Trends and latest developments in the use of PE and PP pipe systems for buildings water supply and sewage

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Abstract

In Europe, polyethylene (PE) and polypropylene (PP) plastics have been used increasingly and with an excellent track record for piping systems inside and around buildings over the past 40 years. Most commonly used are crosslinked PE and specially stabilised PP-R for hot water applications, flexible PE compounds for house connection water and gas pipes and, more recently, high impact strength and stiffness PP-B for sewage. A high level of quality and installation efficiency has been developed over the years through improved raw materials and a clear system approach (raw materials, pipes, fittings, installation procedures, training). This level is safeguarded by CEN, ISO as well as local standards and regulations. In future, the use of PE and PP is expected to continue its strong growth due mainly to the excellent material properties and increasing acceptance among installers, architects, authorities and house owners. Borealis as world-wide the leading supplier and developer of PE and PP raw materials for these applications, now see this trend spreading rapidly into other areas such as China, South America, the Middle East and the USA. This paper gives an overview of the PO systems commonly used for the different applications as well as the relevant technical advantages and limitations, standardisation, track records and future trends for each.

Keywords

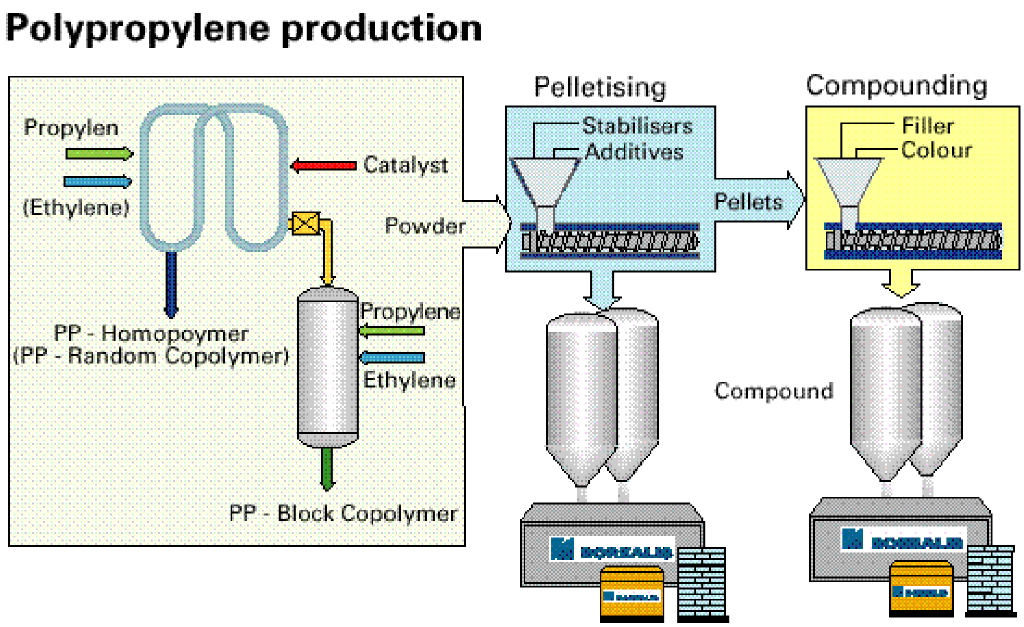
PE and PP pipe systems; building sanitary and heating systems; sewage and waste water

1 Contents

2 What are polyolefins and how are they used for pipe

The most common polyolefins (PO), polyethylene (PE) and polypropylene (PP), are produced by polymerising ethylene or propylene gas in the presence of a catalyst at moderate temperatures and pressures. The monomers are built into a range of molecular weights during polymerisation and by using modern catalysts, different comonomers and polymerisation techniques (such as the two reactor Borstar® process), molecular weight distribution and molecular configuration can be carefully controlled. For all pressure pipe and some non pressure pipe application, ready made PE or PP compounds - produced as illustrated for PP in Figure 1 - are offered to the pipe and fitting producers for quality, accountability and cost reasons.

Figure 1 – Production of ready made polypropylene pipe compounds



As pipe and fitting materials, polyolefins have built up an excellent track record for over 40 years. Properties such as flexibility, non corrosiveness, light weight, weldability and cost competitiveness, have made users aware of the advantages and possibilities polyolefin pipes offer compared to other pipe materials. Furthermore the polyolefin pipe industry has demonstrated excellent innovation in designing raw materials and pipe systems for specific applications. Borealis, being the leading supplier of polyolefin pipe compounds, has participated in this development and is now leading the way into the future with an extensive product portfolio to highlight the benefits of polyolefins as piping materials.

The European plastic pipe market of around 2,5 million tons is today basically equally divided between poly vinyl chloride (PVC) and polyolefins, but polypropylene and polyethylene have over the past 10 years been demonstrating 3-4 times higher growth rates than PVC.

3 Types of polyolefins used in buildings pipe applications

Of the 1,2 million tons total market for polyolefin pipes in Europe, around 8 % found its use in building hot water applications and another 12% in drainage or sewage applications. If you look around typical modern European houses, you would commonly find pipes and fittings made of 4 different types of polyolefins: high density polyethylene (HDPE), cross linked polyethylene (PEX), polypropylene random copolymer (PP-R), and polypropylene block copolymer (PP-B).
It is important to realise that these materials have very different properties and have been designed and documented to fulfil the requirements of different applications. Especially important here is the application temperature for the designed service life of typically 50 years.

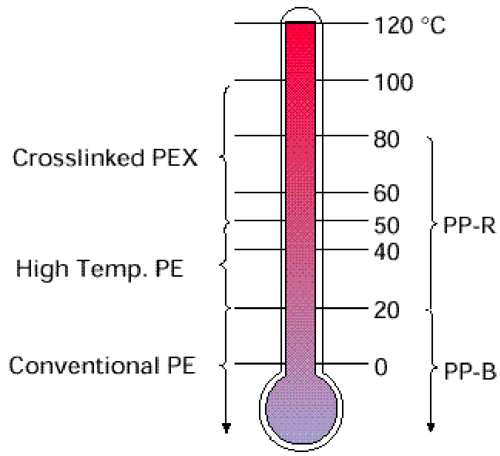
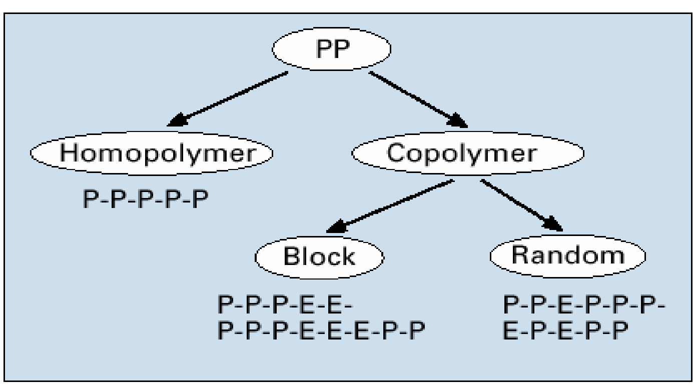


Figure 2 – Application temperatures of different polyolefin plastics

From Figure 2 it can be seen that un-crosslinked PE is suitable for gas and cold water applications (in a specially heat stabilised version for up to 50 °C).
Cross-linking the PE chains by chemical or physical process (PEX) greatly increases the long term temperature resistance, notch resistance and memory effect making these materials suitable for hot water applications.
Figure 3 –Different types of polypropylene



Polypropylene homopolymer, PP-H is made by polymerising propylene and by introducing ethylene as a comonomer, polypropylene copolymer, PP-C can be produced. The ethylene can be introduced in blocks and with a higher percentage for what is classified as a “block copolymer”, PP-B or at random and more dispersed for a “random copolymer”, PP-R (Figure 3).
PP-R, the most recent development, has been further improved to obtain the best long term heat stability, slow crack growth resistance performance and welding performance. This material is used for hot and cold water sanitary systems and heating pipes.

PP-B is typically used for non-pressure applications such as sewage, profiles and cable conduits, where the long term pressure resistance is not critical and cold temperature impact strength and suitability for compounding with fillers are more important.
PP-H shows superior resistance to certain chemicals and is therefore preferred for sheet, filter plates, pipes and fittings in industry application. It also has the greatest stiffness and short term mechanical strength but a lower impact strength at cold temperatures (around 0°C).

4 Illustration of common polyolefin pipe systems

4.1 Hot and cold water supply

In 1997 roughly 1,6 billion meters of sanitary and heating pipes were installed in east and west Europe alone. According to a German study, KWD, 36% of this was plastic based, mostly PEX or PP-R (Table 1).

Material	Million meters installed Europe 1997	Connection
Copper	706 (44 %)	Weld & press
Galvanised steel	309 (19 %)	Weld & thread
Stainless steel	14 (1 %)	Press
PE-X	302 (19 %)	Press & shrink fit
PP-R	147 (9 %)	Weld
PE-X/Al	65 (4 %	Press
PB	44 (3 %)	Weld/press
PVC-C	18 (1 %)	Glue
Total	**1606**	

Table 1 – Raw materials used for sanitary and heating pipes in Europe

Market growth trends, for example in a very large and competitive buildings market like Germany, demonstrate clearly that the acceptance of plastic systems among installers, architects, authorities and house owners is increasing (Figure 4). It is interesting to note that solely plastic systems profited from the building boom after the German reunification.

Figure 4 – Gain in market share of plastic systems in Germany

In countries with a large use of traditional galvanised steel pipes and the big corrosion problems associated with this, the substitution with mainly PP-R has been particularly dramatic. Turkey (Figure 5), Italy, Argentina, East Europe and most recently China are good examples of this. The success of PP-R has globally documented itself by the rapid market growth to today 60 ktons since its introduction for heating and plumbing in Germany more than 15 years ago.

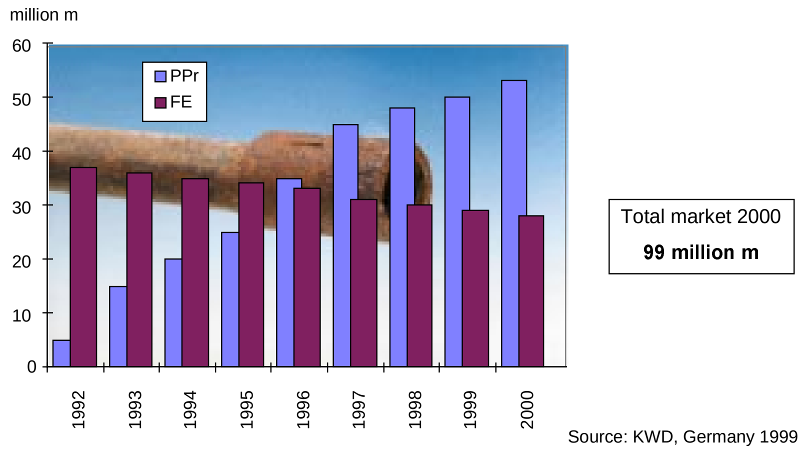


Figure 5 –Growth of PP-R vs. galvanised steel sanitary systems in Turkey

For sanitary systems, different installation techniques are used taking advantage of the material properties. PP-R systems are installed in traditional straight lengths with socket welded fittings (Figure 6) and are typically dimensioned as SDR 6. PEX systems are installed as flexible SDR 7,4 lengths or as a stiff, bendable multi-layer aluminium constructions (Figure 7). Both types of constructions are jointed with press or shrink fit fittings, as PEX can not easily be welded but has excellent memory shrinkage properties.

Figure 6 – PP-R drinking water installation

Figure 7 – Multi-layer PEX/Aluminium pipes

4.2 Under floor and radiator heating

Due to their high temperature resistance, PP-R and PEX pipes are also suitable for radiator connections (Figure 8).

Figure 8 – PP-R systems for radiator connections

Polyolefin pipes have good flexibility making them easy to bend and install for floor heating application (Figure 9).

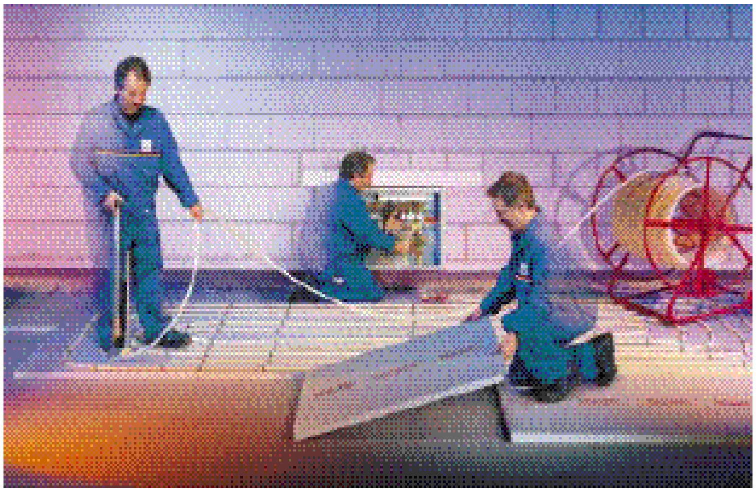


Figure 9 – PEX for floor heating systems

4.3 Wall heating and cooling

An innovative application is the heating and cooling mats for air conditioning in buildings without the disadvantages of circulating air. In addition to the flexibility, the excellent and safe weldability at the many joints makes PP-R the best material choice.

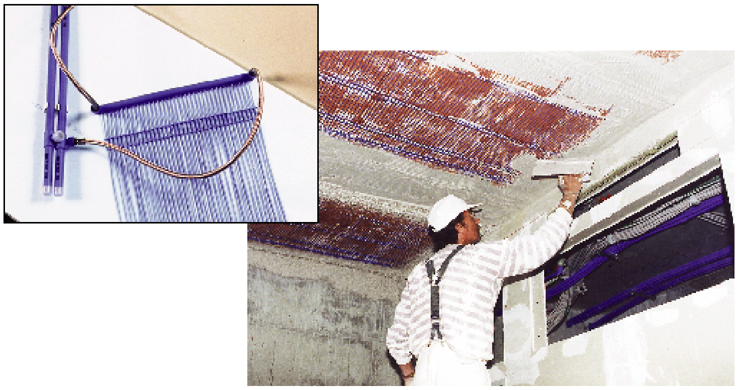


Figure 10: Cooling and heating mats for air conditioning

4.4 Indoor and outdoor sewage and waste water

According to a CDC study published in 2000, plastic systems have at least 90% share of the indoor soil and waste water systems market in most European countries. This is due to their non corrosiveness, ease of installation and cost competitiveness. The only weak aspect is that noise can be a problem in flushing systems, especially in high buildings. Low noise polypropylene pipe compounds and insulation system solutions have been developed to meet the renewed threat from cast iron pipes on the market.

From Figure 11 it can be seen that the soil and waste water application is dominated by PVC. While the PVC market has a matured, however, and growth rates have been stagnating since 1994, the market for PP-B systems has expanded at a rate of 8%.

Advantages of PP-B systems are their good impact strength and form stability in resisting to hot waste water from washing and dishwasher machines (up to 97 °C containing detergents).

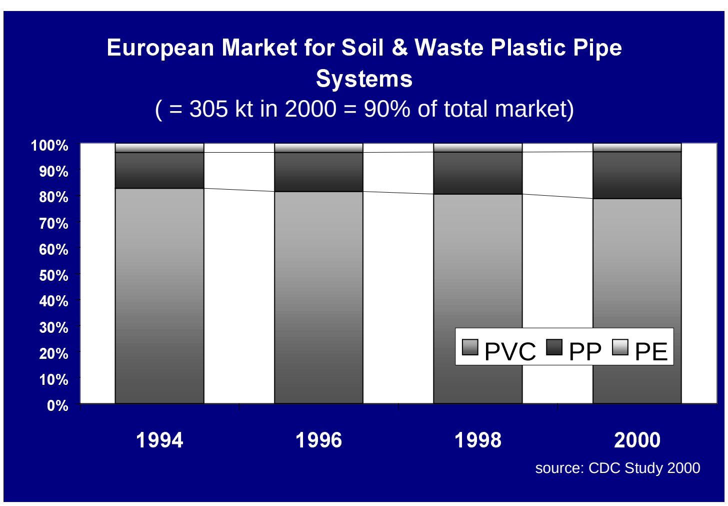


Figure 11: European market for soil & waste plastic pipe systems

For outdoor sewage applications, pipe stiffness and in many climates cold temperature impact strength are especially important. Also, corrugated constructions are very common as they offer improved stiffness with less material (Figure 12). Recently, Borealis has very successfully introduced to the market a new PP-B with greatly improved stiffness and impact strength especially designed for this application. In Sweden, for example, the use of PP sewage pipes has exploded from just 6% in 1997 to over 25% in 1999.

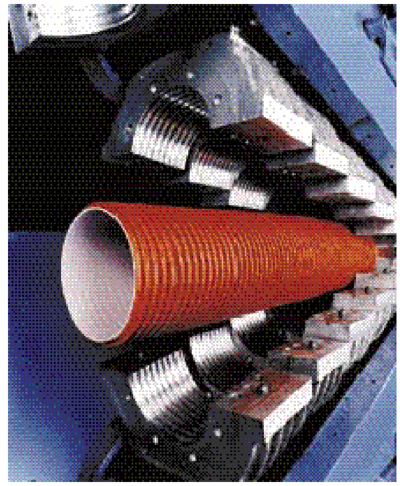


Figure 12: PP systems for sewage applications

5 System quality requirements and standardisation

5.1 The systems approach

Polyolefins have established their position for all indoor pipe applications from sanitary to cable conduits. A key success factor for all plastic pipes has been the systems approach. A system typically includes pipes, all fittings and valves, auxiliary installation materials, installation procedures and in most cases a raw material specification. Advantages of the system approach are the complete availability of compatible parts and the clear approval and liability. Many systems suppliers also provide a corresponding guarantee. Furthermore, the accumulation of know-how and experience by the system supplier leads to excellent training facilities and continuous optimisation of the speed and ease of installation.

5.2 Quality requirements of the system

A good example to illustrate system quality requirements is that of sanitary installations. Here the tricky requirement combination of drinking water neutrality and lifetime of 50 years at 60 - 70 °C pressure application must be met.
For the former, the recipe of the raw material must be according to national and European positive lists and additionally authorities, for instance in Germany, France, Holland and Scandinavia require formalised taste and odour testing of some raw materials and of the final products (Figure 13).

Figure 13 - Steps of taste and odour control of the raw material and pipe

For the latter, it is best practice to use long term pressure testing and standardised extrapolation methods to statistically demonstrate that the elevated temperature lifetime of one raw material or modified type of pipe. More than 400 pipes made of Borealis RA130E - for example - have been tested in different environments (water/water and water/air) at 6 temperatures between 20 ºC and 120 ºC over a period of more than three years. As quality control some points of this extrapolation are regularly cross checked with pipes or welded testing trees (Figure 14).

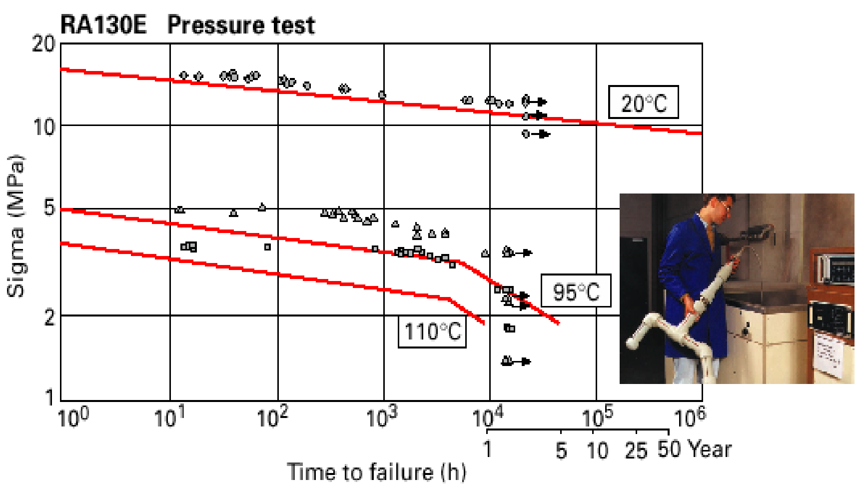


Figure 14 - Pressure testing of PP-R raw materials and systems

Over time, the weakest link in a piping system is often the jointing technology. In sanitary systems this is especially critical due to the severe pressure and temperature changes when the taps are turned on and off. To offer durable connections, different raw materials require different techniques, such as welding, pressing, threading, shrink fit and gluing. In any case, it has to be secured that pipes and fittings fit together in terms of dimensioning and design. To check this, a specific test equipment has been developed as described in Figure 15. The thermal cycling test is carried out under pressure on a sample system consisting of typical fittings and jointing techniques. The temperature of the water running through this system is changing over 5000 cycles every 15 minutes very quickly from 20 ºC to 95 ºC. This test simulates quite well what happens in the field during some years of operation.

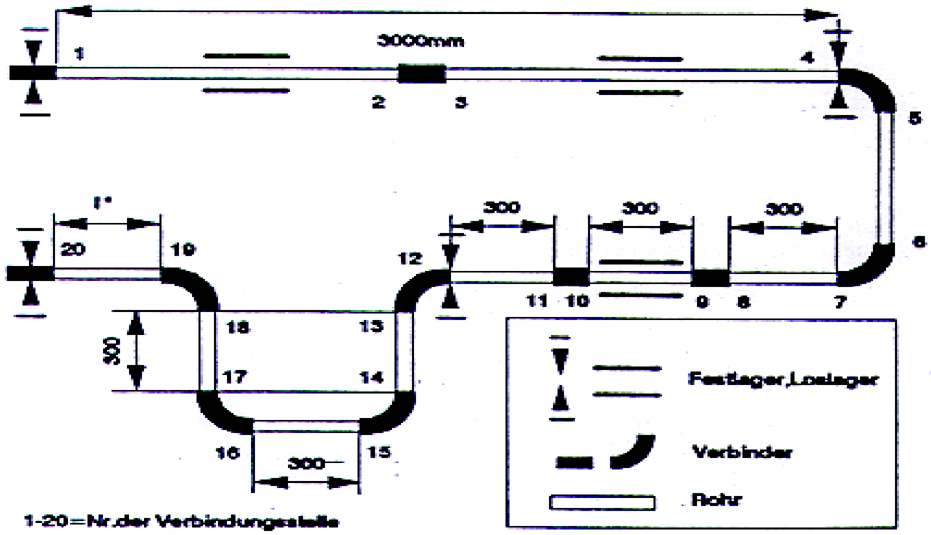


Figure 15 - Temperature cycle test for jointed systems according to EN 12293

5.3 Enforcing these quality requirements through standardisation

The high requirements placed on indoor plastic pipe systems are standardised and enforced to different degrees by a very large network of national standards, international EN and ISO standards, local legislation rules, authority guidelines, quality marks and end user specifications. For example, hot and cold water systems are described by ISO/DIS 15874 for PP-R, ISO/DIS 15875 for PE-X, ISO/DIS 15876 for PB and ISO/DIS 15877 for PVC-C and PP waste water systems by prEN 1451-1. Even once these draft standards are implemented, non-government authorities such as the DVGW in Germany plan to continue to give their quality marks based on their own working documents DVGW W 534, W 542 and W 544. In most cases, national standards world-wide are building on the ISO, CEN or European national standards and guidelines.
Besides representing good business for quality labs and test institutes, experience has shown that a network of high requirements ensure that - in the countries where they are enforced - only thoroughly developed, high quality raw materials are used in best practice conversion to well designed systems.

6 Environmental impact

Today, environmental impact is an important consideration for the construction engineer or architect when planning building projects. Generally, polyolefin plastics have shown excellent life cycle analysis results and this is especially the case for high performance pipe polymers designed and documented to last more than 50 years.

With respect to environmental impact an in depth study was carried out by Professor Dr. Helmut Käufer at the Technical University of Berlin. Using the “VENOB” technique he compared energy requirements as well as impact on the ground, air and water in the production, transport and installation of steel, copper and several plastic systems. The basis for comparison was a 16 living unit house with central warm water supply and installations according to DIN 1988 part 3. Figure 16 clearly demonstrates that plastic systems offer the most environmentally friendly solution.

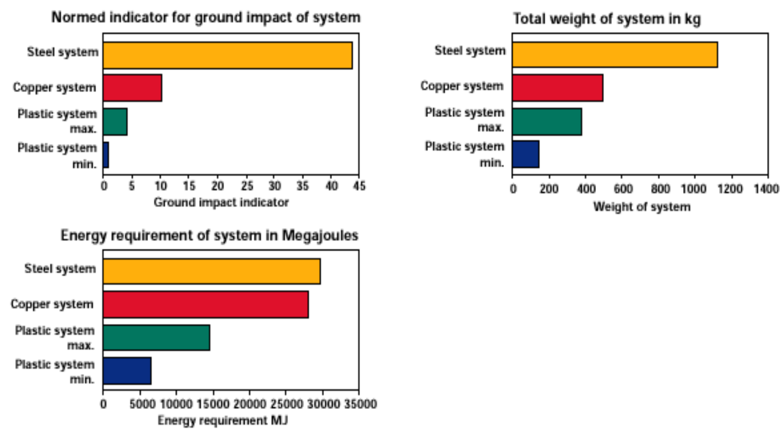
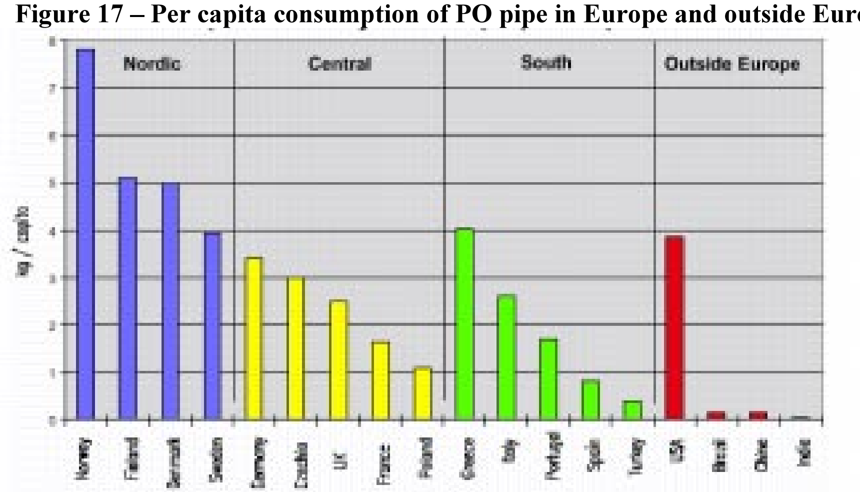


Figure 16 - Environmental impact of different plumbing systems

7 Conclusions and outlook for the future

We have seen a very strong growth of polyolefin pipe systems in sanitary, heating, soil and waste water, electrical conduits, water and gas house connection, and buried sewage applications in Europe and increasingly global. Polyolefins have built up an impressive track record over more than 25 years for hot water and even 40 years for cold water applications and now represent a very sucessful alternative to more traditional piping materials. To sustain this growth, it remains critical to have a very high level of requirements and formalise these through corresponding standards and specifications.

Figure 17 – Per capita consumption of PO pipe in Europe and outside Europe



If we compare the PO pipe trends in Europe with those in different countries around the world, we can see many similarities with some time delay. We have already seen many examples of European polyolefin solutions being adopted and adapted globally and also of new applications being developed. The currently very low PO pipe per capita consumption in for example Brazil, China and India 17 further illustrates the excellent growth potential for PO pipe solutions outside Europe.

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