Material analysis of dripping pipes for micro-irrigation systems

by Jürg Vogt, September 2001

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Content

1. Summary

This report presents first results of a material analysis of dripping pipes from three different producers (IDE India, IDE Nepal, Netafim Israel). The report does not yet include the findings of accelerated ageing tests.
The systems from IDE India and Netafim make use of almost similar grades of LLDPE (linear low density Polyethylene). They use commodity grades with rather high density and stiffness.
The Nepal drip kit is made of a green, softer PVC-compound and a harder, black PVC-compound. It is likely that both contain cadmium stabilizers. Such stabilizers should and can be avoided nowadays.
The costs for the pipes are on a level, that is somehow compareable with prices in western countries. However, it can be assumed, that the share of costs for materials and processing are different.
Based on theoretical assumptions, it should be possible to produce dripping pipes made of special Polyethylene-grades with PVC-like handling properties. However, this could affect the costs and the heat resistance in a negative way.

2. Goal

This investigation was made, to build up basic knowledge related with the choice of raw materials for dripping pipes. The main goals are

- to gain some basic information about the materials used
- to assess and compare the service life of different systems
- to compare costs for raw materials, processing and finished parts
- to judge the potential for optimization (technically, economically and ecologically)

3. Analyzed samples

Samples of the following dripping pipes have been analyzed:

IDE India sprinkler kit

Code:	IDE Ø12
Colour:	black with orange stripe
Diameter:	12 mm
Wall thickness:	1.1 mm

Code:	IDE Ø16
Colour:	black with orange stripe
Diameter:	16 mm
Wall thickness:	1.2 mm

Nepal drip kit

Code:	NDK Ø8
Colour:	green
Diameter:	8 mm
Wall thickness:	0.8 mm

Code:	NDK Ø14
Colour:	black
Diameter:	14 mm
Wall thickness:	1.8 mm

Netafim family system

Code: NFS Ø8
Colour: black
Diameter: 8 mm
Wall thickness: 1.0 mm

Code: NFS Ø25
Colour: black
Diameter: 25 mm
Wall thickness: 1.7 mm

4. Tests

The following tests were carried out:

Test	Conditions	Place	Comment
DSC	25-250°C, 20 K/min, 2 runs	Habasit	only LLDPE
TGA		Sarnafil	only LLDPE
DMA	-50 to 200°C, 2 K/min, 10 Hz, tension	Habasit	
MFI	190°C, 8.7 kg	Habasit	only LLDPE
FT-IR		Habasit	
Tensile test	DIN, 23 °C, 50% rel. humidity	Habasit	
Density	Pyknometer, Ethanol, 25 °C	Habasit	
Extraction	Soxhlet extraction with Diethylether	Habasit	only PVC
Lead test	NH_4S	Habasit	only PVC
Wheatherability	QUV, UVB 60°C 8 h / water 50°C 2 h	Sarnafil	

5. Results of material analysis

5.1 LLDPE pipes

Both, IDE India as well as Netafim are using LLDPE to produce their pipes. Both use only one grade to make the different diameters.
Based on the tests carried out, there is almost no difference between the material quality of Netafim and of IDE India. With a storage modulus of about 620 MPa at 30°C, both have chosen a quite stiff material. Also the mechanical properties are quite the same.
The analysis can't give results on the kind and amount of stabilizers that are used. Special equipment and test procedures would be required to make such analysis. However, the potential supplier of Netafim was found and so it will not be very difficult to match their stabilizer system (see remark 3 / page 5).

For detailed results please refer to the table in the appendix.

5.2 PVC pipes

The green pipes of the Nepal drip kit are made of a softer PVC-compound than the black ones. Based on the detected amount of plastizicer, I would expect that the inital content of plastizicer was 20 - 25% (NDK Ø8) and 10 - 13% (NDK Ø14). The plastizicer detected is DOP (Dioctylphthalate), which is the most commonly used type.
The test to indicate if a lead containing stabilizer is used was negative. That means, that either quite modern, environmental friendly lead free stabilizers are used, or - more likely - even more harmful cadmium containing ones.

6. *Durability*

6.1 UV-resistance

Already before knowing the results of the wheaterabilty test, it can be assumed, that the service life of PVC pipes will be shorter than that of LLDPE pipes. The green PVC compound will suffer stronger from UV-radiation than the black one, on the other hand the black one will in practical use become hotter and therefore suffer more from thermal degradation. Both will loose plasticizer due to evaporation, migration into the soil and microorganisms.

The QUV-wheatherability test is still running and it will take several months until first indications about the service life can be made. The expectations about such results should not be exaggerated: it may be possible to make a ranking of the different samples, but it won't ever be possible to predict the service life exactly. The difference of the climatic conditions at different places are too big and there are many other parameters that can have a major influence on the longevity (e.g. use of pestizides, microorganisms, rain, temperature).

6.2 Heat ageing

Ageing due to heat will mainly be an issue for the PVC-products. Due to the higher volatility of the plastizicer at elevated temperature, the loss of plastizicer over time is a function of temperature.
Also LLDPE will suffer to a certain amount from heat ageing. However, I wouldn't expect this effect to be the one that finally limits the service life. Since the wheatering test takes place at 60°C, heat ageing is (partially) also included in the longevity prediction.

6.3 Attack by microorganisms and animals

Under certain conditions, PVC is susceptible to attack by microorganisms: Microorganisms can intake plastizicer. This is especially the case if 'environmental friendly' PVC formulations are chosen and when the material is surrounded by mud for a longer time.
It is hard for me to say something about the possible attack by insects (e.g. termites) or rodents. I would assume, that due to the chemical nature and the hardness of the material LLDPE is in a better position. However, it is possible, that in both cases nothing will happen at all.

6.4 Environmental stress cracking resistance (ESCR)

Some Polyethylene grades (especially HDPE) are susceptible to mechanical stress in presence of aqueous solutions of detergents. No ESCR-tests have been carried out, since such tests are quite complicated and labor intensive. Based on my personal experience, it is anyhow difficult to make the link between such tests and the performance in the field. Further more, I don't expect ESC to be the limiting factor for the service life of a low pressure dripping system.

7. *Cost comparison*

7.1 Raw material costs

Estimated raw material costs for LLDPE based on European prices[1]

Raw material prices

LLDPE[2], density 0.927 g/cm^3	1.29	CHF/kg	(0.77 $/kg)

[1] All calculations are based on the following exchange rates :1 US$ = 1.095 EURO = 1.67 CHF
[2] KI Information, Nr. 1548, June 2001

Carbon / stabilizer masterbatch[3] 40%	3.10 CHF/kg	(1.86 $/kg)

Costs for complete formulation:

LLDPE	93.75%	1.21 CHF
Carbon / stabilizer masterbatch	6.25%	0.19 CHF
Total	100%	1.40 CHF/kg

Total costs per kg	1.40 CHF	0.84 $
Total costs per liter	1.30 CHF	0.78 $

7.2 Costs for finished pipes

	IDE Ø12	IDE Ø16	NDK Ø8	NDK Ø14
Material consumption cm^3/m	37.6	55.8	18.1	69.0
Total costs CHF/m [4]	0.084	0.15	0.10	0.22
Total costs CHF/kg	2.39	2.91	4.53	2.37
Estimated material costs CHF/kg	1.40	1.40	1.80[5]	1.50[5]
Remaining costs (processing, overhead, profit) CHF/kg	-.99	1.51	2.73	-.87

Based on the cost calculations presented in the table above, I would take the following conclusions:

- It is quite obvious, that there is something wrong with the costs for NDK Ø8 and NDK Ø14. In my opinion, the costs for the green pipes are too high, those for the black pipes are o.k.
- The costs are on a level that would also be possible if the pipes were produced in western countries.
- I assume, that in India or Nepal the costs for raw materials will be somewhat higher than in the calculation above, but the processing costs lower accordingly.

8. Potential for optimization

As far as I understand the situation, there is a wish (or a need) to optimize the following properties:

- Costs
- Longevity
- Flexibility of LLDPE-pipes
- Ecological profile of the whole product

8.1 Optimization of the IDE sprinkler kit

The following thoughts and calculations are based on the assumption, that the same pipes as analyzed are also used for low pressure drip irrigations systems.

8.1.1 Design

The wall thickness of 1.1 mm of the 12 mm pipe is more than enough to withstand the mechanical stress: If a PVC pipe with a wall thickness of 0.8 mm can do the same job, there

[3] Cabot Plasblak PE2668. This masterbatch is specially developped for drip irrigation pipes and according to my source of information used in big quantities by an Israelien company (-> Netafim?)
[4] E-mail from Sudarshan Suryawanshi, June 17. 2001
[5] Estimated costs by M. Villiger, Sarnafil

is no reason why an LLDPE pipe should be designed almost 40% stronger. However, there is one exception: If the design criteria for the pipes is not resistance against water pressure but against buckling.

Pipes with lower tendency to buckle could be designed as follows:

- more flexible material
- smaller outer diameter
- bigger ratio between wall thickness and pipe diameter

Unfortunately, most of the measures to reduce buckling will increase the costs for the pipes. The only exception would be, if it was possible to reduce the inner diameter of the pipes without affecting their functionality.

8.1.2 Material

Basically, the following materials can be taken into consideration as alternatives to LLDPE

Material	estimated costs [CHF/liter]	Melting temperature [°C]	Modulus of elasticity [MPa]
LLDPE (ref.)	1.40	122	620
PVC green (ref.)	2.20	-	54
PVC black (ref.)	2.-	-	114
mLLDPE, density 0.918	1.80	118	270
LDPE, density 0.923	1.54	109	390
VLDPE, density 0.900	2.-	100	130
EVA 5%	2.-	105	270
mPE, density 0.900	2.20	100	110
PP/EPDM-blend	2.50	141	90

- All materials listed above are pure hydrocarbons[6] and have the same base properties concernig ecology.
- The resistance to UV radiation will be on about the same level for all.
- It seems that also LDPE is used for irrigation pipes[7].
- None of the suggested materials is as flexible as the green PVC used in Nepal. However, some are close to the flexibility of the black PVC compound.
- Except LDPE and EVA, all other grades are no commodity products anymore. It therefore could be quite difficult to purches them. For instance it seems that mPE is not markted in Africa so far.
- Except PP/EPDM all materials have a lower melting point than LLDPE (there is a thumb rule: the more flexible the lower the melting point). In some cases, the thermal resistance could become crucial. However this problem could be solved by using another color than black (but this has consequences on the stabilizer systems to be used and will increase the costs).
- LLDPE is the cheapest among the suggested materials. The difference to LDPE is small and can change even in a way, LLDPE becomes more expensive than LDPE.
- The LLDPE-grade used in India is quite stiff[8]. Just by choosing a different LLDPE-grade it would be possible to make the pipes more flexible.
- There are significant differences concerning mechanical strength between the different grades which are not shown in the table.

It is obvious, that there are possibilities to improve the handling of the pipes. To reduce costs (especially if at the same time the flexibilty should be improved) will be more difficult.

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[6] EVA also contains a small amount of oxigen. This has no impact on the ecological profile of the product.

[7] Brochure of Polimeri Europa, Riblene PC 47

[8] Maybe the carbon black is also contributing to a certain part to the relativ stiffness of the measured LLDPE grades

8.1.3 Longevity

As far as no results from the wheatering tests are available, it is hard to say something about improving the longevity. At least one could suggest to use the same stabilizer masterbatch as Netafim. According to my information this is most probable Plasblak PE2668 from Cabot. This masterbatch includes carbon black (40%) and an optimized package of heat- and UV-stabilizers. The amount, the masterbatch has to be added, is 6.25%

8.1.4 Ecology

The actual kit is already on a good level. Due to the chosen plastic, disposal is possible just by burning the articals after use[9]. If the resulting heat energy can be used somehow it is even better. Landfill is also possible. The material will be almost inert to the environment and won't degrade for a very long time.

8.2 Optimization of the Nepal drip kit

The main problems of this kit are in my opinion the following:

- I do not expect a very long service life. After some time the pipes will become more and more stiff, they will shrink and become brittle.
- The correct disposal of old pipes is quite difficult. Neither burning[10] nor landfill[11] is a solution. Recycling is in this case is also not practical and not reasonable due to several reasons.

To improve the longevity and to reduce problems with the disposal, the best solution would be to switch to pipes made of LLDPE or to another polymer listed above.

[9] Although LLDPE will result only in the formation of water and carbondioxide when burnt, under bad burning conditions also carbonmonoxide can be built. Furthermore it must be made sure that no mixing with other plastics (e.g. PVC) occurs

[10] Chloric acid, heavy metals (most probable cadmium) and potentially even dioxides are set free

[11] Plastizicer will contaminate soil, heavy metal containing stabilizers will be washed out