STUDIA UBB AMBIENTUM, LXII, 2, 2017, pp. 45-51
(RECOMMENDED CITATION)
DOI:10.24193/subbambientum.2017.2.05

COMPARATIVE STUDIES REGARDING THE USE OF RECYCLED PVC IN FINITE PRODUCTS

Zosin Sergiu PETRI[1,2*], Dumitru RISTOIU[1], Mihail Simion BELDEAN-GALEA[1], Radu MIHĂIESCU[1]

[1]Babeş-Bolyai University, Faculty of Environmental Science and Engineering, 30 Fântânele Street, Cluj-Napoca, Romania.
[2]TERAPLAST BISTRIŢA, Parc Industrial Teraplast, DN 15A (Reghin-Bistriţa) km 45+500, Romania.
**Corresponding author: sergiu.petri@teraplast.ro*

ABSTRACT. The PVC wastes generated by post-industrial and post-consume activity creates serious problems regarding their wastes management. In the last years, the concept of reusing these wastes in other finite products became very attractive due to some advantages such as: eliminate the problems of their storage, decrease the price of the products in which these wastes are enclosed, and protect the environment against pollution. This paper presents some comparative studies regarding the use of recycled PVC in finite products such as obtaining PVC multilayer pipes. The quality and performances of the new products were compared with products in which only virgin PVC is used. The results showed that the quality of the finite products which contained recycled PVC is comparable with those of virgin PVC. Thus rigidity, flexibility, dimensional variation and shock resistance are similar or even superior if we use recycled PVC as raw material. The conclusion is that recycled PVC can be successful reused for obtaining PVC multilayer pipes being suitable to use in a percentage of 30-50%. Moreover, the economical benefices of this method are considerable.

Key words: *recycled PVC, finite products*

INTRODUCTION

Poly vinyl chloride (PVC) is one of the most widely used thermoplastic materials in terms of world polymer consumption. Globally, the demand for PVC exceeds 35 million tons per year and is ranked third, after polyethylene, which is the leading volume in the plastics industry, and polypropylene (Garcia et al., 2006, Yarahmadi et al., 2003). Due to the particular inherent properties of PVC, namely its low cost and high performance, combined with a wide range of products that can be obtained through different processing conditions and processes, PVC has become universal polymer (Braun, 2001).

Due to it specific proprieties, PVC can be processed currently in a wide variety of short-lived products such as packaging materials used in food industry, cleaning materials, textiles, beverage packaging bottle, various medical devices and also long-life products, such as pipes, joinery profiles, cable insulation, parquet, roof profiles, etc. (Matuschek et al., 2000).

By comparison the total amount of the polymers used surround the world it can be observed that PVC is the fourth used polymer after polyethylene, polypropylene and polystyrene (figure 1).

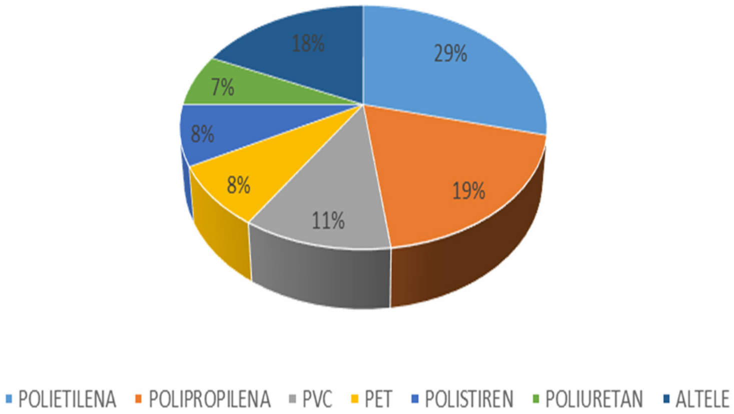

Fig. 1. *Distribution of plastic mass processing*

In the last years, the PVC waste disposal has gained increasing importance because the PVC waste has been a rapid increase and the place of their disposal is limited. Moreover, even the long-lasting PVC products have a long-life span and there is a long time between PVC consumption and the accumulation of PVC waste, they will become waste in time (Braun, 2002).

Thus, the finding ways to reuse of PVC waste has become a priority. In the last time, the researches having as subject the reuse of PVC waste have strongly increased (Garcia et al., 2007, Burat et al., 2009). As a result, the quantity of articles made of PVC introduced into the waste stream is gradually increased as the progressive number of PVC products is approaching the end of their useful economic life (Nakamura et al., 2009, Patel et al., 1998, Patel et al., 2000).

According to Vinylplus (https://vinylplus.eu) the amount of PVC waste reused in different finite products has gradually increased and in 2016 more than 568 thousand tons of PVC wastes were reintroduced in technological fluxes.

Of course, it is not enough to recycle the PVC waste, it is important that the recycled waste to be reused in commercially available products, close to the initial use range. In the last time, different products and technologies have been developed to efficiently absorb these wastes (Sambatsompop et al., 2001). A short radiography of PVC waste reuse showed that it can be successfully used in various products the most important being windows profile and related products (46%), cable (21%), mixed flexible PVC applications (19%), pipes and fittings (10%) or rigid films (4%).

The aim of this study was to compare the quality of two different multi-layer pipes, one obtained from virgin PVC and another containing micronized recycled PVC.

Obtaining PVC multi-layer pipes for indoor or outdoor sewers that contain a micronized recycled PVC middle layer made from pipe waste, fittings, joinery profiles or technical profiles is one of these applications Recycled micronized PVC goes through all stages of mechanical recycling, being brought to a pulverizing form by micronizing scraped waste.

PRODUCTS, PROCESS AND METHOD

Micronized recycled PVC waste can be used in compact PVC pipes used for sewage systems, both inside and outside buildings and using industry standard values, namely:

- at external diameter we have values in the range 110 - 500 mm, with a tolerance between 0.3-0.9 mm,
- for the stiffness class SN 2, SDR 51, the wall thickness is between 2.2-9.8 mm with a towel between 0.5-1 mm,
- for the stiffness class SN 4, SDR 41, the wall thickness is between 3.2-12.3 mm with a towel between 0.6-1 mm,
- for the stiffness class SN 8, SDR 34, the wall thickness is between 3.2-14.6 mm with a towel between 0.4-1.4 mm,
- For the rigidity class SN 12, SDR 30, the wall thickness is between 10.3-16.5 mm with a towel between 1.2-1.7 mm.

Typically, these pipes are obtained by extrusion process using a manufacturing recipe in which the base raw material is PVC with a K value between 64-68, plus Ca-Zn-based stabilizers and lubricants so that we can process the material.

The production recipe is made with the help of dosing and mixing plant, the raw materials dosed after certain proportions are introduced into the mixer, are mixed up to a temperature of 110-130^0 C, after which the mixture is cooled to a temperature of 40-50^0 C, with the help of a cooler. The mixture is stored in bunkers from where it is fed to the production lines.

A PVC pipe extrusion line consists of an extruder, a mold, a calibration/ cooling valve, a tracer, a circular and a dowel.

Micronized Recycled PVC Coated Pipes consist of 3 layers, 2 of the layers are inside and outside and are of virgin PVC and the middle layer is made of micronized recycled PVC (figures 2 and 3).

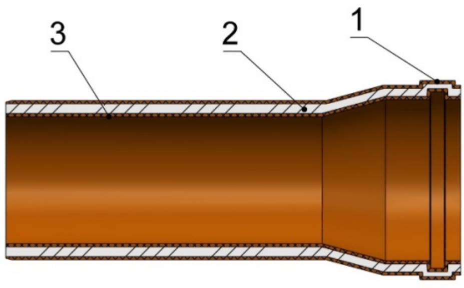

Fig. 2. *Multilayer pipe - cross section*

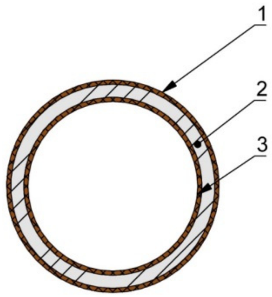

Fig. 3. *Multilayer pipe - horizontal section*

These are obtained by the same extrusion process using manufacturing recipes with identical compositions, the difference being the first raw material used. The extrusion line in this case will consist of an extruder for the micronized recycled PVC middle layer and a co-extruder for the inner and outer virgin PVC layers. The layers are joined in the specially designed die.

Practically, compact PVC virgin K 67 tubes of the SN4 and SN8 stiffness class of 250 mm and 315 mm diameters were extruded using an L/D (length across diameter) extruder =26 and a non-feed block die (sample 1) and micronized recycled PVC medial multilayer (maximum particle size 1400 µm) using an L/D =26 extruder and co-extruder and a feed block die. The proportions used were 70% - 30% (inner layer - exterior with virgin PVC versus medium micronized recycled PVC layer, sample 2), 60% - 40% (interior varnish layer with virgin PVC versus medium micronized recycled PVC layer, sample 3) and 50% - 50% (inner-outer layer with virgin PVC versus medium micronized recycled PVC layer, sample 4). The extrusion temperatures set on the cylinder areas ranged between 170-180^{0}C and on the mold 180-2000C and the manufacturing recipe used was the standard one (Table 1).

Table 1. *Standard recipe*

VIRGIN PVC LAYER		MICRONIZED RECYCLED PVC LAYER	
PVC K 67	83.5%	MICRONIZED RECYCLED PVC	83.5%
CALCIUM CARBONATE	12.5%	CALCIUM CARBONATE	12.5%
STABILIZER CA-ZN	2.9%	STABILIZER CA-ZN	2.9%
POLYETHYLENE WAX	0.2%	POLYETHYLENE WAX	0.2%
CHLORINATED POLYETHYLENE	0.8%	CHLORINATED POLYETHYLENE	0.8%

RESULTS

The samples taken from the tests were subjected to specific determinations such as shock resistance, dimensional variation after heating at 150 °C, ring stiffness and ring flexibility. The obtained results are centralized in the tables 2.

As can be seen in Table 2, ring rigidity increases with the increase in micronized recycled PVC content, and for flexibility, the forces increase without adverse effects on the pipes. We do not break the hitting of pipes with standard weight, handling under site conditions can be done without any problems. Dimensional variation is below the required limit.

Table 2. The results obtained for the tested pipes

PIPE TYPE SN4 250								
No.	**The determined feature**	**Standard**	**UM**	**Standard requirement**	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**
1	Determination of shock resistance by free fall	SR EN 744:2003	%	TIR < 10	Without burglary	Without burglary	Without burglary	Without burglary
2	Determination of dimensional variation after heating at 150 ° C	SR EN ISO 2505:2005	%	< 5	4.2	3.2	3.1	3.3
3	Determination of ring stiffness	SR EN ISO 9969:2016	Kpa/m^2	4	4.47	4.6	4.7	4.75
4	Ring flexibility	SR EN 13968:2009	N	Force to 30% deformation	2806	2850	2886	2912
PIPE TYPE SN4 315								
No.	**The determined feature**	**Standard**	**UM**	**Standard requirement**	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**
1	Determination of shock resistance by free fall	SR EN 744:2003	%	TIR < 10	Without burglary	Without burglary	Without burglary	Without burglary
2	Determination of dimensional variation after heating at 150 ° C	SR EN ISO 2505:2005	%	< 5	3.4	3.55	3.7	3.75
3	Determination of ring stiffness	SR EN ISO 9969:2016	Kpa/m^2	4	4.65	4.7	4.8	4.85
4	Ring flexibility	SR EN 13968:2009	N	Force to 30% deformation	3244	3350	3376	3396

PIPE TYPE SN8 250								
No.	**The determined feature**	**Standard**	**UM**	**Standard requirement**	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**
1	Determination of shock resistance by free fall	SR EN 744:2003	%	TIR < 10	Without burglary	Without burglary	Without burglary	Without burglary
2	Determination of dimensional variation after heating at 150 ° C	SR EN ISO 2505:2005	%	< 5	3	2.75	2.8	2.85
3	Determination of ring stiffness	SR EN ISO 9969:2016	Kpa/m^2	8	8.88	8.92	8.95	8.98
4	Ring flexibility	SR EN 13968:2009	N	Force to 30% deformation	4542	4596	4612	4628
PIPE TYPE SN8 315								
No.	**The determined feature**	**Standard**	**UM**	**Standard requirement**	**Sample 1**	**Sample 2**	**Sample 3**	**Sample 4**
1	Determination of shock resistance by free fall	SR EN 744:2003	%	TIR < 10	Without burglary	Without burglary	Without burglary	Without burglary
2	Determination of dimensional variation after heating at 150 ° C	SR EN ISO 2505:2005	%	< 5	3.4	3.21	3.15	2.95
3	Determination of ring stiffness	SR EN ISO 9969:2016	Kpa/m^2	8	8.62	8.67	8.72	8.75
4	Ring flexibility	SR EN 13968:2009	N	Force to 30% deformation	5472	5483	5491	5508

CONCLUSIONS

It can be seen that the results obtained for the micronized recycled PVC medial tubes are better than the virgin PVC pipes, the benefits being an effective recycling of this waste with a positive impact on the environment and a lower cost of raw materials.

ACKNOWLEDGEMENTS

This work was performing in the frame of doctoral study. The authors are grateful to TERAPLAST BISTRIŢA for their technical support accorded in this study.

REFERENCES

Braun D., 2001, PVC-origin, growth, and future. *Journal of Vinyl and Additive Technology*, **7**, pp. 168-176.

Braun D., 2002, Recycling of PVC. *Progres in Polymer Science*, **27**, pp.2171-2195.

Burat F., Güney A., Olgaç Kangal M., 2009, Selective separation of virgin and post consumer polymers (PET and PVC) by flotation method. *Waste Management*, **29**, pp. 1807-1813.

Garcia D., Balart R., Crespo J.E., Lopez J., 2006, Mechanical properties of recycled PVC blends with styrenic polymers. *Journal of Applied Polymer Science*, **101**, pp. 2464-2471.

Garcia D., Balart R., Sanchez L., Lopez J., 2007, Compatibility of recycled PVC/ABS blends effect of previous degradation. *Polymer Engineering&Science*, **47**, pp.789-796.

https://vinylplus.eu

Matuschek G., Milanov N., Kettrup A., 2000, Thermoanalytical investigations for the recycling of PVC. *Thermochimica Acta*, **361**, pp.77-84.

Nakamura S., Nakajima K., Yoshizawa Y., Matsubae-Yokoyama K., Nagasaka T., 2009, Analyzing polyvinyl chloride in Japan with the waste inputeoutput material flow analysis model. *Journal of Industrial Ecology*, **13(5)**, pp. 706-717.

Patel M., Jochem E., Radgen P., Worrell E., 1998, Plastics streams in Germany-an analysis of production, consumption and waste generation. *Resource, Conservation and Recycling*, **24**, pp.191-215.

Patel M., von Thienen N., Jochem E., Worrell E., 2000, Recycling of plastics in Germany. *Resource, Conservation and Recycling*, **29**, pp. 6-90.

Sombatsompop N., Thongsang S., 2001, Rheology, morphology, and mechanical and thermal properties of recycled PVC pipes. *Journal of Applied Polymer Science*, **82**, pp. 2478-2486.

Yarahmadi N., Jakubowicz I., Martinsson L., 2003, PVC floorings as post consumer products for mechanical recycling and energy recovery. *Polymer Degradation and Stability*, **79**, pp. 439-448.