HOW MUCH RECYCLED PVC IN PVC PIPES?

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This paper demonstrates the excellent recyclability of rigid PVC and the strong possibilities of incorporating recyclate into foamed PVC pipes. Calculations show that it is the availability of rigid PVC recyclate, partly due to the long service lives of PVC pipes, which is the limiting factor in further extending the use of recycled PVC in the foam core pipe market.

Key words: Recyclable, foam, pipe, sustainability

1. Background

Today, any technical system must have a good environmental performance. As a part of this, a low carbon footprint is a clear advantage for private customers as well as for "Green Procurement" policies. In this regard PVC material, with its low fossil fuel content (only 43% oil), already has an advantage. But the fate of a product at the end of its life also has a strong influence on the carbon footprint calculation, so whether or not a product can be recycled and how often it can be recycled is a key issue.

2. Investigation of the recyclability of PVC

PVC material is particularly well suited for recycling mainly because it does not undergo any kind of degradation during its service life, viz.

- No depolymerisation occurs during the service life of the products.
- It is not sensitive to oxidation at room temperature
- All rigid PVC extrusion materials are chemically quite similar, so products from different kinds of extruded products are largely compatible.

It can be extruded again several times into PVC pipes, even using 100% recycled material and without any need for additional additives such as heat stabilisers. But just how many times can it be re- extruded ?

2.1. Experimental procedure

In the lab we made a dry blend having a formulation representative of a Ca/Zn stabilised compact pipe as shown in Table 1 below.

Component	phr
S-PVC K67 resin	100
Ca-Zn Pipe one-pack	2,8
Oxidised-PE wax	0,15
Ester lubricant	0,15
CaCO3 filler	5,0
TiO2	1,0
Carbon black	0,1

Table 1 – Pipe formulation used

This material was processed several times using a Haake extruder in the sequence: extrusion of a strip followed by granulation of the strip, extrusion of the granulated material inot a new strip, followed by granulation and so on. The material was eventually re-extruded 8 times and after each extrusion, the properties of the strip were assessed.

2.2. Results

Extrusion data showed that the torque and head pressure are lower with a material that was already gelled than with the initial dry-blend – see Table II.

T° profile:
170-180-190-200 °C **Screw speed:** **25** **rpm**
Haake ∅19 mm **Die :** **20 x 2** **mm**

Products :	Dry-blend	Ground 1	Ground 2	Ground 3	Ground 4	Ground 5	Ground 6	Ground 7	Ground 8
Torque Nm	32	16,7	16,2	15,2	14,9	16,6	30,4	13,4	17
Head pressure Bars	175	155	154	155	149	146	194	141	140
Temperatures									
Temperature Zone 1 °C	184	191	192	191	191	190	190	192	194
Temperature Zone 2 °C	181	183	184	192	185	187	192	182	195
Temperature Die °C	201	199	198	200	200	199	199	802	202

Table II – Extrusion parameters and data

But no significant changes were observed in the other extrusion data. Regarding the properties of the extruded material there was, of course, a limited reduction in the residual thermal stability, as shown by the dehydrochlorination (DHC) time, but good values of DHC were retained, even after 6 extrusions. No reduction in mechanical properties was seen.

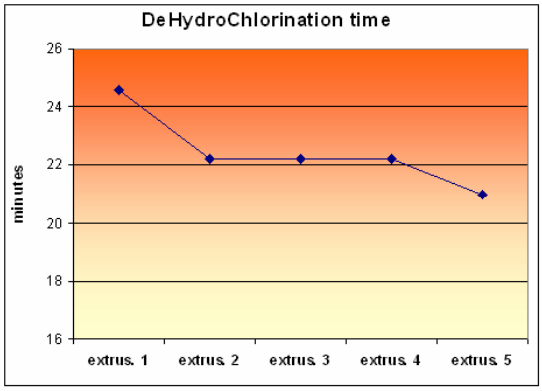

Figure 1. DHC time vs. the number of times extruded

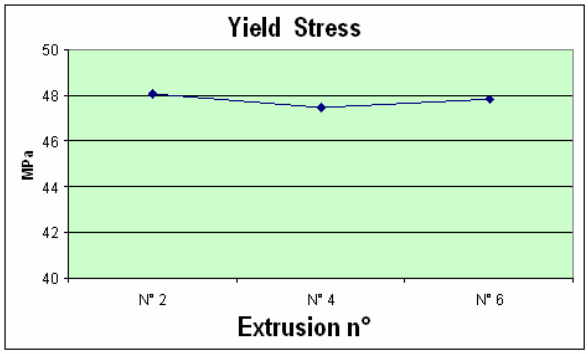

Figure 2. Variation in yield stress vs. the number of times extruded

It should be noted that a study published in Loughborough in 1997 on multiple injection mouldings (1) showed similar results.

3. Laboratory study on the use of recycled PVC in PVC foam

3.1. Investigation of the effects of quality and quantity on properties

Several types of recycled PVC material are available on the market and are used for pipe extrusion. They can differ by the colour or additives types, but these factors don't play an important role in the extrusion of pipes.

The shape or granulometry of the product is more important for the proper use of the material; some grades of recyclates are just milled material (a few millimetres in size), others are micronized (below < 1 mm). The level of impurities (metal particles, rubber, etc...) present can also play a significant role in the quality of the final product

PVC4Pipes started a work program to investigate the effects of recyclate quality and quantity on the properties of a PVC foam. The main target was to check the necessary quality of R-PVC (granulometry, acceptable level of impurities, etc.) But another target was also to look for possible recipe optimisations.

Blends of virgin resin and recycled PVC (50%) were extruded into foamed strips about 25mm wide and 2.5 mm thick (depending upon the degree of foaming.) The main parameters examined on the strips were the density and the homogeneity of the foam structure over the cross section of the strip.

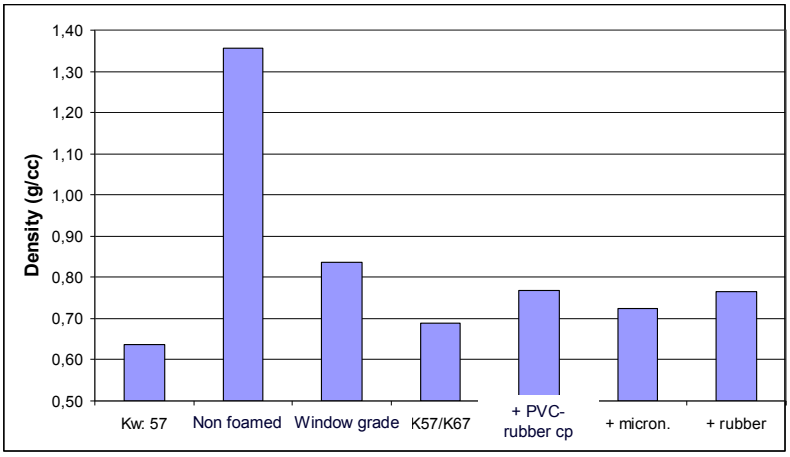

Figure 3. – Density of extruded foam strips, made using 100% virgin and/or 50% recycled PVC

3.2 Appearance of extruded foam strips

Figure 4. Using only virgin K57 resin

Figure 5. Using only virgin k67 resin

Figure 6. Using 50% recycled, micronised PVC.

Figure 7. Using 50% recycled, milled PVC containing rubber.

3.3 Main observations from the study

- Recycled-PVC from window frame (K67) gives higher viscosity and results in lower foaming than when using K57 material unless a modified formulation is introduced.

- A formulation correction can compensate for the higher K-value material, mainly by adapting the level of process aid and lubricant.
- The rubber content is only a problem if it has not been micronised and it is coarse (> 1 mm).
- Good quality foam can be obtained with levels of window-grade R-PVC as high as 50%, provided that a fine R-PVC is used (< 0.8 mm) and that recipe is properly adapted (lubrication).

4. Discussion – how much recyclate is available and how much could be used?

The main source of post consumer recycled rigid PVC is window frames. The reason for this is that buildings are always being renovated and recovery of the building elements, including windows, is now commonly required. Although it is possible to incorporate recycled material into new windows, the main outlet for recycled rigid PVC is in sewage or soil pipes. This application is somewhat less demanding than windows, especially regarding aesthetic appearance and the recycled material can easily incorporate a middle layer of a foam core sewage or soil pipe where it is not visible.

But until today, the limited experience with and availability of recycled rigid PVC has kept the quantities of recycled PVC in pipes generally to less than 10%.

4.1. How much recycled PVC will be available in the future?

The consumption of PVC in Europe reached industrial importance (> 50 kt/y) after 1945. A large part of PVC is used in construction products such as window frames, water pipes, rainwater pipes, etc. The service life of pipes is very long and can easily be 50 years; it can even reach 75 years for some types of pipes. So most of the PVC-U pipes that have been installed are still in service and thus not available for recycling.

But the availability of recycled material is also related to the collection and processing of waste. According to an EuPC model established in 2006 (2), the total amounts of available recycled PVC should show a strong increase in the beginning of 21st century. The real figures of recovered rigid PVC have been reported by Recovinyl (3).

Recovinyl registered recycled volumes per application

	Year 2007*	Year 2009	Year 2010
RIGID PVC APPLICATIONS			
Pipes	18,375	16,928	25,131
Profiles	39,517	82,887	106,657
Rigid Films	2,134	5,890	5,891
TOTAL RIGID PVC APPLICATIONS	**60,026**	**105,705**	**137,679**

Table III - Recovinyl data for rigid PVC

Although recovered materials can generally be used in the same application, in pipes

there are some regulatory limitations to the use of recovered material which has not come from pipes. For example the recycled window frames can only be used as shown in the table below.

Pipe Application	Limitation by standards for recovered PVC not coming from pipes
Not in drinking water pipes	EN-ISO 1452 : = 0%
In compact sewage pipes	EN 1401 : < 10%
In the core of foam pipes	EN-ISO 13476 : up to 100%
In a central compact layer	EN-ISO 13476 : up to 100%

Table IV – Limitations on the the use of non-pipe recycled PVC

4.2. Some more perspectives on the use of recycled PVC in pipes

The weight of material present in the different layers of a foam core pipe may vary from one type of pipe to another, but considering the normative and mechanical requirements for large diameter pipes, we can see that the foamed (middle) layer usually accounts for more than 50% of the total weight of the pipe. This can be calculated as shown in Figure 8 below.

	OD Diam (mm)	thickness (mm)	density	Vol. (L/m)	Mass (kg/m)	
Outer layer	200	0,9	1,47	0,563	0,83	22%
middle layer	198,2	4,5	0,70	2,738	1,92	51%
inner layer	189,2	1,2	1,47	0,709	1,04	28%
TOTAL	200	6,6	0,94	4,010	3,79	100%

	OD Diam (mm)	thickness (mm)	density	Vol. (L/m)	Mass (kg/m)	
Outer layer	315	1,3	1,47	1,281	1,88	19%
middle layer	312,4	7,7	0,80	7,371	5,90	61%
inner layer	297	1,4	1,47	1,300	1,91	20%
TOTAL	315	10,4	0,97	9,952	9,69	100%

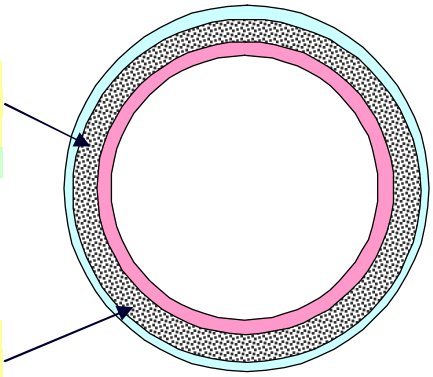

Figure 8. Calculation of the proportion of foamed material in 200 and 315 mm diameter pipes.

Our laboratory study on foamed strips showed that the limitations to the foaming of the mix came from a loss of foam homogeneity as a result of using a dry blend which contained resin of K-value 67. Previous studies using recycled PVC bottles, where the K-value was 57(4) have shown that satisfactory structures can be obtained using even 100% recycled PVC.

In a compact 3-layer pipe, these limitations are not present and the total amount of recycled PVC can be up to 100% without any extrusion difficulties.

Regarding the characterisation of the pipes in European standards, multilayer PVC pipes (foamed as well as ‘multi-layer’ compact pipes) are covered by EN 13476-2.

The possibilities for the use of recycled PVC in pipes are very large as the following analysis shows

- PVC sewage pipe market in Europe is > 1 000 000 tonnes per year.
- If these were produced with a content of 25% recycled-PVC, the pipes would consume > 250 000 tonnes per year of recyclate.
- As of today, recyclate in these amounts is not available, but the amounts are growing each year.

As mentioned previously, a high recycled content is a key argument to show the sustainability of PVC pipes. The analysis above demonstrates that PVC pipes can practically use every tonne available of recycled rigid PVC, giving products of high quality and conferring excellent sustainability credentials to the PVC pipe industry.

6. Conclusions

The work reported above shows that

- it is possible to recycle rigid PVC into foam core pipes numerous times; given that the service life of a foam core pipe is at least 50 years, the overall life of the PVC material used could be in excess of 300 years.

- If windows or pipes are recycled, the PVC will have a k-value of about 67. This places limitations on the type of recyclate (ground versus micronized) and quantity that can be used in foam core pipes if they are to meet the requirements of current European standards

- Use of recycled PVC at a level of only 25% in foam core pipes would consume more recycled rigid PVC than is currently available on the market.

References

1. Leadbitter J, Bradley J. ‘Closed loop recycling opportunities for PVC.’ Current Trends in PVC Technology Conference, Institute of Polymer Technology and Materials Engineering. Loughborough University; 3-4 November 1997

2. Joachim Eckstein ‘New PVC post consumer waste estimation 2005 - 2020 Calculated with the EuPC Model. EuPC:European Plastics Convertors, 2006. www.plasticsconvertors.eu

3. Vinyl 2010 Progress Reports for 2009, 2010 and VinylPlus Progress Report 2011.

4. S.Dupont, C. Dehennau, P.Benjamin, B Rijpkema and G. Voiturin, ‘Recycle 91’, 4th Annual Int. Forum & Exposition, Davos, Switzerland, 3rd – 5th April 1991.