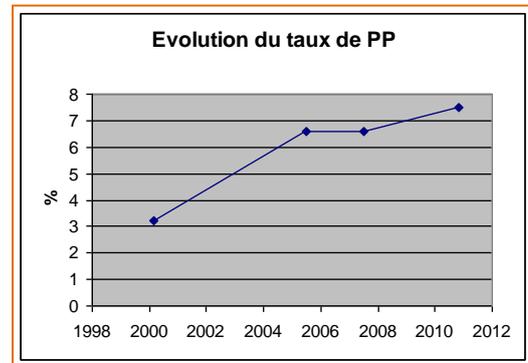


# General Notice

## Influence of polypropylene (PP) content in the High Density Polyethylene (HDPE) bottle stream

### 1/ ANALYSES OF PP CONTENT IN THE HDPE STREAM:

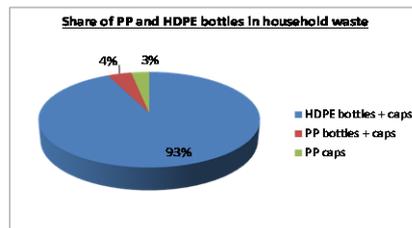
TEST DATES	NUMBER OF SAMPLES ANALYSED	MEASURED PP CONTENT
FEBRUARY 2000	9	3.2 +/- 0.3%
JULY 2005	5	6.6 +/- 0.5%
JULY 2007	7	6.6 +/- 0.5%
OCTOBER 2010	7	7.5 +/- 0.3%



- The PP content in HDPE increased significantly between 2000 and 2010, after the HDPE stream admitted PP bottles in 2003. It can therefore be assumed that the 3.2% present in 2003 corresponds mainly to PP bottle caps.

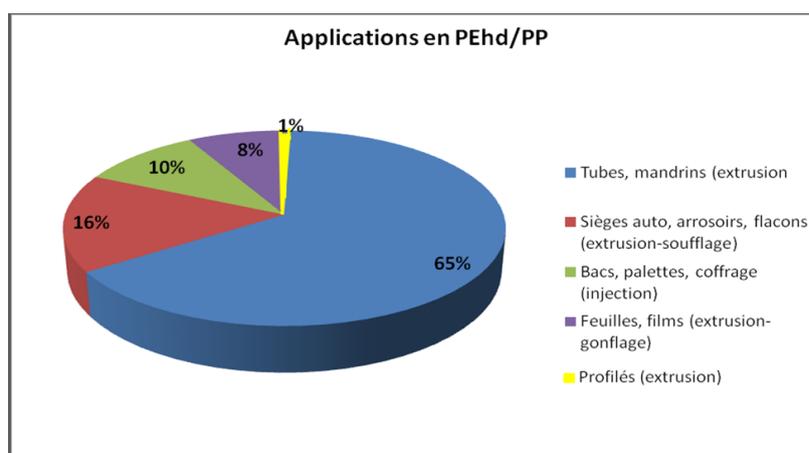
- The content subsequently stabilised at 6.6% between 2005 and 2007. Similarly, we may assume that a little over 3% – in other words half of the 6.6% – comes from bottle caps, with the remaining 3% coming from PP bottles.

- New analyses carried out in 2010 show that this content had risen to 7.5% - an increase that can be explained by the fact that some bottles, originally made of HDPE, are now made of PP.



## 2/ PP AND RECYCLABILITY – TESTS AND RESULTS

### a. Outlets for the HDPE/PP stream in 2009



### b. Preliminary analyses (July 2005)

Specimens were produced by compression moulding followed by stamping, based on samples containing various proportions of PE and PP.

Viscosity index (MI<sup>2</sup>) and impact resistance (Charpy test) were then measured.

The results were as follows:

- ⇒ The addition of up to 10% PP has no significant influence on the mechanical properties of the blend.
- ⇒ The addition of PP >10% renders the blend very fragile and is therefore not recommended.

Consequently, we decided to carry out recycling tests with varying concentrations of PP added, so as to give a clearer indication of the critical concentration threshold for PP in HDPE.

### c. Recycling tests

Various processing tests (pipe extrusion, bottle extrusion blow moulding) and assessment of mechanical properties (compression and breakage) were conducted, which required the production of a number of samples. The study procedure and results are given below (see results in the final table).

- Sample base

Control C: standard rHDPE granules, obtained by regeneration of bottle bales collected in France and containing less than 10% PP.

Sample S: granules with variable proportions of PP.

- Pipe extrusion

Extruded pipes are double-walled tubes with a ringed outer surface (made of virgin HDPE) and a smooth inner surface (made of rHDPE).

- Pipes were extruded for the control (C) containing 6-7% PP and for a sample (S1) containing 13 – 14% PP. Similar extrusion parameters were used in both cases (200 to 220°C).
- Lower fluidity was noted in Sample S1 during the extrusion process.
- Compression tests and impact tests were then carried out on these two types of pipe.

- **Bottle extrusion blow moulding and resistance tests**

- Extrusion blow moulding test (test series 1):

Extrusion blow moulding conversion was carried out both on a control containing 6 to 7% PP and on the same sample S1 (13 to 14% PP).

During the extrusion blow moulding process for the control and sample bottles, in both cases a weld line could be seen on the base of the bottles.

Different adjustments were necessary for the control and the sample during the extrusion blow moulding stage.

- End-of-screw pressure was higher for the control,
- Screw speed had to be increased to extrude the sample.

The need to use different parameters between the control and the sample suggested that they have different mechanical properties. In order to validate this theory, resistance tests were carried out.

- Tests for resistance to impacts and breakage (test series 2):

The threshold for the proportion of PP that causes changes in the mechanical properties of the material was assessed at 10% (see 2/b). To complete this study, breaking strength (drop) was also tested.

For this, various samples (S2, S3, S4 and S5) were made up, with PP content ranging from 0% to 9.7%.

During processing, screw speed and die gap had to be increased slightly in the case of samples containing recycled HDPE/PP. However, generally speaking all samples were easy to process.

Drop test conditions:

Impact on the front side of filled and capped bottles, dropped onto an inclined metal plate. These tests were conducted at room temperature and at -18°C (cold breakage).

- Dynamic compression

Bottle strength was tested by top load and side load compressions on the weld line on all controls and samples used in test series 1 and 2.

d. Summary of recycling tests and results

- **Summary table of tests carried out**

Type of test	Pipe		Bottle Test series 1		Bottle Test series 2			
	Control	Sample	Control	Sample	Control	Sample 1	Sample 2	Sample 3
<b>PP content</b>	<b>6-7%</b>	<b>13-14 %</b>	<b>6-7%</b>	<b>13-14 %</b>	<b>0 %</b>	<b>8 %</b>	<b>9.3 %</b>	<b>9.7 %</b>
<b>Conversion analysis</b>	No problems noted in pipe extrusion for control or sample		It was necessary to adjust conversion settings between control and sample		Control and samples proved easy to process			
<b>Impact/drop test analysis</b>	Impact test results were satisfactory for control and sample		Tests not carried out		No breakage	Breakage on weld line for 5.6m drop (cold) and 6m drop (at room temperature)	<b>Cold: breakage along the weld line at 1.3m</b>  Room temperature: breakage on bottle neck at 4.7m	<b>Cold: breakage along the weld line at 1.3m</b>  Room temperature: breakage along the weld line at 4.5m
<b>Compression test analysis</b>	Compression test results were satisfactory for control and sample		No breakage	<b>Bottle broke at weld line under very low compressions</b>	No noticeable difference between control and samples in compression tests			

- **Results analysis**

For pipe conversion: The addition of PP in the tested proportions caused **no significant difference in terms of conversion and properties.**

For **bottle conversion:** there was a **lower mechanical performance in samples containing PP.** This embrittlement caused breakages along the weld line. This type of breakage caused by fragility is due to the appearance of a non-soluble PP phase in the HDPE phase when PP content approaches 10%.

## CONCLUSION

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The proportion of PP in the stock of household HDPE/PP bottles in France **does not currently pose a problem in terms of the main applications concerned** (pipe extrusion and extrusion blow moulding of hollow parts).

This proportion appeared to have stabilised at around 6.5% since 2005, but **it increased in 2010 and was measured at 7.5%**. The current content exceeds the required threshold for certain applications. **However, recyclers are currently dealing with this issue by carrying out dilution processes.**

If **this increase becomes significant** (proportions >10%), **PP bottles will have to be separated from HDPE bottles** (which is currently possible using infra-red recognition).

The technical and economic feasibility of a new, specific PP chain for recyclers remains to be assessed, and could prove advantageous, leading to the implementation of a viable and profitable system.