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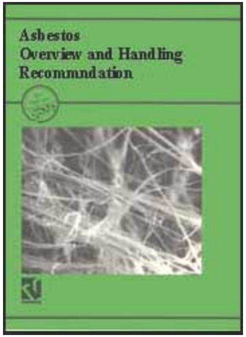

Asbestos Overview and Handling Recommendations (GTZ, 1996)

Annex 8: Questionnaire on country profiles regarding Asbestos

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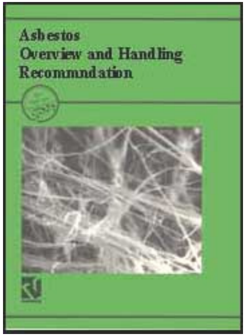


Asbestos Overview and Handling Recommendations (GTZ, 1996)

Overview and Handling Recommendations

1996

prepared by

ERM Umwelt Consult Rhein-Main-Neckar GmbH, Bensheim

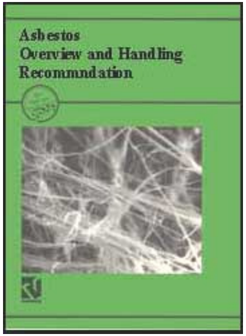
commissioned by the
Deutsche Gesellschatt fr Technische Zusammenarbeit (GTZ) GmbH, Eschborn

in cooperation with

Kreditanstalt fur Wiederaufbau, Frankfurt/Main

on behalf of
Bundesministerium fr wirtschaftliche Zusammenarbeit und Entwicklung (BMZ), Bonn

Home"" """"> ar.cn.de.en.es.fr.id.it.ph.po.ru.sw



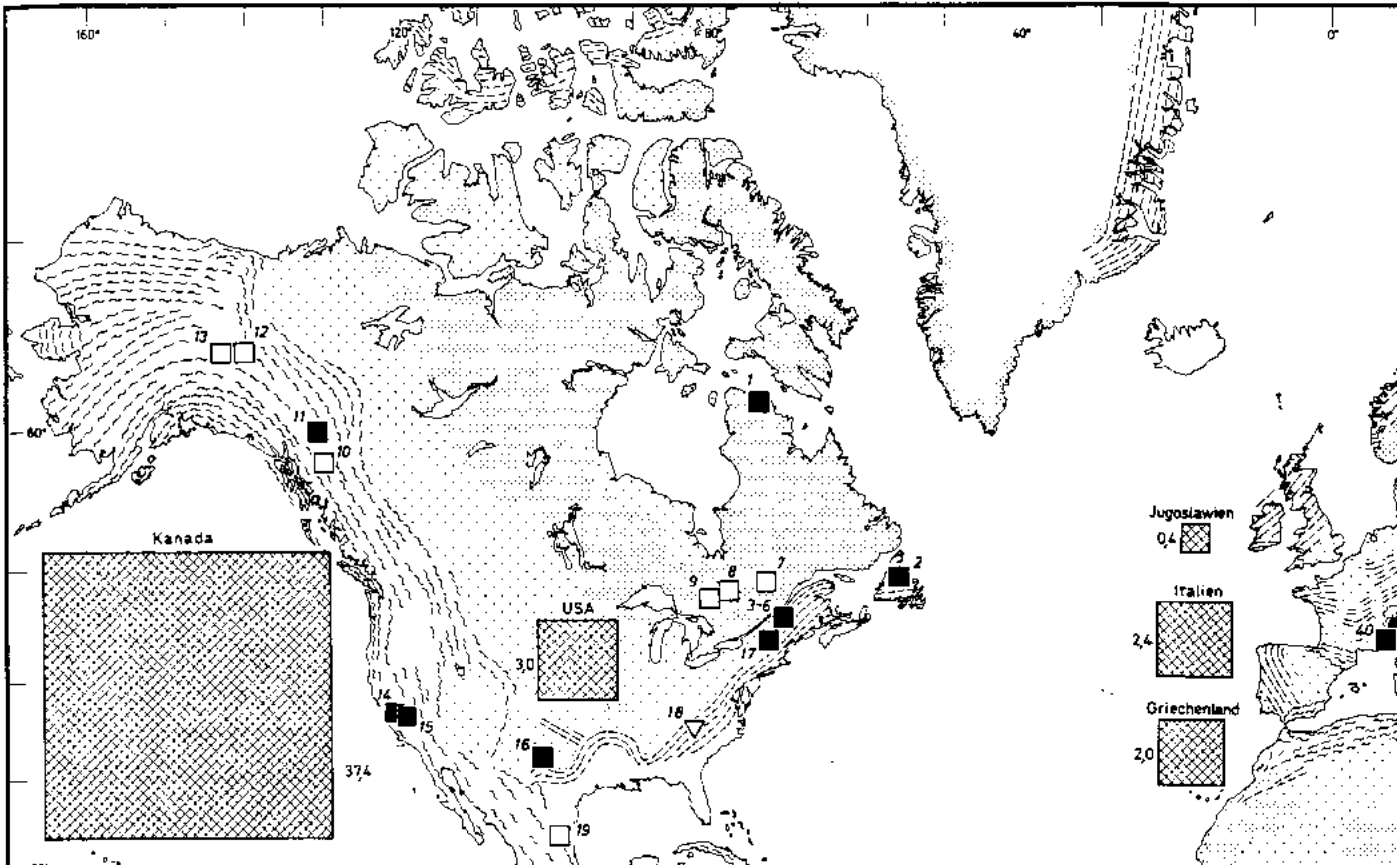
Asbestos Overview and Handling Recommendations (GTZ, 1996)

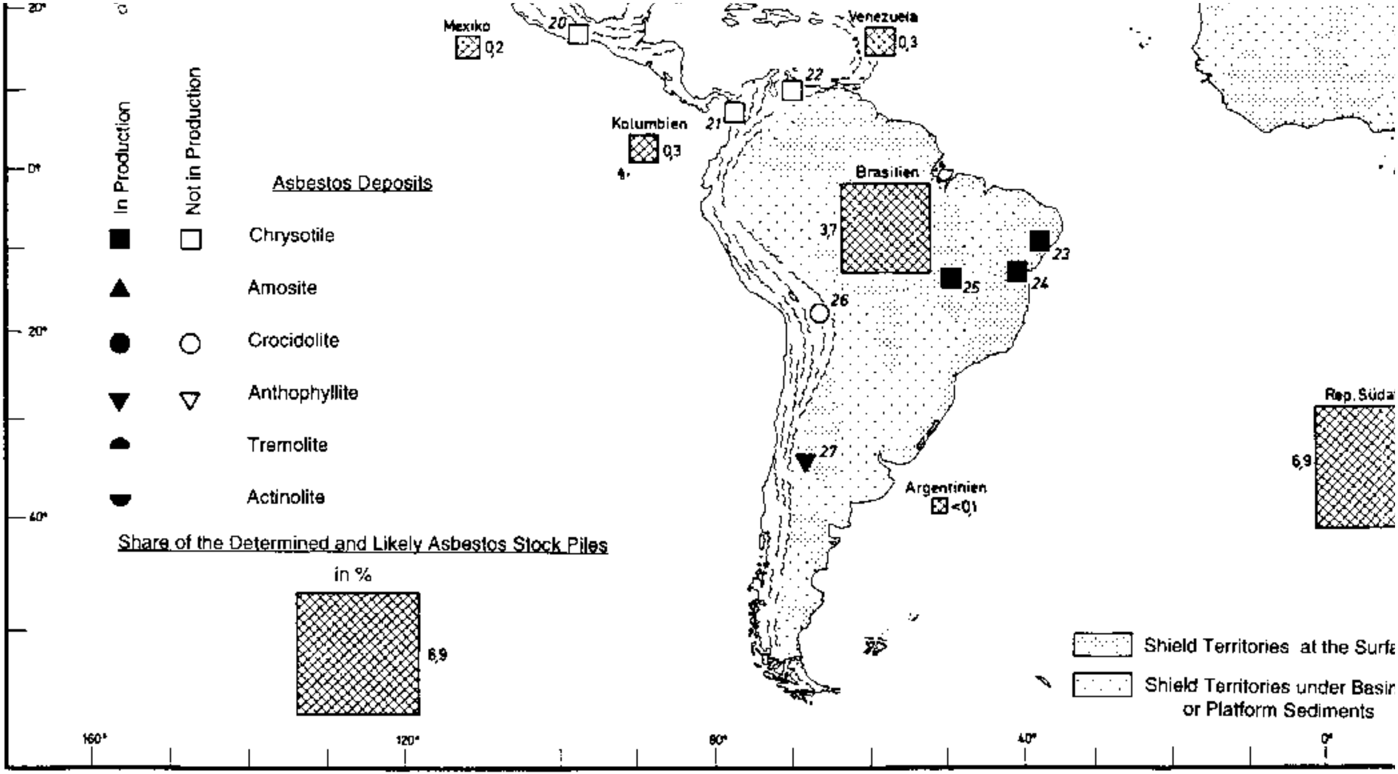
Part VII Annexes

Asbestos Overview and Handling Recommendations (GTZ, 1996)

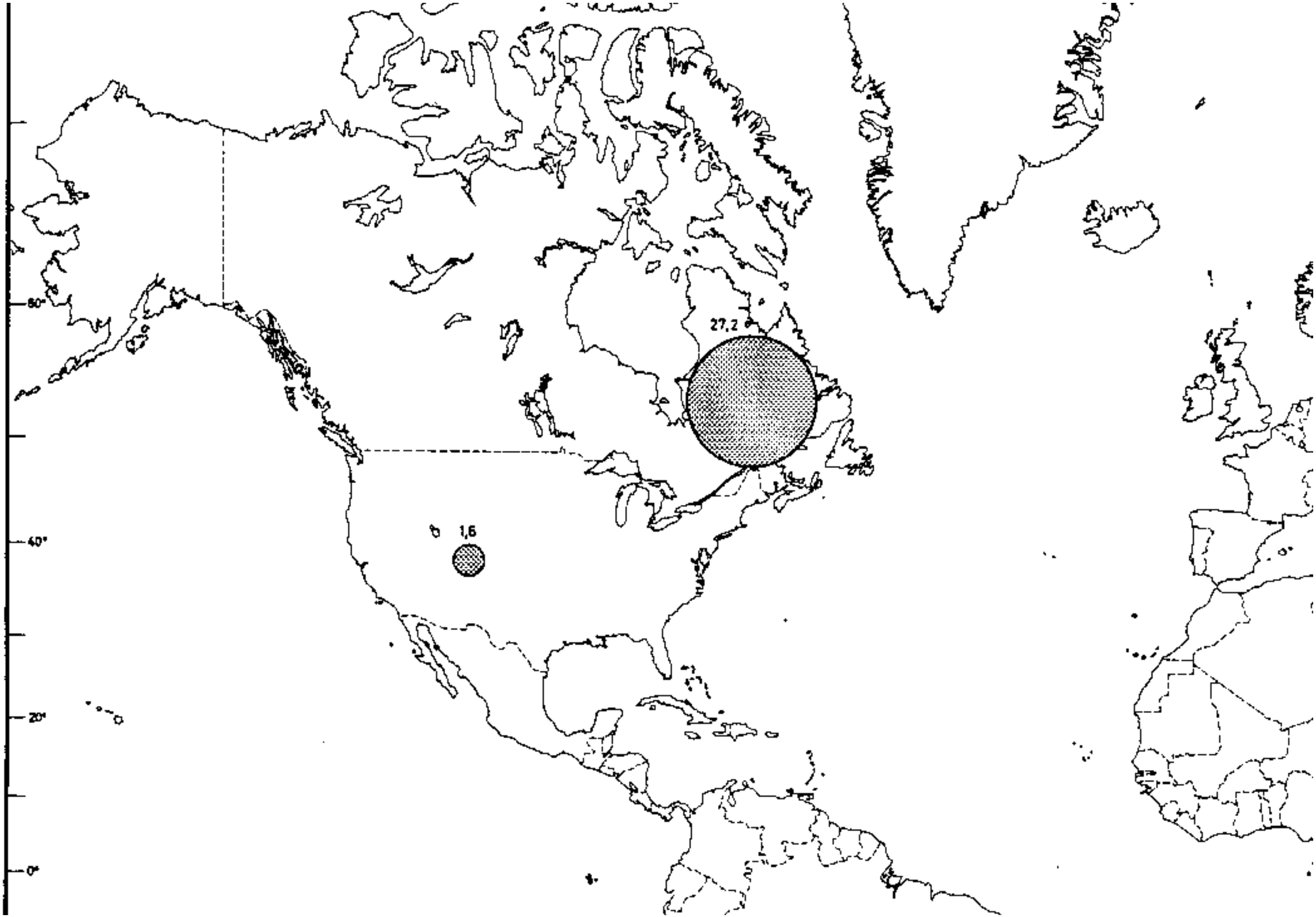
Part VII Annexes

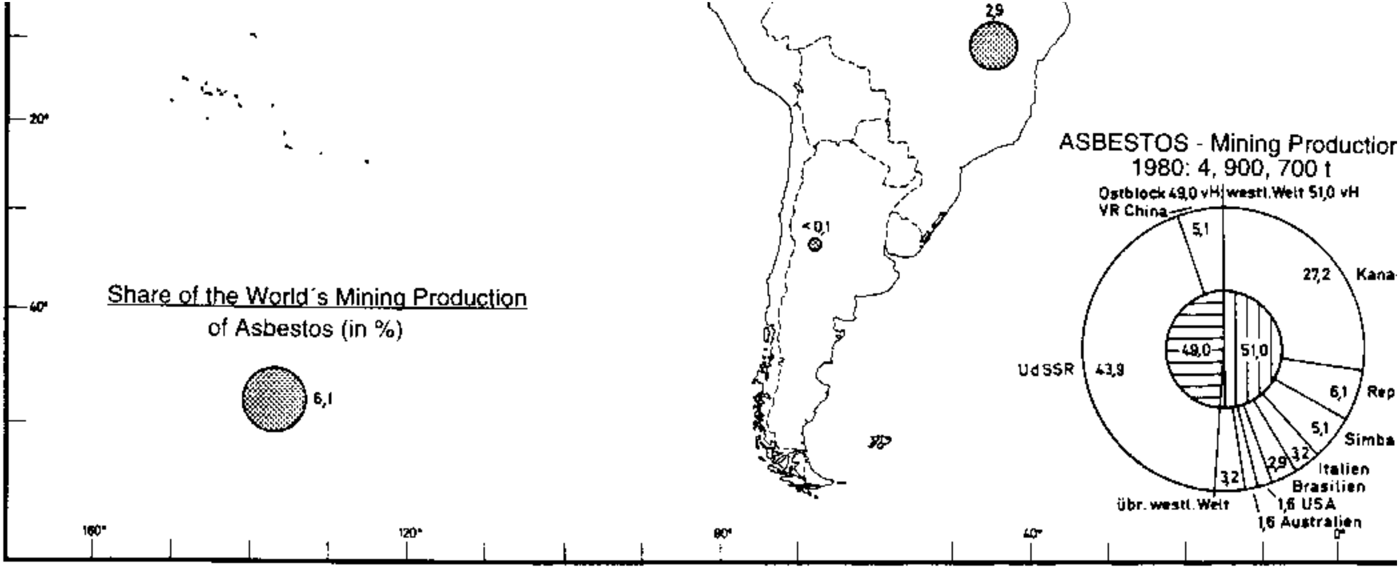
Annex 1: Maps on the deposits of Asbestos, Asbestos consumption and commercial trade of raw Asbestos



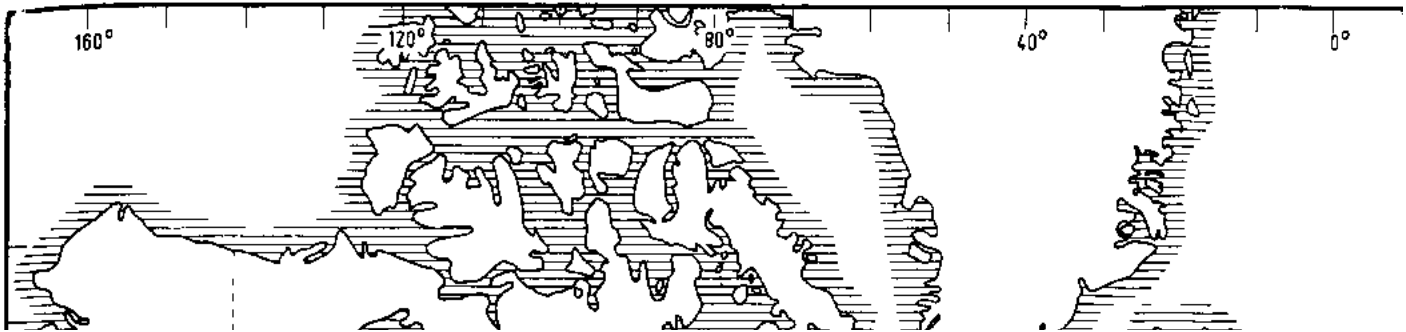


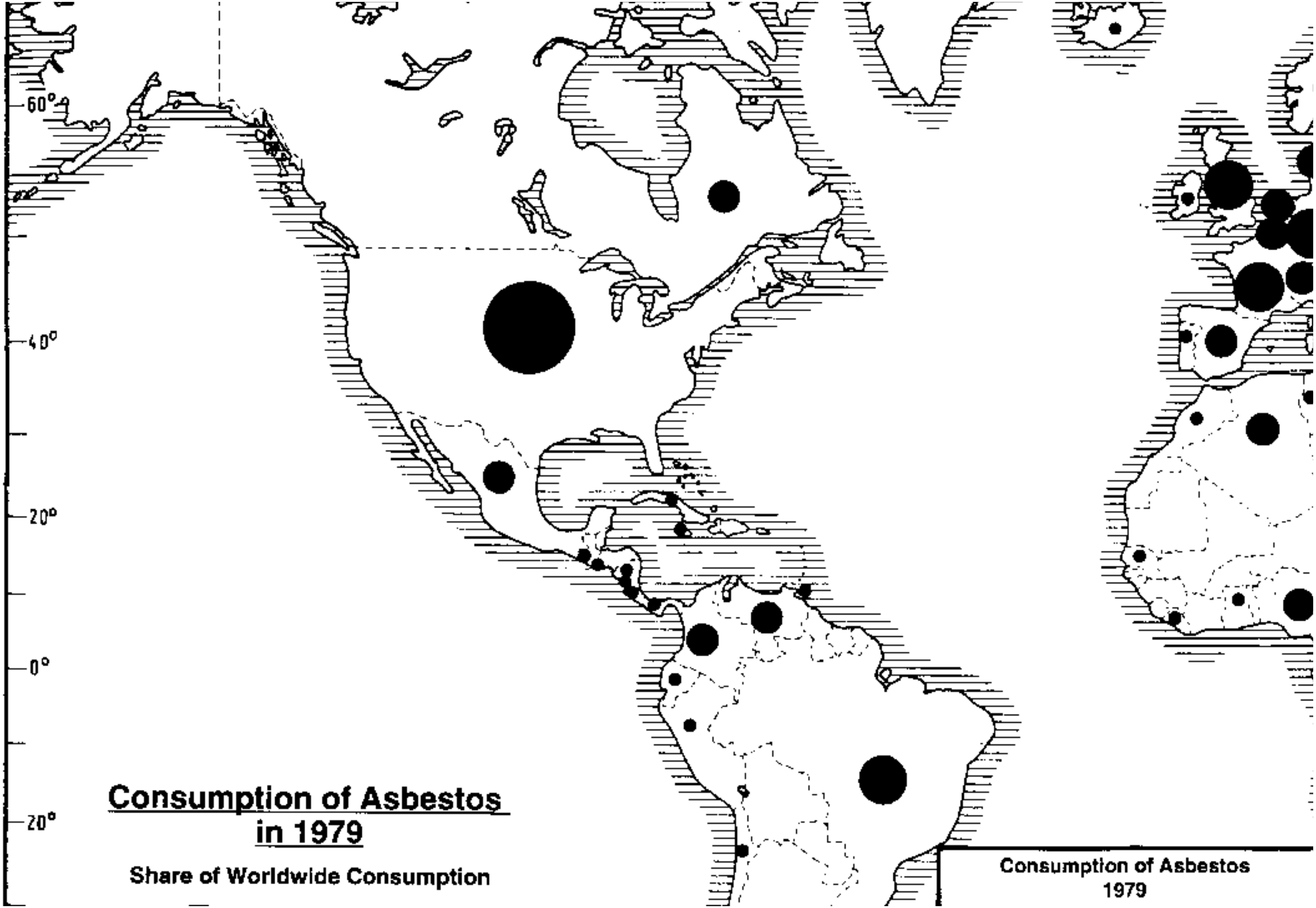
Map 1 (Asbestos - Deposits and Deposit Zones as well as Stock Piles 1981)


27,2
1,6
60°
40°
20°
0°



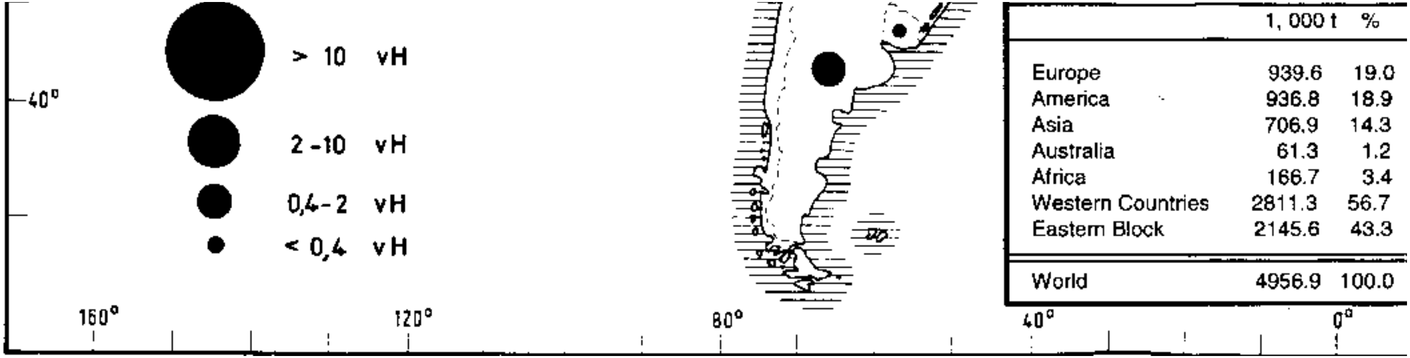
Map 2 (Asbestos - Mining: 1980; Stock Piles 1981)





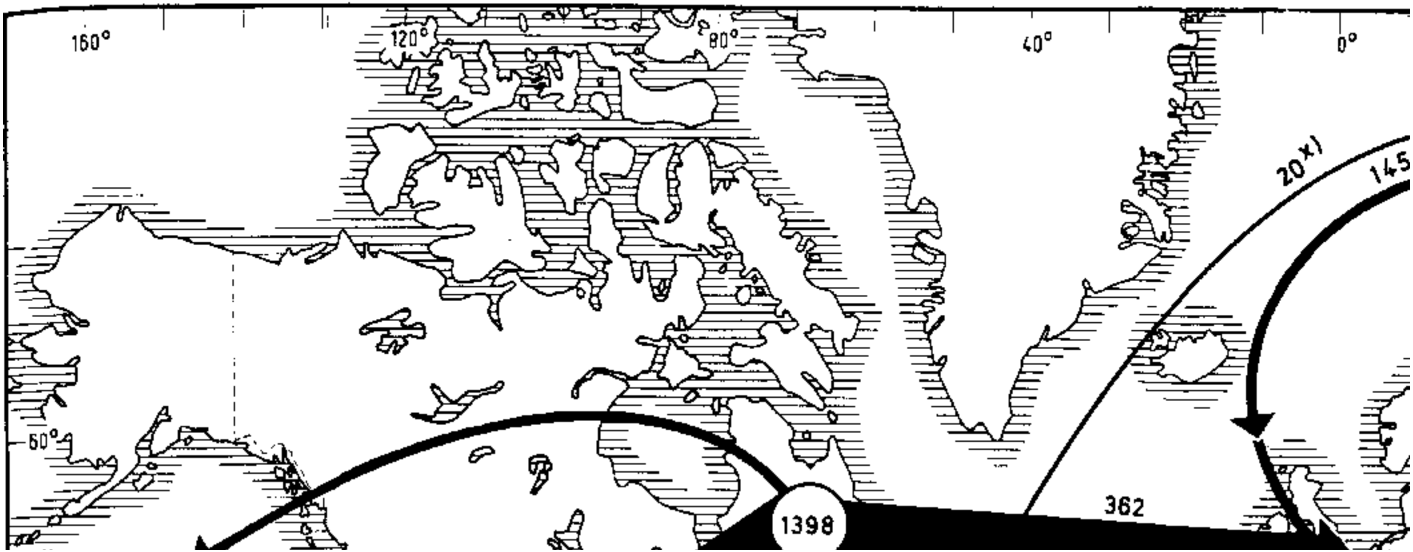
Consumption of Asbestos in 1979

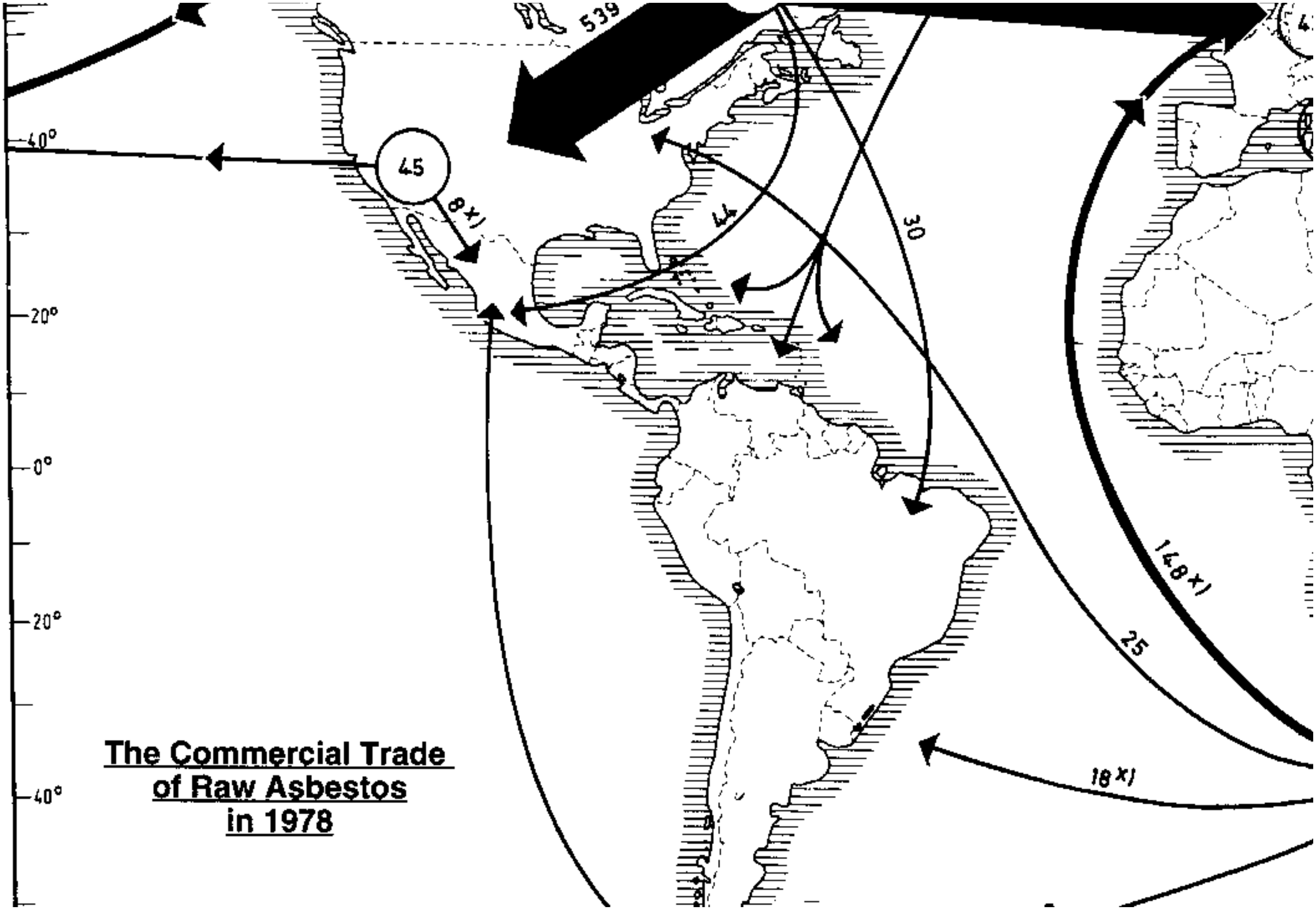
Share of Worldwide Consumption



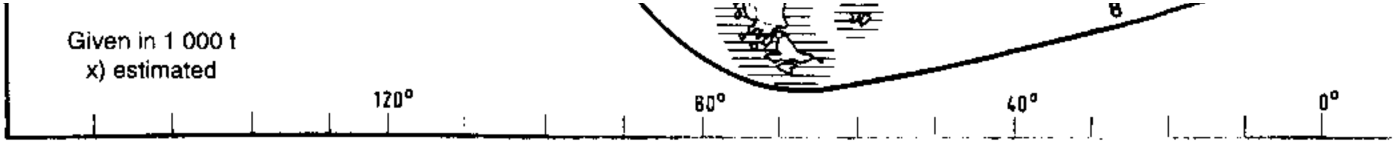
	1, 000 t	%
Europe	939.6	19.0
America	936.8	18.9
Asia	706.9	14.3
Australia	61.3	1.2
Africa	166.7	3.4
Western Countries	2811.3	56.7
Eastern Block	2145.6	43.3
World	4956.9	100.0

Map 3 (Consumption of Asbestos in 1979)





The Commercial Trade of Raw Asbestos in 1978



Map 4 (The Commercial Trade of Raw Asbestos in 1978)

Annex 2: Health and safety data sheet for Asbestos cement in UK

14 December 1994

Scope: This information is provided in compliance with the Health and Safety at Work Etc. Act 1974. Section 6 (as amended by the Consumer Protoction Act, 1987)

Manufacturer:

Product Names

'X' Asbestos Cement Corrugated Sheets for Roofing and Cladding of Industrial and Agricultural Buildings

'Y' Asbestos Cement Slates for Roofing and Vertical Cladding of Houses and other Buildings such as Schools, Hospitals, Offices etc.

Composition

Asbestos Cement corrugated sheets and slates are cement-based materials reinforced with chrysotile Asbestos (white) fibres. They contain approximately 10-12 % chrysotile Asbestos fibre and 88-90 % Portland Cement mixed with water.

Asbestos Cement corrugated sheeets are light grey in colour in their natural state, but

some sheets are painted with a coloured acrylic surface coating.

Slates have a carbon black pigmented base and an acrylic surface coating.

Physical Properties

Corrugated sheets have a density of 1500 kg/m³ and a bending strength of 4,400 N/m width, when tested at 1100 mm clear span. Asbestos Cement slates are fully compressed and have an average bending strength of 27 N/mm² at a density of 1950 kg/m³. Industrial pollution will cause a slight softening of the surface of natural Asbestos Cement sheets.

Asbestos Cement products are non combustible when tested in accordance with BS476: Part 4 but are not suitable for fire resisting applications and should not be exposed to direct flame.

Potential Health Hazards

Inhaling dust which contains Asbestos fibres can seriously damage health and should be avoided.

The diseasses which may arise from the inhalation of Asbestos dust are Asbestosis - a form of fibriosis of the lungs, Lung Cancer, and Mesothelioma - a cancer of the lining of the chest or abdominal cavities. Because of synergistic effect of tobacco and Asbestos, smoking greatly increases the risk of Lung Cancer in Asbestos workers.

Provided recommended working practices are followed when working with Asbestos cement any risk to health will be very small.

Legislation

The Control of Asbestos at Work Regulations (CAWR) 1987, as amended by The Control of

Asbestos at Work (Amendment) Regulations 1992 apply to everyone at risk from work with Asbestos and extend specific statutory protection to all those who encounter Asbestos at work or may be affected by work activities involving Asbestos.

In particular they place duties on employers to prevent or reduce to lowest level reasonably practicable the exposure of employees to Asbestos and the spread of Asbestos from the workplace.

The regulations set Control Limits and Action Levels for Asbestos. The Control Limits are the maximum concentrations of airborne Asbestos fibres averaged over any continuous 4 hours or 10 minute period, to which employees must not be exposed without appropriate protection.

The Control Limits for chrysotile Asbestos are 0.5 fibres/ml over 4 hours or 1.5 fibres/ml over 10 minutes. If after all reasonably practicable measures have been taken to prevent and/or reduce the level of exposure, it still reaches or exceeds the Control Limit, suitable personal protective equipment, (which includes respiratory protective equipment, protective clothing and footwear) must be provided.

The Action Level is expressed as the cumulative over any continuous period of 12 weeks. (It is the exposure in fibres/ml multiplied by the number of hours over which the exposure occurs expressed as fibre hours/ml. Those exposures are added together to give a total cumulative exposure).

The Action Level for chrysotile Asbestos is 96 fibre hours/ml.

If this Action Level is liable to be exceeded additional regulations in CAWR come into operation namely notification of work with Asbestos (Regulation 6), medical surveillance (Regulation 16) and designation of works areas (Regulation 14).

Guidance

Guidance on the Regulations is provided in the Approved Code of Practice on The Control of Asbestos at Work Regulations, as amended by The Control of Asbestos at Work (Amendment) Regulations 1992.

Further guidance is given in EH36 Work with Asbestos Cement and MS13 Asbestos.

Assessment

The first decision employers should make is whether it is reasonably practicable to avoid exposure to Asbestos altogether by using a substitute product.

If Asbestos cement must be used the employer should make an assessment of the likely exposure before starting work. The assessment should normally be in writing, unless the work is simple, on a small scale and exposures are low so that the assessment can be easily reported and explained. The assessment should cover the type of work and duration; the steps to be taken to prevent or reduce the exposure to employees to the lowest level reasonably practical; the release of Asbestos to the environment; the provision and use of protective equipment and its cleaning (if appropriate); the procedures for removal of waste and the procedures for dealing with emergencies.

Personal Protective Equipment

Approved Repiratory Protective Equipment (RPE) should be worn if the exposure is likely to exceed the Control Limit. All personal protective equipment provided, including RPE, should comply with the requirements of the Personal Protective Equipment (EC Directive) Regulations 1992, and bear the European Communities conformity mark 'CE'. Until the new legislation comes into effect, employers may continue to buy equipment which does not carry the 'CE' mark, and existing PPE can continue in use. In these cases, RPE must be of a

type approved by, or conform to a standard approved by HSE.

Workers should be trained how to use respirators. The equipment should be maintained in good working order, cleaned and disinfected after use and stored in a suitable locker or container.

Workers should be provided with Protective Clothing if a significant quantity of Asbestos is liable to be deposited on their clothes. Protective Clothing will not be required where dust levels are very low and exposures are brief and there is little risk of Asbestos sticking to clothing. This may include activities such as handling of new Asbestos cement, hand drilling of damp Asbestos cement sheets or scribing and breaking of slates which are unlikely to result in the deposit of a significant quantity of fibre. Industrial working clothes such as jackets and overalls may be regarded as suitable. At this level of contamination washing facilities can be shared with other workers.

As the amount of cutting, breakage and drilling increases there will be a point where a significant quantity of Asbestos is deposited on the clothing and Protective Clothing, which includes clothing and footwear, must be provided.

Protective Clothing contaminated with Asbestos should either be disposed of after use, as if it was Asbestos waste or sent to a laundry equipped with facilities capable of handling Asbestos contaminated clothing. This should never be taken home for cleaning.

Protective Clothing should be removed before leaving the working area, on all occasions including meal breaks, other breaks and completion of work.

Air Monitoring

Air monitoring should be carried out periodically to check the level of exposure, the effectiveness of controls and the adequacy of protective equipment, where exposure

exceeds or is liable to exceed the control limit.

This can be once a year provided that the results of the two preceding measurements have not exceeded half the control limit and there is no substantial change in the work methods and workplace conditions.

Where exposures are low and not likely to approach the control limit, monitoring may not be appropriate. Guidance on typical fibre levels for work with Asbestos cement products is contained in HSE Guidance Note EH35 'Probable Asbestos dust concentrations at construction processes'.

Precautions

Prevention of exposure is the first objective and Asbestos products should only be used where a less hazardous substitute is not reasonably practicable eg. where substitutes cannot meet a critical technical performance requirement of an application. If this is not possible, precautions should be taken to keep exposure as low as reasonably practicable and to ensure that workers are adequately protected.

Information, instruction and training should be provided so employees are aware of the risks and precautions.

Transport and Storage

Other than good haulage practice in securing the consignment, no special transport precautions need to be taken with Asbestos Cement products. Products should be appropriately labelied including specific saftey instructions. Sheets should be stored as near as possible to the area where they are to be used, and away from roadways and moving vehicles. They should be stacked horizontally on level, firm ground on timber bearers.

Handling and Use

Low levels of exposure will arise if the following precautions are taken:

Use exhaust ventilation equipment where reasonably practicable;

Keep the material wet wherever possible;

Carry out sawing and drilling out in the open air;

Use hand saws and low speed reciprocating saws for mitring and cutting of corrugated sheets. Use hand drills in a downward direction for drilling sheets and slates;

Scribe and break slates;

Keep the work areas clean and tidy, take care to prevent the spread of contamination and accumulation of waste materials and clean using a dustless method such as washing or by using vacuum cleaners suitable for Asbestos.

Substantial releases of dust will be created in excess of the Control Limit, if work is carried out with power tools such as cutting and grinding discs and high speed circular saws. These should not be used under any circumstances if exhaust ventilation has not been provided.

Special Precautions

Asbestos Cement sheets are fragile within the meaning of Regulation 36 of the Construction (working places) Regulations 1966, roof ladders and crawling boards must be used.

Waste Disposal

Asbestos Cement dust should be vacuumed at frequent intervals during working so there is no accumulation of dust. Only vacuum cleaning equipment fitted with high efficiency filters such as type H (BS 5415) vacuum cleaners are suitable for use with Asbestos. Where vacuuming is not possible, the dust should be dampened and collected while still damp and bagged in double plastic bags, sealed and labelled.

Small pieces of Asbestos cement waste should be placed in double plastic sacks which are tied or sealed. Larger pieces should be wrapped in plastic sheets and placed in a sealed container or securely sheeted skip. The containers should be labelled and removed by a registered waste carrier to a licensed waste manager.

Annex 3: Asbestos fiber emissions from particular processes

DUST CONCENTRATIONS

The figures below arc a guide lo the airborne fibre levels that may be expected close to the operator's breathing zone in a number of different processes. The following points should be borne in mind when using them.

(a) They are based on measurement taken by HSE. Different processes in different locations may result in higher or lower concentrations than those listed in the table;

(b) They are average concentrations for the time during which the process is actually taking place. To check whether a control limit or action level is exceeded a time-weighted average over the appropriate reference period must be calculated;

(c) Selection of a figure from the list is not itself an assessment. The person making the assessment must consider whether it is reasonably practicable to use methods that give a still lower value.

Process	Concentration	Process	Concentration

Process	**Concentration fibres/ml**	**Process**	**Concentration fibres/ml**
Asbestos Stripping Operations		**Asbestos insulation board and titles (normally amosite and chrysotile)**	
(a) De-lagging		(a) Sanding and surforming	
(i) dry stripping of crocidolite	100-1000		
(ii) dry stripping, except crocidolite	greater than 20	(b) Machine cueing without exhaust ventilation	
(iii) stripping with water sprays	540	(ii) circular saw greater than	20
(iv) controlled wet stripped		(iii) jig saw	5-20
(thorough soaking of insulation)	1-5	(with exhaust ventilation)	(1-5)
(c) Drilling overhead	5-10		
(b) Removal of insulation board and tiles		(d) Drilling vertical columns	2-5
(i) breaking and ripping out	5-20	(e) Hand sawing	5-10
(ii) unscrewing and careful removal with application of local exhaust ventilation less than	2	(f) Scribing and breaking	1-5
		(g) Rough handling of insulating board	15

		(g) Rough handling of insulating board and greater than removal of pieces	
		(h) Careful removal of whole boards	Up to 5
		Note: The dust levels are likely to be highest if amosite is present and the material is handled roughly. Bad handling practices may result in much higher concentrations.	
Asbestos cement sheets and pipes (normally chrysotile)		**Decorative Plasters**	
(a) Machine cutting without exhaust ventilation		Scraping painted plaster	0. 1-0.2
(i) abrasive disc cutting	15-25	Light hand sanding of unpainted areagreater than 0.3	
(ii) circular sew	10-20	Mixinggreater than	0.1
(iii) jig saw	2-10		
(b) Machine sawing without exhaust ventilation	below 2		
(c) Reciprocating saw	below 1		
(d) Hand sawing	below 1		
(e) Machine drilling	below 1		
(f) Removing of Asbestos-cement sheeting	below 0.5		
(g) Stacking of Asbestos-	below 0.5		

(g) Stacking of Asbestos-cement sheet after removal	below 0.5		
(h) Remote demolition of Asbestos-cement structures	below 1		
Caution: subsequent clearance may give rise	greater than 1)		
(i) Cleaning of Asbestos cement:			
	Roofing	Vertical cladding	
Dry brushing (wire)	3	5-8	
Wet brushing (wire)	1-3	1-2	
Water-jetting	0-0.5	1-2	

(Note: water jetting may produce debris and slurry which is difficult to control.)

Annex 4: US Federal Regulations for Asbestos

	Occupational Standards
OSHA	6/72 permanent standard: for occupational exposure of 5 f/cc. to be lowered to 2 f/cc in 1 976.
OSHA	10/75 proposed lowering standard to 0.5 f/cc.
OSHA	7/76 2 f/cc standard became effective
NIOSH	12/76 recommended OSHA lower the standard to 0.1 f/cc.
MSHA	3/76 2 f/cc standard in coal mines.

MSHA	11/78 2 f/cc standard in metal and nonmetallic mines (includes sand. gravel & crushed stone operations.)
OSHA	11/83 issued emergency temporary standard (ETSI of 0.5 f/cc.)
OSHA	11/83 ETS stayed pending legal arguments by Asbestos industry
OSHA	3/84 ETS overturned in Federal District Court.
OSHA	4/84 proposed lowering pesmissible exposure level lo either 0.5 or 0.2 f/cc. Air Emissions
EPA/NESHAP	3/71 Asbestos listed as a hazardous air pollutant.
EPA/NESHAP	4/73 "no visible emissions" standard for milling and manufacturing of Asbestos products and demolition of buildings-prohibited spray application for most uses of friable materials containing more than 1 % Asbestos.
EPA/NESHAP	10/75 waste collection and disposal Included under the no visible emissions standard, added several processing industries to those already covered: renovation operations regulated.
EPA/NESHAP	6/78 extended provisions to cover all uses of friable spray-on material and no visible emissions standard to cover ail friable Asbestos-containing materials during demolition and renovation, U.S. Supreme 1178 decision in the Adamo Wrecking Co. case Court ruled that EPA did not. prior to the 1977 Clean Air Act amendments, have the authority to impose work practice requirements, thus invalidating those pares of the NESHAP regulations which are not emissions standards.
EPA/NESHAP	7/83 proposed reinstatement of these provisions.
EPA/NESHAP	4/84 provisions reinstated by promulgating current standard, Asbestos In Schools
EPA	3/79 through the OTS. EPA initialed a technical assistance program to help schools identify and control friable Asbestos-containing materials.
EPA/TSCA	9/79 ANPR on Asbestos-containig materials in schools.

EPA/TSCA	9/80 proposed rule on identification and notification of friable Asbestos-containing materials In schools
U.S. Dept of	9/80 under the Asbestos School Hazard Education Detection and Control Act. proposed a rule to establish a gram and loan program to reimburse schools for detecting and controlling friable Asbestos-containing materials in schools.
U.S. Dept of	1/81 final rule-funds have not been education appropriated to conduct this program.
EPA/TSCA	5/82 final rule on identification and notification of friable Asbestos-containing materials in schools.
EPA/TSCA	2/83 granted a Section 21 petition from the Service Employees Intl Union to commence regulatory action on schools and buildings Asbestos abatement.
EPA/TSCA	2/83- granted a Section 21 petition from the 5/84 Service Employees Intl Union to commence regulatory action on schools and buildings Asbestos abatement.
EPA	8/84 under the Asbestos School Hazard Abatement Act of 1984. administers a loan and grant program to help schools eliminate Asbestos hazards. Commercial Use of Asbestos
CPSC	12/77 rules prohibiting use of Asbestos In consumer patching compounds and embertzing agents.
EPA/TSCA	10/79 ANPR with CPSC announcing intent to consider regulations of commercial uses of Asbestos
EPA/TSCA	12/79 ANPR modification.
EPA/TSCA	9/80 proposed rule under Section 8(a) to require reporting of production and exposure data on Asbestos.
EPA/TSCA	7/82 final rule under Section 8(a) to require reporting of production and exposure dale on Asbestos. Water Emissions
EPA/FWPCA	2/74 effluent guidelines for Asbestos manufacturing point sources and new source

	performance standards. Waste Disposal
EPA/RCRA	5/80 Asbestos listed as a hazardous waste in proposed rule.
EPA/RCRA	11/80 when Issuing interim final rules on portions of the disposal regulations. EPA staled it would "temporartly defer" promulgation of the listing of Asbestos while investigating the extent to which NESHAP facilities afford comparable protection. Other Actions
DOT	8/79 rule toe require controls during transportation of friable Asbestos.
FDA	3/75 rule to prevent release of Asbestos from fillers used for some drugs.
FDA	1/76 rule lo revoke permission to use the electrolytic diaphragm process for salt

Annex 5: Commercial names of Asbestos containing products

Aboglas
Accobest
Accobest AN-8012
Acoa
Aertite
AFD
Aircel
Aircell
Akoustikos Felt
Aland
Albaseal
Aluma-Seal
Alum-I-Flex
Amberlite
Amerbestos
American Colonial

Anti-Sweat
Apac
Apac Board
Applon C TFE
Applon T TFE
Armaturo Asbestos Tape
Armor Spray
Armor Temp
Armstrong LT Cork Coverings
Asbaltic
Asbestall
Asbestex
Asbestibel
Asbestile
Asbestite
Asbestoboard
Asbestocel
Asbestocite
Asbestogard

Asbestolux
Asbeston
Asbestone
Asbestone Standard 400
Asbestoroc
Asbestos Ebony

Asbestos-Ebony
Asbestos Fibrated
Asbestos Firetard
Jacket
Asbestos Grapevine
Finish Felt
Asbestos Liquid
Asbestos Lumiclad
Asbestos Millboard
Asbestos Sponge
Asbestos Sponge Felt
Asbestos Roll Fire
Felt
Asbestrolan
Ascarite
Atlas
Aubeston
BB
BBA
Bellowseal
Best Felt
Bes-Tos
Bestolite
Bestophalt
Beswick
Black Top Asbestos
Jacket
Blastape

Calidria Asbestos
Cal Temp
Caposite
Carbac
Carey
Careybesto-Bord
Careycel
Careyclad
Carey Duct
Careyflex
Careysote
Careystone
Careytemp
Cedargrain
Cellamite
Cell-O-Tone
Cemesto
Cemesto Structural Insulating Panels
Centripac
Century
Century Apac
Certain-teed
Chemlon
Chempac
Chemstone
Chemtite
Chesterton Sixty Four
Chesterton 1000

Chroma Tex
Chroma-Tone
Chrom-Tex
Cleangard
Cogasa
Cohrlastic
Colonial Stone

Colorator
Colorbestos
Color Ground
Colorlith
Color-Tex

Contico
Copperclad
Coronet
Covergard
Crystal White
Cutno
CW
Deltabeston
Designer Solids
Dominique
Doublex
Double Sanded
Asbestos
Dualay
Duplex

Dura-Color
Duraform
Dura Shake
Durocell
Du Shield
Ebonized Asbestos
Electrobestos
Enduro
Etemit
Etemit Stonewall
Excelon

Facespan
Featherweight
Felbestos
Fl-ACS
Fiberock

Fiberock Asbestos
Felt
Fiber Shake
Fiberspray Asbestos
Fibra Flo
Fibre Coating
Asbestos
Fibre Kote
Fibrocel
Fibro-Cell
Fibrofil

Fibro-Fill
Fibroid
Fibroid Stove Putty
Fil-lnsul
Filpaco
Fire Chex
Fire-Chex
Fireclad
Fire Felt
Firegard
Fireguard Jacketing
Fire Halt
Firetard
Flamemaster
Flamegard
Flamesafe
Flexachrome
Flexboard
Flexgold
Flex-Slate
Flexstone
Flintite
Fluorobestos
FMC
F.O.P.
Form Pack 2

Foster
Frost Proof

GAF
Gardwell
Gardwell Products
Glatex
Goetze Metallic
Gaskets
Gold Bond
Grafil
Gralam
Grizzly
G.T. Ring
Guardian Line
Gum-Bestos
Herco
Hi Seal
Hoodex-22
Hopaco
Homeblende
Hy Temp
Imperial
Imperial Excelon
Imperial Pipe
Covering
Industrial
Industro-Tile
Insulation Seal 820
Insulcolor
Isobestos
Janobestos

Janos

Jewett
JM or Johns-Manville
Kaobestos
Kaylo
Kearsarge

K-Fac
Klingerit
K & M Aircell
Kornmetal
K Therm

Lasco
Linabestos
LK
LO-CA
Lok-Tab
Marinite
Mastic
Maticove
McKim
Microbestos
Mightyplate
Mimco
Minkote
Modernaire
Monobestos

Monoblock
Montasite
Multi-Ply
Mundct
New Era

Niagrite
Nicolet
Non -Con - Du x
Noriscell
Novabestos
Nu Grain
Nu Side
Nu Way
Ohmstone
ONC

One Cote Cement
Pabco
Paknmetal
Pal-lite
Palmetto
Palmetto Cutno
Palmetto Super Sheat
Pamco
Panelstone
Permaboard
Permatherm
Permatone

Piedra
Plastic
Plastibest
Pliaboard
PlastiClad
Plasticrylic
Plia-F-Lex
Pluto
Portugese Asbestos
Powminco
Prasco High Temperature
Prenite
Prismatic
Profile
Pyrotex Felt
Q-Beston
Quinorgo
Quinterra
Ranch Style
Red Mastite
Rendezvous
Resistal
Ring-Tite

Ripple Tone
R-M or Raybestos Manhattan
RM 7504

R/M 24 H120
R/M E-66

Roca
Rock Slate
Romanaire
Rondelle
Rubber Coat
3 R
Salamander
Salon
Sal-Mo
Scandiva
Sea Ring Packing
Selko-Flo
Service Sheet Packing
& Cut Gaskets
Shasta Snow
Sheetflextos
Shingle Seal
Simco
Sindanyo
Soundgard
Spintex
Spiroflex
Spirotallic
Splashgard
Spray-Cote
Spray Craft

Sprayed,,Limpet"
Asbestos
Sta Safe Long Life
Sterlbestos
Stik-On
Stone Chip

Stoneglow
Stonewall
Stratate
Stri-Color
Strip-N-La
Summit
Supcrbestos
Super Cutno
Superheat
Super X
Super 66
Supradur
Sure-Stik
Tadpole
Target
Tempcheck
Terraflex
Terratex
Thermal Kote
Therrnalon
Thermatite
Thermobestos

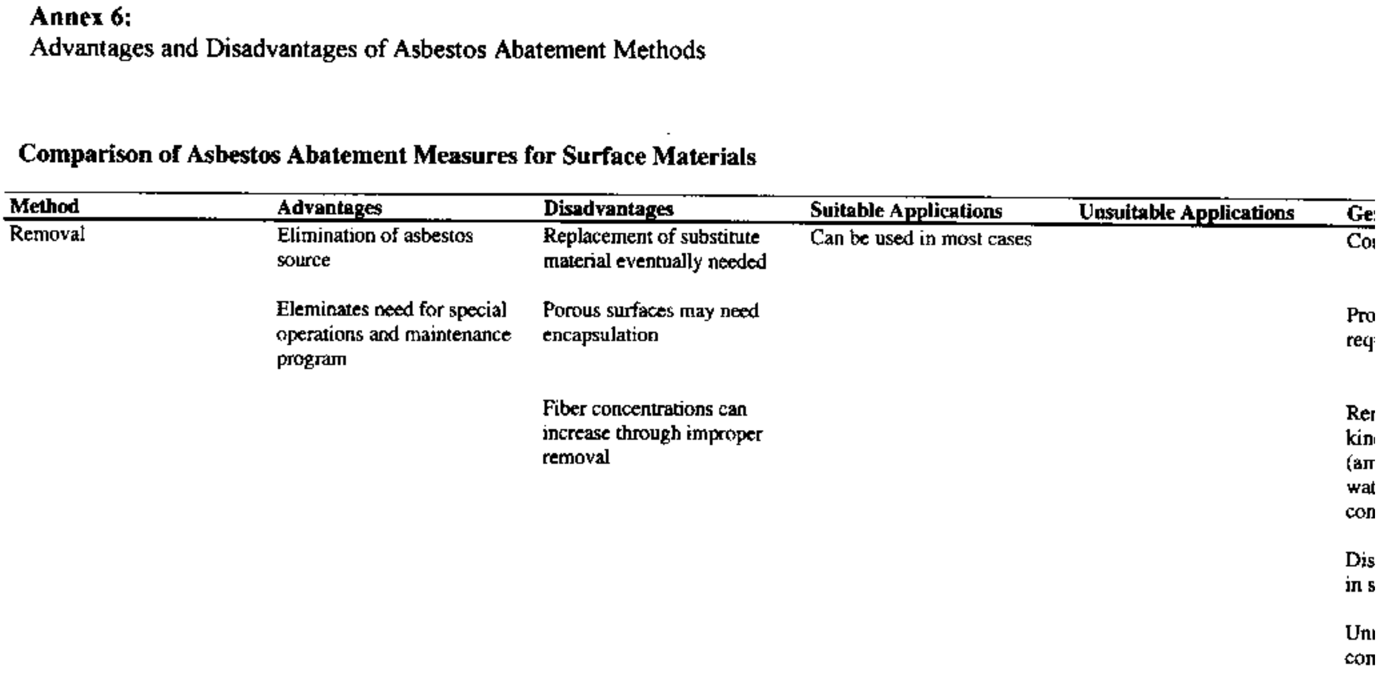
Thcrrno-Bord
Thermofelt
Therm-O-F1akc
Thcrrnoflex
Therrnomat
Thermo-Pac
Therrnostone
Thermo-Tape

Thermotex B
Thermo-Wrap
ThnDt-T
Thru Chip
Tile-Tex
Tilostone TK 33
Transhield
Transite
Transite-Korduct
Transitop
Tru Flame
Tropag
U F P
Ultra-Fine
Unibestos
Unibestos 750
Unibestos 1200
Uni Syn
Uni Syn Style No. 239
V Dent

Ventsulation
Victopac
Vitribestos
Vitrobestos
Vulca-Dek
Weldgard
White Top Asbestos Jacket
White Tope
Whittaker
Wirepak
Woodflex
York Asbestos
Zerogloss
Zeroseal
Zetabond
Zip Stik
0-0-7-9
0-0-10-6
No. 60 Service Sheet
99 Finishing Cement
No. 100 Kearsarge Sheet
No. 101 Mobilene Sheet
Grade 115 Cement
No. 1 16 Kearsarge Gaskets
No. 1 18 Kearsarge

Gaskets
Grade 214 Cement
No. 302 Insulation
Cement
303 Asbestos Cement
707 Asbestos Cement

Annex 6: Advantages and disadvantages of Asbestos abatement methods

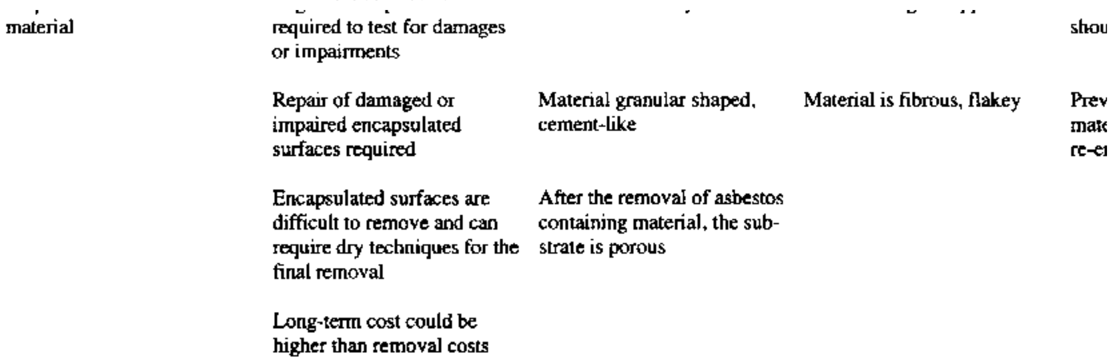


Annex 6:
Advantages and Disadvantages of Asbestos Abatement Methods

Comparison of Asbestos Abatement Measures for Surface Materials

Method	Advantages	Disadvantages	Suitable Applications	Unsuitable Applications	Ge
Removal	Elimination of asbestos source	Replacement of substitute material eventually needed	Can be used in most cases		Co
	Eleminates need for special operations and maintenance program	Porous surfaces may need encapsulation			Pro req
		Fiber concentrations can increase through improper removal			Rer kin (am wat con
					Dis in s
					Un con

					wi spe
Enclosure	Reduces exposure in areas outside enclosure	Asbestos source remains and must be removed later	Asbestos containing materials exist in small areas (e.g. a pillar)	Damaged or impaired materials cause rapid fiber emissions	Co
	Initial costs could be less than removal unless utilities need relocating or major changes	Fiber emissions continue behind enclosure	Damage or entry into enclosed area is unlikely	Water damage evident	Rec wit equ filt adv
	Normally does not require the substitution of materials	Special operations program required to supervise access to enclosure for maintenance & renovations		Damage or entry into closure likely	Wo
		Repeated periodic inspections required to test for impairments		Ceiling to be enclosed is low	
		Repairs required of damaged enclosure			
		Fiber emissions in dry form during the installation of the enclosure			
		Long-term costs are often higher than those of removal			
Encapsulation	Reduces asbestos fiber emissions from the material	Asbestos sources remain and must be removed later	Material has sufficient bonding strength	Material does not adhere well to sub-surfaces	Con
	Initial costs may be less than removal	If material in poor condition, sealing compound can lead to detachment of material layers	Damage of the material unlikely	Material is impaired or damaged, or likely damaged	Prot nece
	Requires no substitute	Regular reinspections	Material not easily accessible	Water damage is apparent	Air-



material	required to test for damages or impairments			shou
	Repair of damaged or impaired encapsulated surfaces required	Material granular shaped, cement-like	Material is fibrous, flakey	Prev mate re-e
	Encapsulated surfaces are difficult to remove and can require dry techniques for the final removal	After the removal of asbestos containing material, the substrate is porous		
	Long-term cost could be higher than removal costs			

Source: EPA: Guidance for Controlling Asbestos Containing Materials in Buildings, Edition 1985, Pg. 58 & 59.

Annex6

Annex 7: Asbestos data from the environmental handbook Vol. III: Compendium of environmental standards

ASBESTOS

DESIGNATIONS

CAS No.:	1332-21-4
Registry name:	Asbestos
Chemical name:	Asbestos

Synonyms, Trade names:	Serpentine Asbestos, amphibole Asbestos, fibre Asbestos, blue Asbestos
Chemical name (German):	Asbest
Chemical name (French):	Amiante
Appearance:	fibrous, impure minerals whose colour varies between pure white and green, brown or grey depending on the iron-oxide content; crocidolite is blue (blue Asbestos); the fibres are between 20 and 25 nm long; Asbestos fibres are smooth and greasy to the touch.

BASIC CHEMICAL AND PHYSICAL DATA

Asbestos is not a chemical element, but rather an umbrella term for two groups of minera (serpentine and amphibole Asbestos)

	Serpentine	**Amphibole**				
	Chrysotile	**Crocidolite**	**Amosite**	**Anthophyllite**	**Tremolite**	**Actinolite**
Empirical	Mg_3	$Na_2Fe_2(Fe,Mg)_3$	$(Fe,Mg)_7$	Mg_7	Ca_2Mg_5	$Ca_2(Mg,Fe)_5$
formula:	$Si_2O_5(OH)_4$	Si_8O_{22} $(OH)_2$	$Si_8O_{22}(OH)_2$	$Si_8O_{22}(OH)_2$	$Si_8O_{22}(OH)_2$	$Si_8O_{22}(OH)_2$
Rel						
molecul.	277.13g	1,008.82g	1,171.83 g	780.88 g	812.42 g	1,091.67 g
Density:	2.2-2.6	2.8-3.6 g/cm³	2.9-3.3	2.8-3.2 g/cm³	2.9-3.2	3.0-3.21

	g/cm³		g/cm³		g/cm³	g/cm³
Melting point:	1,500°C	1,200°C	1,400°C	1,450°C	1,31 5°C	1,400°C

Flash point Asbestos is non-combustible, resistant to heat and features a lo conductivity in water: insoluble

ORIGIN AND USE

Usage:
Because of its heat-resistance and suppleness and its capacity for being incorporated into inorganic and organic binders, Asbestos is used in industry for thermal insulation, fireproofing and sealing in addition to acting as a filler in the production of countless composites (more than 3000). Economic exploitation is centred on chrysotile Asbestos from the serpentine group (95 %). 5 % of amphibole Asbestos is used for Asbestos-fibre production.

Spun Asbestos is used for fireproof, chemical-resistant clothing. When mixed with cement, Asbestos is cast to form panels and pipes (70 - 90 % of the world production is used in the construction industry in Western Europe; ace. WHO, 1987). Asbestos has also been used as a filter material in the drinks and pharmaceutical industry and for the manufacture of brake and clutch linings for motor vehicles.

Origin/derivation:
Asbestos is extremely widespread in nature. The most important deposits are to be found in the former Soviet Union, Canada and South Africa. Natural emissions are produced for example by the weathering of serpentine rocks.

Production figures:

Worldwide production in 1983 was in excess of 4 million tons (WHO, 1987). The main producers are as follows (WHO, 1986):

USSR	1983:	2,250,000 t/a
Canada	1983:	820,000 t/a
South Africa	1983:	221,111 t/a
Brazil	1983:	158,855 t/a
Zimbabwe	1983:	153,221 t/a
Italy	1983:	139,054 t/a
China	1983:	110,000 t/a

TOXICITY

Humans:	TCLo 2.8 fibres/cm³/5 years	acc.UBA, 1986
	TCLo 1.2 fibres/cm³/19 years without interruption	ace. UBA, 1986
Mammals:		
Rat	TDLo 100 mg/kg, intrapleural	ace. UBA, 1986

As yet there are no known characteristic toxicology data (DVGW, 1988).

CHARACTERISTIC EFFECTS:

HUMANS/MAMMALS:

Various Asbestos-induced illnesses are known from the industrial medicine sector in which the size of the fibres plays a crucial role. Generally speaking, fibres with a diameter of less than 2 ym and a length of more than 5 ym are considered to be hazardous to health

(diameter: length = 1: 3). Such a fibre size is capable of entering the lungs, gathering there and becoming encapsulated. Fibres have also been found to have a certain migration capability in the organism and the cell metabolism. Accumulation in the lungs causes sclerosis of the pulmonary alveoli and thus impairs the oxygen exchange. The inhalation of large quantities of fibre can cause asbes otosis which increases the risk of bronchial cancer. In particular, dusts < 200 ym are highly toxic and suspected of being a direct cause of tumours. Exposure to Asbestos irritates the eyes and the respiratory tract. Direct penetration into damaged skin produces excessive horrification. Fibres in the lungs bring about chronic bronchitis, irritation of the pleura and pleurisy. l:)istension of the lungs can result in lung cancer. Workplace exposure may produce periods of latency in the gastro-intestinal tract lasting up to 40 years.

ENVIRONMENTAL BEHAVIOUR

Water:
Asbestos fibres cause water to become turbid, but are not soluble in water.

Air:
The dwell time in the atmosphere is dependent on the fibre size. Asbestos fibres can be transported over hundreds of kilometres in the atmosphere. Weathering produces short and thin Asbestos fibres from the coarse dust.

Soil:
If Asbestos fibres get into the soil, they accumulate on the surface and may be scattered again at any time. Particles in excess of 2 ym are not washed into the soil pores. In the soil itself and in sediments, Asbestos is considered to be harmless (DVGW, 1988). Asbestos dusts in refuse or on dumps must be covered or moistened during transportation to stop them ingressing into the air. Soils and sediments in general are considered as accumulation sites.

Half-life:
The half-life of fibres on mucous membranes is a matter of minutes - hours or days years after penetration into the tissue (HORN, 1989).

Food chain:
Asbestos fibres penetrate into organisms via drinking water. The pollution of drinking water is caused by fibres in Asbestos-cement pipes. The impact is a function of the calcium-carbonate saturation of the water and depends on the number of iron-oxide deposits in the pipes. There is as yet no proof of oral Asbestos intake causing cancer.

ENVIRONMENTAL STANDARDS

Medium/ acceptor	Sector	Country/ organ.	Status	Value	Cat.	Remarks	Source
Air:	Workp	A	L	250,000f/m^3		chrysotile [1991]	acc. Albracht, 1991
	Workp	B	L	150,000 f/m^3		crocidolite [1987]	acc. Albracht, 1991
	Workp	B	L	1,000,000 f/m^3		other Asbestos [1987]	acc. Albracht, 1991
	Workp	CH	L	1,000,000 f/m^3		dusts [1988]	acc. Albracht, 1991
	Workp	DK	L	300,000 f/m^3		crocidolite, celling value (15min) [1988]	acc. Albracht, 1991
	Workp	DK	L	300,000 f/m^3		other Asbestos [1988]	acc. Albracht, 1991
	Workp	F	L	500,000 f/m^3		crocidolite [1987]	acc. Albracht,

	Workp	F	L	1,000,000 f/m³		other Asbestos [1987]	acc. Albracht, 1991
	Workp	D	L	250,000 f/m³	TRK	chrysotile [1990]	acc. Albracht, 1991
	Workp	D	G	50,000 f/m³	TRK	crocidolite, remediation [1990]	acc. Albracht, 1991
	Workp	GB	L	200,000 f/m³		crocidolite, 4h [1984]	acc. Albracht, 1991
	Workp	GB	L	500,000f/m³		other Asbestos, 4h, [1984]	acc. Albracht, 1991
	Workp	DDR	L	1,000,000flm³		dusts [1983]	acc, Albracht, 1991
	Workp	DDR	L	2,000,000 f/m³		short time value(30 min) [1983]	acc. Albracht, 1991
	Workp	GR	L	500,000 f/m³		crocidolite [1988]	acc. Albracht, 1991
	Workp	GR	L	1,000,000 f/m³		other Asbestos [1988]	acc. Albracht, 1991
	Workp	IRL	L	500,000 f/m³		crocidolite [1989]	acc. Albracht, 1991
	Workp	IRL	L	1,000,000 f/m³		other Asbestos [1989]	acc. Albracht, 1991
	Workp	NL	L	200,000 f/m³		crocidolite, ceiling valu (10 min) 11989]	acc. Albracht, 1991
	Workp	N L	L	2,000,000		Other Asbestos, 4h	acc. Albracht,

				f/m³		119891	1991
	Workp	S	L	200,000 f/m³		Asbestos (except chrysotile) 119871	acc. Albracht, 1991
	Workp	USA	L	200,000f/m³		Asbestosl1986]	acc. Albracht, 1991
	Workp	USA	G	200,000 f/m³		amosite	AMIH, 1988
	Workp	USA	G	500,000 f/m³		crocidolite	ACGIH, 1988
	Workp	USA	G	2,000,000 f/m³		chrydile,other Asbestos	ACGIH, 1988
	Air	F	(L)	0.1 mg/m³		Emission (dust)	acc.MEEKetal, 1985
	Air	D	L	0.1 mg/m³		TA-L fine dust, mass flow 2 0.5g/h	acc.DVGW, 1988
	Air	DDR	L	0.005 mg/m³	MlK_k		ace. HORN, 1989
Foodstiff:	Drinkw	USA	L	7,100,000 UI		Average and long fibre	acc.wGW, 1988

Note:
There is virtually a complete ban in Denmark on materials containing Asbestos for production, import and utilization. Norway, Sweden and Holland control the Asbestos content of insulating materials and consumer goods in supplementary legislation.

COMPARISON/REFERENCE VALUES

Medium/origin	Country	Value	Source
Surface water:			

Northem Lake Constance (1981)	D	< 5 fibres/l x 10^3	acc. DVGW, 1988
Southern Lake Constance (1981)	D	10-20 fibres/l x 10^3	acc. DVGW, 1988
FranconianForest(1981)	D	10-50 fibres/l x10^3	acc. DVGW, 1988
Bavarian Forest (1981)	D	< 5-30 fibres/l x 10^3	acc. DVGW, 1988
Groundwater:			
Northern Germany (1981)	D	4-100 fibres/l x 10^3	acc. DVGW, 1988
Franconian Forest (1981)	D	< 5-60 fibres/l x 10^3	acc. DVGW, 1988
Drinking water:			
10 utility companies (1981)	D	5-1000 fibres/l x 10^3	acc. DVGW, 1988
Montreal(1971)	CDN	2,000-9,500 fibres/l x 10^3	acc. DVGW, 1988
Toronto (1974)	C D N	700-4,100 fibres/l x 10^3	acc. DVGW, 1988
Duluth(1974)	USA	20,000-75,000 fibres/l x 10^3	acc. DVGW, 1988
Chicago(1977)	USA	80-2,300 fibres/l x 10^3	acc. DVGW, 1988

ASSESSMENT/COMMENTS

Asbestos fibres are released into the environment by natural and anthropogenic processes. The liberation of Asbestos during the manufacture and processing of materials containing Asbestos must be significantly reduced especially in confined areas and at workplaces because of the great hazard to the respiratory organs and in particular the lungs. There is increasing speculation that the oral intake of Asbestos can cause tumours. Therefore, there is no justification for the further use of Asbestos cement in drinking

water pipes. Numerous products containing substitute materials are now making it possible to dispense with the use of substances containing Asbestos.

Annex 8: Questionnaire on country profiles regarding Asbestos

Environmental Resources Management

Asbestos

Country Profiles

Mining of Asbestos,
Manufacturing, (Production)
Use and Remediation of ACM
(Asbestos Containing Materials)

Legislation
Research and Development
Substitutes and
Risk Evaluation

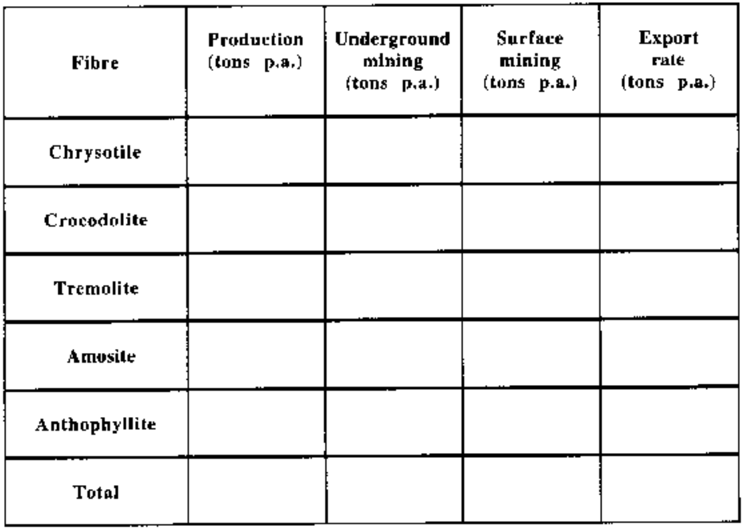
INTRODUCTION

Thank you very much for assisting in our approach of performing a world wide study concerning ASBESTOS. As an introduction we would like to give you some information regarding this questionnaire:

This questionnaire is divided into several chapters such as mining, manufacturing or production, use of and remediation of Asbestos containing products. We are also very interested in the way the legislation, research and the development and risk evaluation in

terms of Asbestos is practiced in your country, and if there are substitutes used in place of Asbestos.

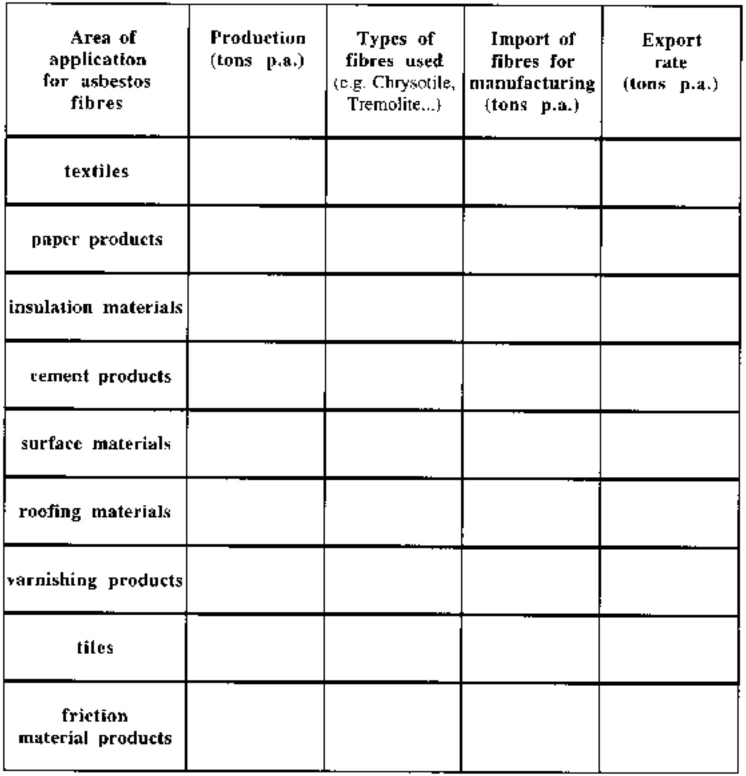
MINING:
stands for digging Asbestos fibres from natural deposits of Asbestos minerals in the earth.



Fibre	Production (tons p.a.)	Underground mining (tons p.a.)	Surface mining (tons p.a.)	Export rate (tons p.a.)
Chrysotile				
Crocodolite				
Tremolite				
Amosite				
Anthophyllite				
Total				

Questionnaire about Asbestos mining

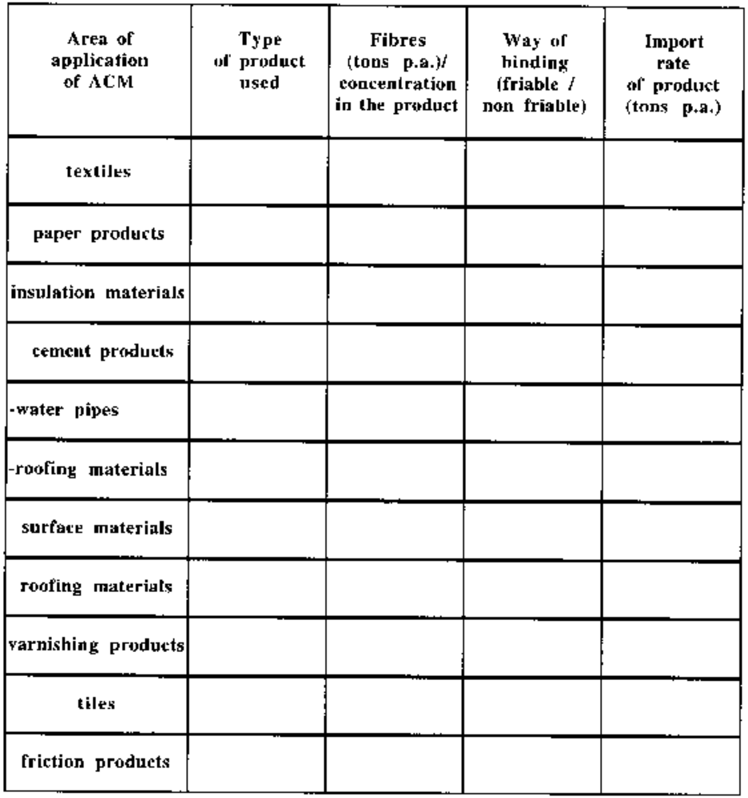
MANUFACTURING:
stands for processing the Asbestos fibres into a finished products like textiles, insulation materials, paper products, cement products, surface materials, roofing materials, varnishing products, tiles, friction products



Area of application for asbestos fibres	Production (tons p.a.)	Types of fibres used (e.g. Chrysotile, Tremolite...)	Import of fibres for manufacturing (tons p.a.)	Export rate (tons p.a.)
textiles				
paper products				
insulation materials				
cement products				
surface materials				
roofing materials				
varnishing products				
tiles				
friction material products				

Questionnaire about Asbestos processing

USE:
stands for the applying Asbestos containing materials (ACM).



Area of application of ACM	Type of product used	Fibres (tons p.a.)/ concentration in the product	Way of binding (friable / non friable)	Import rate of product (tons p.a.)
textiles				
paper products				
insulation materials				
cement products				
-water pipes				
-roofing materials				
surface materials				
roofing materials				
varnishing products				
tiles				
friction products				

Questionnaire about Asbestos use

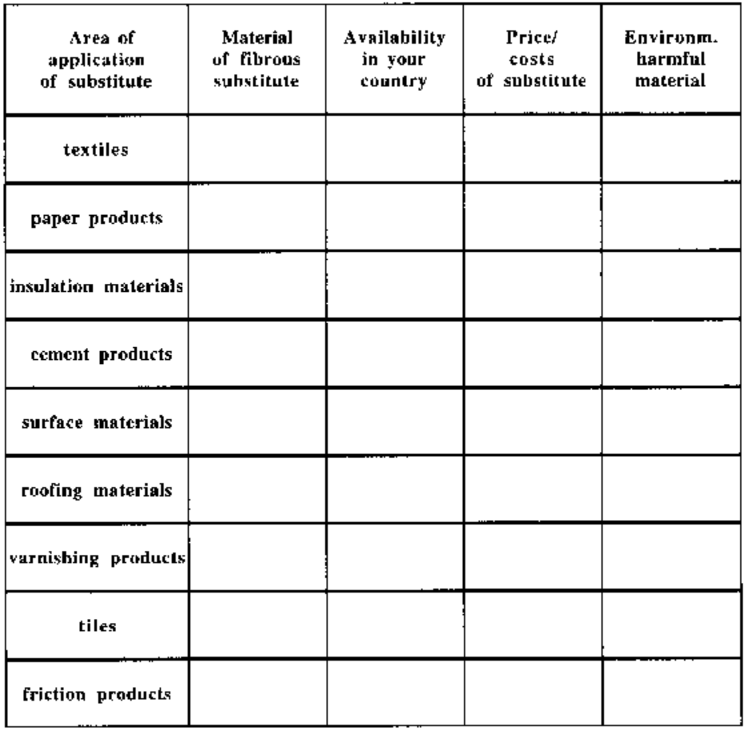
REMEDIATION:
stands for removing or treating used Asbestos containing materials.

LEGISLATION:
stands for the existing laws concerning Asbestos made by a legislative body.

RESEARCH AND DEVELOPMENT: stands for scientific investigation or inquiries concerning Asbestos.

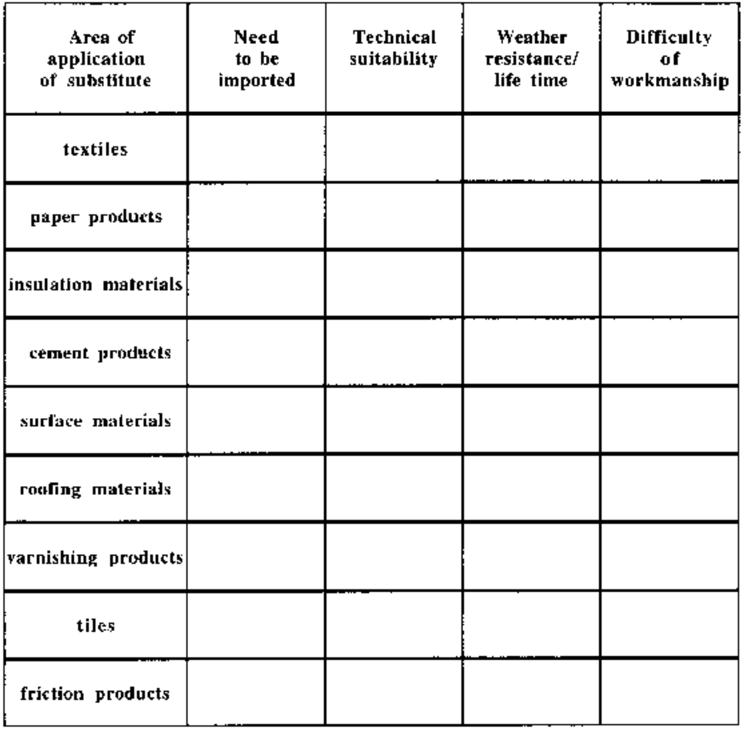
RISK EVALUATION:
stands for judging the risk to human health posed by Asbestos.

SUBSTITUTES:
stands for the use of adequate materials which have the same qualities as Asbestos.



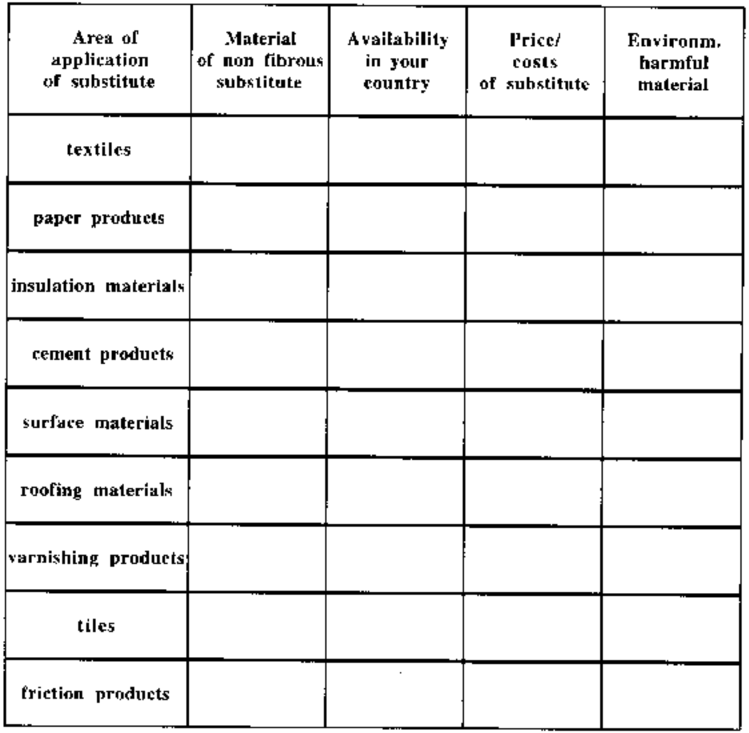
Area of application of substitute	Material of fibrous substitute	Availability in your country	Price/ costs of substitute	Environm. harmful material
textiles				
paper products				
insulation materials				
cement products				
surface materials				
roofing materials				
varnishing products				
tiles				
friction products				

Questionnaire 1 about Asbestos substitutes



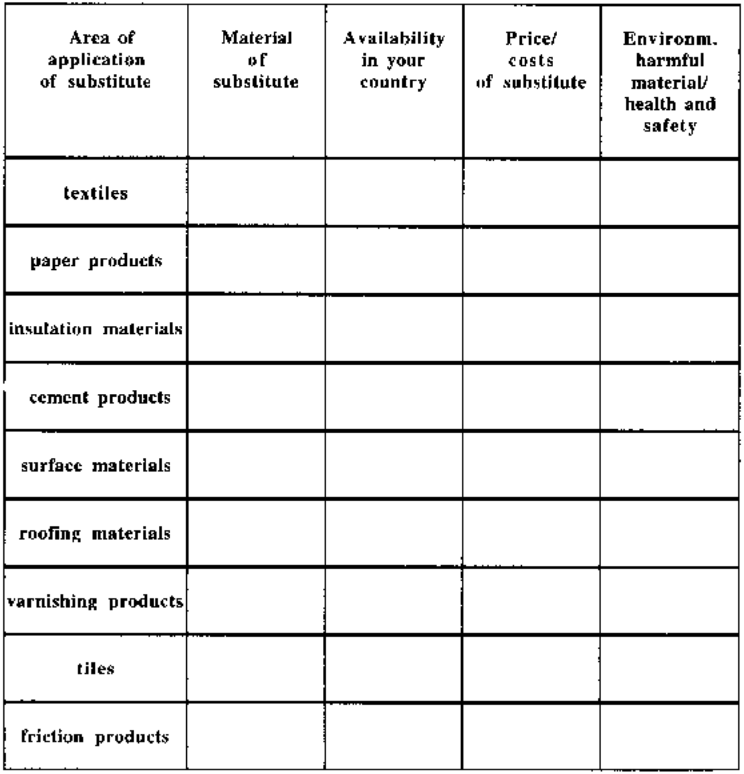
Area of application of substitute	Need to be imported	Technical suitability	Weather resistance/ life time	Difficulty of workmanship
textiles				
paper products				
insulation materials				
cement products				
surface materials				
roofing materials				
varnishing products				
tiles				
friction products				

Questionnaire 2 about Asbestos substitutes



Area of application of substitute	Material of non fibrous substitute	Availability in your country	Price/ costs of substitute	Environm. harmful material
textiles				
paper products				
insulation materials				
cement products				
surface materials				
roofing materials				
varnishing products				
tiles				
friction products				

Questionnaire 3 about Asbestos substitutes



Area of application of substitute	Material of substitute	Availability in your country	Price/ costs of substitute	Environm. harmful material/ health and safety
textiles				
paper products				
insulation materials				
cement products				
surface materials				
roofing materials				
varnishing products				
tiles				
friction products				

Questionnaire 4 about Asbestos substitutes

We hope you could understand all our questions and are able to complete the questionnaire. In case of problems, please contact us to ensure that there will be no information missing due to misunderstandings.

Thank you very much in advance for your support.

28 November 1992
ERM Umwelt Consult

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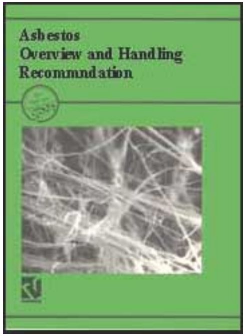

Acknowledgments

Kreditonstalt fr Wiederaufbau

Kreditanstalt fr Wiederaufbau (KfW) was founded by law in 1948 as a corporation under public law domiciled in Frankfurt am Main. Its function is that of a promotional bank for the domestic economy and a development bank for the economies of the developing

countries. Its capital is DM I billion, of which 80% is held by the Federal Government and 20% by the governments of the Federal Lander. Under the Financial Cooperation of the German Federal Government with developing countries KfW finances investments and project-related consultancy service to develop economic and social infrastructure, private sector investment and, to a growing proportion, projects to protect the environment and natural resources. KfW appraises the eligibility of projects for promotion in regard to developmental aspects, assists the partner countries in implementing them, and conducts a final evaluation of their success.

Deutsche Gesellschaft fr Technische Zusammenarbeit (GTZ) GmbH

The government-owned GTZ operates in the field of technical cooperation. 2200 German experts are working together with partners from about 100 countries of Africa, Asia and Latin America in projects covering practically every sector of agriculture, forestry, economic development, social services and institutional and material infrastructure. The GTZ is commissioned to do this work both by the Government of the Federal Republic of Germany and by other government and semi-government authorities.

GATE

GATE (German Appropriate Technology Exchange), a programme of the Deutsche Gesellschaft fr Technische Zusammenarbeit (GTZ) GmbH, acts as a centre for the dissemination and promotion of appropriate technologies for developing countries.
The Information and Advisory Service on Appropriate Technology (ISAT), was established as a section of GATE, in 1991. It has at its disposal the full range of services the GTZ offers, and is financed through the German Ministry for Economic Cooperation and Development (BMZ). ISAT spezializes in a large variety of appropriate technologies for developing countries, whereby the technologies that ISAT focusses on principally include those which:

- **help satisty basic needs,**
- **make efficient and environmentally sound use of locally available resources,**
- **mobilize existing skills and promote self-help,**
- **extend user's scope for action and promote independent action.**

ISAT offers its services (question-and-answer service, various types of publications and films) to German development co-operation organizations as well as organizations and individuals in developing countries. Requests for literature and documentation on specific areas of appropriate technology can be addressed to ISAT.

Deutsches Zentrum fur Entwicklungstechnologien GATE in: Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH

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ERM Umwelt Consult Rhein-Main-Neckar GmbH is a member of Environmental Resources Management (ERM) Europe and the ERM International Group. ERM serves as an international environmental consultancy to industry and the public sector and has offices at more than 90 locations worldwide. ERM's experience includes provision of comprehensive Asbestos reviews for the World Bank and the Deutsche Kreditanstalt fr Wiederaufbau.

***Cover*: Chrysotile Asbestos fibres (Photograph: TRW Deutschland GmbH, Scanning Electron Microscopy, Magnitude: 1000)**

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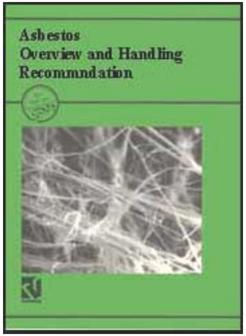

Preface

For decades, Asbestos was known as a versatile and readily available construction material that could be produced in a variety of forms and was suitable for numerous uses. Thus Asbestos was found - and is still found today - in the drinking water sector of many of the world's countries, in fire prevention elements, even in cooking stove covers in kitchens and in gardens as roofing material and flower pots.

Since certain Asbestos varieties are known to be carcinogenic, discussion continues on the efforts of removing construction elements containing Asbestos - the nature of the discussion ranging from making light of the whole matter to panic-driven activism. The costs of renovation and disposal of building segments containing Asbestos can be enormous, yet the negative effects on health depending on the manner of contact - are clearly proven!

The man in the street - but also experts who have not studied the problem specifically - are faced with a flood of information, which we have attempted to compile in this publication. Not only are the various forms of Asbestos presented - its common uses,

identifying features, and negative impacts but also the regulations of various countries and implementing organizations concerning the substance.

In 1990, in view of the danger to human health, in the Federal Republic of Germany a decision forbidding the production or use of Asbestos came into force. Based on this decision, in January 1995 the Federal Ministry for Economic Cooperation and Development (BMZ) applied the ban within international and bilateral development cooperation with the following provisions:

At the end of 1994, the complete prohibition of Asbestos manufacturing and use in Germany came into effect. Danger to human health arises mainly from the inhalation of fine Asbestos dust, particularly during the production and processing of Asbestos products.

The main areas of application in Development Cooperation are: low-cost-housing (sheets, insulation material, etc.) the water supply/wastewater area (Asbestos cement pipes), and many minor uses (gaskets, machine parts, etc.).

For the Federal Ministry for Economic Cooperation and Development the following 'Asbestos Policy' applicable. It has been considered that transitional regulations were valid in Germany and thus should also be allowed for the developing countries.

In development projects, the use of Asbestos is prohibited as a matter of principle.

The prohibition is geared towards projects to be sponsored, in particular new projects, in which it is planned to use products containing Asbestos.

The following differentiation is necessary, based on the different health dangers: Asbestos use in housing construction is prohibited; for the water supply/wastewater area, the following rule applies: the use of Asbestos is prohibited as a matter of principle.

Exceptions can be made in special cases (acceptability for low hazard potential and corresponding protection measures in cases of economic/social restraints). In suitable cases, assistance will be offered to the partner country for the financing of incremental costs for substitute materials in development projects. The use of Asbestos in exceptional cases within a suitable transitional period is only possible if it is deemed necessary and acceptable based on an extensive investigation (EIA).

The following individual or special regulations are valid:

- **in the area of General Commodity Aid and Structural Adjustment Support, the negative list will be expanded to include Asbestos.**

- **in co-financing, the Asbestos prohibition applies only to the object under German financing (in the dialogue, a comprehensive solution should be urged).**

We hope that this publication may serve not only as background information but will help you in making decisions in case you are confronted with the issue of Asbestos.

Brigitte Baumer

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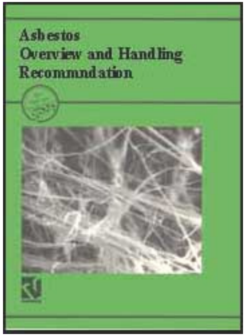

Asbestos Overview and Handling Recommendations (GTZ, 1996)

Part I. Introduction

1. Introduction

ERM Umwelt Consult Rhein-Main-Neckar GmbH (ERM, formerly ERL) was commissioned by the Deutschen Gesellschaft fur Technische Zusammenarbeit (gtz) mbH to perform an Asbestos study. A total of 1.5 FM was available for this assignment. The first phase of the project was completed in June 1992. In a second phase the main focus was placed on the use of Asbestos containing materials in the areas of housing and water mains construction, as well as on the available Asbestos substitutes in these areas. Furthermore, the use and handling of Asbestos should be more closely discussed on the basis of selected countries and donor organizations. The selection of the countries and donors was performed in collaboration with the contractor or the Kreditanstalt fur Wiederaufbau (KfW). External budgets were formed for the acquisition of information from the selected countries. For the performance of the second phase 2 FM were available.

The study "Asbestos" serves as an estimation of the risks resulting from the handling of Asbestos materials. The practices in mining and use of Asbestos containing materials in the developing countries (DC) should be given special attention. One goal of the study is the development of recommendations for handling the Asbestos problem for people involved in joint projects with developing countries. The study should also be helpful in practical use for better handling of the Asbestos problem in DC.

2. Structure

As described above, the present report is based on an overview analysis, which was performed by ERM in 1992. As an extension to that study, new points of focus were defined and compiled in a new report in which the findings of the first study have also been incorporated in another format.

The study contains four independent parts:

(Part I: Introduction)

Part II: Asbestos

In this part a basic introduction to the subject of Asbestos is provided. This part was the result of the first phase of the study and includes:

- **Introduction: Asbestos - Deposits, Uses, Types, Characteristics**
- **Legal Regulations**
- **Environmental Aspects and Heath Hazards**
- **Application Areas of Asbestos Materials and Asbestos Products**
- **Health and Safety Measures in Handling Asbestos**
- **Aspects of Asbestos Abatement and Disposal of Asbestos Containing Materials**

Part III: Asbestos Substitutes

Here the principally available substitutes for Asbestos containing materials in the areas of housing and water mains construction are discussed. This part includes the following sections:

- **Technical Requirements for Asbestos Substitutes**
- **Properties of Typical Asbestos Substitutes - Overview**
- **Fiber Substitutes for Asbestos Fibers in Building Construction**
- **Fiber-free Substitutes in Building Construction**
- **Fiber-free Substitutes in Water Mains**

Part IV: Country Analysis

As described above, the handling of Asbestos in different countries should be studied. Aside from a general introduction and the discussion of the Asbestos subject in developing countries, the situation in other selected countries is also described. The country-specific information was compiled on the basis of the questionnaire which is presented in the Annex.

Part V: Development of Handling Recommendations

In the last part of the study handling recommendations are developed based on the experiences of other donor organizations and other considerations.

(Part VI: Literature)
(Part VII: Annexes)

3. Definition of terms

Asbestos is a collective description for different naturally occurring fibrous minerals. The legislative definition describes Asbestos as a collective term for naturally occurring crystalline silicate with fibrous structure. The term "fiber" is defined by its geometry: fibers having a length > 5 km, a diameter < 3 km and a length/diameter ratio of at least 3:1. An important property of Asbestos materials is the continual splitting along their length down to the very smallest fibers.

Asbestos minerals are natural components of the Earth's crust. The name "Asbestos" originates from Greek and means "inextinguishable", whereby one of the material characteristics is mentioned which led to the great usefulness and industrial interest in this material.

The differentiation among Asbestos containing products is made between nonfriable and friable Asbestos:

nonfriable	Asbestos cement or hard Asbestos with a gross density significantly higher than 1000 kg/m³ and an Asbestos percentage of 10 - 15 % (remainder is cement)
friable	Sprayed Asbestos/soft Asbestos with a gross density under 1000 kg/m³; ca. 60 % Asbestos powder, ca. 40 % cement

Friable Asbestos can easily be released from the surface by hand. As of 1979, sprayed Asbestos has been prohibited in the Federal Republic of Germany, due to the associated health hazards. Asbestos cements were permitted to be manufactured until the end of 1993; about 70 % of the applied Asbestos amounts are fabricated into Asbestos cements.

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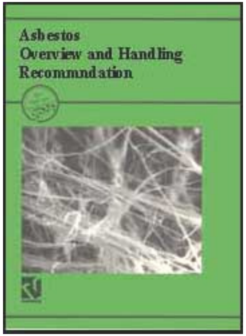
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Asbestos Overview and Handling Recommendations (GTZ, 1996)

Part II. Asbestos

1. Introductory part: Asbestos - Deposits, uses, types, characteristics

The different Asbestos minerals in the Earth's crust, their deposits and characteristics are presented in detail in this part. In particular, the minerals concerned are: chrysotile, amosite, crocidolite, anthophyllite, tremolite und actinolite, which are categorized on the basis of their chemical composition and fibrous structure as serpentine Asbestos (chrysotile) or amphibole Asbestos.

The following presents a classification of Asbestos minerals and a description of the chemical composition, physical properties and specific figures for Asbestos fibers. In addition, the important mines for the different Asbestos fibers are named.

1.1 Types, deposits, and uses of Asbestos, chemical structure

Asbestos is a collective term for a group of silicate fibers. The aforementioned six different Asbestos minerals can be categorized on the basis of their chemical composition (primary cation) and their crystalline and fibrous structure into the groups amphibole or serpentine Asbestos.

Serpentines have a leafy or layered structure. Amphiboles have a chain-like crystalline structure.

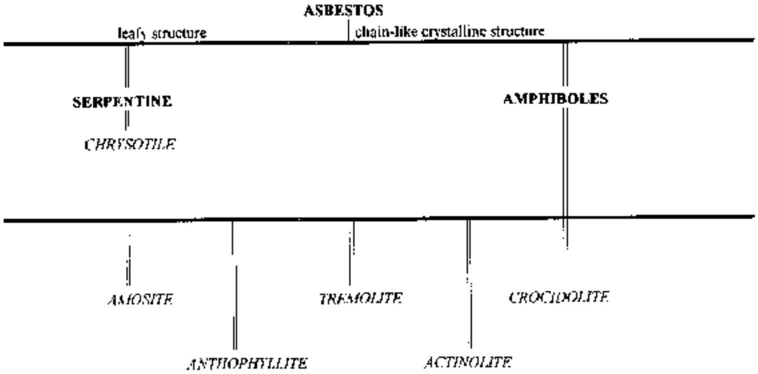


Figure 1: Classification of Asbestos Types

- **Serpentine Asbestos:**

Serpentine Asbestos (chrysotile, as most important type, and antigorite) is leaf structured and consists of fine fibers. The leaves consist of alternating layers of silicate tetrahedron (SiO4), which are held together by hydroxide groups (OH) and magnesium ions. The structure is similar to that of serpentine minerals.

Chrystolite Asbestos:

Chrysotile Asbestos fibers have a very small diameter, are tubular, very soft and bendable. The individual fibrilles have a diameter of 100 - 250 Angstrom (A). Chrysotile originates from the hydrothermal decomposition of ultra basic, primarily olivine-containing rock; particularly severe weathering occurs in subtropical and tropical climates.

Mines are located primarily in Ural (Bazenovo, Asbest, Dzetygara, Kiembaj), in Canada

(Quebec, Ontario, British Columbia, New Foundland), as well as in South Africa (Zimbabwe, Botswana, South Africa).

Chrysotile, or white Asbestos, is the most widely used form of Asbestos. In the USA cat 95 % of all Asbestos types used in buildings is white Asbestos. Of the total German use of Asbestos, 96 % is chrysotile (1976).

- **Amphibole:**

Amphibole Asbestos types have a chain-like crystal structure, which stipulates their fibrous nature. Individual fibers have larger diameters, are straight, firm and hard, but elastic.

Amosite:

Amosite is a long-fibered Asbestos. Fiber length can reach 35 mm. Due to its needle-like structure it is a very dangerous type of Asbestos. On the basis of quantity (ca. 1% of all used types in Germany in 1976), amosite or brown Asbestos is second to only chrysotile as the most common form in buildings. It is primarily used in the manufacturing of light, fire-proof insulation sheets. The important mining areas are in South Africa.

Crocidolite:

The blue Asbestos is the most hazardous type of Asbestos and is primarily applied in pressure resistant pipes made of Asbestos cement. Economically, it is the most important type of amphibole (amphibole represented 3% of all Asbestos used in Germany in 1976, whereby > 90 % was from the manufacturing of pressure resistant Asbestos cement pipes). The diameter of fibers is very small: 0.1 - 0.2 mm; the surface of crocidolite consists of SiO_4 - tetrahedrons. Important deposits are in South Africa and in West Australia.

- **Mining:**

The world production of Asbestos increased steadily until the early 1980's, since the economic value of the fibers stood in the foreground, although the risks of Asbestos have been known at least in part since cat 1930. The total world production of Asbestos peaked around 1976 at approximately 5.2 million tons (Mt). Currently the trend shows a steep decline (1986: 4.1 Mt, 1991: 3.5 Mt., US Bureau of Mines). The main producing and consuming countries were (see also the maps in Annex 1):

Table 1: Percentage of Asbestos Production among the Main Producing and Consuming Countries

Mining	**(1976)**	**(1979)**	**(1987)**	**(1991)**
Canada	(30 %)	(27 2 %)	(15.7 %)	(19.7 %)
USSR	(44 %)	(43.9 %)	(60.3 %)	(57.3 %)
South Africa	(12%)	(6.1 %)	(3.2 %)	(4.3 %)

Source: own compilation from different sources

Other important producing countries are currently: Brasil, Zimbabwe, China, Greece, India, Swaziland, Columbia and Japan. Meanwhile, the market shows a surplus of supply. The known worldwide supply of Asbestos ores will be sufficient to last far into the next century.

The largest part of Asbestos production is chrysotile (over 90 %), the remainder primarily crocidolite (ca. 4 %). The types amosite, anthopyllite, tremolite and actinolite are quantitatively (together < 2 %) of subordinate importance.

The annual tonnage, location and type of Asbestos at each mining site can be found in

Tables 2 through 4 and the respective references.

Some of the most important Asbestos deposits are listed in Table 2.

Table 2: Asbestos Deposits

Country	Location	Asbestos Type	Rock Formation	References
USSR	S-Central Ural Sverdlosk, Tuva& Kustanay Region	C	US	Harben & Bates (1984)
Canada	Eastern Quebec	C	US	Lamarche & Riordon (1981)
	N-E Quebec	C	US	Hanley (1987), Stewart (1981)
	Newfoundland	C	US	Williams et al. (1977)
	British Columbia	C&T	SP	Burgoyne (1986)
USA	N-Central	C	P&D	Chidester et al. (1978)
	Vermont	C	SP	Mumpton & Thompson (1975)
	California	C&T	AL	Harben & Bates (1984)
	Arizona	An&C	U	Ross (1982), Puffer et al. (1980)
	Georgia-Maryland New Jersey	C&T	AM	Germine & Puffer (1981)
Yugoslavia	Croatia	C	SP	Harben & Bates (1984)
Greece	Macedonia	C	H&I	Harben & Bates (1984

South Africa	Transvaal	C	AS	Dryer & Robinson (1981)
	Transvaal	A&Cr	BI	Ross (1982)
	Lyndenburg N-Cape Province	Cr	BI	Dryer & Robinson (1981)
Swaziland	Northern	Region	C	S&C Harben & Bates (1984)
Zimbabwe	Eastern Bulawayo	C	D&P	Harben & Bates (1984)
Australia	New South Wales	C	H&D	Butt (1981)
Finland	Karelian Mts.	An	US	Ross (1982)
Italy	Western Alps	C&T	S	Ross (1982)
China	Various Locations	C&T	U&Do	Hodgson (1986)
Brasil	Goias State	C	D&P	Beurian & Cassedanne (1981)

Asbestos Type

C = Chrysotile
T = Tremolite
An = Anthophyllite
A = Amosite
Cr = Crocidolite

Rock Formation

Se = Serpentine Rock
P = Periodotite

AS = Altered Sedimentaries
H&I = Harzburgite & Iherzolite
Do = Dolomite
AL = Altered Limestone
BI = Banded Ironstone
SP = Serpentinized Periodotite
D = Dunite
AM = Altered Marble
S&C = Altered Schist&Carbonates
US = Ultramafic Serpentinite
U = Ultramafic Rock

Source: Schreier, H.: Asbestos in the Natural Environment, Studies in Environmental Science, Amsterdam 1989

Table 3: Estimated Production Capacity of Asbestos Useable in Industry

Country	**Asbestos (in Tons)**
USSR	3.100.000
Canada	1.500.000
South Africa	400.000
China	300.000
Zimbabwe	300.000
Brasil	200.000
Italy	200.000
USA	120.000
Greece	100.000

Greece	100.000
Australia	100.000
Germany	90.000
Swasiland, Cyprus, India, Japan, Yugoslavia, Columbia, Turkey, etc.	> 50 000
(for each country)	

Source: Schreier, H.: Asbestos in the Natural Environment, Studies in Environmental Science, Amsterdam 1989

- **Processing:**

In the western world 75% of Asbestos rock is produced in openpit mining with blasting, and in total 85% of the worldwide Asbestos rock is produced in this manner. Mining production refers to the amount of fiber gained from Asbestos mills. The mass content of fibers in rock lies around 3 - 10%. The crude rock is crushed in the mines with breaking and pan grinding operations and separated into fiber bundles. This is a largely mechanical process, which consists of many steps of screening and air sifting. These procedures are illustrated in Figure 2.

The conditions in the important Asbestos producing countries in Africa are markedly different. In Simbabwe and Swasiland Asbestos production is performed exclusively through deep mining, in the Republic of South Africa to 95% extent. Asbestos production in China is also 40% underground mining. In Canada the percentage of deep mining for Asbestos lies just above 5%, in the former USSR deep mining is not considered to play a significant role.

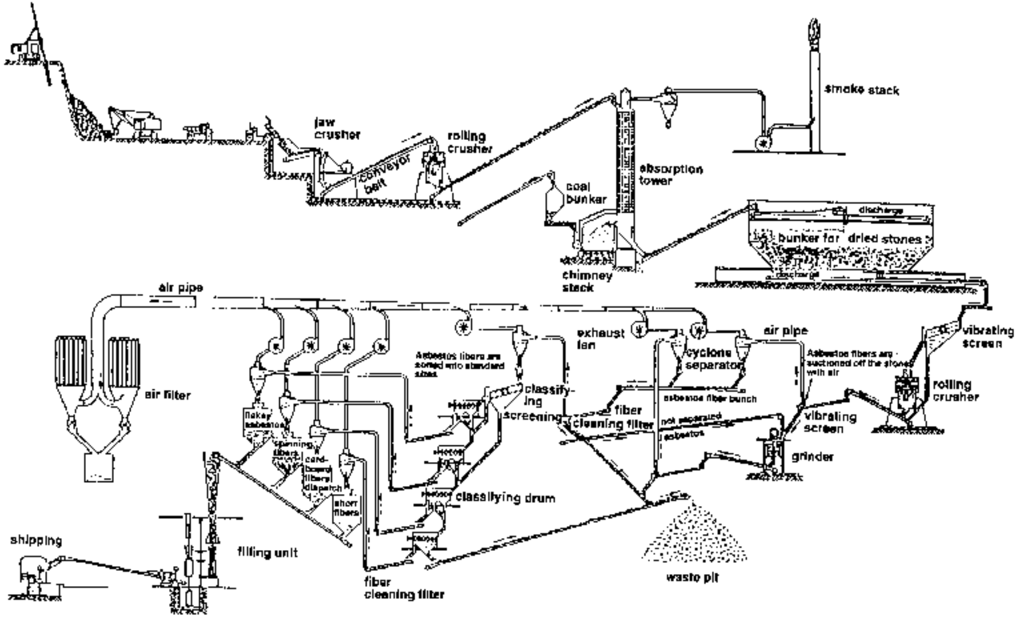


Figure 2: Illustration of Asbestos Mining Along a Slope and Dry Processing (Source: 1980)

- **Further Processing Asbestos Cement**

Asbestos cement is a fiber composite material made of primarily chrysotile Asbestos and cement and in some cases other additives, such as quartz, pigments, etc.. The first technical and economic procedures for manufacturing this construction material were developed by Hatscheck (1900).

Currently, even in the developing countries the large-scale technical procedures used are exclusively variations of that introduced by Hatschek, which is according to paper

technology.

The manufacturing of Asbestos cement pipes according to Mazza and Mattei (1913) is also based in principle on the suggestions of Hatscheck.

In a continuous procedure, Asbestos, spread open to fine fibers, is mixed with cement and a great deal of water into a thin liquid suspension and then thickened to paper-like sheets as the excess process water is removed via felt cloth. Depending on the type of production, further manufacturing operations are performed with presses for sheets or with wrapping machines for pipes. (A detailed description of the historical and technological development of Asbestos cement is provided by Klos, 1967)

Table 4: Asbestos Percentages and Types in the Most Important Asbestos Cement Forms

Asbestos Cement Products	Asbestos content in matter wt -% relative to solid	Type of Asbestos	Supplements (outer Cement)
Standard sheets (flat sheets for walls. roofs, etc., corrugated sheets for roofing) and pipeline fittings	9 -12	Chrysotile	none
Pressed pipes - sewer- and drainage pipes	12 - 15	Chrysotile (approx. 85%); Crocidolite (approx. 15 %)	none
Light construction sheets (primarily for fire	15 - 30	Chrysotile;	Cellulose;

protection purposes)		Amosite	Pearlite (Calcium silicate)
White sheets	6 - 9	Chrysotile	Quartz

Source: UBA - Report 1/80

- **Consumption**

In 1979, the countries with the highest consumption of Asbestos in percent of the total were:

Table 5:Asbestos Consumption (1979)

USSR	(31.7 %)
USA	(11.3 %)

Source: own compilation

From the maps in Annex [(with 1978-1981 data from the BGR/DIW study), it is apparent that the use of Asbestos materials primarily took place in the industrial nations. From this standpoint it can be argued that Asbestos is not a specific problem of the developing countries. Upon further analysis, however, it becomes clear that the present situation is different from that in 1981. Furthermore, in the study (BGR/DIW) no statements were made regarding how many Asbestos products are exported to the developing countries, leading to health risks there.

1.2 Mineralogical and mechanical properties of Asbestos

The majority of application areas for Asbestos result from the synthesis of different

technical properties:

- **high tensile strength**
- **resistance to moisture**
- **resistance to heat**
- **flexibility, elasticity**
- **cability of being spun**
- **flame retardant, fireproof**
- **insulation capacity**
- **good binding capability in many inorganic and organic binding materials**
- **chemical resistance (depending on Asbestos type, resistant against acids or bases)**

The different Asbestos minerals demonstrate different characteristics influencing:

- **potential application possibilities,**
- **the attractiveness of substances for multi-purposes,**
- **the resulting health hazards from the use.**

In view of the above differences, there are different evaluation criteria among Asbestos minerals.

From a technological standpoint, chrysotile or white Asbestos demonstrates the most valuable characteristics, such as very high flexibility, fineness of fibers, capability of being spun, heat resistance, and alkali resistance. White Asbestos is therefore particularly important in addition to blue Asbestos (crocidolite) and amosite.

Table 6 shows an overview of figures for the most important types of Asbestos. More information can be found in the health and safety data sheet for Asbestos cement in the UK (Annex 2), and in an excerpt from the Compendium of Environmental Standards (KUSt, Katalog umweltrelevanter Standards), BMZ/GTZ (Annex 7).

1. 3 Analytical methods of determining Asbestos fibers

A number of techniques have been developed for the analytical determination of Asbestos fibers. The determination is generally performed in three steps: the sampling, fiber counting and determination of the type of fiber. These steps are presented below along with the most widely used determination procedures.

Sampling

For the determination of Asbestos in fluid media (air, water), a defined volume of the media is drawn through a filter, upon which the fibers are deposited. The typical filter materials are gold-coated track-etched membrane filters or cellulose membranes. In order to determine the number of fibers in solids (e.g. in material samples or in dust), the sample can be directly used.

Fiber Counting

Generally, microscopic techniques are applied for fiber counting. The optical counting of fibers proceeds in the simplest case under the phase contrast microscope. Since the optical resolution can at best include structures of 1 mm in size, whereas in airborne particulates the main fraction of fiber bundles has sizes ranging from 2 - 0.2 mm, phase contrast microscopy can at best be used as a screening method in cases of very high fiber concentrations (e.g. for the investigation of material samples). In the case of investigations of drinking water, phase contrast microscopy is totally unsuitable (sizes around 0.06 mm).

Sufficient resolution can be achieved with using scanning electrion microscopy (SEM) or with transmission electron microscopy (TEM). These procedures are relatively expensive, however, and require extensive measures in the preparation of the samples, in addition to well-educated operating personnel.

Asbestos fibers in particulate samples can also be determined on the basis of their characteristic absorption lines using infrared spectroscopy. However, the determination limit lies relatively high at 1-5%, depending on the type of fiber.

Table 6: Data on the Most Important Types of Asbestos

	Serpentine	**Amphibole**				
	Chrysotile	**Anthophyllit**	**Crocidolite**	**Actinolite**	**Tremolite**	**Amosite**
Chemical formula	$Mg_3(OH)_4Si_2$	$(Mg,Fe^{2+})_7$	$Na_2(Fe_2+,Mg)$	$(Ca,Na)_2$	$Ca_2(Mg,Fe)_5$	$(Fe^{2+},Mg.Al)$
	O_5	$(OH)_2Si_8O_{22}$	$3Fe_{23}+(OH)_2$	$(Fe,Mg,Al)_5$	$(OH,F)_2Si_8O_{22}$	$(OH)_2Si, Al)_8$
			Si_8O_{22}	$(OH, F)_2$		O_{22}
				$(Si, Al)_8O_{22}$		
Chemical composition in (%)						
SiO_2	35 - 44	52 - 64	49 - 57	0 - 63	50 - 63	45 - 56
MgO	36 - 44	25 - 35	3 - 15	18 - 33	18 - 33	4 - 7
Al_2O_3, Iron oxide	0 - 9	1 - 10	20 - 40	2 - 17	2 - 17	31 - 46
CaO, Na_2O	0 - 2	0 - 1	2 - 8	1 - 10	1 - 10	1 - 2
H_2O	12 - 15	1 - 5	2 - 4	1 - 4	1 - 4	1 - 3
Physical	fine light	prismatic	long, brittle	prismatic	prismatic	prismatic

properties	fibers	crystal and fibers	fibers	crystal and fibers	crystal and fibers	crystal and fibers
Color	white, grey, greenish	grey-white	blue	green	white, grey-white, greenish	ash grey
Texture	soft to rough, mostly silky	rough	soft to rough	rough	rough	rough
Flexibility	very high	low	good	low	low	good
Mohs-strenght	2,5 - 4	5,5 - 6	5,5 - 6	6	5,5 - 6	5,5 - 6
Fiber diamiter (nm)	18 - 30	60 - 90	50 - 90	0 - 90	60 - 90	60 - 90
Resistance (N/nm^2)	210 - 560	< 28	280 - 420	7	7 - 56	70 - 140
Modulus of elasticity(N/nm²)	160.000	-	190.000	-	-	160.000
Melting point (C)	1.500	1.480	1.180	1.393	1.320	1.400
Specific heat (kj/kg C)	1,1	0,85	0,8	0,9	0,9	0,8
Surface (m²/g)	10 - 60	7	10			9
Thickness g/cm³	2,2 - 2,6	2,8 - 3,2	2,8 - 3,6	3,0 - 3,2	2,9 - 3,2	2,9 - 3,3
Breeking index						
n (alpha)	> 1,53	> 1,59	> 1,68	> 1,61	> 1,60	> 1,64
n (gamma)	< 1,57	< 1,63	< 1,70	< 1,65	< 1,63	< 1,69
pH-Value	9,5 - 10,3	9,4	9,1	9,5	9,5	9,1
Electrical charge in aqueous	+	-	-	-	-	-

suspension						
Stable towards acids	unstable	very good	good	fairly good	good	good
Alkali resistant	very good	good	good	good	good	very good
capability of being spun	easily spinnable	barely spinnable	mostly spinnable	unspinnable	unspinnable	partially spinnable

Source: Umweltbundesamt (Publ.): Analysis of the Asbestos Industry, written by the Battelle-Institut Frankfurt e.V., Report 4/78, Berlin 1978

Determination of the Type of Fiber

The determination of the type of fiber and particularly the differentiation from other inorganic fibers can be directly performed under the transmission electron microscope using small angle electron diffraction (SAED). Another possibility is the energy dispersive X-ray analysis (EDXA). The arising diffraction or energy spectra are evaluated using numerical methods. The required infrastructure is relatively expensive and places high requirements on the operating personnel. The previously common use of phase contrast microscopy to determine the type of fiber in airborne particulates based on fiber geometry is unsuitable, due to low resolution.

The type of fiber can also be identified with infrared spectroscopy based on the characteristic absorption bands of chrysotile and amphibole types. This method is inexpensive, but only applicable if the fiber concentration in the sample exceeds about 1-5 percentage by weight.

In Germany there are two accredited American procedures for the measurment of Asbestos fiber concentrations. These VDI Guidelines are for fiber in particulates and in indoor air and replace the previously common phase contrast microscopy procedures:

VDI Guideline 3861

This guideline specifies a procedure for the determination of the fraction of Asbestos fibers in particulate mass, e.g. as they occur in air vents. The sampling proceeds through deposition of particulates onto a nitro-cellulose filter. This filter undergoes cold ashing, and the fiber concentration is then determined using infrared spectroscopy with the help of the KBr Pressure Technique. The analytical result is obtained as the weight fraction in g/kg.

VDI Guideline 3492

This guideline specifies a procedure for the determination of Asbestos fibers in indoor or outdoor air. The Asbestos fibers from a defined air volume are deposited onto a gold-coated track-etched membrane, which is then cold-ached, and subsequently the fibers are counted under the scanning electron microscope. The type of fiber is determined using energy dispersive X-ray analysis.

Due to the cost of this analytical procedure, it may be assumed that in developing countries at best the phase contrast microscopy and infrared techniques are available (cost of equipment < 50,000 DM). The electron microscopy procedures (costs >>100,000 DM) would currently be applied exclusively in industrial nations. Therefore, in developing countries it is questionable whether any existing limits, e.g. for indoor air concentrations, can be monitored.

2. Legal regulations for the production, introduction to the market and use of Asbestos containing materials and Asbestos products

For the hazardous substance Asbestos there are many legal regulations covering the different steps of production, introduction to the market and use of Asbestos containing products. Additionally, there are occupational safety regulations and legal specifications in

context with the necessity of abatement of Asbestos containing areas and the disposal of Asbestos containing materials.

In this chapter the relevant laws, administrative rules, occupational safety requirements, operational safety requirements and other legal regulations are presented and discussed. Different industrial nations (Germany, USA), developing countries (DC) and supra-national agreements (KU, UNO [WHO and ILO]) are analyzed.

2.1 Federal Republic of Germany

In German federal environmental and health and safety law as well as in other areas, there are a number of regulations concerning Asbestos. In many sources, e.g. from Construction Law (State Construction Ordinances) to Occupational Safety Law, the Immission Protection Law (TA-Luft administrative rules) and Waste Law (TA-Abfall, LAGA-Instruction Sheet "Disposal of Asbestos Containing Wastes"), there are rules and regulations on the manufacturing, introduction to the market, and use of Asbestos containing products. Additional extensive rules are also required by the Employers Association for Accident Insurance (Berufsgenossenschaft).

The following legislative works are of particular interest: The Hazardous Substance Ordinance and its related Technical Rule for Hazardous Substances (TRGS) 517 "Asbestos" and TRGS 519 "Asbestos- Remolval, Abatement or Maintenance Work", as well as the Asbestos Guideline (Guideline for the Evaluation and Remediation of Friable Asbestos Products in Buildings). The latter guideline will be discussed in Chapter 6.1.

Hazardous Substance Ordinance

The Hazardous Substance Ordinance (Gefahrstoffverordnug-GefStoffV) dated 26/08/1986, BGBI. I, currently valid in the version from 29/09/1994 (BGBI. 1.), regulates the introduction to the market of hazardous substances, the handling, storage and destruction

of hazardous substances. The ordinance is based on the Chemical Law (Chemikaliengesetz).

In the Second Amendment to the Hazardous Substance Ordinance on 23 April 1990, the regulations concerning the handling of Asbestos were significantly tightened. The manufacturing and use of Asbestos containing hazardous substances became prohibited, however this refers only to the materials explicitly listed in Annex 11 under 1.3.1.2, which include the most important light Asbestos cement sheets (unit weight < 1.0 g/cm³), coating substances, substances or preparations for spraying or trowelling as well as insulation materials for fire, sound or heat protection and floor and street coverings. Furthermore, all crocidolite containing substances are listed.

A prohibition for manufacturing refers to fiber-reinforced thermoplast masses.

A central regulation of the Hazardous Substance Ordinance is the Substitution Order, whereby the applied amounts of Asbestos are to be limited as far as possible and the possibility of using nonhazardous substitutes is to be examined. In support of the Substitution Order, the authorities have the option to forbid the use of carcinogenic products.

The Hazardous Substance Ordinance is the central regulatory element in Germany for the handling of and protection against hazardous substances. In 1986 it replaced the Working Medium Ordinance including another 35 relevant ordinances and incorporated 14 EU-Guidelines into national law. The EU-Guideline on Asbestos referred to under 2.2 was also included.

In January 1995 a general prohibition ordinance for the manufacturing, introduction to the market and use of Asbestos containing materials came into effect. The same exceptions and interim deadlines are foreseen that were in the Hazardous Substance Ordinance. A new rule is the prohibition of working on Asbestos cement products (which were

permitted to be manufactured until the end of 1993) in a manner which could destroy the surface. The production and use of sprayed Asbestos has been forbidden since 1979.

Further requirements on occupational safety in handling Asbestos are:

Technical Rules of the Board for Hazardous Substances at the Federal Ministry for Work and Social Order:

Technical Rules on Hazardous Substances (Technische Regel Gefahrstoffe) TRGS 517 "Asbestos"

Technical Rules on Hazardous Substances TRGS 519
"Asbestos - Removal, Abatement or Maintenance Work"

The technical guideline concentration (technische Richtkonzentration, TRK) in the workplace air is specified in the TRGS 102, and for chrysotile Asbestos it is 250,000 Fibers per m^3 air (as of 1990 after adjusting to the Second Change of the Hazardous Substance Ordinance). As of the newest version of the TRGS 102 in January 1994, there is no longer a TRK value for Asbestos fibers in work involving Asbestos removal, abatement and maintenance, which means that in these work areas the full spectrum of measures according to the TRGS 519 must be followed. For amphibole Asbestos, there was not a TRK value in 1993, since its use had already been prohibited.

Table 7 Exposition Limits for Asbestos Fibers According to German Occupational Law

	MAK-Value	**TRK-Value**
Asbestos containing fine particles:	6 mg/m^3 1)	-
Chrysotile:	6 mg/m^3 1)	250,000 F/m^3

	6 mg/m³ 1)	
Amosite	6 mg/m³ 1)	_2)
Anthophyllite	6 mg/m³ 1)	_2)
Actinolite	6 mg/m³ 1)	_2)
Tremolite	6 mg/m³ 1)	_2)
Crocidolite	6 mg/m³ 1)	_2)

1) general limit for particulates

2) the latest TRGS no longer has a limit for this, since the substance is not allowed to be used anymore

Source: own compilation

Measurements of Asbestos fiber concentrations are to be performed according to ZH1/120.31. In plans for abatement, a maximum value of 50,000 fibers per m³ air is given. The TRGS 100 defines the limits for hazardous substances above which additional measures must be undertaken. The TRgA 124 (Technical Rules for Hazardous Working Substances, Technische Regeln fr gefhrliche Arbeitstoffe) defines the limit for Asbestos.

Technical Rules for Hazardous Working Substances TRgA 601
"Substitutes for Asbestos"

Technical Rules for Hazardous Working Substances TRgA 402
"Measurement and Determination of the Concentrations of Hazardous Working Substances in the Air; Application of the Maximal Workplace Concentrations (MAK) "

In addition, there is an extensive regulatory work from the Employers' Association for

Accident Insurance (Berufsgenossenschaften BG) in the form of rules on accident prevention and safety measures. There are also regulations on identifying Asbestos (ZH 1/120.30), on lung-endangering fibers (ZH 1/120.31), and guidelines for the evaluation and abatement of friable Asbestos products in buildings (Asbest-Richtlinien, in the version from January 1990), which will be discussed further in Chapter 6.2 of this part.

2.2 Directives of the European Community

In 1983 the Commission of the European Community enacted the Council Directive on the protection of workers from the risks related to exposure to Asbestos at work (83/477/EEC). This directive is based on the 1980 Council Directive on the protection of workers from the risks related to exposure to chemical, physical and biological agents at work (801 1107/EEC, EC-Agents Guideline) It contains the minimum requirements for the protection of workers from Asbestos containing hazardous materials, comparable to the TRK values in Germany.

The rules of this guideline are applicable to workplaces with a concentration of more than 0.25 fibers per cm³ air and/or a cumulative dosis of more than 15 fiber-days per cm³ air over a period of 3 months.

For this type of classified areas the following regulations apply, among others:

a) prohibition of working with Asbestos by means of spraying;

b) a limit for Asbestos fibers, except for crocidolite, of 1.0 fibers per cm³ air measured or calculated for an 8 hour reference period;

c) a limit for crocidolite of 0.5 fibers per cm³ air measured or calculated for an 8 hour reference period;

d) for mixed Asbestos fibers a limit from b) and c) according to the ratio of crocidolite to other Asbestos fibers;

e) a distinct labelling using relevant warning symbols,

f) prohibition of smoking.

These limits apply only for Asbestos fibers with a length/diameter ratio of 3: 1.

Where the above limits are exceeded, appropriate measures to reduce Asbestos emissions must be performed, or if that is not possible, appropriate protective clothing and respiratory protection must be worn.

The guideline also contains general duties for employers (e.g. investigational duty, supervision duty, order to minimize the concentration of Asbestos in the air, duty to submit notification of the manufacturing and use of Asbestos containing materials).

Another EU-Guideline governs the labelling of Asbestos containing preparations and products. In 1983, the "a" for the labelling and the formulation "Achtung, enthlt Asbest! Gesundheitsgefahrdung beim Einatmen von Asbeststaub" ("Warning, contains Asbestos! Inhalation of Asbestos particles is hazardous to health" was incorporated into the general European Law to protect against potential health hazards. This Guideline (83/478/ EEC) represented a change to the Guideline 761769/EEC. The same applies to the Guideline 85/610/EEC, which more strictly limited the introduction to market and the use of Asbestos containing substances and preparations in 1985. Further changes followed. The latest change in the guideline dated 3 December 1991 (91/659/EEC) prohibits production and use of Asbestos containing materials in many areas of application, and in some instances intermediate provisions are stipulated.

2.3 United States of America

The Asbestos regulations in the USA are primarily determined by the two federal authorities "Environmental Protection Agency (EPA)" and "Occupational Safety and Health Administration (OSHA) ". The EPA is the federal environmental authority, OSHA determines formulations and implementation of occupational measures.

- **EPA**

The regulations of EPA are related to:

- **use and removal of ACM (Asbestos containing material) in new buildings or during renovation of buildings;**

- **identification of Asbestos in public buildings (schools) and control of fiber emissions;**

- **industrial Asbestos fiber emissions.**

The first regulations of the EPA on Asbestos date from 1973. They were in the frame of the NESHAP-Program (National Emission Standards for Hazardous Air Pollutants), which directly addressed the Asbestos processing industry and prohibited the use of sprayed Asbestos in new buildings. Furthermore, measures in handling Asbestos during abatement/removal plans were formulated. This legislation was appended and modified several times (1975,1978, 1990). Today the use of sprayed Asbestos in connection with renovation and constructional modifications is forbidden; additionally, there are rules and limits for the disposal of Asbestos containing materials.

The second legal regulation of the EPA falls under the "Toxic Substances Control Act (TSCA)", which can be compared to the (German) Hazardous Substance Ordinance and is the main legal reference source for the control of Asbestos in the USA. The Rule 40 CFR, Part 763 or AHERA 1987, "Final rules and notice (Friable Asbestos Containing Materials in School)" referred to Asbestos in schools and consequently established very strict rules.

This Rule included, in particular, the regular supervision and analysis of friable Asbestos fibers, documentation of all suspected cases and the results, and information of the affected public.

The maximum allowable Asbestos fiber concentration in the air according to the AHERA-Rule is dependent on the size of the critical area:

(1) In an area with less than 160 ft² or with a length less than 260 ft, the limit is 0.01 F/cm³ (F=Fibers). The analysis is to be performed according to NIOSH 7400. At least 5 samples must be analyzed.

(2) The documentation of a successful abatement by removing Asbestos containing materials is performed in 3 steps: visual inspection; new sampling of the air in the problem area and outdoors; and microscopic determination of fiber concentrations.

- **OSHA**

The OSHA-Laws apply to occupational safety in all work places which have contact with hazardous substances. Hence, they also apply to Asbestos. Their application is limited to only the industrial area. The goal of the formulation of the OSHA-rules on Asbestos was health protection, particularly against the already known risks Asbestosis, mesotholioma and cancer, primarily due to inhalation of Asbestos fibers into the lungs.

The first regulations under OSHA were implemented in 1972 and were modified in 1976 and 1986. They specified limits for fiber concentrations in the air at workplaces for the employees in the Asbestos industry, in addition to control mechanisms, medical exams (preventive care), workplace practices and necessary protective clothing for workers.

OSHA refers to the so-called TWA (= time weighted average), meaning that the allowable concentrations depend on the period of exposure. Different time periods were referenced

in the legislature, whereby the 8-hour cycle is the most important, since it matches the length of shifts.

The most important rules and limits are as follows:

(1) PEL = permissible exposure limit

0.2 F/cm³ for a weighted average over 8 hours

This value of 0.2 F/cm³ for a fiber length of > 5 ym was fixed in 1986 by the amendment 29 CFR 1926.58 and represents a significant reduction of the former limits.

(2) Above 0.1 F/cm³ for a weighted average over 8 hours there are specific health and safety measures to be undertaken.

These include primarily particular protective clothing, but also obligatory instructions and training measures as well as medical exams.

A summary of the development in the U.S. federal legislation on Asbestos is presented in Annex 4.

2.4 Standards in other countries (incl. developing countries)

Table 8 shows an overview of the international standards for Asbestos limits. They have been taken from the "code of practice" of the International Labor Organization (ILO) on "Safety in the use of Asbestos" from 1984, and refer to the situation up to 1983.

The table describes only the state of the legislation in 1983, which certainly limits the application for the current situation. For instance, in the USA the limits are no longer checked, but rather a ban on Asbestos and Asbestos containing products has been discussed for all types of Asbestos applications with a deadline of 1996, and for some

particular ones a deadline of 1993 has been fixed.

With regard to the table, it is apparent that between industrial, verging and developing countries there are no large differences in the legislation concerning maximum Asbestos exposure. However, based on these data, a qualitative statement cannot be made on the actual situation nor on the implementation of the legislation. Furthermore, only a few developing countries are explicitly listed in the table.

Table 8: International Regulations on Asbestos

Country	**Regulations**	**Limit values (f = fiber)**
Australia	National Health and Medical Research Council	Amosite 1.0 f/ml
		Chrysotile 1.0 f/ml
		Crocidolite 0.1 f/ml
Austria	July 1980	1,250 particles/cm³ (dust cont. < 2,5 % Asbestos)
		650 particles/cm³ (dust cont. 2,5-15 % Asbestos)
		300 particles/cm³ (dust cont. 15-50 % Asbestos)
		150 particles/cm³ (dust cont. > 50% Asbestos)
Belgium	January 1980	Amosite 2.0 f/ml
		Chrysotile 2.0 f/ml
		Crocidolite 0.2 f/ml
Canada	Special regulation in each province	1982 Ontario:
		Amosite 0.5 f/ml

		Chrysotile 1.0 f/ml
		Crocidolite 0.2 f/ml
		other provinces including Quebec still have a time
		weighted average (TWA) of "less or equal" to 2.0
		f/ml for Asbestos in general
Cyprus	Amendment 1981, No. 1705	All types of Asbestos 2.0f/ml
Czechoslovakia	Ministry of Health, Czechoslovak Socialist Republic, Guidelines No. 46, 1 I May 1978	Dust containing Asbestos
		(a) below 10 %: 4 mg/m³
		(b) over 10 %: 2 mg/m³
Denmark		Crocidolite 0.1 f/ml
		All other types of Asbestos 2.0 f/ml
Finland	23 September 1976	All types of Asbestos 2.0 f/ml
France	Decree No. 77-949, 17 September 1977	All types of Asbestos 2.0 f/ml
Fed Republic of Germany	1 July 1982	All types of Asbestos 1.0 f/ml
India	Model Rule 123-A under section 112 of the Factories Act	Amosite 2.0 f/ml
		Chrysotile 2.0 f/ml
		Crocidolite 0.2 f/ml
		Other forms 2.0 f/ml

Indonesia		Amosite 1.0 f/ml
		Chrysotile 1.0 f/ml
		All other types of Asbestos 4.0 f/ml;
		no standard given for Crocidolite, which is
		understood to be banned
Ireland	1972, 1975	Amosite 2.0 f/ml
		Chrysotile 2.0 f/ml
		Crocidolite 0.2 f/ml
Israel	Jan. 1980, March 1982	All types of Asbestos 1.0 f/ml
Italy	All types of Asbestos 1.0 f/ml	
Japan	Japan Industrial Health Society 1981	Crocidolite 0.2 f/ml
		All other types of Asbestos 2.0 f/ml
Netherlands	October 1983	Chrysotile 2.0 f/ml
		Crocidolite forbidden
New Zealand	24 August 1981	Actinolite, Amosite, Anthophyilite, Chrysotile,
		Tremolite:
		(a) 1.0 f/ml for any 4 hours' exposure
		(b) 6.0 f/ml for any 10 minutes' exposure
		Crocidolite: 0.2 f/ml for any 10 minutes' exposure
Nigeria	Draft Code of Practice	All types of Asbestos 2.0 f/ml
Norway	May 1983	Amosite 0.5 f/ml
		Tremolite 0.5 f/ml

		Crocidolite 0.2 f/ml
		All other types of Asbestos 2.0 f/ml
Spain	August 1982	All types of Asbestos 2.0 f/ml
Sweden		All types of Asbestos (except corcidolite) 1.0 f/ml
Thailand	30 May 1977	All types of Asbestos 5.0 f/ml
United Kingdom	1 January 1984	As from I August 1984:
		Amosite 0.2 f/ml
		Chrysotile 0.5 f/ml
		Crocidolite 0.2 f/ml
United States	1 July 1976, OSHA	All types of Asbestos 2.0 f/ml (currently under revision) threshold limit values (TLV's) recommended by ACGIH (American Conference of Governmental
		Industrial Hygienists), 1982:
		Amosite 0.5 f/ml
		Chrysotile 0.5 f/ml
		Tremolite 0.5 f/ml
		Crocidolite 0.2 f/ml
		all other forms of Asbestos 2.0 f/ml
USSR	GOST, 12-1-005-76	Dust containing over 10 % Asbestos: 2 mg/m³
		Asbestos cement: 6 mg/m³
		Asbestos bakelite: 8 mg/m³
Zambia	1 January 1984	Amosite 0.2 f/ml
		Chrysotile 0.5 f/ml

		Crocidolite 0.2 f/ml (is not imported into Zambia)
		All other types of Asbestos 1.0 f/ml

Quelle: ILO: Safety in the use of Asbestos, 1984

2. 5 International standards: International Labor Organization

The ILO was founded in 1919, as a forum for the development of common measures for governments, employers and unions to support social fairness and to improve living conditions throughout the world. In 1946 the ILO became the first special organization in the United Nations. Today the ILO has 149 member nations.

One of the most important duties of the ILO is the working out of agreements and recommendations for the improvement of working conditions. Agreements and recommendations specify minimum requirements and provide examples and suggestions for the international law of the member nations. With the ratification of an agreement, the member nations are obliged to apply the stipulations of the agreement and to submit themselves to international controls. A recommendation is comparable to an agreement, does not require ratification and contains detailed guidelines.

The ILO published the Code of Practice on Safety in the Use of Asbestos in 1984. These guidelines include recommendations on the following matters, among others:

- **Responsibility of employers and employees in the Asbestos processing industry,**
- **Asbestos investigations at workplaces,**
- **Use of alternative materials,**
- **Occupational safety measures and training,**
- **Packaging, transport and storage of Asbestos containing products,**
- **Disposal of Asbestos containing wastes and**

- Information on the labelling of Asbestos containing products.

The guidelines do not contain exposure limits.

Further, measures to reduce Asbestos exposure are recommended, particularly for Asbestos mining and the processing of Asbestos containing textiles, cement, insulation, clutches and break linings.

Based on these recommendations, an agreement on Asbestos was passed in 1986, and has since been ratified by Canada, Finland, and 9 other member nations (see Table 9).

Table 9: Asbestos Convention, 1986 (Date of entry into force: 16/06/1989)

States	Ratification registered	States registered	Ratification
BOLIVIA	11.06.90	GUATEMALA	18.04.89
BRAZIL	18.05.90	NORWAY	04.02.92
CAMEROON	20.02.89	SPAIN	02.08.90
CANADA	16.06.88	SWEDEN	02.09.87
ECUADOR	1 1.04.90	UGANDA	27.03.90
FINLAND	20.06.88		

Total ratifications: 11

Source: ILO

The agreement on Asbestos was appended by the "Recommendation on Safety in the Use of Asbestos" in June 1986.

3. Environmental aspects and health hazards due to Asbestos

3.1 Introduction

In the discussions on environmental aspects and health hazards of Asbestos, the focal point is particulate generation (fiber emissions) and inhalation of fibers. Other process-caused environmental impacts (e.g. production wastewater, energy consumption, etc.) from the further processing of Asbestos to marketable products are not mentioned here.

The environmental hazards of Asbestos are primarily in the form of health impairments. The carcinogenic effect of asbests from inhalation of microfibers has been scientifically confirmed in many studies. Asbestos is classified as particularly carcinogenic in the Hazard Group I of the German Hazardous Substance Ordinance (chrysotile at a mass content 2 than 2%, amphibole Asbestos 2 0.5%. Additionally, there are confirmed results on the so-called fibrogenic effect of Asbestos, by which scar tissue forms as a result of Asbestos inhalation. As a consequence, functional tissue of the lungs is destroyed and connective tissue increases.

3.2 Asbestosis

The hazard of Asbestos is due to the size and shape of the fibers. The prerequisite for damage to humans is the occurance of Asbestos particulates which can enter the lungs. Such fibers have aerodynamic diameters at or below 7 micrometers, whereby the aerodynamic diameter is about 3 times larger than the actual diameter (IACS). The resulting health damaging effect has been recorded since the beginning of this century. In 1927, the term "Asbestosis" was assigned to the symptoms of a lung disease, and referred to the chronic lung disease with a change in the lung tissue due to the fibrogenic effect of Asbestos. Asbestosis ends frequently with lung cancer, in which case Asbestos is the promoter or co-carcinogenic agent.

In 1955, the significant link between Asbestos exposure and lung cancer was first confirmed scientifically. Another Asbestos-caused form of cancer, the mesothelioma of the pleura and peritoneum, has been researched since 1960.

In the Federal Republic of Germany the described diseases were recognized as occupational sicknesses (1936: Asbestosis; 1943: Asbestosis in combination with lung cancer, 1970: mesothelioma of pleura and peritoneum).

Asbestosis has been known of and observed the longest. Its occurance is linked to the exposure of high fiber concentrations; the exposure period is extends from years to decades. The average latent time of Asbestos-caused lung cancer is considered to be 25 years. However, it must be considered that different factors can influence the outbreak of the disease. For instance, the danger of acquiring Asbestosis increases by a factor of 53, if in addition to Asbestos exposure the risk factor of smoking is present, since the main human protection mechanisms, e.g. the mucuciliar transport of fibers by the cilia, are not functional or at least strongly impaired. (IACS)

3.3 Mesothelioma

Mesothelioma of the lining of the pleura and peritoneum is one of the most malignant forms of cancer. The occurance is relatively seldom and stands in direct correlation with occupational exposure to Asbestos. From previous studies it is known that at least 70 % of the known cases were due to occupation. Characteristically, there is an extremely long latent period of up to 50 years; in general about 25 - 35 years is found and the minimum latent period is 20 years.

3.4 Other health hazards

The above named diseases can be considered the "classical" Asbestos-caused diseases. The cause-effect relationship has been confirmed. In contrast, there is not complete

epidemiological verification of this relationship for other diseases (malignant tumors e.g. of the urinary bladder, the gastrointestinal tract, the larynx, the esophagus), whose causes are traced to Asbestos handling. Due to the complexity of the cause-effect relationships and the multitude of other possible influences, a selective causal relationship between Asbestos exposure and the listed diseases is very hard to methodically prove.

Oral intake of Asbestos fibers is considered by some researchers to be another health risk. An existing Asbestos contamination of drinking water from geogenic background contamination can be differentiated from that due to Asbestos containing cement pipes. Asbestos cement pipes have been used for drinking water conduits and for wastewater sewers for over 100 years. They contain about 10-15 wt.-% Asbestos fibers, usually chrysotile. The possibility that Asbestos fibers will be released and enter the drinking water is given through mechanical and chemical wear. For instance, the layers can be damaged through the grinding effect of sand. In 1974 the American Water Work Association investigated the danger of fiber release from intact pipe connections and could not find any evidence for this. However, in old pipes (> 30 a), particularly unlayered pipes, and/or as a consequence of a pipe burst (e.g. due to frost), continual or periodic releases of Asbestos fibers can occur. An elevated Asbestos fiber release rate is particularly expected with the presence of chemically aggressive water. It has been proven that the binding of hardened Asbestos cement can chemically react with different liquids and gases (for example with NH4+ and Mg-salts, high sulfate-concentrations, humine acids, carbonic acid, etc.). The strength of the cement matrix can be reduced through the reactions, and the binding impaired or partly destroyed by the dissolution of individual components. As a consequence, a significantly higher amount of Asbestos fibers can be released. To prevent this process, it is recommended to exactly determine the drinking water chemistry with respect to pH and carbonate saturation.

International literature on oral intake of Asbestos fibers via the gastrointestinal tract and the resulting effects has grown to nearly 200 works (Martels/Schormann, in Asbest-

Handbuch, No. 4570, Asbest im Trinkwasser und ihre Bewertung (Asbestos in Drinking water and ids Evaluation)). Epidemiological studies on the effects of oral intake of Asbestos fibers have been performed in different countries, in particular Canada and the U.S.A., without being able to prove significant relationships to increased cancer cases or increased mortality, although in some cases very high Asbestos fiber values in drinking water were present (up to several million fibers per liter) (UBA-Reports 5/91). These investigations can be distinguished as follows:

- **Asbestos contamination through natural sources (Quebec-Study, San Francisco-Bay-Studies, Puget-Sound-Study)**

- **Contamination by Asbestos mining (Duluth-Studies)**

- **Contamination of drinking water by Asbestos water pipes (Utah-Study, Connecticut-Studies, Florida-Study)**

Only the San Francisco-Bay-Studies (Kanarek, Conforti et al.) provide through the results of linear regression analyses indications of a causal relationship between cancer of the gastrointestinal tract and the oral intake of Asbestos fibers through water, food and beverages. However, since these results are overlaid with a number of other factors, the explanation of the factor "oral intake of Asbestos fibers" for the cancer arisings is doubted by a number of scientists.

In the Federal Republic of Germany the measured Asbestos fiber concentrations in drinking water range from < 5,000 up to 60,000 fibers per liter (UBA-Report 5/91). However, it should be noted that these fiber concentrations cannot be viewed as representative for Germany, since they are the result of 38 samples.

Numerous investigations confirm that the Asbestos concentrations in drinking water vary greatly from that in the air. They are generally much thinner and shorter than in the air

(median values for the fiber length are between 0.5 ym and 0.8 km in water, the diameter lies between about 0.03 ym and 0.08 ym). The amount of fibers potentially released from the water into the air (e.g. by showering, cleaning, etc.) is largely agreed by all researchers to be classified as relatively unhazardous to the health. Research performed in the U.S.A., however, shows that with very heavily Asbestos-contaminated drinking water (fiber concentrations between 10(6) and 10(13) FA), fiber concentrations in the surrounding air inside houses were found up to 52,000 F/m³ (in comparison: in residential buildings with low Asbestos-containing water only 7,600 Faser/m³),. and the outdoor air of these very heavily contaminated houses showed values of up to 20,000 F/m³. Within buildings peak values of up to 240,000 F/m³ (during vacuuming) were measured.

With regard to the arising health hazard, it should be pointed out that due to the shorter fibers, the danger of intake through inhalation is decreased. (Usually fibers had lengths < 0.5 km; the average fiber length was FL = 0.61 ym; for comparison: in the few less contaminated residences FL = 0.81 ym). Nevertheless, with the optimistic assumption of just 2 % of the fibers having a length > 5 ym, a contamination of cat 1,000 F/m³ is calculated, which represents the tolerable value for a lifelong contamination as defined by the German Federal Health Agency (Bundesgesundheitsamt).

3.5 Risk determination

There is no way to directly measure the health risks, in particular the cancer risk, caused by Asbestos fiber concentrations in the environment. A risk quantification is only statistically possible through evaluation of sickness data or mortality numbers of persons occupationally subjected to Asbestos. Based on relationship known for over 50 years, there have been longterm investigations on this question, in Germany particularly through the Employers Associations for Accident Insurance (Berufsgenossenschaflen). Usually, however, direct measurement of Asbestos concentrations at the workplace is no longer possible, since due to the relatively long latent period, the past working conditions can

only be approximately reconstrued. Through such experiments, the Asbestos fiber concentrations can only be estimated, and particular experimental conversion factors are scientifically applied. Additionally, a number of other factors play a significant role in this relationship, as described.

The investigations indicate that the Asbestos concentrations in the workplace in the '30s and '40s were a factor of 3-4 higher than the typically found Asbestos concentrations today, which originate primarily from old Asbestos contaminations. The emission from Asbestos processing has been greatly reduced, due to the strict legal regulations and the resulting limitations or prohibitions in use.

Table 10 presents the results of measurements of the ambient concentration of critical Asbestos fibers (> 5 ym in length, < 3 ym in diameter and ratio of length to diameter > 3:1) in Germany during 1984 and 1989. Table 11 provides further results of outdoor air measurements of Asbestos.

Table 10: Asbestos Fiber Concentrations

Concentration (F/m³)	
50 - 140	in the area of use of Asbestos cement corrugated sheets
50 - 150	in urban areas, including those noted with elevated traffic density
80 - 350	in the area of factories processing Asbestos fibers

Source: Central Employers Association for Accident Insurance (Hauptverband der Gewerblichen Berufsgenossenschaflen), St. Augustin, Germany

The range of Asbestos fiber concentrations resulting from various activities is evident in Table 10. Asbestos cement products which were used outdoors, typically as roofing or as

facade sheets, are considered to be relatively low health risks, as are indoor wall and ceiling coverings made of Asbestos, given the following limiting conditions: no mechanical processing occurs; the Asbestos is firmly bound in a cement matrix; and the binding in the matrix has not been impaired by age or mechanical wear. For outdoor air, Asbestos cement sheets on roofs and facades currently represent the most important emission source in Germany. This can vary from country to country, however. For instance, products of friction (especially Asbestos containing brake linings) in urban areas with elevated traffic in countries which have not prohibited such brakes, can lead to high fiber releases. This is apparent from the Table 11.

Table 11: Asbestos Fiber Concentrations

Fiber Concentration (F/m³)	**Areas**
< 100	rural areas
100 - 200	urban areas
100 - > 300	immediate vicinity of Asbestos emitters
to > 20 Million	exhaust from Asbestos containing car breaks with compressed air or from abrasive cutting of Asbestos containing materials
to > 500 000	roofing as well as drilling work on Asbestos cement
occasionally > 20.000	indoor air: in areas of sprayed Asbestos (depending on the condition of the material's surface)

Source: UBA-Report 5/91 - changed

The health risk due to Asbestos fiber concentrations can only be quantified on the basis of

case numbers. As shown in Table 12, nearly 70% of the compensated occupational illnesses in Germany between 1978 and 1986 were caused by Asbestos. Therefore, Asbestos is the primary carcinogen in the workplace. It should be noted that due to the long latent period, an increase in the reported occupational illnesses caused by Asbestos may be expected in the future. This holds for both Asbestos-caused lung and larynx cancer as well as for mesothelioma.

Table 12: Occupational Illnesses for which Compensation has been Paid in the Federal Republic of Germany during the Period of 1978 - 1986

Cause	**Number of Cases**	
	no.	**%**
Asbestos	1,021	68. 5
aromatic amines	149	10.0
quartz	66	4.4
pitch, tar, tar oil	54	3.6
benzine	38	2.5
chromates	38	2 5
uranium. decay products	28	1.9
oak and beach wood dust	22	1.5
halogenated hydrocarbons	20	1.3
arsenic and compounds	16	1.1
halogenated ether	12	0.8
others	29	1.8
Total	1.491	100

Source: Central Employers Association for Accident Insurance (Hauptverband der Gewerblichen Berufsgenossenschaften), St. Augustin, Germany

Table 13: Mortality Risk of Various Activities and Occurances

	Individual Risik per Year	Average Risk per 1,000 Persons/Year
automobile accidents	2.2 E - 04	0.22
fire and explosions	3.7 E - 05	0.037
30 mrem radiation exposure	1.5 E - 05	0.015
accidents in the home	1.2 E - 05	0.012
therapeutical, medical or surgical treatment	6.3 E - 06	0.0063
electrical shock	5.0 E - 06	0.005
1000 Asbestos fibers/m³ (Mesotheliom)	1.2 E - 06	0.0012
struck by lightning	4.4 E - 07	0.00044
bites and stings (from poisoness animals)	1.2 E - 07	0.00012

Source: Umweltbundesamt (Publ): Asbestos - Construction Material, Health Risks, Report 5/91 of the UBA, Berlin 1991

Table 13 compares the mortality risk associated with mesothelioma caused by Asbestos fiber inhalation with other risk factors.

In general, the risk of becoming ill from Asbestos depends on the following factors:

- **age during exposure,**
- **length of exposure,**
- **fiber concentration,**
- **type of Asbestos.**

It is not possible to define limits below which health risks can be entirely excluded. For this reason, the goal is always to achieve a minimal Asbestos fiber exposure. New research in the U.S.A. particularly emphasizes the health hazards from amphibole Asbestos and pleads for a general prohibition of this type of Asbestos.

In summary, the following has been determined:

- **The health risk from the inhalation of Asbestos fibers which can reach the lungs is generally considered critical and is undisputed worldwide, with few exceptions. The actual health hazard depends on further factors (type of Asbestos, exposure length, fiber concentration, age during exposure, other stimuli (e.g. smoking), etc.).**

- **The health risk of oral intake of Asbestos fibers from Asbestos contaminated drinking water has not been as well researched and is currently the focus of further studies. Past investigations have reached different interpretations.**

- **According to the current research findings, a release of Asbestos fibers from liquid media (drinking water, beverages) into the surrounding air is only regarded as potentially critical to the health for extremely high fiber concentrations in the liquid (>> I million fibers/liter).**

- **For industrial uses of water with high Asbestos fiber concentrations, particularly in industrial cleaning processes, there is a danger of high Asbestos concentrations in the outdoor air. This area has not been researched very much.**

4. Application areas of Asbestos materials and Asbestos products

4. 1 Introduction

Due to the material properties of Asbestos, there are a large number of application areas. Asbestos is an excellent insulation and binding material and a component of numerous building materials. The start of industrial use of Asbestos dates back to the last century. The number of marketable Asbestos products is estimated as several thousand. (see IACS, p. 1.1)

The most important application areas for Asbestos were:

- **surface materials**
- **prefabricated products for heat insulation**
- **textiles**
- **cement type products for building construction (Asbestos cements): cement pipes (also in drinking water supply facilities) and cement sheets**
- **paper products**
- **roofing materials**
- **tiles**
- **wall paneling**
- **paints/coatings**

- **friction products (brakes, clutches)**
- **pipe wrap made of sprayed Asbestos**
- **membrane and filter technologies, separators, gaskets**

4.2 The meaning of composite fibrous materials

The main application area of Asbestos is currently in the area of composite fibrous materials. These are materials in which fibers are bedded in an unorganized form in a continual matrix of a second material. Such composite materials combine the mechanical properties of fibers, such as the high tensile strength, in an ideal way with the properties of the matrix (anisotropic properties, pressure resistance, easy manufacturing). The basic prerequisite for the manufacturing of a composite fibrous material is a good bonding between the individual fibers and the material of the continual matrix, so that the tension in the material is conveyed to the fibers, thereby ensuring that their mechanical properties are usable.

The great advantage of Asbestos is that it occurs in nature in fine fibers and does not have to be manufactured in extensive processes - such as in the case of glass fibers. Furthermore, Asbestos fibers adhere well to cement, so that there is a conveyance of the tensions in Asbestos cement to the fibrous portion. These properties, as well as the high thermal stability, the electrical properties and the low price, have led to a wide spread of Asbestos containing materials and insulation materials in the building construction area.

4.3 Asbestos in the building construction area

The quantitatively most important use of Asbestos is without a doubt in building construction materials. There it is differentiated between tightly bound Asbestos (nonfriable Asbestos) and weakly bound Asbestos (friable Asbestos). In Asbestos cement

products, Asbestos is tightly bound by cement, and the Asbestos fraction is generally < 15 %). In sprayed Asbestos and similar Asbestos products, Asbestos is only weakly bound with at the same time a relatively high weight fraction of up to > 60 wt -% Due to this weak binding, Asbestos fibers can be released to the environment in relatively high amounts from weathering or even light mechanical impacts.

4.3.1 Asbestos in Housing Construction

The use of sprayed Asbestos and similar Asbestos products with a very high fraction of Asbestos (generally > 60 wt.-%) is particularly problematic. Large amounts of Asbestos fibers can be released from these sources. Preferred areas of application for these materials were or are: (UBA-Report 5/91)

- **fire protection, e.g.**
wood wrappings, fill between ceilings, electrical wiring shafts, inner coatings for roofs, ceilings, and walls, covering of openings, wrapping of air shafts and ventilation pipes near fire shutters, etc.

- **vibration protection, e.g.**
ceilings and wall coatings, inner coatings of ventilation pipes

- **thermal protection and humidity protection, e.g.**
coatings of ceilings, fire extinguishing blankets, wrappings of steam and water pipes and boiler units

- **other uses, e.g.**
gaskets, safety curtains, storage masses in heat recovery units, ventilation pipes made of sheets, hot pads for pots

Products made of friable Asbestos are considered the greatest source of risk and are

largely no longer permitted in the construction sector. Therefore, in the following, only nonfriable Asbestos materials are considered, which in particular are used in the form of roofing. The most important of these products are Asbestos cement corrugated sheets and Asbestos cement sheets.

Due to the high tensile strength of Asbestos fibers, which is achieved in spite of their fineness, Asbestos fibers are a favored reinforcing material for cement products. The resistance to tearing of e.g. chrysotile is like that of iron wire. Asbestos fibers are hollow, which accounts for their insulation capacity and the good attachment with all binding materials. Asbestos fibers do not burn, have a high melting point and are largely insensitive against chemicals. They are resistant to alkalis, salts, alcohols, mineral oils, and tar, and do not corrode and are resistant to dry gases.

Asbestos cement products show in general a limited resistance against moss formation, fungus accumulation or moulding. They are not resistant to acids, vegetable oils and fats, solutions of magnesium salts, sulfates, ammonium salts, iron chloride, warm distilled water and hot condensed water. Other harmful agents are chlorine, sulfur dioxide and smoke over long periods.

4.3.2 Asbestos in Water Mains

In water mains Asbestos cement pipes are particularly relevant due to their many technical properties. Asbestos cement pipes are normed for DN 65-600 and up to PN 16. The high tensile strength of Asbestos fibers (750-2250 N/mm²) permits their use as reinforcing material in cement pipes.

The deciding criteria in the use of Asbestos cement pipes are the resistance against inner and outer corrosion for most soils and waters, the low weight for small nominal diameters, the simple manufacturing of the pipe joint, the mobility lengthwise, the

bendability in the sockets and also the smooth pipe wall. The inner pressure of Asbestos cement pipes is generally 10 bar, or a maximum of 16 bar.

Aside from the health hazard, other negative aspects to be mentioned are: the low bending tensile strength, the very low breaking elongation, and the sensitivity against additional stresses primarily for small nominal diameters. In addition, special care is required for the transport and bedding of the pipes, and the pipeline fittings are partly made of other materials. Special measures are needed to take up the axial forces, and an additional effort arises for the processing of cut pipe ends, since the equipment must be permitted (prevention of Asbestos dust).

The application areas for Asbestos cement pipes are primarily in soils with relatively high corrosiveness and in rural areas. However, Asbestos cement pipes are not more resistant to corrosion than concrete pipes. In developing countries, primarily the H2S-corrosion of cement-bound materials needs to be considered.

<TOC5>> 4.4 Other application areas

Aside from the structural elements and other construction products, the so-called friction products are an important application area for Asbestos. These are primarily in the form of Asbestos containing brake and clutch linings, which are to some extent still found in numerous countries.

The many mechanical, physical and chemical properties of Asbestos have generated many additional application forms. Table 14 presents an overview of these Asbestos containing products. In total, Asbestos manufacturing (manufacturing of Asbestos containing products) amounts to about 30 - 40 million tons per year (1985).

Table 14: Summary of Asbestos Containing Products

Product	**Average percent Asbestos**	**Binding Agent**	**Period of Use**
Friction products	50	various polymers	1910 - present
Plastic products			
Floor tile and sheet	20	PVC, asphalt	1950 - present
Coatings and sealants	10	Asphalt	1900 - present
Rigid plastics	< 50	Phenolic resin	? - present
Cement pipe and sheet	20	Portland cement	1930 - present
Paper products			
Roofing felt	15	Asphalt	1910 - present
Gaskets	80	Various Polymers	? - present
Corrugated paper pipe wrap	80	Starches, sodium silicate	1910 - present
Other paper	80	Polymer, starches, silicates	1910 - present
Textile Products	90	Cotton, wool	1910 - present
Insulating and decorative products.			
Sprayed coating	50	Portland cement, silicates, organic	1935 -

		binders	1978
Trowelled coating	70	Portland cement, silicates	1935 - 1978
Preformed pipe wrap	50	Magnesium carbonate, Calcium	1926 - 1975
Insulation hoard	30	silicate	
Boiler insulation	10	silicate	unknown
		Magnesium	1890 - 1978
		carbonate, calcium silicate	
Other Uses	< 50	Many types	1900 - present

Source: US-EPA Asbestos Waste Management Guidance - Generation. Transport, Disposal; 1985

Comment: The stated dates are to be taken relatively and can vary depending on the country; the term "present" indicates that these products can still be found.

Due to the combination of material properties, Asbestos is also used in street construction, in the manufacturing of rubber and tires and in the production of vehicles, airplanes and ships.

Table 15 shows the main uses of chrysotile Asbestos and their typical trade classifications.

Table 15: Usual Trade Classification of Chrysolite Asbestos

Classification*	Description	Primarily used for:

1	Crude 1	Woven textile, protective clothing, gasket
2	Crude 2	High quality It-sheets
3	Spun fiber	Pressure pipes, filters, etc.
4	Slate fiber	It-sheets, Asbestos cement sheets, pipes and formed pieces of pipe, gasket, Asbestos paper, spraying Asbestos, etc.
5	Long cardboard fiber	Asbestos cement sheets, Asbestos pipes, Asbestos singles, Asbestos cardboard for example for cushion-vinyl-lining, brake lining and clutch lining
6	Cardboard fibers	Clutch lining
7	Short fibers	Asbestos cardboard, friction lining, PVC-floor lining, and for casing of welding electrodes, etc.
8	Sand and waste	

***) Classes 1 and 2 refer to hand-picked unprocessed Asbestos pieces with fibers of more than 19 mm (Crude 1) and of cat 9.5 to 19 mm lengths (Crude 2); Classes 3-8 refer to Asbestos qualities according to mechanical processing (milled fibers): Classification according to normed sifling methods of the QAPA (Quebec Asbestos Producers Association).**

Source: Frank, K.: Asbestos Hamburg 1952, (cited from the UBA-Report 1180)

5. Occupational safety measures in handling Asbestos

The following alternatives are principally available as safety measures against fine Asbestos dust:

5.1 Suitable fiber binding

Since fine Asbestos particulates arise with every type of mechanical processing of Asbestos containing materials, it is necessary to reduce the release of fibers as far as possible by suitably binding them in the matrix. This can be achieved by selection of a suitable binding agent or through the lowest possible fiber amount (fiber number / unit weight).

Due to the very weak binding of sprayed Asbestos, it is one of the most hazardous applications. In most countries sprayed Asbestos is no longer permitted to be used. A relatively strong fiber binding is found in all Asbestos containing flat packing materials, in which the fibers are bound with elastomeres. In the relevant Technical Guidelines for Asbestos (Technischen Richtlinie fur Asbest, TRGS 517), it is therefore assumed that the exposure is below the limit when working with pressing and cutting tools. Other examples of Asbestos containing materials with relatively strong fiber binding are:

- grouting compounds, which are used in the electronic industry for the manufacturing of collectors

- yarns or bands impregnated with rubber or artificial resin, which are further processed by wrapping, calendering, pressing and hardening.

5.2 Wet operations

In many cases the release of fibers can be reduced by technical measures in processing the materials, for instance, by using slow running saws, instead of the abrasive cutter typically used in the past.

A further reduction in the release of fibers during the processing of Asbestos containing materials is achieved through the use of so-called wet operations. The following

techniques are representative:

1. The processing of wet mixtures on calenders and form presses in the manufacturing of Asbestos cement, gaskets, friction linings, grouting compounds and filters;

2. The cutting of wet materials, e.g for construction parts made of Asbestos cement;

3. Forming and other processing of Asbestos cement products while wet;

4. Interweaving of moist Asbestos yarn.

However, with all of these techniques it must be noted that after drying, the material remains on the processing tools tend to release more fibers, and therefore special safety measures are needed during cleaning.

5.3 Enclosure

The best control of fine Asbestos dust exposure is achieved through enclosure of the working area. This prevents people from direct contact with Asbestos fibers and prevents fibers from reaching areas where people are situated. Enclosure is primarily used in the feeding of raw Asbestos to mixing and stirring plants for the manufacturing of materials. This process can be described as follows:

1. Asbestos fibers are brought in air-tight plastic sacks to the feeder.

2. The closed sacks are opened automatically in special facilities.

3. The Asbestos fibers are transported from the feeding point in closed conveyor systems to the processing point.

4. After the mixing process, the Asbestos fibers are embedded in moist binding agents,

and additives and are brought in this state to the manufacturing station.

These process methods are state of the art for nearly all areas, such as production of Asbestos cement, friction linings, yarns, gaskets, and filters, as well as manufacturing of intermediate materials (mixtures, nonwoven, formed fabric, etc.).

In addition to the use of closed circuits, the avoidance of the generation of fine Asbestos dust in the processing of Asbestos containing materials is also possible through enclosure for discontinuous systems, e.g. automatic stamping, pressing and other mechancical processing operations in the manufacturing of e.g. gaskets and friction linings at stations with tool feeding and retrieval equipment. These processes can be characterized as follows:

1. The processing stations at which Asbestos dust arises are encapsulated dust-tight.
2. The operating personnel stand outside of the capsule.
3. The arising Asbestos dust from the processing is vacuumed up by an air exhaust cleaning unit.

A regular and careful cleaning of the processing station within the enclosure is important in order to prevent an accumulation of easily releasable fibers.

5.4 Vacuuming of dust near the point of origin

The processing of Asbestos containing materials to products, such as gaskets, brake and clutch linings, is only conditionally feasible in closed circuits or in the above-described enclosure. If in these cases, a nonpermissable generation of fibrous dust cannot be achieved through adequately strong binding of fibers in the materials, the arising dust must be directly vacuumed up at the processing point.

The main attention must be on the design of the vacuum element, which guarantees on the

one hand that the fine dust does not reach the breathing area of the operating personnel, and on the other hand that the view and tasks of the operating personnel are not impaired. The vacuum element must also be fitted to the special requirements in each case. Basically, the vacuum elements should be positioned on the opposite side of the dust source from the operating person, so that the dust is vacuumed away from the breathing area.

With stamping and pressing machines, the machinery cleaning must be considered. These operations are generally not adequately performed by vacuuming, so that mechanical cleaning procedures are necessary. The cleaning of the machines should not be performed with compressed air guns.

If vacuuming directly at the site of origin is not possible or not adequately effective, an appropriate room ventilation system must be installed. The system of air conduction should be arranged in such a way that the personnel do not work in the stream of contaminated air. The efficiency of the room exhauster is typically less than that of vacuuming directly at the point of origin. With local dust accumulation, an uncontrolled elevation of concentration can temporarily arise.

Generally, the vacuumed air is permitted to be returned to the working area only under strict requirements. Stationary facilities of this kind require permits. The approval of the supervising authority (Trade Supervision Authority, Employers' Association for Accident Insurance) is only given in exceptional cases.

Financial studies show that direct vacuuming at the dust source is typically the less expensive alternative. The safety rules for air quality facilities at the workplace must be followed in operating the exhaust system.

5.5 Limiting the areas in which Asbestos dust may arise

Work areas in which Asbestos or Asbestos containing products are processed cannot typically be kept completely free of Asbestos dust, at least not through room air exhausting.

For this reason, such areas must be labelled and isolated so that the exposure cannot be carried over to neighboring rooms. This presumes an areal separation between Asbestos operations and others. Whether air transfer tubes are needed to prevent the spread of contaminated air depends on the individual case. Frequently, a slightly lower pressure in the contaminated area is sufficient.

The Asbestos particulates exhausted from the operating stations and rooms must be cleaned in particulate filters before being released outdoors. Filtering separators are used for the cleaning of Asbestos contaminated exhaust. The guideline value for the cleaned air emitted is defined as 0.1 mg/m³ in the Technical Instructions on Clean Air (Technischen Anleitung zur Reinhaltung der Luft).

5.6 Personal respiratory protection

If the required purity of air at the workplace cannot be maintained through technical or operational means, the workers at the workplace must wear respiratory protection. This basically applies when:

1. The particulate concentration exceeds the guideline value of 1x106 fibers/m³.

2. The limit of 0.25 X10^6 F/m³ is exceeded, and due to the process or the spatial and climatic conditions, elevated intake of fine Asbestos dust may occur via the lungs.

The wearing of respiratory protection should not be a permanent protection measure.

5.7 Regular and thorough cleaning of workplaces

The importance of regular and thorough cleaning of workplaces has already been emphasized by most of the safety measures. Which cleaning intervals need to be maintained depends on the operational circumstances. It is recommended to exactly prescribe the frequency based on experiences and measurements at individual workplaces and to monitor the compliance. This applies especially to work with rewards depending on productivity. Special attention should be given to the compliance with applicable regulations of the Employers Association for Accident Insurance (Berufsgenossenschaften).

The cleaning of workplaces is not only a technical and supervisory problem. Priority should be given to developing awareness of the problem among the workers through training and provision of information.

5.8 Dust-free waste collection and landfill disposal

Asbestos fibers and dust wastes. as well as Asbestos containing materials waste arising during the processes, and Asbestos containing dust from filters must be collected in dust-tight containers. In order to avoid unnecessary transferrals, these containers should also be usable for transportation.

For fine-grained Asbestos containing wastes, plastic bags with sufficient sturdiness can be used. Rough-edged pieces of waste should only be collected and transported in containers. For example, sealable drums in which the raw materials were delivered would be suitable. Furthermore, it should be tested whether moistening can further reduce particulate release. The wastes should be brought to permitted landfills under dust-free conditions. The further treatment should be negotiated with the responsible authorities.

6 Aspects of Asbestos abatement and disposal of Asbestos containing materials

Before Asbestos abatement using different methods is performed, it must first be clarified

whether or not Asbestos materials are present. This trivial question represents a frequent problem in the practice of investigating old sites. Since in the developing countries specialized laboratories for definite microscopic determination of Asbestos fibers are not available in some cases, it is recommendable to analyze the building materials used. In Annex 5, examples of different Asbestos containing building materials are listed.

A visual investigation of the applied building materials by trained personnel is recommended as a first survey of potential Asbestos containing materials. Particular attention should be paid to fibrous and easily breakable building materials. The main application areas for Asbestos containing materials (see Part II Chapter 4) should be particularly investigated during the visual inspection.

Identification of the particularly hazardous sprayed Asbestos can also be performed visually to some extent: "Sprayed Asbestos is a white-gray, gray or gray-blue typically soft material which can be indented by the finger. The surface is typically scarred, even if it is protected with laitance or paint." (UBA-Report 5/91).

6.1 Evaluation guidelines on the urgency of abatement

The Asbestos Guidelines (Guidelines for the Evaluation and Abatement of Friable Asbestos Products in Buildings) describe the procedure for Asbestos abatement in Germany. These guidelines have proved effective in practice and are presented below.

On the basis of these rules the following criteria play a rule in evaluating the urgency of abatement:

- **Type of Asbestos use**
- **Type of Asbestos**
- **Surface condition of the product (structure/damage)**
- **Impairment of the product from the outside**

- **Use of room**
- **Position of the product**

The investigated object is assigned a grade on the urgency of abatement based on the above criteria.

The following urgency levels exist (see Evaluation form on the following page):

Urgency Level I	(>= 80 Points)	Abatement is required without delay
		Such uses pose a definite hazard in the sense of Article 3 of the Framework Building Ordinance (Musterbau-ordnung). If abatement is not immediately possible, measures should be quickly undertaken to reduce the hazard by reducing the Asbestos fiber concentrations indoors. The final abatement should begin within 3 years.
Urgency Level II	(70-79 Points)	Abatement is required in mid-term.
		A repeated investigation and evaluation is required at intervals of at most 2 years.
Urgency Level III	(< 70 Points)	Abatement is required in the long-term.
		A repeated evaluation should be performed after a maximum of 5 years.

The form for the evaluation of the necessity of abatement with the weighting of individual criteria is presented on the following page. It is well-designed for a practical risk estimation.

6.2 Asbestos abatement techniques

After the urgency of abatement has been checked, abatement can basically be performed according to 3 methods:

Method 1: Removal

The removal of Asbestos is preferred when the Asbestos product has the following characteristics:

- poor physical condition,
- frequent repairs needed,
- exposed to vibrations and impacts,
- simple geometric form,
- necessary prerequisites for these methods are present (e.g. sufficient space for the removal technique and for the health and safety measures),
- no violations of necessary and required regulations concerning protection against fire, heat, noise or vibrations would result due to the elimination of the Asbestos product.

Standard Form for the Evaluation of Priority of Removal (Annex 1 of the Asbestos Remediation Guidelines)

Line	Groupe	Asbestos Products - Evaluation of Priority of Removal		
		Building:	Evaluation*	Corresponding Evaluation

				Grade
		Room:		
		Product:		
	I	**What kind of Asbestos hag been used?**		
1		Sprayed Asbestos	O	20
2		Asbestos containing wall finish	O	10
3		Lightweight Asbestos containing slabs	O	5
4		Other Asbestos containing products	O	5-20
	II	**Kinds of Asbestos**		
5		Blue Asbestos	O	2
6		Other Asbestos (white, gray)	O	0
	III	**Condition of surface/structure of Asbestos product**		
7		Loosened fiber structure	O	10
8		Firm fiber structure with or without sufficiently sealed surface cover	O	4
9		Laminated, sealed surface	O	0
	IV	**Surface condition/damage of Asbestos product**		
10		Heavy damages	O	6
11		Light damages	O	3
12		No damages	O	0
	V	**Exposure to wear / damages of Asbestos product**		
13		Damages of product due to direct access (floor to reaching height)	O	10
14		Occasional works done at product	O	10

15		Product is exposed to mechanical impacts	O	10
16		Product is exposed to vibrations	O	10
17		Product is exposed to extreme climatic changes	O	10
18		Product is exposed to excessive air flow	O	10
19		Excessive air circulations in room with Asbestos containing products	O	7
20		Improper operation may cause wear of product	O	0
21		No external damage to product possible		
	VI	**Room use**		
22		Room is used regularly by children, youths, athletes	O	25
23		Room is permanently or frequently used by other persons	O	20
24		Room is used temporarily	O	15
25		Room is rarely used	O	8
	VII	**Location of Asbestos product**		
26		Directly in room	O	25
27		In ventilation system of room (lining or jacket of leading ducts)	O	25
28		Behind a suspended unsealed ceiling or panel	O	25
29		Behind a suspended sealing ceiling or panel. behind dustproof lining or lamination. outside of tightly sealed ventilation ducts	O	0
30	**Total Points of Evaluation**			
	Removal:			

31	urgently required	(Urgency level I)	O	80
32	required	(Urgency level II)	O	70-79
	long range project	(Urgency level III)	O	70

*** Check. when applicable. If more than one item was checked in one group, use only one - the highest evaluation figure. when total is calculated (Line 30).**

Method 2: Encapsulation

This Asbestos abatement method is generally preferred if the Asbestos product:

- **has sufficient resistance to ripping,**
- **has a hard, sealed surface,**
- **is not worn through repairs and physical impacts,**
- **has a complicated geometric form,**
- **is hard to reach,**

or

- **if the Asbestos product cannot be removed for reasons of protection against fire, heat, noise and /or vibrations.**

Method 3: Enclosure

Is to be applied, if the Asbestos product:

- **is in perfect physical condition,**

- **is located on easily accessible building parts with simple geometric forms and dimensions which are not too large,**

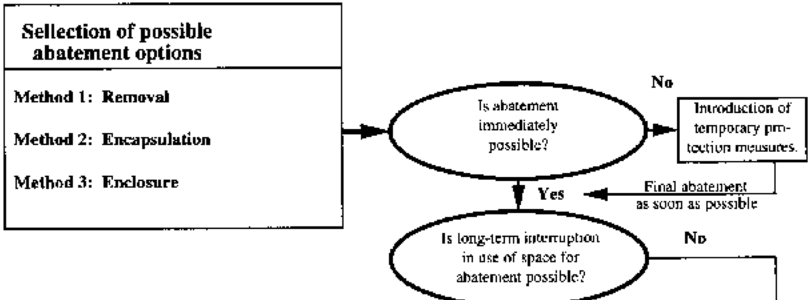
- **lies in an area endangered by physical impacts,**

or

- **if the Asbestos product cannot be removed from the site for reasons of protection against fire, heat, noise and/or vibrations.**

The following page presents the decision process for the selection of the Asbestos abatement method to be applied.

The selection of the abatement method is primarily dependent on the condition of the Asbestos containing material. The removal of the material is appropriate in most cases, as long as the listed restrictions are not the determining factors. Removal is also the only permanent solution. With the other two methods of enclosure as well as encapsulation, it should be noted that in a later state, e.g. during building demolition, the Asbestos containing material will have to be removed. From this standpoint, both of these latter methods represent only a time-limited intermediate solution.



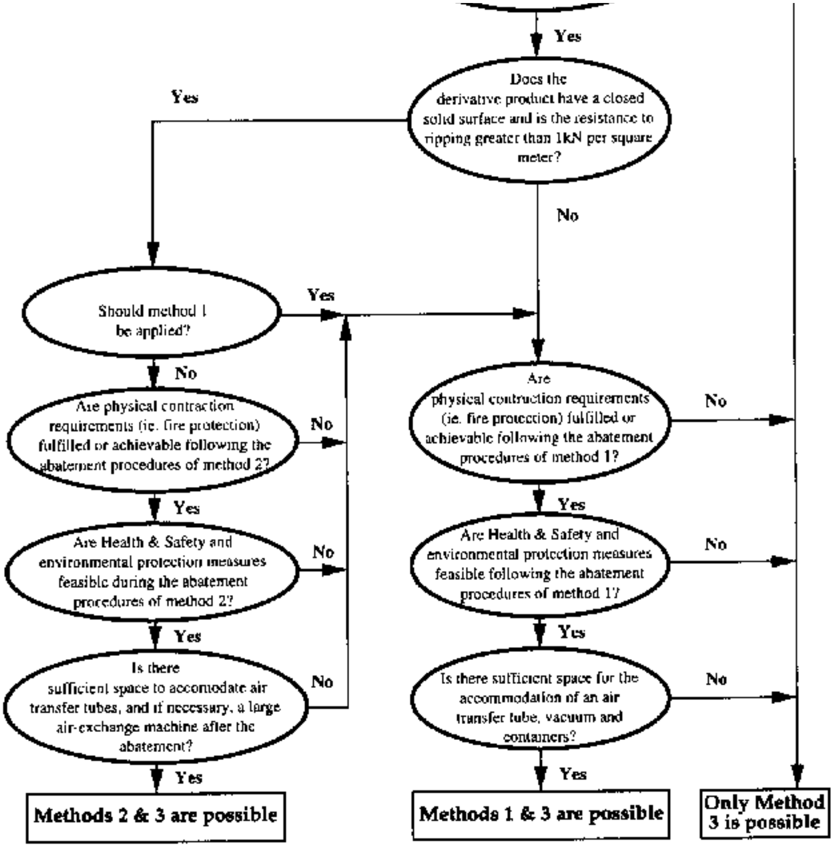


Figure 3: Selection of the Potential Abatement Method

Furthermore, enclosure can only be applied, if it is possible to isolate Asbestos containing

materials in narrowly defined regions. Additionally, it must be noted that constant and regular inspections are necessary or ensure proper health protection.

With encapsulation, it should be considered that in some cases the later removal of the Asbestos containing substances might be more difficult and therefore more expensive.

In general, the abatement methods "encapsulation" as well as "enclosure" should only be performed, if the Asbestos containing materials are in good condition.

Aside from these rather general considerations, the actual case is certainly decisive, namely: which Asbestos containing materials in which amounts and in which condition are to be abated under consideration of relevant secondary considerations (e.g. form of use).

In Annex 6, the advantages and disadvantages of the individual abatement methods are summarized together in a table from the US EPA Guidance For Controlling Asbestos-Containing Materials In Buildings, 1985.

6.3 Disposal of Asbestos containing materials

Although nearly a complete substitution of Asbestos containing products is currently possible, in the future further increases in the arisings of Asbestos containing wastes are expected, since many of the products produced in the past are nearing the end of their lifespan. Asbestos abatement projects are another source of Asbestos containing wastes.

The main portion of Asbestos containing wastes arise from building materials (Asbestos cement and sprayed Asbestos). For a long time the disposal situation was such that these materials could be mixed with other building debris in a more or less carefree manner, and be deposited at landfills for building debris and excavated soil, (IACS, S. 12.1) without provision of measures against dust formation and possible Asbestos fiber release.

Just the more recent national and supra-national legislation considers the hazard of Asbestos containing wastes. The Basel Convention against cross-boundary transport of wastes, for example, lists Asbestos containing wastes in the catalogue of substances to be controlled. The EC-Guideline 78/319/EEC from 1978 also categorizes Asbestos dust and fibers as hazardous wastes. The federal German waste legislation treats Asbestos dust and sprayed Asbestos as wastes requiring particular supervision according to Article 2 Para. 2 of the Waste Law (§ 2 Abs.2 AbfG). The foreseen disposal paths are: deposition at a special waste landfill or domestic waste landfill, as well as chemical/physical treatment.

Based on the environmental relevance of Asbestos containing substances, there are no arguments against the deposition at domestic waste landfills, since no special measures are necessary regarding discharge of leachate with subsequent potential soil and groundwater contamination. The environmental relevance of Asbestos containing wastes arises from the health damaging effect from Asbestos exposure. For this reason, fiber emissions during the disposal are to be minimized. There are relatively simple possibilities for this minimization of emissions:

- **Encapsulation with binding agent (cement)**
- **Reduce dust by maintaining wet conditions**
- **Transport Asbestos containing wastes in closed containers**

The German States' Working Group on Wastes (Landerarbeitsgemeinschaft Abfall, LAGA) have published instructions on the disposal of Asbestos containing wastes with the following recommendations:

1. Abestos containing wastes are not reusable/recyclable.

2. The incineration of Asbestos containing wastes is not allowed.

3. Asbestos dust and wastes with friable Asbestos and other Asbestos containing wastes

in which Asbestos fibers can easily be released are to be treated so that they can be disposed of at domestic waste landfills or mono-landfills. The treatment includes basically the encapsulation with hydraulic binding agents, if possible at the site of origin.

4. Wastes with nonfriable Asbestos fibers should be kept moist until they are deposited at the landfill (mono or domestic wastes), in order to avoid dust generation.

In summary, the transport and disposal of Asbestos containing wastes should be performed using measures to prevent dust development and the release of Asbestos fibers. Firm binding, e.g. with cement, is recommended for the final deposition.

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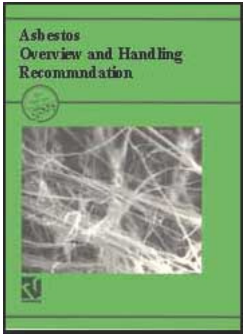

Asbestos Overview and Handling Recommendations (GTZ, 1996)

Asbestos Overview and Handling Recommendations (GTZ, 1996)

Part III. Asbestos substitutes

1. Technical requirements for Asbestos substitutes

Due to the intense discussions about the environment in recent years, extensive efforts have been made to find substitutes for Asbestos containing materials.

The requirements on the substitutes are given by the physical-chemical properties of the Asbestos product to be replaced, which strongly depend on the technical area of application. The wide breadth of application areas for Asbestos has led to many substitute products. The German Environmental Agency (Umweltbundesamt, UBA) commissioned Battelle-Institut e.V. Frankfurt with the compilation of a catalogue of Asbestos substitutes, which was published in 10-volumes in 1985. According to this work, in spite of the unique properties of Asbestos, there are Asbestos-free alternatives for nearly every application. This is because not all of the properties are required for the individual applications, but rather the dominating characteristic for the application must be substituted. The following matrix provides useful information:

Table 16: Technical Properties of Asbestos Containing Materials Depending on their Binding in the Material

Area of Application	**Fiber Form**	**Mechanical Properties**		**Chemical Properties**		**Thermal Stability**	**Insulation**		**Specific Friction Characterisiti**
		Tensile strength	**E-Modulus**	**Alkalines**	**Acids**		**Thermal**	**Electrical**	
Asbestos in inorganic matrix									
- Asbestos cement	+	+	+	+					
- Fire proof sheets	+	+	+						
- Spray compounds	+	+	+						
Asbestos in organic matrix									
- Friction lining	+	+	+	+	+				
- Gasket	+	+	+	+	(+)	(+)			
- Plastic reinforcement	+	+	(+)	(+)					
Asbestos products with little binding									

- Asbestos textiles	+	+	+	+					
- Asbestos cardboard and paper	+	+	+	+					
- Filter materials									

Legend + of prime importance (+) for special products of importance

Source: Schreiber: Asbest-Ersatzstoffe, in: IACS, Page 13.4

2 Properties of typical Asbestos fiber substitutes - Overview

From the previous discussions it is apparent that Asbestos can be substituted in most application areas by other fibrous materials. These can be natural or synthetic fibers. Primarily those fiber types listed in Table 17 come under consideration.

Table 17: Fiberous Materials for Asbestos Substitution

		Wollastonite
	inorganic fibers	Attapulgit
Natural Fibers		Sepiolite
		virgin wool
	organic fibers	cotton
		cellulose.

		flax and hemps
		crystalline fibrous materials:
	inorganic fibrous	- steel
	materials	- carbon fibers
		- SiC-Whisker
		- polypotassium titanate
		amorphous fibrous materials:
		- textile glass fibers
Synthetic		A-glass, C-glass, D-glass,E-glass, R-glass,
fibrous		glass, Z-glass
materials		silicic acid fiber
		-non-textile glass fibers (insulating fibers)
		glass wool,
		mineral wool,
		ceramic wool
		polyester
	organic fibrous	polyaramide
	materials	polytetrafluoroethylene
		viscose
		polypropylene
		polyacrylnitale

Source: Schreiber: Asbest-Ersatzstoffe, in: IACS, Page 13.4

Applying the Asbestos property matrix shown in Table 16 to the potential Asbestos substitutes results in the property matrix for the substitutes presented in Table 18.

Table 18: Technical Properties of Asbestos Substitutes

Fibrous Materials	**Mechanical Properties**		**Chemical Properties**		**Specific friction Characteristic**	**Thermal Stability in C Degrees**				**Insulati**
	Tensile strength	**E-Modulus**	**Alkaline**	**Acids**		**350**	**550**	**750**	**1250 and >**	**Thermal**
Inorganic amorphous										
Fibrous materials										
Textile glass fibers	+	(+)			?		+			+
A-Glass					+					
C-Glass										
D-Glass										
E-Glass										
R-Glass										
Z-Glass				+						
silicic acid fibers	+	(+)			(+)			+		+
non-textile glass fibers	(+)	(+)			?					+
ceramic wool				+					+	
glass wool							+			

glass wool										
rock wool and mineral										
wool					(+)			+		
Inorganic crystalline										
fibrous materials										
Steel	+	+	(+)		+ ?					
Carbon fiber (highly resistant, highly modular)	+	+	+	+	+ ?				(+)	
Carbon fibers (Pitch Type)	+	+	+	(+)						
Carbon felt										(+)
Potassium titanate										(+)
Silicium carbide-Whisker	+	+	+							
Organic fibrous materials										
Polyester	+	+		+						+
Polyaramide (Arenka)	+	+	+	+	+	+				+
(Kevlar 49)	+		+	+		+				+
Polytetrafluoroethylen										
(Teflon)	+		+	+		+				+
Polyacrylnitrile	+		(+)	+						+
Plovaramide (Nomex)	+		+			+				+

Viscose (Reyon)	+				+					+
Polypropylene	+		+	+						+

Legend + suitable (+) conditionally suitable ? possibly suitable
Source: Schreiber: Asbest-Ersatzstoffe, in: IACS

The main result of this section is that particularly for the quantitatively important applications of Asbestos, namely

- **fire protection,**
- **thermal insulation,**
- **structural elements, construction products (Asbestos cement products),**
- **friction products,**

substitutes are available which enable the replacement of Asbestos. The respective health risks of the substitutes must be specially investigated.

Table 19: Areas of Application for Fibers and Filling Materials as Asbestos Substitutes, their Price Range and Health Effects

	Health & Safety	Fire Proof	Thermal Insulation	Electrical Insulation	Gasket	Filtration	Friction linings	Constructio Prod.
Textile glass fibers	+		+	+	+		+	
SiO2- fibers	+	+	+	+	+			
carbon fibers					+		+	
Non-textile glass								
fibers	+		+		+	+	+	+

Ceramic fibers	+	+	+	+				
Gypsum fibers			+					
Wollastonite	+		+	+			+	+
Attapulgit								
Sepiolite								
Polyacrylnitrile						+	+	+
ox. PAN	+		+			+	+	
Vinylal/Polyvinylalcoh.								+
Polypropylene				+	+			+
Polytetrafluoroethylene				+	+	+		
Aramide	+	+	+		+		+	
Woo	+	+						
Cotton	+			+				
Cellulose-fibers					+	+	+	+
Flax and hemp								(+)
Mica					+		·	
Talk					+			
Bentonite							+	
Diatomite							+	

+ substitutes are available (+) restricted possible uses 1) ++substantially cheaper + cheaper • similar prices - more expensive - - much more expensive n.d. no data 2) (Carcinogenic effects were defined based on the critical diameter range): + not critical -

critical -- very critical n.d. no data

Source: Schreiber: Asbest-Ersatzstoffe, in: IACS. Page 13.9 - expanded -

Table 19 shows a summary of the application areas of Asbestos substitutes and information on their carcinogenic effects. In Germany, the recent controversial classification of glass fibers with particular characteristics as carcinogenic, according to the TRGS 905 of May 1995, could potentially influence application areas for glass fibers.

For detailed information, the substance catalogue of UBA and the substitute list of the Federal Institute for Occupational Safety and Accident Research (Bundesanstalt fur Arbeitsschutz und Unfallforschung) are referenced.

The current state on Asbestos substitution is presented in the following table. The product groups can generally be divided into two classes:

- **Product groups with complete substitution possibilities;**
- **Product groups with partial substitution.**

Table 20: Possibilities for Asbestos Substitution Product Groups Area of Use

Fibrous/filling material	**Inorganic synthetic fibers**	**Inorganic natural fibers**	**Organic synthetic fibers**	**Organic natural fibers**	**Non -fibrous filling material** **- lamina (flakes)** **- particles**	
Health & Safety	Personal thermal resistant	Thermal resistant glass	Flat textile prints	Materials for specific workplaces		

	clothing					
Fire proof	Fire proof boards & surfaces	Spraying compounds, insulating plaster	Plastic masses, paints, cement and filters, fire proof mortar	Cardboard, cords, fleeces inorganic foam(pastic) material fire protection cushion	Textiles - fire extinguishing blankets - curtains	Protective clothing for fire fighting
Heating insulation	Boards & surfaces	Inorganic spraying compounds	Material for filling joints and cavities	Formed parts and moulding compounds	Textile products	
Electrical insulation	Wire and cable	Insulating materials	*moulding compounds*	Household appliances		
Gaskets	*Static* *- flat gaskets*	*Dynamic packaging*	*Cylinder* *- head gasket*	Heating gas gasket	Compensators	
Filtration	*Liquid filtration fine and sterile filter media, filtering aid media*	Gas filtration/ ventilation process air dust collection	Respiratory filter for respirator	*Diaphragms, separators*		
Friction Lining	*Disk brake*	*Drum brake*	*Brake soles*	*Brake lining*	*Clutch lining*	

	lining	*lining*		*for industrial use*		
Construction elements (Asbestos cement)	Small formatted flat boards	Small formatted corrugated board	Pipes for underground construction - pressure pipe - sewer pipe	Pipes for household and property drainage - ventilation - waste gas	Landscaping	
Chemical products and others	Paint materials and filler	Adhesive materials, gasket compounds, cement	Special products with asphalt or tar matrix	Moulding compounds with plastic-matrix(duro plastic)	Moulding compounds with synthetic material(thermoplastic)	

Note: Since Asbestos substitutes (other substitute products) are now available, the use of Asbestos products is therefore no longer necessary.

Source: Schreiber: Asbest-Ersatzstoffe, in: LACS, Page 13.14

3 Fiber substitutes for Asbestos fibers in the building area

In the building area Asbestos primarily is applied in the form of Asbestos cement, so that the most effective substitution is with Asbestos-free fibers (hereafter referred to as substitute fibers - SF- or substitute fiber cement - SFC).

After trials with plant fibers, such as flax or hemp, it was found that such fibers are not very appropriate because of their swelling capability and their low resistance against

microbes. Steel fibers, on the other hand, are not appropriate due to their poor dispersing ability in the cement matrix. Trials with polyamides, such as nylon or perlon, also had to be given up after a longer period.

Very promising trials have been performed with polypropylene fibers, which bind extensively with cement. Presently, the following are mainly used as reinforcement for fibrous cement: polyacrylic fibers, such as Dolan 10 fibers, plastic fibers made with polyvinylalcohol or also cellulose fibers. In addition, non-textile glass fibers and wollastonite fibers are used. The spectra of properties of these types of fibers are described in the following sections.

3.1 Non-textile fibers made of glass wool rock wool and mineral wool as well as ceramic wools

Glass fibers produced with diameters in the range of 0.1 pm to 20 pm have become particularly important. Since lengthwise fracturing is not to be expected, these fibers only conditionally lie within the range for penetration to the lungs. Based on their compatibility, the residence time in the organism is relatively short.

Application areas for these mineral fibers are in the loose form in stuffing insulations, mats, felts and sheets, as well as in fibrous filling materials in the areas of fire protection, thermal insulation, noise or vibration insulation, filtration, friction linings and also chemical products and fibrous cement.

Glass fiber concrete (Heidelberger Zementwerke AG) is made of a cement-bound matrix and alkali-resistant, highly firm glass fibers. This material produced in a mixing concrete process has very good properties, especially for facade elements, because of its high bending tensile strength, high impact resistance, corrosion resistance and its good ductility. Its relatively low weight and high fire resistance (Fire Class Al) enable the manufacturing of complicated and multi-functional building parts.

3.2 Wollastonite

The inorganic natural fiber wollastonite is a calcium metasilicate with a chain structure consisting of at least 96.5 % CaO and SiO2. The fiber diameter ranges from 10 pm to 100 pm; under mechanical wear a fracturing into fibrous pieces with diameters as small as 0.1 pm is possible. Critical diameter ranges can be prevented through the use of appropriate production methods, however.

Wollastonite is used as filling material in the areas of fire protection (sheets), thermal and electrical insulation (sheets, fill for moulding material), friction linings, structural elements and other construction products, chemical products and others (paints, glues and moulding material).

3.3 Cellulose fibers

Fibers made of cellulose are used as additives in building products to enable the dispersion of synthetic fibers in the cement matrix.

An example for the application of cellulose fibers which is under development is a so-called fiber cocktail, consisting of cellulose and cellulose fiber acting to disperse polyvinylalcohol or polyacrylnitrile fibers in the cement matrix (Eternit AG). Through special processing procedures, an orientation of the fibers is also achieved, which leads to an improvement in the mechanical properties.

3.4 Polyacrylnitril

Organic synthetic polyacrylnitrile fibers (PAN-fibers) can be manufactured for technical applications with a diameter above 18 pm. They therefore lie outside the range penetrable to the lungs. A lengthwise splitting under mechanical wear is only conditionally possible. PAN-fibers are used for reinforcement in the areas of filtration, friction linings, structural

elements and other construction products (as reinforcement up to 2 % in fibrous cement), etc..

3.5 Polyvinylalcohol (PVA)

Organic synthetic polyvinylalcohol fibers (PVA - fibers, PVA fraction at least 85%) can be made water insoluble through combination with aldehydes. The fiber diameters typically lie between 10 pm and 20 pm and are therefore not penetrable to lungs. Data on the lengthwise splitting do not exist, however it may be assumed that this does not occur. PVA- fibers are applied in the building area for reinforcement of fiber cement products (Fraction 2 %).

3.6 Polypropylene (PP)

Organic synthetic polypropylene fibers (PP - fibers) can be manufactured with diameters of 20 pm to 100 pm and are therefore not penetrable to lungs. Lengthwise splitting is not to be expected. The fibers are applied in the areas of gaskets and structural elements and other construction products, particularly fibrous cement. Trials with fiber mats and fiber fleeces showed, however, that due to the arising separation of layers between mats and cement paste, no satisfactory results could be achieved. In Europe only Moplefan (Italy) still manufactures fibrous cement sheets from short-fibered PP fleeces or PP - fiber and cement paste.

3. 7 Summary

The fiber substitute technique has not yet reached the standard of quality of Asbestos fiber reinforcement. Deficiencies, such as frost uplifting and fine fissures from thinning of fibers, occurred particularly with corrugated SFC products.

Aside from several disadvantages which SF have over Asbestos fibers, such as reduced

binding and higher price, the new SFC products also have advantages, such as higher elasticity and easier processing.

The mechanical resistance of fibrous cement products is dependent on the mixture of ingredients, which is different for each application area, and on the particular manufacturing process. The maximum temperature resistance lies around 150°C.

As with Asbestos fiber products, SFC products have generally limited resistance against moss formation, fungus collection and mold. This is true to the same extent for Asbestos containing and Asbestos-free products. They are also impaired by acids, vegetable oils and fats, magnesium salt solutions, sulfates, ammonium salts, iron chloride, warm distilled water and hot condensed water. Chlorine, sulfur dioxide and smoke also act destructively over long periods.

SFC products, however, resist alkalis, salts, alcohols, mineral oils (bitumen), and tar. They do not corrode and resist dry gases.

Cement contains free unbound alkali metals, which partly separate during the hardening process, and lead to the formation of hydroxyl ions in aqueous medium. (Cement reacts as an alkaline substance).

These characteristics also apply for housing construction and water pipelines, with the limitation that no adequate SFC pipe products have been found for high pressure requirements.

Aside from SF substitutes, other fiber-free substitutes are usable in the building area, and their application is especially gaining importance in housing construction and water pipeline construction. Their possible applications are therefore discussed in the next two sections.

4 Fiber-free substitutes in construction area

4.1 Fiber-free substitutes in housing construction

In housing construction the substitution of Asbestos containing products in roofing is of primary interest, since the release of Asbestos fibers from weathering is particularly critical. Therefore, substitutes for these application areas are presented below.

4.1.1 Material made of rock and ciay

- **Roof slate**

Roof slate is a natural sedimentary rock with fine-grained texture, which can easily be split into thin plates in one plane. Its color is usually blue-gray to black-blue, seldom blackish, reddish, greenish or whitish. In general, the following quality requirements are made:

1. The slate should easily be processed, split, axed, holed, or sawed, without resulting in large splittings.

2. It should largely be flat, have a smooth surface and an even grain size, because then the area of attack is smaller; the break should be thin-leaved.

3. The highest resistance to breakage is advantageous, nevertheless the hardness should not be too great.

4. Hair splits and visible inclusions (nodules, veins) should not be present.

5. Color fastness, i.e. even lightening and no spotty changes.

Chemical analyses are also used for the evaluation of roof slate, since its durability and

structural properties depend greatly on the chemical composition. While the large presence of silicium and aluminum-compounds improves the quality of slate, its quality is impaired by the presence of lime, pyrites and carbon in higher quantities. The feldspar in slate belongs to the minerals which relatively quickly break down under weathering influences. With roof slate, therefore, the requirement of very weather-resistant mica layers is of great importance: if these form thick congruent layers, then the damaging substances (carbonic acid, sulfuric acid) from the air and rainwater cannot penetrate, and the slate can be durable even in urban areas in spite of lime and pyrite contents. Weathering effects consist primarily of color changes, moss growth, leafing and complete degradation.

- **Roofing Shingles**

Roofing shingles are flat, ceramic construction parts for the covering of sloping roof surfaces. They are formed out of clayey compounds, in some cases with additives, and are fired in an oven. Roofing tiles formed out of concrete, plastic, metal or other materials are not roofing shingles. For the manufacturing of high quality wall or roofing shingles, the use of appropriately dosed clay mixtures is a prerequisite. Since the correct clay mixture is seldom found in mining, the desired ratio must be prepared in centrifuges by the addition of quartz sand or its washout.

The shingles can contain components which greatly reduce the quality, if they were not removed or neutralized. Such impurities are in particular: calcium carbonate (mussels, snails), quartz fragments and various salts. These substances are dehydrated during the firing and can then absorb water again when in contact with humid air, thereby potentially leading to fine fissures, swelling and even the destruction of the whole shingle (particularly through frost effects). Overly sandy clay mixtures also promote growth of lichens and algea. The shingle material must have a fine grain size for frost resistance. Nevertheless, the shingles should have a particular porosity enabling active breathing,

which to a small extent leads to water permeability. Bending and pressure resistance should be high, but should not negatively influence the weight of the shingle. Additionally, roof shingles should not flake, engobe and glaze must be durable, and the color even.

The quality of roofing shingles can be determined visually. One can judge the tendency for fissures, the water conductance as well as the color, surface density and surface condition. The resonance test provides an indication of the hardness of the shingle, which depends on its density and the length or intensity of the firing. Good shingles have shrill tones, their coloring does not rub off, they have sharp fracture edges, and their inclusions should not be above a grain size of I mm.

- **Concrete roofing tile**

Concrete roofing tile is a flat or synclinal covering element with or without grooves. The basic components of concrete roofing tile are sand, cement and water. The sand must have adequate hardness and resistance to weathering. Therefore, prepared quartz sands and Portland cement as the binder are primarily used. Depending on the final product, the mixing ratio of cement to sand ranges from about 1:3 to 1:3. 5.

Substances damaging to cement, such as salts, sugar-containing and humic substances, acids, gypsum, and soft rain water, reduce the quality. In particular, salty liquids form bonds with cement components. The resulting swelling pressures generally lead to damage through bursting. Sugar-containing and humic substances are much more dangerous than salts, since even in low concentrations they have a negative impact on the hardening of the binder. Therefore, the purity of the sand used must be assured.

Another problem is posed by cement swelling, which arises from the dissolving effect of soft rain water and in an extreme case leads to destruction of the cement structure. In contact with acidic solutions, crumbling of the concrete occurs. However, to a certain degree cement can be made resistant to damaging substances through treatment with

silicones, fluorine compounds or bitumen.

Due to the manufacturing in long-stringed machines, complicated forms and grooves are not possible, the joint seal is limited along the length sides to two-sided double-ribbed grooves, while for the head seal only double supporting ribs are present. The joint seal is improved, though, through a high precision in size and a low plasticity.

Missing head grooves and the simple lengthwise grooves are often problematic in regard to weather resistance. Concrete roofing tiles are not very resistant to heavy rain and snow and are therefore categorized in the lower range for weatherproofing. High expectations on the water-tightness of roofs cannot be met, particularly when the lowest roof slope and lowest height of covering are used.

Water-tightness and frost resistance of concrete roofing tiles themselves are generally assured by the fine sand grains, the manufacturing and the additional steam hardening.

Concrete roofing tiles do have high resistance to breakage and high bearing strength, at least according to the values of the norm examinations. On the other hand, this resistance leads to difficulties in processing. With large formatted concrete roofing tiles, the otherwise advantageous accuracy to size is disadvantageous in the stone plane, since through vibrations of the roof construction in the case of strain there is little flexibility between the coverings, so that particularly the stone edges break off easily.

The weight of the roofing tile itself and the net weight (without safety addition) is relatively high at 40 to 55 kg/m². Therefore, special attention should be paid to the design of the supporting construction

4.1.2 Building metals

- **Iron/Steel**

Iron is the most widely used metal in the technical field, due to the good availability of the raw materials (iron ore, energy supply) the adjustable profile of characteristics through different alloy additives, the versatile processing possibilities and the excellent mechanical properties (in particular the high tensile strength, shearing resistance and bending resistance.

For roofing, galvanized steel suspension sheets are suitable (Class I 0.2 to 0.6 mm thickness, zinc coating at least 0.022 mm thick), which generally are also coated with synthetic resin, or for special requirements are also enamelled with polyvinyl fluorides or PVC, AMMA or PVF sheets.

Steel suspension sheets can bridge breadths of up to 8 m. Their useful width varies depending on manufacturer and profile type and lies between 610 and 1035 mm. They must be laid out so stiffly, that they do not buckle when walked upon and do not bend more than 1/300 under the highest permissible straint. For this reason, roofing sheets should be at least I mm thick and have an adequate profile. Roof areas should have a continuous decline up to the water drain. Therefore, a minimum slope of 15° is often required.

Corrosion promoted through humid air and oxygen containing water is problematic for roofs made of steel suspension sheets. Rust promoting agents are also acids and most salt solutions; consequently, smoke, sodium chloride, salt water, and binders such as magnesite mortar and gypsum. On the other hand, bases protect iron and can stop or reverse the destruction which has already begun. This fact enables the joint use of iron and cement, since the cement acts as a base. Lime loses its rust-protecting property through carbonation during hardening.

Damage through contact erosion can primarily occur with copper and tin, and to a small extent lead as well. Cast iron and highly alloyed steels do not rust as easily as pure iron

types. Stainless steel is the only totally corrosion-free type, however.

There are two possibilities for corrosion protection- one is constructive measures and the other is special surface treatments (galvanic or spray coverings, rust protection coatings).

- **Aluminium**

Aluminum is rather soft and very easily molded. It is also resistant against water and air, due to the formation of a firmly binding and durable oxide layer. Sheets with a typical thickness of 0.7 mm and 0.8 mm are used for roofing.

Aluminum is attacked by most acids, and particularly by lye, and must be protected against them. Thus, lime and cement or concrete act destructively towards aluminum, particularly during the hardening phase. Aluminum is compatible with gypsum, however. Aluminum reacts sensitively in the presence of electrolytes (water) in contact with other metals (contact corrosion). Zinc, cadmium and rustproof steel are compatible. Appropriate surface treatment through pickling or artificial oxidation can protect against corrosion and chemical attacks.

The importance of aluminum lies in its low weight, the good thermal and electrical conductivity and the adequate alloy possibilities. For the construction industry its weather resistance, good warm and cold forming characteristics and the possibility of numerous types of binding (riveting, welding, soldering, gluing) make the metal interesting.

The lower strength compared to steel can usually be increased through special alloys, or compensated for through special construction methods. In addition, the savings in weight of aluminum constructions compared to those of steel is about 50%.

- **Zinc**

Zinc is generally only applied in the form of alloys as sheets for roofs, roof gutters and rain collection pipes.

Through its manufacturing, alloyed strip zinc has anisotropic material characteristics. Hence it can be somewhat better trimmed perpendicular to the direction of rolling. The strength of zinc sheet is largest perpendicular to the direction of rolling.

In air, zinc forms a protective oxide layer, which essentially protects the metal from corrosion. However, zinc is sensitive to acids and can be destroyed quickly by strong bases. In contact with more precious metals in an aqueous medium, contact corrosion occurs.

Zinc is valued primarily because of its comparatively low price and its normally high resistance to corrosion in clean air, giving it a lifetime of up to over 50 years in unaggressive atmospheres. There are zinc sheet roofs which have remained functional for almost 100 years. It is easy to handle in use, it can be easily cut, sawed, soldered and bent as well as embossed through heating. Due to its heat expansion, roof sheets and gutter elements must be movably placed.

- **Lead**

Lead is a light metal which is easily cut, rolled, pressed and embossed. Its heat conductivity is relatively low. The high coefficient of thermal expansion and the brittleness of the material forbid the rigid binding of longer sheets. The metal is so soft, that it only expands in a straight line to a small extent, and buckles up.

In the air, lead becomes covered with an oxide layer, which is barely soluble and therefore largely protects the lead from corrosion. Neither sulfur gases nor diluted carbonic acids are damaging to lead, even diluted hydrochloric acid does not affect lead. The sulfate or carbonate protective layer makes lead also resistant against contact corrosion.

Some organic acids, strong bases and distilled water are harmful to lead. Therefore, it should not come in contact with moist wood. In contact with quicklime or nonhardened cement, lead reacts very sensitively (localized corrosion) and must be protected against this by protective layers or bituminous coatings. Distilled water dissolves lead quickly. Lead is compatible with gypsum.

Lead and its oxides are toxic. Even low amounts are taken up by the body and stored. The result is lead poisoning.

- **Copper**

Copper is a very soft but relatively ductile material and is a very good thermal and electrical conductor. Alloys, which are widely possible, can reduce these properties and introduce significant changes. Pure copper has a tensile strength of about 200 N /mm² which can be increased by twofold through cold forming and even higher through alloy additives. The ductile material can be easily cold-formed and embossed. Copper and its alloys can primarily be soldered and welded.

Copper's durability in air and water is practically unlimited. It becomes covered with a dark brown, water insoluble layer of copper oxide, which protects it from further corrosion. Through the influence of sulfur dioxide or carbonic acids over time a very hard and weather resistant green protective layer forms of alkaline copper carbonate or copper sulfate. Strong acids (aside from hydrochloric acid) dissolve copper. Some organic acids form copper salts, which generally are toxic, such as verdigris induced by acetic, lactic or tartaric acids.

Damages to copper are limited to a few exceptions. Lime, cement and gypsum do not attack copper. The low damage through seawater is compensated by special alloys.

4.1.3 Building materials made of wood

Wood roofing with wooden shingles is among the oldest roof coverings, whereby only weather resistant types of wood come into consideration (Canadian red cedar, yellow Alaskan cedar, Chilean Alerce, beech and oak; also used are white cedar, pine and spruce, the latter primarily as wall shingles). The main advantages of wood as a building material lie in its good availability, easy processing, high resistance to aging and resistance against environmental impacts.

Without special constructive measures, wood is not a good insulator of heat, sound or vibrations, however.

In the selection of wood, attention should be paid to irregularities, such as crooked growth, irregular annual rings, strongly twisted growth, resin galls, shrinkage cracks, core cracks, internal annular shakes and frost cracks.

The good ability to process, particularly the easy splitting of wood, is due to the lengthwise structure of the plant cells. The strength of wood is strongly dependent on the water content and increases with increasing dehydration. Recently felled wood contains up to 50% wt moistness and should therefore not be statically burdened. Good values are around 10 to 15 %. The loading capacity of wood parallel to the grain is manifold that perpendicular to the grain. Basically, the tensile strength is larger than the pressure resistance.

Wood is very resistant against chemical impacts. It is not affected by diluted acids and bases and is superior to most metals in this aspect. Concentrated acids destroy wood, however. Oxygen has practically no negative impact, and wood is unlimitedly durable under water.

A negative trait is the swelling and shrinking of wood due to moisture changes, which can lead to significant changes in size. Cut pieces of wood often deform during drying. The swelling and shrinkage amount is less in the direction of the trunk axis and can generally

be neglected. All wood types are rather susceptible to fire, insects and fungus. The maintenance of the quality of wood through professional installation and protective treatment is as important as the corrosion protection for metals.

The destruction by insects occurs almost exclusively through insect larva. Some of the known fresh wood insects are:/pidae, Cerambycidae, and Siricidae. They do not reproduce in the wood of buildings, however, in contrast to the dry wood pests (Hylotrupesbajulus, termites etc.).

The outer appearance of the wood decomposing activity of fungus is termed rotting. Growth requirements are abnormal moisture and enough oxygen. Destruction types are corrosive rotting, destruction rotting and mildew rotting (e.g. Merulius domesticus)

As preventive protection measures against fungus, insects and fire, chemical agents can be applied, such as protective oils and salts.

4.1.4 Bituminous roof and sealing sheets

Bituminous roof or sealing sheets are flat coverings consisting of a support soaked and coated with waterproof substances (bitumen, tar). Good supports are crude felt, glass fiber quilt, spun glass fabrics, jute, metal supports (aluminum or copper foils), plastic foils and polyester fiber quilts. The sheets can be sprinkled with stones or stone dust or be coated with plastic foils.

The thermal conductivity (0.16 W/mK) is very low in comparison to other substances. Consequently, bitumen is a thermal insulator. The electric strength is high and the conductivity low.

The effectiveness of the bituminous sealing is based on its waterproofness and its deformability. The latter gives the sealing the capability of adjusting to small movements

of the building and its parts without impairing its effectiveness. Even the hardest bitumen qualities must be regarded as fluids, which can be plastically deformed and can therefore give with movements. This also means, however, that bituminous layers yield to sudden impact and thereby lose their binding. Because of this, there are strict guidelines for application, which must be adhered to in all cases: bituminous layers must be free of hollow space and lie on even surfaces and may not be burdened point-wise. Furthermore, bituminous layers may not be used to bridge movement joints.

Another important criterion are the thermoplastic properties of bitumen. These lead to the requirement that the thermal impact may only reach an upper value which is markedly below that of the softening point of the applied bituminous type. Bitumen reacts to even small elevations of temperature. Formation of ripples is the result. Free-lying bituminous layers become coated with particulates often containing aggressive substances, which affect the bitumen in addition to solar radiation and lead to premature aging and embrittlement of the uppermost layer. Net rips and circular rip formations then arise, as well as embrittlement through aggressive gases and rained-out contaminants. For these reasons bituminous sheets may not be left unprotected against weathering and may not be used as a single layer. They attain their sealing effect only through the homogeneous fusion of several layers.

Based on the above remarks, one notes that bituminous sheet roofs require very exact installation and careful maintenance and care (e.g. renewal of the protective coatings).

Bituminous roof shingles, whose lifetime is longer due to the very laborious installation, and bituminous corrugated sheets for light constructions and subordinate buildings are also used as roofing materials.

4.1.5 Plastic roofs

The multitude of different plastic types can be divided into three large groups, which basically differ according to their deformation properties:

1. Thermoplasts are thermally deformable, through solvents a softening to a lacquer-like condition is possible.

2. Elastomers are elastic like rubber bands, a lasting deformation is no longer possible after manufacturing.

3. Duromers are chemically hardened plastics, which cannot be plastically deformed, the processing must therefore be performed through machining. Duromers are very thermally resistant.

For the flat roof sealing the first two plastic groups are primarily applied. Plastic roofing sheets can be installed in single layers for flat roofs. The sheets should be at least 1.2 mm thick. So-called plastic foils are not suitable for sealing, they serve only as a separating and protective layer.

Among the currently most common plastic materials in the area of roofing, the following product types are found:

- **Polyvinyl chloride- PVC - soft**

On roofs, primarily soft PVC nb (not bitumen-compatible, Thermoplast) is used in the form of prefabricated sheets (width 1.2 m - 1.5 m). For protection against the lower-lying surface, a separating layer of crude glass fiber quilt or crude felt sheets is installed. Direct contact with bitumen or with particular plastic foams as thermal insulators is to be avoided, due to the danger of softener migration, ie. the migration of solvents used for softening in the manufacturing of PVC sheets. This migration results in shrinkage and embrittlement of the material.

The installation of roofing sheets proceeds loosely in connection with a gravel covering or a plate covering as superimposed load or as mechanical securement. The gluing of the seams occurs through solvent welding or through hot air welding, high frequency welding and heated wedge welding. Connections to other building parts can be attained with contact glues.

Under thermal impact over time, plastic foils regain their original manufactured size. The shrinking process associated with thermal impacts and the shrinkage due to softener migration require a mechanical fixation of the sheets at all roof edges, roof penetrations and connections. However, these effects can also be prevented by including a fabric insert in the foil manufacturing.

In building scalings the bituminous-compatible PVC-soft is currently increasing in use. Due to the lack of solar radiation, the feared softener migration does not occur in this area. Gluing is achieved with normal hot bitumen.

- **Polyisobutylene-PIB (Thermoplast)**

The processing possibilities are similar to those of PVC. However, PIB is always bitumen-compatible and can therefore be glued in the area with hot bitumen.

- **Ethylene, Bitumen- Copolymer- ECB (Thermoplast)**

Plastic roofing sheets out of this material, which is made from a combination of polyethylene and bitumen, enable a different application technique from that of the previously described Thermoplasts. Gluing is performed using the conventional methods.

ECB - roofing sheets can be glued in the area with normal gluing bitumen. Consequently, prefabrication of sheets and installation of these materials is not possible. The gluing of seams and joints can be performed with hot air welding. Due to the areal gluing with hot

bitumen, the underlying surface is first covered with an additional glass fiber quilt bituminous roofing sheet.

- **Chloropolyethylene- CPE (Thermoplast)**

This roofing sheet is also made of a modified thermoplastic polyethylene. It can be applied loosely under a heavy surface protection, whereby the seams and joint connections are sealed with solvent welding. PEC has a low strength, which is why fabric-strengthened roofing sheets are often offered.

- **Vinyl- Acetate- Ethylene- Copolymer- VAE (Thermoplast)**

The seams and joint connections of this bitumen-compatible plastic roofing sheet can be sealed with solvent welding or warm gas welding (hot air welding), whereby an additional protection with a VAE solution is necessary.

- **Isobutylene- Isoprene- Rubber- IIR (Elastomer)**

These roofing sheet can be installed in the form of prefabricated planes or also as sheets. The material has an excellent expanding and restoring capability, which however makes it tough to deform. This disadvantage has been compensated through the prefabrication of common formed pieces.

The sheets can be glued in the area with a modified bitumen. The sealing in the area of seams and joint overlaps is done according to the principle of cold vulcanization.

- **Polychloroprene- CR (Elastomer)**

Due to the technical application possibilities for installing roofing sheets of this basic material unglued or with bitumen gluing masses, this material can assume multipurpose

tasks. Aside from the possibilities of planes and sheets installation, this material can be used as an elastic interface between bituminous roof sealing and connections of all kinds. A connection with other plastic roofing sheets is not always possible, though. All seams can be sealed with a polychloroprene glue.

- **Ethylene- Propylene- Dien- Mixture- EPDM (Elastomer)**

The gluing of this material proceeds with hot bitumen glue on all conventional subsurfaces for the flat roof The seam connections are achieved with specially developed gluing tape.

- **Chlorosulfonated Polyethylene- CSM (Elastomer)**

These roof sealing sheets are suitable for bitumen and plastic gluing in the form of sheets and also as prefabricated planes. In order to guarantee good adhesion, these roofing sheets are generally delivered with a coating of fibers on the bottom side. Similar to PVC sealing sheets, the seams and joints are sealed with solvent welding or hot air welding. Additionally, all connection points can also be sealed with a foil cement.

As a fluid product, chlorosulfonated polyethylene can also be applied layer-wise with a roller, thereby enabling the application onto complicated building parts.

4.1.6 Reed and straw

Reed and straw are among the oldest roof coverings. Reed and straw are placed on roofing batten (typical cross-section 4 x 6 cm), which lie on rafters with an axial distance of about 1 m. Wire nails are used for securement of the raflers. To afix the reed and straw covering, wire is applied with which the roof can either be sewn or bound.

Reed grows everywhere on flat sloping banks of standing or slowly flowing waters and reaches 2-4 m in height. It should be ripe, leaf-free, thin stalked, straight stalked and well

cleaned. If professionally treated and processed, it has a lifetime of 40 to 50 years on the northern side and on steep roofs up to 100 years.

Rye and wheat straw must be fully grown, straight, as long as possible and well threshed. Machine threshed is not usable, because the stalks are beaten wide and broken. Good, well treated straw lasts on roofs 25 years and longer.

A disadvantage of reed and straw roofs is the hazard of fire. In order to reduce its flammability, one uses soaking substances to make the reed or straw incombustible to some degree, as well as sprinkler systems in order to protect the roof from flames. Protective measures against lightning need particular attention.

The susceptibility to weather is reduced by a steep roof slope. The steeper the roof, the longer the lifetime of reed and straw roofs, because a long covering by rainwater and snow is prevented, and the pulling effect of wind is reduced. The typical slope of the roofs is 45°, in windy areas such as coastal areas at least 50°.

Reed and straw roofs are inexpensive to purchase, however they require very careful installation. Mistakes such as too thin spots can be taken care of by recovering, but nevertheless leave unsealed spots, since the total binding is destroyed. The rotting and rusting of the binder can then slowly progress.

4.2 Fiber-free substitutes in water mains construction

The properties of materials used in water mains construction were already introduced in Section 4.1. Consequently, they are mentioned below only with respect to their application as pipe material.

4.2.1 Metal pipes

- **Steel Pipes**

Steel pipes have a high strength with great fracture strain and a high notch impact strength. Additionally, a shifting of forces and tensions is possible. The installation of long pipes and the line installation are feasible. Adjustment to the local conditions and heights by cutting and welding in situ as well as simple manufacturing of pipeline fittings and axial force closing joints make this material very popular.

Application occurs primarily where high strength and fracture strains are required, high inner pressures and high pressure surges are likely, and where large pipe sizes occur, for instance at supplier and long-distance pipelines and at special constructions, such as inverted siphons or intersections. Initially, seamless steel pipes were used, and with improvement in welding techniques, welded pipes have been applied increasingly. The seamless and welded pipes are available up to DN 500, above DN 600 only welded pipes.

Disadvantageous are the required corrosion protection measures, such as encasement and lining, since there is a high corrosion probability with insufficient encasement and inadequate protective lining. During transport, installation and bedding, additional measures for protection of the pipe wrapping are needed. For corrosion protection in the interior, cement mortar lining (DIN 2614) has proven effective. The earlier and still frequently typical bituminous coating has not proven successful. In pipeline fittings the cement mortar lining still presents problems, however. For the outer protection the polyethylene wrapping is used in general. Longer steel pipes are frequently protected cathodically. The electrical conductivity can be either advantageous or disadvantageous, depending on the application area.

- **Cast iron pipes**

The gray cast iron pipe has been in use for the past 500 years and was previously cast horizontally in two-part sand moulds and later standing in sand moulds. Since 1926

centrifugal casting has become prevalent. Pipeline fittings continue to be cast in sand forms. The important material progress occurred in 1965, when the ductile cast was introduced. The gray cast has a brittle fracture behavior, due to its morphology. However, through special melt additives one acquires the ductile cast, which is superior by its elevated fracture strain coupled with high strength.

The cast iron pipes are offered in 3 classes for water pipes, depending on the nominal widths DN. The corresponding permissible nominal pressure is determined from the nominal width.

The simple manufacturing of the pipe joints is advantageous, as are the bending ability and axial mobility in the joints. Particular measures are required for the uptake of the axial strengths, however. The pipe joints are usually not electrically conductive. Pipeline fittings are available in a wide sortiment.

With the change to ductile cast iron, the corrosion resistance of the gray cast iron has been lost, and hence the pieces must be protected like steel. The cement mortar coating (DIN 2614) is typically used for the inner corrosion protection. Suitable for the outer protection are: PE-encasement (manufacturing plant), cement mortar encasement (manufacturing plant), and PE-foil encasements for joints at the construction site; galvanizing by spraying with a bituminous covering or only bituminous covering may only be applied by proven non-aggressive soils.

4.2.2 Plastic pipes

In water supply mains, primarily polyvinyl chloride (PVC, free of softeners) and polyethylene (LDPE, HDPE) are applied. PVC is used mainly in distribution nets, while HDPE/LDPE-pipes are specially used for house connections and for supply lines of smaller nominal widths, e.g. in rural areas. The properties of both pipe types can be characterized

as follows:

- **PVC, softener-free**

An advantage is the resistance to corrosion, the low weight, the simple manufacturing of the elastically sealed plug socket joints, the axial mobility of the plug socket joints and a very smooth pipe wall.

Difficulties can arise with temperature fluctuations and extreme climate conditions. The sustainable tensions can become reduced depending on temperature and operation time. The impact sensitivity increases at temperatures c 5°C. Particular care must be taken during the bedding of the pipes. PVC pipes are very sensitive to external stress. Generally, there is a very low bending ability in the pipe joints. Furthermore, transition problems sometimes occur, since often the only pipeline fittings available are made of other materials.

- **LDPE (Low density PE), HDPE (High density PE)**

LDPE/HDPE-pipes are also very corrosion resistant and are often used because of their low weight. They are bendable (particularly LDPE) and are available as endless pipes, which are available on a ring or drum. Relatively long pipes are feasible which do not need bends and can be installed in narrow pipe beds. A very smooth pipe wall and an axial strength joint support the application of these pipes.

As with PVC pipes, the sustainable tensions are reduced in correlation with the temperature and operation time. At low temperatures marked stiffening can arise. The pipes are also very sensitive against local peak tensions (e.g. caused by sharp-edged stones or damage to the surface). Furthermore, the high thermal coefficient of expansion is also disadvantageous. In some cases, only pipe joints made of other materials are available.

4.2.3 Concrete pressure pipes

Concrete pressure pipes are mostly applied for supplying and long-distance pipelines having large nominal widths with low to medium pressures and few built-in components and fittings. The long period of use and the high resistance against inner and outer corrosion are particular advantages of this type of pipe. Furthermore, the static measurement can be determined exactly according to the local loads. The high resistance to denting is also positive.

Negative aspects are the high weight and the brittleness of the pipe material. A good deal of technical knowledge and knowledge of statics are needed, because no axial strength joints are possible, the fittings generally not being pre-tensed, but designed constructively in another fashion or available in steel. Difficulties can also arise through later manufacturing of bonds and through repairs. During the installation great care must be taken, particularly in making the bottom of the ditch and the pipe joints.

Nowadays the following concrete pipe types are primarily used:

- **Reinforced Concrete Pressure Pipes**

Reinforced concrete pressure pipes are mostly used as pressure pipes, protecting pipes or jacket pipes for holing-through and underground driving as well as sewer pipelines with pressures up to PN 2.5 bar. They are manufactured as jolted, rolled and spun concrete pipes with DN 250-4000 (and larger), lengths of 2.5-Sm and with unstressed ring and axial reinforcement.

- **Prestressed Concrete Pipes**

The reinforcement is prestressed in the ring direction, for which the winding process and

prestressing through core expansion are available. Generally, prestressing of the axial reinforcement is also performed. The diameters lie between DN 400 and 2500, the wall thicknesses are 55-150 mm, the construction length is 5m. The concrete quality of B 55 should be met or exceeded; typically a concrete strength 100 N/mm² is attained.