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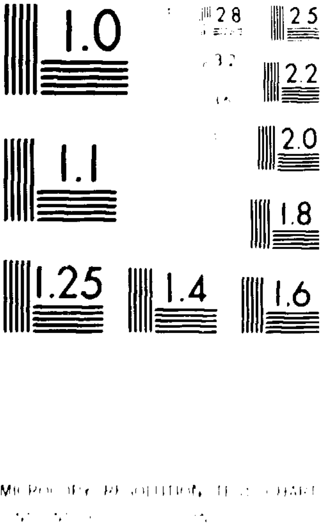
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Enka

Textiltechnisches Institut

Man Made Fibre Developments - Raw Materials and the Environment

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Paper presented at the Unido-Training-Programme in Wien, 24.10. [illegible]

Akzo group member

Introduction

During the past 15 years people often asked themselves where development trends will lead man-made fibres production. And they were looking for answers to several questions:

- in the first place they wanted to know in what amounts which types of fibres will be produced,
- then - particularly since the oil crisis of 1973 - they wondered whether it will be possible to ensure the flow of raw materials,
- another aspect relates to the effect of the man-mades on textile techniques generally,
- and finally the question arose in how far the final consumer will be able to profit by these developments.

The nature of the above queries clearly indicates that it is anything but easy to trace the development trends in the field of man-made fibre production. Moreover, additional factors arose during the last 3-4 years which tend to shake the bases of many possible answers. - All these things considered, the subject requires study within a somewhat enlarged context such as sketched in fig. 1:

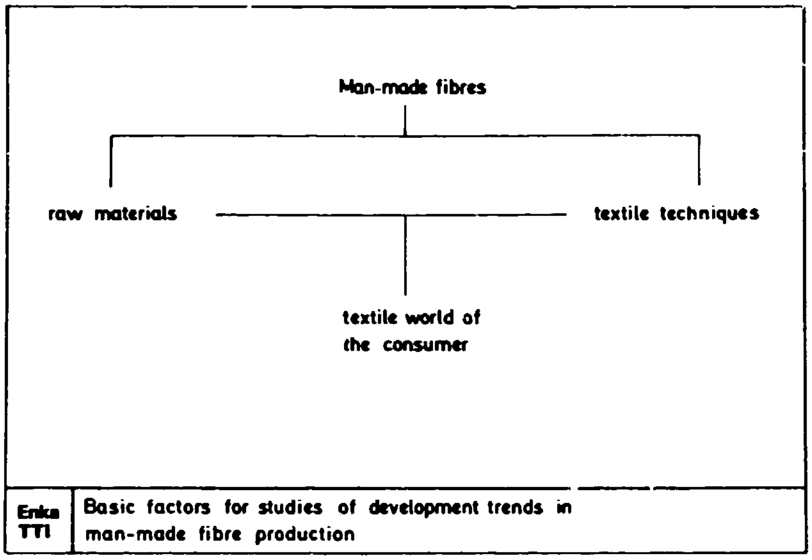


Figure 1 - Basis factors for studies of development trends in man-made fibre production

This slide also illustrates the interaction between supplies, preferences and necessary textile techniques and is therefore a suitable guideline for me to follow.

The textile world of the consumer

It may help to cast a look at the ideas which people have of textiles. First we should remember that man has three basic needs:

- food - protection of the body - shelter -.

These needs are the sum of fundamental precessities which must be fulfilled to ensure human survival, and additional wants. In the case of textiles, necessity and want can be particularly well combined which places textiles into a quite a special position among the things which man requires to cover his basic needs, and we understand why man in the course of time and with growing supplies of textiles used them not only for protection but also for self-expression. And since man-made fibres now add their vital contribution the have become symbols of the modern way of life.

But when we study this modern way of live more closely we soon realise that it is affected by quite a number of influential factors which plunge it into a condition of constant change. Textiles are superbly suited to adapt to, emphasise and themselves influence these changes. One of the consequences is shown in fig. 2, viz. the interaction between the utilitarian and aesthetic values of textiles which opens up most interesting opportunities for the consumer, the more so as he or she is allowed to chose among them quite freely.

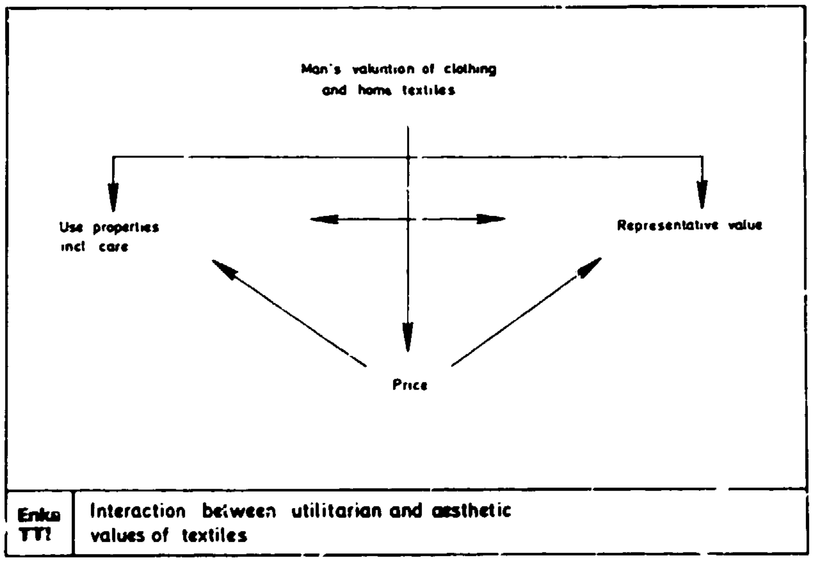


Figure 2 - Interaction between utilitarian and aesthetic values of textiles

Fig. 2 also indicates that it is neither possible to develop on their own the purely utilitarian properties, however important they may be in the eyes of the textile engineer, not the aesthetic values emphasised by the social sciences. The two are closely interrelated and have their price. Its importance can be read from fig. 3 which also points to the clear relationship between income and textile consumption, a fact that may be taken as confirming the theory that higher incomes prompt people to turn so single-purpose and away from multi-purpose textiles.

Per capita consumption of textile fibers in kg

	USA		Germany		Italy		Spain	
1964	17,4	2712	12,9	1357	8,0	832	6,1	492
1968	21,9	3898	17,0	2005	9,7	1317	6,6	730
1972	25,0	4981	19,7	3739	10,5	1987	8,5	1239
1973	24,9	5554	19,2	5040	13,2	2298	9,7	1606

Income in US $

Enka TTI | Per capita textile fibre consumption and income

Figure 3 - Per capita textile fibre consumption and income

Apart from higher per capita consumption, the textile cake also profits from the rapid increase in population. The fact that world population meanwhile has passed the 4 thousand million mark should be assessed also in the light of textile supplies. The theories based on this statement are reflected in fig. 4 which gives both the growth in world population and the fibre requirements, with per capita consumption determined by sophisticated methods of research. These graphs include clothing and home textiles as well as those amounts of textile fibres which are used for industrial and medical purposes.

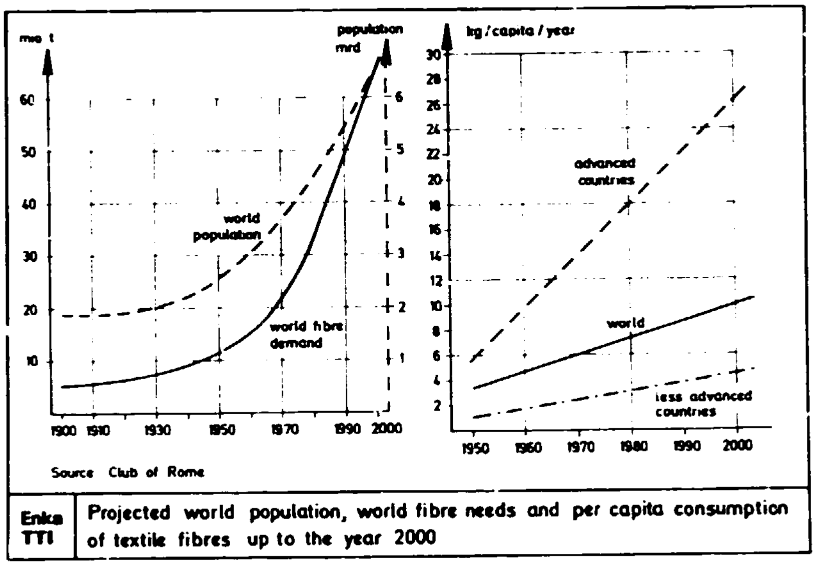


Figure 4 - Projected world population, world fibre needs and per capita consumption of textile fibres up to the year 2000.

If we combine the various elements of this sketch of the consumer's textile world, the following should be specially noted:

- World population will continue to grow. Developments up to the year 2000 are already mapped out.
- Depending on local conditions textile per capita consumption will grow at different but measurable rates.
- The increase in per capita consumption of textile fibres is based on the general increase of living standards and the growing use of fibres in technical and quite new areas.

The raw materials for man-made fibre production

Before entering into a discussion of the problem of supplying man-made fibres producers with their required raw materials we shall have a look at world textile fibre production and the composition of man-made fibre supplies.

Fig. 5 traces the growth over the years of the 3 leading textile raw materials. You will see that - except for some disturbances caused by strong outward influences - cotton production still shows a more or less straight growth, wool has settled for a virtually constant level while the man-mades are still in an almost exponential growth phase.

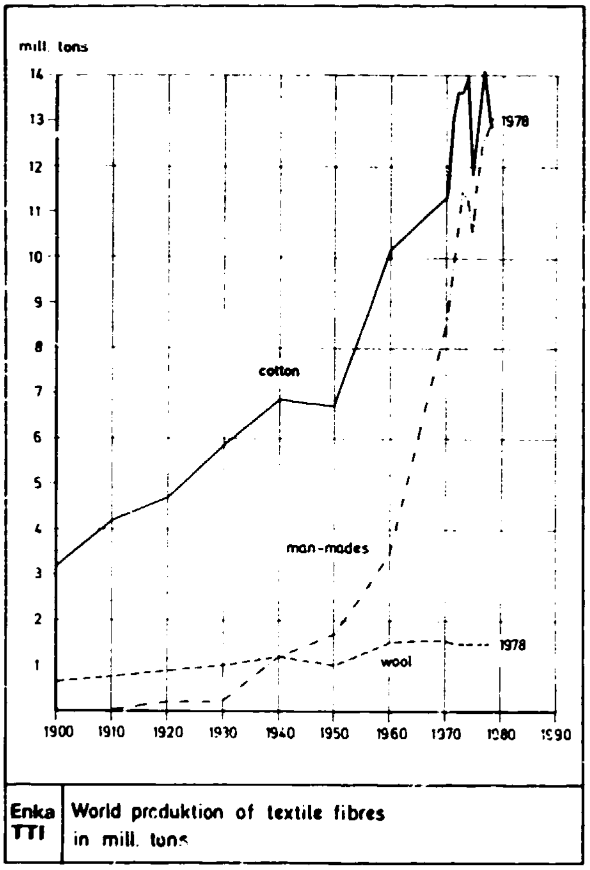
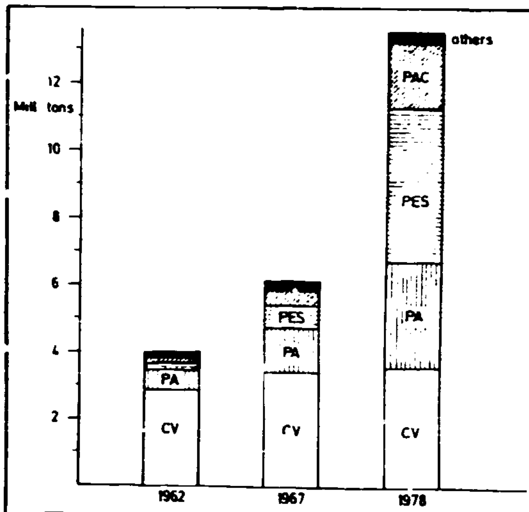


Figure 5 - World production of textile fibres in million tonnes

A closer look at the man-made fibre supplies reveals the picture given in fig. 6 which shows the distribution of man-made fibre production over types of fibres as well as the share of continuous filaments and staple fibres.



	1962	1967	1978
Filament	1,8 = 45 %	2,8 = 46 %	5,8 = 43 %
Staple	2,2 = 55 %	3,3 = 54 %	7,8 = 57 %

CV	Filament	1,2	10^6t	1,3	10^6t	3,6	10^6t
	Staple	1,7		2,1			
PA	Filament	0,5		1,2		3,1	
	Staple	0,1		0,1			
PES	Filament	0,1		0,2		4,6	
	Staple	0,1		0,5			
PAC	Filament	0		0		2,0	
	Staple	0,2		0,5			
others	Filament	0		0,1		0,3	
	Staple	0,1		0,1			

Enka TTI | World man-made fibre production 1962 - 1978

Figure 6 - World production of man-made fibres 1962-1977

Particular attention should be paid to the facts that

- the regenerated cellulosic fibres have shown no quantitative growth during the past 15 years,
- the growth rate of the polyamide fibres has become distinctly lower,
- the polyacrylics are virtually exclusively made in the form of staple fibres,
- the group of the "Other man-made fibres" shows little change,
- and that the relation of staple to filament has been surprisingly constant over the whole period under consideration.

Man-made fibres can be made from

- mineral oil -synthetic fibres - led by polyamide, polyester, polyacrylics, polypropylene in filament or staple form, or from
- natural cellulose as found in wood
  - regenerated cellulose fibres, led by viscose staple and rayon filament yarns.

Raw materials for synthetic fibres

At the present state of the art, oil is the most important starting material for the petrochemical raw materials used by the man-made fibre industry. At the same time mineral oil also is the most important carrier of energy in the widest sense of the word. In order to rightly assess the supplies to our petrochemical industries and power generation, fig. 7 breaks down total power consumption in the world (without the communist countries) into its different sources of supply.

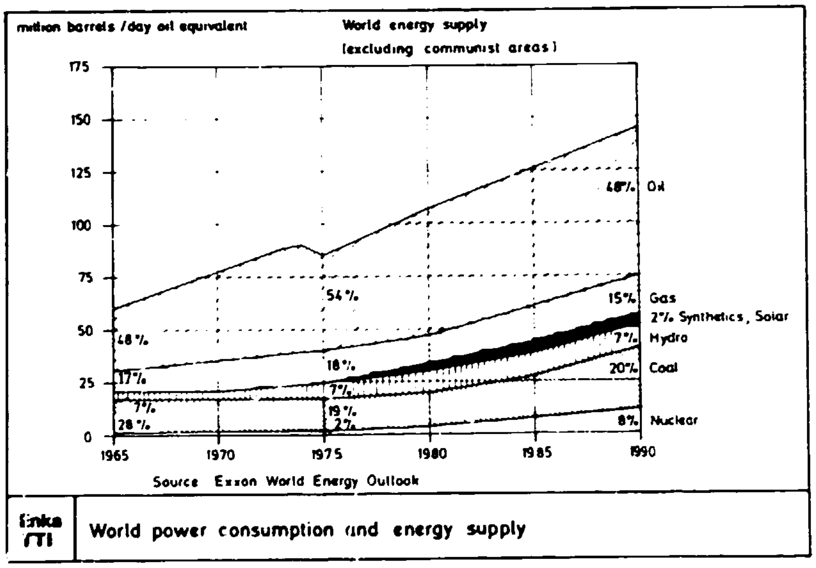


Figure 7 - World power consumption and energy supplies

Fig. 7 clearly illustrates:

- The rapid increase in oil consumption
- that the relative share of mineral oil as a source of energy may be reduced by 1990 by some 6 % to 48 %, but that the quantitis consumed will increase,
- that the shock inflicted by the 1973 oil crisis, while felt very acutely at the time, seems to have worn off.

The same considerations apply to Western Europe whose energy consumption is shown in fig. 8.

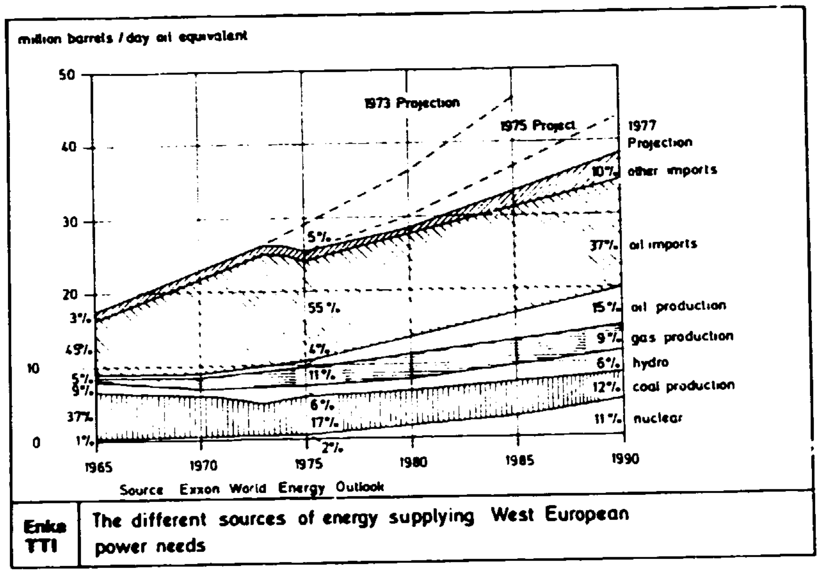


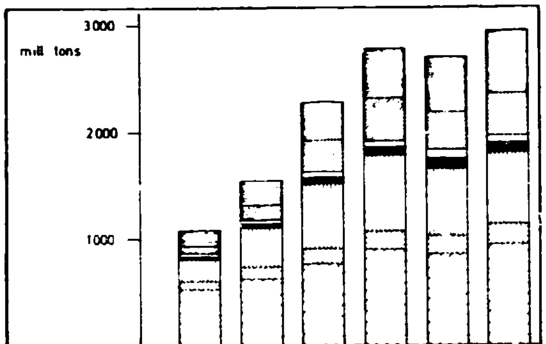
Figure 8 - The different sources of energy supplying West european power needs

This graph is based on the following assumptions:

- in Western Europe power consumption will continue to grow too,
- by forceful increase of native oil production and continued expansion of nuclear power generation oil imports can probably be reduced by some 18 % to ca. 37 % of energy requirements by 1990; this would be quite a remarkable achievement.
- On the other hand, the trend plotted for coal as a source of native energy is rather surprising in the light of statements made by politicians of various colours.

Mineral oil consumption of different groups of countries is broken down in fig. 9. It shows unmistakably

- how rapidly oil consumption has increased
- that North America with 4.5 % only of world population uses more than 30 % of mineral oil, while Western Europe shows a similar picture although on a lower level.
- Interesting information can also be derived from the last column which indicates that power consumption in the countries not only shows rapid increase but soon may have equalled their share in population.



	population %	1960 %	1960 mill t	1965 %	1965 mill t	1970 %	1970 mill t	1973 %	1973 mill t	1975 %	1975 mill t	1977 %	1977 mill t
North-America	4,5	48,8	526,4	40,0	618,8	33,6	761,9	32,2	892,7	31,3	843,4	32,2	943,6
Central- and South-America	5,0 5,8	7,6	82,0	7,1	109,8	6,5	146,9	6,3	174,8	6,6	178,0	6,4	187,8
Western Europe	7,8	18,5	199,6	24,4	377,5	26,9	610,3	26,1	724,3	23,8	640,9	22,9	670,8
Middle-East	27,4	2,7	29,1	2,7	41,8	2,7	60,4	2,7	75,9	3,0	81,5	3,1	90,2
Africa	5,3	2,3	24,8	2,0	30,9	1,8	41,6	1,8	49,9	2,1	56,0	2,0	59,5
Far-East Australia etc	25,4	6,9	74,5	9,5	147,0	13,4	304,3	14,9	412,9	13,6	366,8	13,5	395,1
East Europe, USSR, PR China	23,8	13,2	142,4	14,3	221,2	15,1	343,1	16,0	445,1	19,6	528,2	19,9	564,6
World total	100	100	1079	100	1547	100	2269	100	2776	100	2695	100	2931

Enka TTI — World mineral oil consumption 1960 - 1977

Source Oeldorado

Figure 9 - World mineral oil consumption

Now, where is mineral oil found and where is it used?

Fig. 10 maps out oil production in the various parts of the world in 1976. Western Europe, it is seen, runs a grave deficit in its oil producing oil consuming balance. With 1.3 % of total production it consumes as much as 24 %. Apart from the exploitation and use of new energy sources this imbalance may be reduced by the oil finds in the North Sea, although any remarkable alleviation will become effective only during the next decade - as we already saw in fig. 8. Verified natural oil reserves in Western Europe totalled 3.658 billion tonnes in 1977, equivalent to as little as 4.2 % of worldwide oil reserves.

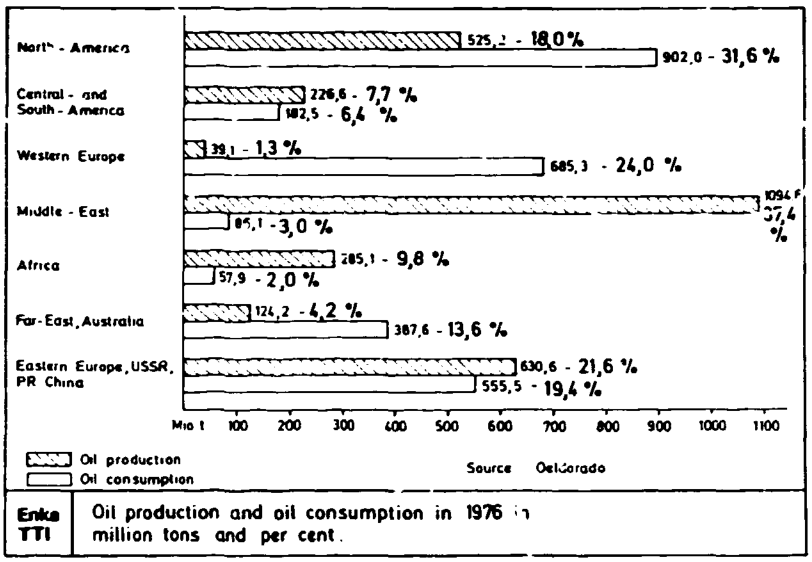


Figure 10 - Oil production and oil consumption in 1976 (in mill. tonnes and in %)

Besides oil consumption, oil prices are serious considerations for the man-made fibres industry. Therefore, fig. 11 gives a listing of crude prices for the years 1972 - 1977; and we must always remind ourselves that further price raises would invariably entail serious consequences, also for the man-made fibres industry. In addition, oil processing is coming increasingly under pressure from growing car fuel demand and tougher environmental requirements. This will have twofold consequences:

- a switch of refinery methods to cracking and hydrocracking, resulting in larger amounts of olefins, and
- increased demand for aromatics to replace lead.

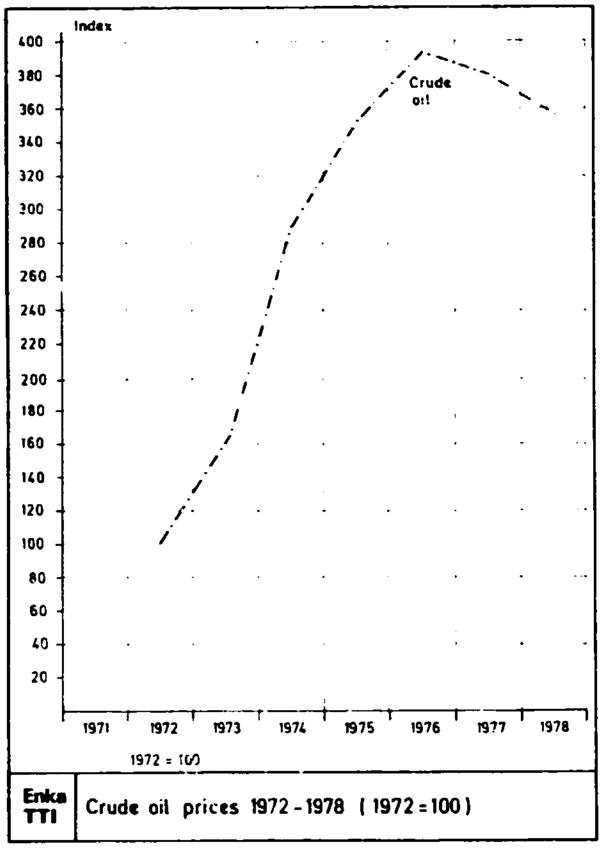


Figure 11 - Crude oil prices from 1972 - 1977 (1972 = 100)

Fig. 12 gives an outlook on the changes which can be expected to occur in the oil refining field. They will lead to:

- an increase in the percentage of petrol from the present 25 % to max. 55 % (depending on the origin of the oil), and
- an increasing percentage of ethylene as well as propylene as by - products - from whom we have no proper uses yet.

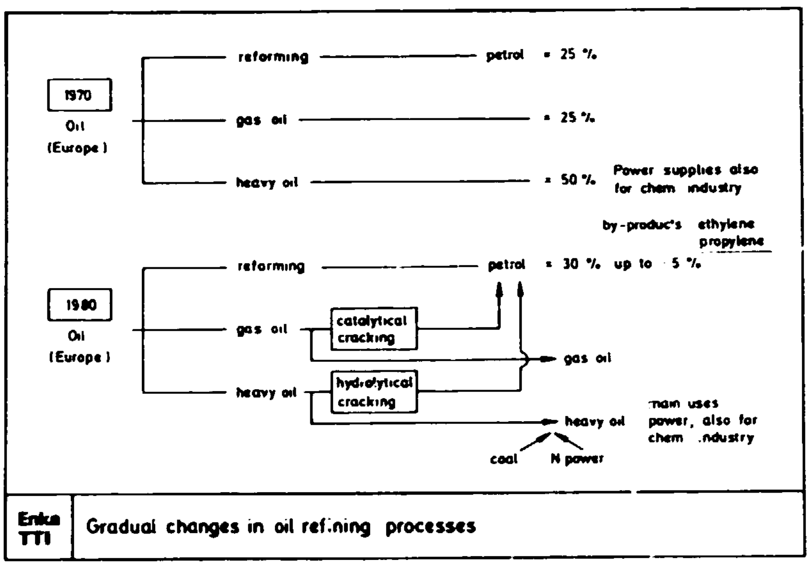


Figure 12: Gradual changes in oil refining processes

For industry greatest importance attaches to heavy oil which is used for both energy supplies and chemical raw materials. Man-made fibre requirements actually amount to only some few per thousands as can be calculated off-hand from oil production at ca. 3 billion tonnes compared with a mere 9 mill. tonnes of man-made fibre production.

Oil refining, i.e. the breaking down of crude oil into its various component parts, produces among other things the aromatics paraxylene and benzene as well as the aliphatics ehtylene, butadiene and propylene. All of them are used as starting materials for man-made fibre production.

Fig. 13 lists the components used by the man-made fibres industry to produce polyamide and polyester fibres.

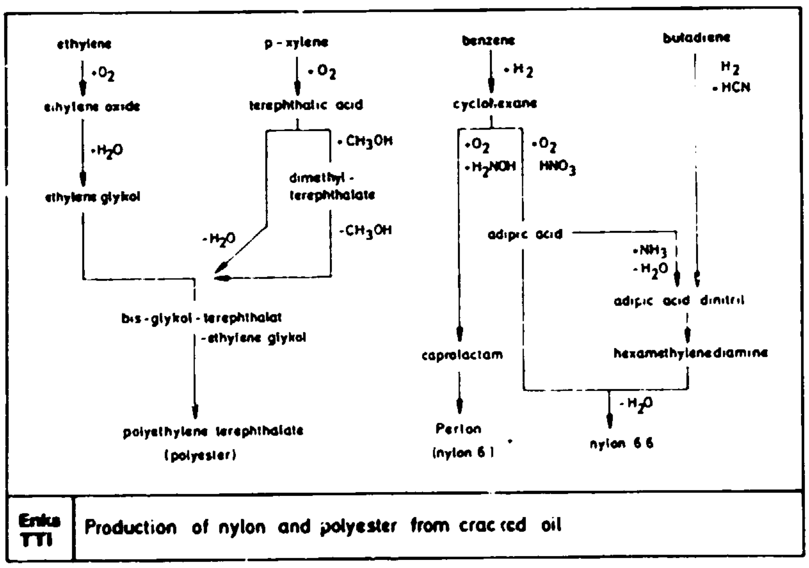


Figure 13 - Production of nylon and polyester from cracked oil

Although fig. 13 does not trace all routes used in the production of the starting materials for polyester and polyamide, it gives a clear impression of the mutual dependency of the raw materials on each other. In practice this is even more complicated - shall we say fortunately or unfortunately.

At this point the question arises which of these two kinds of synthetics will be the more reliable supply-wise and the cheaper to produce.

A relatively simple question, but very difficult to answer. Since their raw materials are also used in other, far greater processes, the demand emanating from these rival uses will certainly have its effect on the raw material supply position of the man-made fibres industry. Ethylene, e.g., goes into antifreezes, technical grade ethyl alcohol, vinyl products and detergents. Butadiene is the main raw material for synthetic rubber and aqueous rubber paints; benzene is used in the manufacture of most detergents and plastics while paraxylene also goes into coatings, solvents and as anti-knocking agent into petrol gasoline. - On a purely quantitative scale most of these uses take up infinitely greater amounts of the above chemicals than synthetic fibre production. All this boils down to the conclusion that the fibre industry, although quite important in size, is a dwarf compared with other industries which use the same raw materials. Therefore, the man-made fibres industry is altogether unable to exert any influence on the prices of the raw materials it purchases. State regulations such as those against lead in petrol, phosphates in detergents etc. have much more effect on man-made fibre and raw material prices than the industry itself. This ist the main reason why we have no reliable indication as to whether polyamide or polyester will be better places price-wise in the future. What we can say with some reliability is that man-made fibre prices are inescapably tied to raw material prices, investment costs and labour costs. If these remain unchanged, no change will occur in fibre prices. The possibilites to absorb cost increases via more sophisticated processes have been all but exhausted during past years and little can be expected from this side.

Raw materials for regenerated cellulose fibres

Unlike the synthetics which are based on petrochemical raw materials, regenerated cellulose fibres can rely on natural raw material resources which automatically replenish themselves:viz. cellulose as found in plants. Without enlarging upon the chemical and technical details of production it may suffice to recall that the cellulose manufacturers produce their material from natural resources - mainly wood, but also other plants such as reeds and sugar cane. Their main customers are the paper and the viscose industries. For viscose-grade cellulose the main raw materials are fir and pine trees, and to a much lesser degree beech, poplar and eucalyptus. Manufacture of industrial-grade, high-tenacity viscose yarns requires very high-grade cellulose made from conifers after the sulfate process.

In the USA some 37 % of wood consumption are used to make cellulose - the US, by the way, are among the largest producers of cellulose in the world. In the Fed. Rep. of Germany, on the other hand, only 12 % of felled trees go into paper and cellulose production. The share of the fibre producing industry in total cellulose consumption is not very great compared with total wood consumption. For the year 1978 world cellulose production is estimated at some 146.5 mill. tonnes of which less than 4 % are used for cellulosic fibre and foil production.

Concluding this chapter I would like to mention that cellulose will continue to be generated as long as the world will exist hence raw material supplies for the production of regenerated cellulose fibres will always be available. Even at the peak of viscose staple and rayon production in Germany, the industry never used more than 3 % of new tree growth for its purposes. Threfore it is and will be quite worthwile also in the future to study methods to produce cellulose and cellulosic fibres and to solve persistent problems.

In summarizing the following can be said on the problem of assuring raw material supplies for man-made fibre production:

On the one hand it may be felt to be an advantage that only small portions of the basic starting materials are required for man-made fibre production, since this tends to indicate safe supplies - but on the other hand this very fact is also disquieting since relatively small quantities are more dependent price-wise on other larger product groups such as wood, paper, petrol and fuel. Additional problems are created by the cost of reducing pollution of the environment during preparation of the basic materials and processing them into fibres. This means that the costs for the protection of the environment from dangerous side-effects of cellulose preparation and cellulose processing in the fibre producing plant must be covered, same as the costs for reducing the lead content in petrol by adding equalising substances which, at the same time, are important fibre raw materials. Moreover, increased petrol demand will prompt the use of production methods previously not employed or employed only on a negligible scale and which produce so much propylene as a by - product that one should seriously think about what could be done with it.

Another important subject to be considered in this connection is the availability of the fibre raw materials themselves. This might grow into a veritable problem if all incentives to produce them are removed because other uses for theses chemical basics are more economical. It will, therefore, not come as a surprise if I tell you that at the present capacities for man-made fibre raw materials distinctly lag behind the fibre spinning capacities proper. Although this does not lead to bottleneck shortages seen the present worldwide under-utilisation of spinning capacities, it should be remembered in the light of present efforts to restore the balance within the next few years.

Short-listing this chapter on raw materials results in the following:

- Cellulosic and synthetic starting materials for the production of man-made fibres are available in sufficient quantities;
- Their prices are determined by the main uses of the basic starting materials;
- Environmental problems affect the manufacture of man-made fibre raw materials, but they can be solved;
- Competition among the various synthetic fibres resulted in largest growth rates for the polyester fibre;
- Besides the four main groups of man-made fibres, those belonging to the "Other fibres" group have not for various reasons, reached the degree of importance which one might have expected on the ground of trade publications about them.

Securing fibre supplies by blending man-mades with other man-made or with natural fibres

The combination of different types of fibres is one of the main challenges for the textile engineer. It can be done in a number of ways:

- blending the fibres (filament or staple)
  - giving blended spun yarns
  - or filament mixes (hetero yarns), or
- feeder blending.

The classic staple fibre blend yarns combine
- polyester and cotton,wool,polynosics, HWM, viscose, PAC, linen
- polyamide and wool,PAC and viscose.

In the course of the last two decades practical experience resulted in a number of standard combinations. They are based on tests - mostly made by the man-made fibre producers themselves - which, during the introductory period, aimed at optimizing certain textiles with the help of the then available types of fibres. The methods used in this process are illustrated in fig. 14. With the help of four examples from the outerwear field it clearly indicates the value of close examination of fibre blends. By the way these requirements can be changed ad lib or increased in number for any given article.

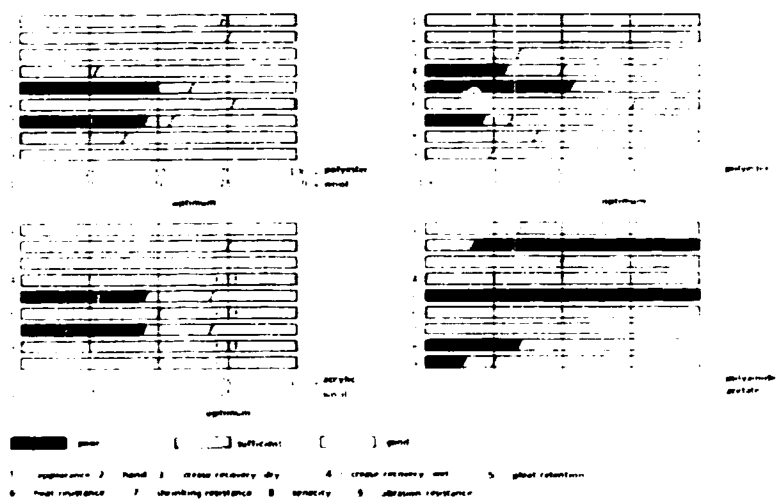


Figure 14: Optimisation of outerwear fabrics by fibre blending

Apart from optimal fabric properties sophisticated blending can produce still other effects. It may, e.g. be desirable or to combine staple fibres of different lengths or titres to improve processing properties and/or yarn characteristics. Novel dyeing effects and other optical or tactile effects can be obtained by including fibres of different dyeing behaviour or different cross-section and/or shrinking behaviour. A list of blending effects is given in figures 15 and 16; fig. 16 also includes some filament yarn mixtures.

Aim of blending	compared with	Solution
Savings		
- raw materials	100 % CO	65 / 35 % CO/CV
	100 % WO	70 / 30 % WO/CV
- increased performance	100 % CO	65/ 35 % CO / CV (CO = short staple)
Improved properties		
- yarns	100 % CO	50/50 % or 65/35 % PES/CO
	100 % WO	55/45 % or 70/30 % PES / WO
- woven fabrics		
- weight	100 % WO	55/45 % or 70/30 % PES / WO
- durability /	100 % CO	50/50 % or 65/35 % PES/ CO
easy care	100 % WO	55/45 % or 70/30 % PES/ WO
- dimensional stability/ light weight	100 % WO	55/45 % or 70/30 % PES/ WO
- knitted fabrics		
- bulk	100 % WO	100 % PAC

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Figure 15 - Reasons for fibre blending

Spezial effects	Solution
Sheen	dull / bright fibres, cross - section
dull appearance	OE rotor - spun yarns
bulk	admixture of HB / HS fibres
differential dyeing	blending fibres of different dystuff affinity
cross - dyeing	inclusion of black and white fibres, e g
increased stiffness	blending fibre titres or admixture of star-shaped cross-section fibres
yarn swelling	use fibres with high swelling value
linen- or other effects	use fibres of different lengths und e g neps
fused yarns	inclusion of binder fibres
reduced hairiness	longer staple, -stretch - breaking
coverage	titre selection, bulk, spinning method
work absorption	strength and elongation
antistatics	admixture of suitable fibres
moisture absorption / transport	blending low- and high - swelling fibres

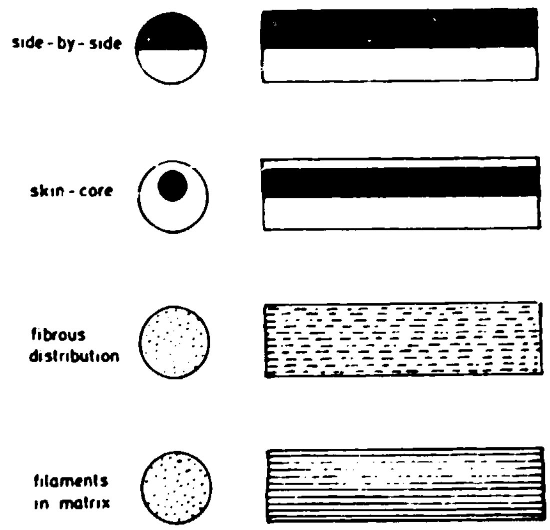
Enka TTI | Reasons for fibre blending

Figure 16 - Reasons for fibre blending

During the last years many of the possible ways to modfiy filament properties have also been widely explored. We now have yarns with differential shrinking or dyeing filaments as well as yarns combining filaments of a different chemical nature such as polyamide and viscose.

The variety offered by feeder blending on knitting machines as well as the use of different types of yarns in the warp and weft directions of woven fabrics is being increasingly exploited for production and cost reasons and to produce fabrics of a special type.

A review of fibre blending should also include a short survey of bicomponent fibres. They were devised in an effort to combine the desirable properties of different polymers in one single fibre construction. The basic principles are shown in fig. 17. Whether it will pay to spin bicomponent fibres for special textile articles is a matter of weighing their merits in each single case.



Various types of bicomponent fibres

Figure 17 - Types of bicomponent fibres

Exchangeability of textile fibres

This is a subject which should be studied from the lowest end of the textile pipeline - the availability and the price of raw materials.

If there were ample supplies of natural fibres at low prices, then man-made fibres were only required for technological reasons and to produce special effects. However, this is quite a hypothetical assumption - at least for our parts of the world, since Europe is dependent on the import of natural fibres.

For many countries of the world the above assumption is becoming more and more theoretical since they need more and more of their land to produce food. They, too, will see no alternative but to cover their textile needs with the help of man-made fibres.

Such global considerations should not leave unmentioned the fact that the cellulosic and synthetic man-made fibres offer an attractive and most important degree of freedom to the economy of the country concerned, which it can use in many ways. The exchangeability - or substitution - of fibres, therefore, is another wide field as it embraces the naturals as well the various man-mades.

- Polyamide/wool -

This blend used to be quite popular one time, as was the viscose/wool blend. In this case the polyamides were mainly used to upgrade the wearability of certain types of outerwear. No improvement was reached in dimensional stability while the yarn geometry required for these yarns resulted in limitations to fabric design. If this blend is to be used for which reason whatever, the blend limits are drawn at 20-35 % polyamide and 80-65 % wool. Fabrics of this type incorporate all the advantages which can be derived from this blend, but many wishes, which we meanwhile have come to take for granted remain open.

- Wool/PAC -

Both fibres are characterised by crimp, high bulk and high resilience. Therefore, one could very well take the place of the other. Blends of the two offer no practical advantage.

- Wool/polyester -

This is by a wide margin the most popular blend in the field of wool textiles. Properly constructed it will result in optimal yarn, processing and garment properties. This requires a polyester content of at least 50 % and a wool content of at least 25 % - setting the blending limits at between 50-75 % polyester and 50-25 % wool. With these blends, very lightweight yet dimensionally stable fabrics can be produced which give outstanding wearing service.

In this wool-type fabric area the admixture of high-shrinking staple fibres allows yarn constructions of such hign bulk that the polyester content of the yarn can be raised to 100 %. This yarn/fabric construction is one of the most attractive examples of substitution.

Blends in the cotton field

- Polyester/cotton, modal fibres/cotton -

The polyester/cotton fibre blend is the most important of all. It ensures dimensional stability, strength, abrasion resistance. The polyester in the cotton blend, as well as in blends with polynosics and HWM rayon staple, should not be less than 40 %, otherwise the fibre will fail to contribute its full share to the final fabric properties. - Blends of modal fibres with cotton, quite a common blend on the market, could be easily replaced by blends of polyester/modal fibre if cotton became dearer; again the polyester content should be above 40 %.

These considerations, however, apply only to staple fibre operations. - With filament yarns, which are virtually all made of man made fibres, a twofold problem may arise:

- is substitution desirable to cover the wearing requirements of the textile product, or
- is substitution necessary to make up for short supplies.

Polyamide/viscose hetero yarns (filament mixes) are a good example for the first of the above questions. They find growing use in lining fabrics. The second problem is much more difficult to decide. It would certainly be possible to substitute polypropylene fibres for polyamides in some carpet constructions, but this refers more to the construction of the carpet and/or its ultimate use.

Substitution in this case can never be the ultima ratio, since the properties of the polypropylene fibre are vastly different from polyester. Where such problems come up it is, therefore, necessary to examine, compare and weigh the requirements and fibre properties.

Reclamation of used textiles

In connection with the problem of ensuring adequate textile raw material supplies and the growing awareness of environmental protection we should not leave unmentioned the much discussed subject of recycling.

Recycling is the reclamation and renewed use of raw materials. In textile terms this would mean

- collection
- sorting
- cleaning
- shredding and
- recarding

of used textiles and textile waste.

In terms of machinery the recycling of used textile materials would pose no problem. The difficulties start with

- cost of collection. This would require setting up a special organisation. Before and during World War II this was done in Germany by the then existing organisations;

- sorting of the used textiles according to colour and also to kind of material. This last point would again pose problems as used textile generally lack adequate labelling.

In addition
- this operation is wage intensive and
- smooth flow in the textile pipeline cannot be guaranteed.

Neither should it be overlooked that used textiles often arrive at the point of re-use in a most desolace state. The re-user would be responsible to alleviate hazards for the processing personnel.

Man-made fibres and protection of the environment

It has already been repeatedly mentioned that the supply of raw materials and the processing of these raw materials into man-made fibres may pose environmental problems. This applies particularly to the production and processing of cellulose and polyacrylonitrile.

Cellulose process cause water pollution and noxious odours. While water pollution can be eliminated at a price, the emission of noxious ordours seems to defy complete elimination, but it must be stated that immission values at the present state of the art do not constitute any health hazards. - When the cellulose is turned into fibres after the viscose process, water and air pollution occurs again. And again water pollution could be solved and odours reduced. Moreover, work is progressing on manufacturing processes which no longer rely on sulfuric solvents for the cellulose. Although this work is still in its early stages, it is by no means hopeless. Already we know of ways and means to produce regenerated cellulose fibres which use much less or even no sulfur at all and there are good prospects for this problem to be sucessfully solved in the end.

In polyacrylonitrile fibre manufacture attention must be paid to the fact that at least the acrylonitrile monomer must be regarded as a dangerous substance. For modern process techniques this is no problem at all as the process techniques ensure that there is no direct contact between man and chemical. - In the fibre spinning process proper the main problem is to use the right type of solvent and to optimize the process accordingly.

Some years ago loud cries were heard demanding bio-degradability of synthetic fibres. These cries have subsided since it became known that degradation substances are not without their own problems and that it may be better if certain products did not degrade. Non-degradation, moreover, requires orderly disposal of the products involved.

While the manufacture of some man-made fibres creates certain environmental problems which, however, can be solved, all the man-mades make important contributions to improved conditions in textile processing at the later stages.

Progress in this respect as made partly possible by purposeful modification of the man-mades ranges from improved working conditions at the spinning mill - be reducing dust - via noise abatement -- by development of new weaving technologies for the synthetics - up to low-pollution dyeing and printing methods. Let me add some details on the solutions sketched above.

Spinning mill

Spinning of staple fibres into yarns - particularly cotton spinning - invariably creates dust which is irritating to the environment, the health of the workers and also the quality of the yarn.

Dust generated at the machines whirls into the ambient air and is aspirated by the workers. Exposure over long periods of time to such condition, particularly in cotton operations may lead to diseases of the respiratory apparatus, a condition called byssinosis. With man-made fibres there is no dust in the air, and this is one of the reasons, why yarns with as high a polyester content as possible should be preferred.

Weaving

With conventional looms, i.e. shuttle looms, high levels of noise are generated at the weavers workplace which generally comprises a number of machines. Noise is caused by the dispatch and braking of the newly inserted weft and by the movement of the shafts. The development of new, shuttleless looms has made weaving much less noisy operation as borne out by fig. 18.

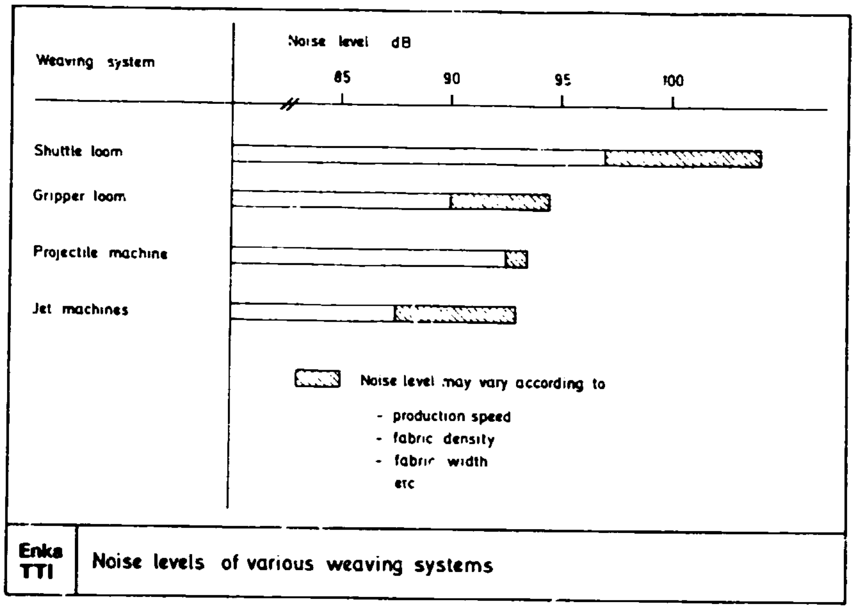


Figure 18 - Noise levels of various weaving systems

In modern weaving mills the following types of shuttleless weaving machines can be found:

- projectile looms
- gripper looms
- hydraulic machines (water jet)
- pneumatic machines (air jet).

From fig. 18 it is seen that the jet weaving machines cause the least noise.

Textile finishing

The textile industry of the Fed. Rep. of Germany needs some 250 mill. m^3 of water per year, which is equivalent to some 2 % of total industrial water consumption. If we deduct average evaporation and the water used for boiler operations, waste water amount to some 220 mill. cbm. Of this an estimated

150 mill cbm or 68 % come from textile finishing. The large amounts of waste water generated by textile finishing were reduced as the share of man-mades increased, since man-made fibre finishing requires less aqueous treatments. And there was technical progress in the finishing industry too, viz.:

- short bath processes,
- the use of organic solvents instead of water,
- transfer printing.

Of these, transfer printing is a typical case of man-made fibre technology. It has no adverse environmental consequences and opens new freedoms to production.

Progress in textile care

Textiles are mainly cleaned by water with the help of power. Both resources are limited. The low moisture absorption of the synthetic fibres, their low washing temperatures and the longer life of the synthetics and synthetic blends togehter with their lighter weight therefore constitute true progress. Today these advantages are so much taken for granted that the natural fibres have fallen way back. In the USA it has been found by meticulous calculation that a polyester/cotton shirt, 50/50 blend, requires much less energy to produce and carry through 50 launderings than a comparable all-cotton shirt.

Summary

Developments in the man-made fibres area during the last decades were truly spectacular both qualitatively and technically. But the course which the man-mades have taken through their various development phases always followed the general trend of the textile industry. These two are an unseparable entity. Inspite of all the problems, the general outlook for the man-mades continues to be encouraging. On the strength of a growing world population and and increasing general standard of living, world fibre requirements will continue their upward trend during the decades to come. In the face of growing food demand, which must be given priority for economic, social and political reasons over increased fibre production, only the man-mades will be able to fill the gap.

Raw material supplies - oil as well as wood - can be assumed to be assured in view of the size of the respective world markets. Moreover and if property used the man-made fibres can be widely substituted for naturals and offer numerous opportunities to improve the environment and the working conditions in the textile processing industries.