the below ground pressure transportation of drinking water, over a distance of 100 m (from the exit of the water plant to the water meter of the building), by typical public European PVC-O (bi-oriented – MRS 31,5 MPa) pressure pipe water distribution system (Ø 110mm) over its complete life cycle of 100 years, calculated per year".

The environmental impact of the PVC-O pressure pipe system primarily originates from the installation of the PVC-O pressure pipe system at the trench and the production of the raw materials for the PVC-O pressure pipes.

A more detailed analysis of the installation phase of the PVC-O pressure 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.

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 impact of the stabilizers and pigments is insignificant.

The environmental profile of the PVC-O pressure pipe system also shows that the converting processes of the PVC-O pipes and the injection moulding of the PVC-U fittings (core business of the TEPPFA member companies) only have a minor influence on the total environmental profile, with an exception in the category eutrophication, where the extrusion of PVC-O pressure pipes has a fairly important impact.

The other life cycle phases are little important, some have even a negligible influence on the total contribution to most environmental impact categories.

For global warming (carbon footprint) the contribution of the PVC-O pressure pipe system for water distribution (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 39 kilometres (Ecoinvent datarecord: transport, passenger car, petrol, fleet average/personkm – RER).

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 aspects encountered during the life-span of particular applications of plastic pipes. With this framework in mind, TEPPFA commissioned a project which was carried out by the Flemish Institute for Technological Research (VITO) in Belgium.
The aim of this project was to carry out a life cycle assessment (LCA) consistent with [ISO 14040, 2006] and [ISO 14044, 2006] to analyse the environmental aspects which are associated with different plastic pipe systems.
Summarised the objectives of the overall LCA-project for TEPPFA were:

- to analyse the environmental impacts of different applications of plastic pipe systems in selected application groups;
- to investigate the relative performance of various plastic pipe systems at the system level in order to show that material choices 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.

In a first phase the integral environmental impacts of 4 pipe systems were calculated by means of an LCA and later extended to 6 pipe systems.
TEPPFA decided to further extend these LCA-studies up to 10 different pipe systems by considering 4 additional pipe systems:

- **PVC-U and PVC-O pipe systems for water distribution**
- **Polymer/Al/Polymer composite pipe system for hot and cold water in the building**
- **PVC pipe system for soil and waste removal in the building**
- **PP multilayer pipe system for sewage**

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 commissioned by The European Plastic Pipes and Fittings Association (TEPPFA). It was established in the timeframe of July 2011 to January 2012.
After the receipt of the 4 draft LCA background reports from VITO (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 improvements of the studies were included. 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 December 2011. 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 PVC-U and PVC-O (bi-oriented) pipe systems for water distribution (according to EN 1452)". 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) background report and the discussions with the authors of the study and TEPPFA.

6.4 Critical Review Findings

This particular LCA-study aims to examine the PVC-U and PVC-O (bi-oriented) pipe systems for water distribution, to gather and assess comprehensive and reliable information regarding the environmental performance of these pipe systems, generated over their entire life cycle. At the same time, this study helps to provide a reliable database for the development of a Type III Environmental Product Declaration [ISO 14025, 2006] on the European level for the particular pipe system.
The scope of the study was defined by the functional unit. The basic assumption was that the definition of the functional unit should represent the function of the PVC-U and PVC-O pipe systems over their entire life cycle: raw material extraction, material production, production of the pipes and fittings, the construction phase, the use phase and the processing of the waste at the end of life of the PVC pipes and fittings. The functional unit of the PVC-U and PVC-O (bi-oriented) pipe systems for water distribution has been defined as: "The below ground transportation of drinking water, over a distance of 100 m (from the exit of the water purification plant to the water meter of the building), by a typical public European PVC-U or PVC-O (bi-oriented) pipe system for water distribution (Ø 110mm) over their complete life cycle of 100 years, calculated per year".
Based on this goal and scope of the project the following conclusions can be drawn from the review process:

- The widely accepted state-of-the-art methodology was adopted in this comprehensive LCA study and thus the study is scientifically and technically adequate. The authors of the study at VITO put a lot of effort into designing the systems and gathering respective data to be able to give a thorough picture of the pipe systems under investigation over their entire life cycle.

- Quality of required data and data sources as well as data collection procedures are appropriate, sufficient and reasonable. They are in accordance with the goal and scope of the study. Life cycle information of the different materials used was taken from up-to-date literature and databases representing European conditions or directly from the respective industries.
- 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 systems under investigation over their total life cycle from the cradle to the grave. The complete study has been established in a transparent, consistent and logical way.

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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