1.5 RECYCLING / RECOVERY

EPS can be treated in the most environmentally appropriate manner via a range of waste management options.

1.5.1 REDUCTION

It is a common misconception that many of our waste problems are caused by plastics. In fact, the total amount of plastics in our municipal solid waste is only seven percent by weight. Of this, EPS accounts for only a very small fraction – just 0.1 percent. EPS products used in the construction industry have a very long effective lifetime because of their durability, so disposal of the product is minimized.

1.5.2 RECYCLING / DISPOSAL SCHEMES

There are several options to treat EPS construction and demolition waste. Each with environmental, technical and economic implications to consider.

Generally the most beneficial is direct re-use by grinding clean EPS waste and adding it to virgin material during production. This waste can also be used to improve soil condition.

Alternatively, EPS can be melted and extruded to make compact polystyrene, for items such as plant pots, coat hangers and a wood substitute. Medium toughened polystyrene from which sheets for thermoformed articles, such as trays, can also be made. As part of mixed plastic waste, EPS can be recycled to make, for example, park benches, fence posts and road signs, ensuring the plastic material has a long and useful second life.

1.5.3 ENERGY RECOVERY

This involves the recovery of energy, usually in the form of heat from incineration. This gives EPS-waste a genuine post-consumer use. The calorific value of EPS available for heat recovery is slightly more than that of coal by weight.

In a modern incinerator, EPS releases most of its energy as heat, aiding in the burning of municipal solid waste and emitting only carbon dioxide, water vapour and a trace of non-toxic ash. The fumes are non-toxic and are not harmful to the environment as no dioxins or furans are emitted. The energy gained can be used for local heating and generation of electricity.

1.5.4 LIGHTWEIGHT CONCRETE

EPS is used successfully as an aggregate for lightweight concrete for both structural and thermal insulation applications. Optimum physical and thermal properties are achieved with low density spherical EPS aggregate due to it's effective "arching properties within the cement matrix, low moisture absorption to minimize water/cement ratios and maximum strength/weight ratios and a permanent uniform resistance to the flow of heat. Consequently, lightweight concrete containing EPS aggregate has captured a growing market throughout the world for such structural and thermal insulation applications including sandwich panels, precast concrete building systems, insulation roof fill and decorative architectural and landscaping products.

1.5.5 LANDFILL

Although currently a large proportion of EPS waste is disposed of in landfill, it is EPSASA’s least preferred option since it does not create a “second life” and is therefore not an optimal use of natural resources.

However, landfill-using EPS does bring advantages. EPS waste is inert and non-toxic, so the landfill site becomes more stable. EPS aerates the soil, encouraging plant growth or reclaimed sites. EPS does not degrade and will not leach any substances into ground water, nor will it form explosive methane gas.

2.7 TOXICITY

As discussed earlier it is difficult to predict the behaviour in fires from small-scale tests. The same considerations apply to assessing the hazards of gaseous emissions from burning materials. In practice, two approaches are follows; firstly the determination of thermal decomposition products and, secondly studies of their biological effects. It is necessary to combine the two approaches to obtain a realistic overall estimate of the hazards.

Although burning EPS gives off black smoke, the toxicity of the released smoke fumes is considerably less than those of other commonly used materials. This was already concluded in 1980 by the TNO Centre for Fire Safety for EPS in both standard and FR grades. Extensive research into the toxicity of smoke fumes from burning EPS has also been conducted in accordance with the DIN 53436 method which is a small scale combustion toxicity test, which gives results of relevance to full scale fires.

In this test, samples are heated respectively to 300, 400, 500 and 600°C. As well as various types of EPS, individual natural products such as pine wood, chipboard, expanded cork and triplex, rubber, felt and leather were also studied. The results are summarized in the table below. The smoke fumes from EPS appeared to be less toxic, or at most equally toxic to those from the natural products throughout the whole of the range. EPS itself scored very well based on equal volumes of the test samples, due to the extremely low density and lightweight of EPS (98% air). In addition, no negative effect on smoke development from the fire retardant was found in FR grades of EPS.

The table shows that insignificant amounts of carbon monoxide and styrene monomer are given off when EPS is burnt.

Their relative toxicity can be estimated from the figures for their acute inhalation-toxicity value (L/C_{50} inhalation period 30 min) of 0.55% v/v for carbon monoxide and 1.0% v/v for styrene. Thus, the acute inhalation toxicity of styrene is less than that of carbon monoxide, and its concentration in the EPS composition products is also less at elevated temperatures found in a fire. Carbon monoxide can be fatal if inhaled for 1 minute to 3 minutes at concentration of 10 000 p.p.m. to 15 000 p.p.m. Styrene has an odour which can be detected at 25 p.p.m and which becomes intolerable between 200 p.p.m and 400 p.p.m. This warns of the necessity of immediate evacuation of an area. Eye irritation and nausea may occur at 600 p.p.m and some neurological impairment may occur at 900 p.p.m. In a fire the styrene is likely to be further decomposed to form carbon monoxide, carbon dioxide and water.

THE TOXICITY OF SMOKE FUMES FROM EPS AND VARIOUS "NATURAL" MATERIALS

Sample		**Emitted fractions (v/v) in ppm at different temperatures**			
	Smoke gases in a fire	300 °C	400 °C	500 °	600 °C
EPS (standard grade)	Carbon monoxide	50*	200*	400*	1,000**
	Monostyrene	200	300	500	50
	Other aromatic compounds	fractions	10	30	10
	Hydrogen bromide	0	0	0	0
EPS- FR (fire-retardant grade)	Carbon monoxide	10*	50*	500*	1,000*
	Monostyrene	50	100	500	50
	Other aromatic compounds	fractions	20	20	10
	Hydrogen bromide	10	15	13	11
Deal	Carbon monoxide	400*	6,000**	12,000**	15,000**
	Aromatic compounds	--	--	--	300
Chip board	Carbon monoxide	14,000 **	24,000**	59,000**	69,000**
	Aromatic compounds	fractions	300	300	1,000
Expanded cork	Carbon monoxide	1,000*	3,000**	15,000**	29,000**
	Aromatic compounds	fractions	200	1,0000	1,000

* smouldering/glowing ** as a flame -- not detected

Remarks: Test conditions specified in DIN 53436; air flow rate 100 1/h;
300mm x 15mm 20mm test specimens compared at normal end-use conditions

For FR grades, traces (10 – 15 p.p.m) of hydrogen bromide were detected by the DIN 53436 method. The LC_{50} value of HBr is similar to that of carbon monoxide. Since its concentration is so low, relative to carbon monoxide, its presence in the fumes given off from burning FR grade EPS does not add significantly to the health hazard. Owing to the small amounts of HBr generated, no significant corrosive effects are expected.

Combustion of FR grade EPS under the conditions prescribed in DIN 53436 yields no traces of brominated dibenzodioxins, either in the gaseous phase or in the solid residue, only negligible proportions of brominated dibenzofurans, none of which are a toxic substance as defined in the (German) Prohibited Chemicals Order 1994.

3. HEALTHY BUILDING WITH EPS

EPS does not present a risk to health during production, handling, or during demolition and renovation.

Expanded Polystyrene (EPS), is a material which is used extensively in the building industry as an insulator, as well as being a natural choice for packaging purposes. EPS has many positive attributes, not the least of which is its proven safety record during all stages of its life cycle – from production, during use, through to re-use or recycling.

Health and safety are of paramount importance in everyday life. It is therefore not surprising that health and safety take top priority in the building industry. However, the evaluation of building materials is not only concerned with technical specifications, but with factors such as total environmental impact. The increasing demand for sustainable buildings means that the building industry has had to take a fresh look at the materials it uses, and the way it uses them.

Insulation is of course a necessity in any building. But most materials used for insulation are not readily associated with safety and good health. This is due in part to the fibres associated with mineral wool, and the perceived problems with radon and quartz. There is one insulation material however, which performs particularly well when it comes to health and safety: EPS, whose physical properties make it an ideal insulation material.

3.1 HEALTH DURING PRODUCTION

During the manufacturing of EPS, emission levels are negligible, due in part to the fact that its volume constitutes 98% air.

THE COMPONENT PARTS OF EPS

STYRENE

Extensive research has shown that Styrene monomer, the raw material for the production of expandable polystyrene, is perfectly safe in use. Polystyrene has a maximum styrene content of only 0.1% by weight, and since EPS contains only 2% polystyrene by volume, this minute trace of styrene monomer poses no threat to health whatsoever.

PENTANE

About 6% of pentane is incorporated into the expandable polystyrene granules as a blowing agent. It is a saturated hydrocarbon, not to be confused with (H)CFCs. Pentane is non-toxic and constitutes no threat to the ozone layer.

FIRE RETARDANT
EPS is available either with or without the fire retardant hexabromocyclododecane (HBCD), which constitutes a weight of maximum 0.5% of the final product. It is a cycloaliphatic fire retardant and not comparable with the aromatic fire retardants (PBBs and PBBOs). HBCD is present in EPS in such a minute quantity that it poses no risks to health whatsoever. Moreover, it remains within the closed cells of EPS and does not dissolve in water.

3.1.1 FIBRES AND DUST

The insulation manufacturing industry continuously evaluates its products. Research into fibres and dust in production premises is mainly concentrated in mineral wool plants, where it may be assumed sufficient protective measures are taken.

However, the situation is less satisfactory in the handling of insulating materials on the building site, or in demolition and renovation work. Perhaps the practical inconvenience of wearing protective equipment during work does some way to explain this.

Workers do not always follow safety regulations which can cause health problems, and will make the work slower, and therefore less profitable. The structure of organic plastics such as EPS is very different from the inorganic fibre structure of mineral wool, so no fibres whatsoever are released. This explains why no protective equipment is necessary when working with EPS.

There are virtually no physiological or toxic effects of EPS and EPS dust will therefore have no adverse effects on health, beyond the minor nuisance associated with any dust –such as sneezing.

3.1.2 RADIATION AND RADIOACTIVITY

Misunderstandings about radiation in plant manufacturing insulation materials have arisen, possibly as a result of recent discussions on radon and mineral building products.

Natural geological processes can cause higher than average concentrations of radioactive isotopes to be present in certain minerals. This means that in many mineral building materials, radioactivity can be detected. Extensive scientific research has shown however, that no radioactivity is emitted by EPS, nor does it contain radon or cause radon emission.

3.2 HEALTH DURING HANDLING ON THE BUILDING SITE

Close supervision on the building site is often difficult. As a result health and safety regulations are not always fully complied with. Moreover, it is here at the handling stage, when personnel are in direct contact with building materials that they can suffer most from the effects of harmful products and substances.

3.2.1 FIBRES AND DUST

Sawing, cutting and just touching certain building products can lead to irritation of the skin, eyes and respiratory tract. The degree of irritation depends on how the products are handled and the level of ventilation in the area. Although this is not life threatening, it is of course essential to minimize any risk to workers in the building industry. EPS is universally recognized as a pleasant material to work with. It does not sting hands, skin, or mucous membranes. EPS does not have any of the adverse effects on health often associated with some other building products.

3.2.2 EXCEPTIONALLY LIGHT WEIGHT

Another benefit of EPS in respect of safety, health and well being is its exceptional light weight. Even assembled EPS building products do not normally causes heavy work for construction personnel.

3.2.3 THE EFFECTS OF BINDERS

Binders are used to stabilize and strengthen many of the building materials used today. These binders may be given off during handling of materials on the building site, which can lead to health problems, EPS does not contain binders of any kind. This is because the loose EPS beads are bonded together with only the help of steam to produce the familiar EPS building products, so nothing more than pure water is used.

3.2.4 PROTECTIVE EQUIPMENT

Building workers generally find protective equipment unpleasant and inconvenient to wear. So in practice protective equipment is frequently not used. From a health point of view, this is quite difficult to understand. However if you consider having to wear gloves, a dust mask, overalls, safety goggles, a P2 mask, a P3 mask, and cream during the working day it is understandable that some personnel will take risks. Because none of these precautions are needed with EPS, it therefore scores highly in terms of safety, health and well-being.

3.3 HEALTH IN USE-INDOOR ENVIRONMENT

Indoor climate quality is of prime importance when a building is in use, both for the health of the occupants and for the continued stability of the building itself. Good thermal insulation is known to contribute to a comfortable interior, and it is recognized that insulation and ventilation should go hand in hand. When the right materials are used, the lifespan of a building increases considerably.

IN CONSIDERING CLIMATE QUALITY THE FOLLOWING PARAMETERS COME INTO PLAY:

3.3.1 MOISTURE

Moisture in buildings is one of the greatest problems faced by builders. It can lead to fungal growth, undermining the integrity of the structure, and creating a poor, unhealthy indoor environment.

Remarkably, EPS is virtually insensitive to moisture and will absorb almost no water even when immersed for long periods. This means that moisture has virtually no effect on EPS insulating products after installation, and the original insulation value of EPS is therefore guaranteed for a long time.

3.3.2 EMISSION IN USE

German research in 1987 showed that styrene emissions from EPS are very low, even less than 1% of the Maximum Admissible Concentration (MAC) value in Germany at the time (100 mg/m^3). Even when the detection limit of 0.05 mg styrene per m^3 was lowered to 0.01 mg/m^3, no styrene was measurable. The fire retardant which may be present in EPS is insoluble in water, and does not leach out of the product. There is widespread use of EPS as packaging in the food industry, an industry which must adhere to the most stringent hygiene and safety standards. Even accidental ingestion of EPS has no effect on humans or animals, since it will pass straight through the digestive tract and remain unchanged.

3.4 HEALTH DURING DEMOLITION AND RENOVATION

Insulating material has been used to an increasing extent in Europe since the 1960s. Slowly but surely some of the building stock from that period is now reaching the demolition stage. In the future, selective demolition should ensure that insulating materials are carefully removed and recycled for appropriate re-use, which will mean some changes for workers involved in demolition or renovation. An example of this change came with the comprehensive regulations on removal of asbestos, which by now is very familiar. But it is absolutely clear from what we have seen that there need be no fears on health grounds about the removal of EPS after a building has reached the end of its useful life.

4 LIFE CYCLE ASSESSMENT (LCA)

Recent years have shown growing concern for the environment, and in particular an increased demand for sustainable building and development. For the construction industry this means a need for accurate information about the environmental impact of the building materials and products that they use. The most reliable way to present this information has proved to be the Life Cycle Assessment (LCA) approach.

This approach investigates the processing involved in the manufacture, use and disposal of a product or system – from cradle to grave.

4.1 ABOUT LCA – FREQUENTLY ASKED QUESTIONS

What are the steps in the Life Cycle Assessment?	Goal Definition and Scoping, Inventory, Impact Assessment, Evaluation, and Improvement Analysis.

What does Goal Definition and Scoping imply?	The unit (in this case 1kg of EPS material) is defined, data gathering and validation procedures are determined, and the required level of data quality is established.
What does inventory mean?	First, an inventory of relevant inputs and outputs to and from the environment are compiled. From this information, know as the Life Cycle Inventory (LCI), any potential environmental impacts are evaluated and interpreted.
What's Impact Assessment?	In this stage all the environmental impacts and effects are calculated from the data gathered at the Inventory stage, such as global warming, smog etc.
What's involved in the Evaluation process?	In this final stage of the study all the information gathered throughout the study is analyzed. There are several considerations: sensitivity analysis, reliability analysis, qualitative and quantitative analysis, and finally, appraisal.
What about the data gathered?	All data has been gathered Europe wide and is based on 1998 research. However, LCA studies are dynamic and will be updated, should new information relevant to EPS become available.

4.2 LIFE CYCLE ASSESSMENT OF EPS

Expanded polystyrene (EPS) is a material widely used in the building sector, mostly for insulation purposes, and also in the packaging industry. A cost-effective, easy-to-use material, it performs as an acoustic and thermal insulator, is moisture resistant, recyclable and environmentally sound. It is produced when pentane is dissolved in a polystyrene base material, which is then steam-heated to form EPS beads. The beads can then be moulded to exact specifications, to form insulation boards, blocks or customized shapes for the building and packaging industry.

ENVIROMENTAL EFFECT/ASPECT	ABB.	CHARACTERISATION SCORES	UNIT	NORMALISATION SCORES	UNIT
ENVIRONMENTAL EFFECT					
Abiotic depletion	APD	0,83	-	1,04E-11	yr
Global warming	GWP	5,98	kg	1,42E-12	yr
Ozone depletion	ODP	2,11E-06	kg	3,75E-14	yr
Human toxicity	HCT	0,0357	kg	9,06E-13	yr
Aquatic ecotoxicity	ECA	101	m^3	2,29E-13	yr
Smog	POCP	0,0207	kg	3,28E-12	yr
Addidification	AP	0,0278	kg	8,19E-13	yr
Nutrification	NP	0,00241	kg	2,81E-13	yr
Land use	LU*t	0,00274	m^2		yr
ENVIRONMENTAL ASPECTS					
Cumulative energy demand (excl. feedstock energy)	CED-	48,9	MJ (lhv)*	8,45E-13	yr
Cumulative energy demand (incl. feedstock energy)	CED+	93,1	MJ (lhv)*	1,61E-12	yr
Not toxic final waste	W-NT	0,0453	kg	8,43E-14	yr
Toxic final waste	W-T	0,0124	kg	3,09E-13	yr

* lhv = lower heating value

The figures above show the weighted averages of the characterization and normalization scores for the life cycle of 1kg of EPS material. These are European averages for densities varying from 15-20 kg/m^3. Proper comparison with other insulating materials is only possible when the same "functional unit" is used in calculations, e.g. one square meter of insulated area with the same thermal properties.

With this LCA we now have a complete picture of EPS, and it can support its inherent benefits with detailed, accurate information. The following environmental impacts and indicators were disregarded in the study: biological depletion potential, terristic exotoxity, noise, casualties, radiation and heat to water. The study was carried out in 1998 by PRC-Bouwcentrum in the Netherlands, fulfilling the requirements of the SETAC – approach and the international ISO 14040 standard [1)]. INTRON B.V., the Quality Assessment Institute for the Building Industry carried out the external critical expert review [2)] according to ISO 14040 and concluded "that the EUMEPS LCA was carried out in a very scrutinized way, which was transparent and very well documented. It reflects the best available LCA data on EPS that can be made available in 1999."

1) European LCA-data for EPS building products, Seijdel R.R., Bouwcentrum report 886.001, August 1998.
2) Critical review on LCA-data for EPS, Schuurmans A., Intron report M715490, 13 October 1998.