When using unsaturated polyester (UP) resins, workers are potentially exposed to evaporating styrene monomer. The chemical has a very strong distinctive smell even at very low exposure levels.
Best practice advice is to control exposure to styrene to a level below the workplace exposure limit (WEL).

The WEL for styrene in the UK is 100 parts per million (ppm) averaged over an 8-hour day. There is also a short-term exposure limit (STEL), currently 250ppm averaged over a 15-minute period. Ref: HSE guidance EH40/2005 Workplace Exposure Limits.

Health hazards

Styrene vapour can cause irritation to the nose, throat and lungs at moderate exposure levels. Neurological effects include difficult in concentrating, drowsiness, headaches and nausea. The vapour and splashes are also irritating to the eyes and skin. Long-term exposure may also affect brain functions, including memory and colour vision. At high exposure levels, loss of consciousness and death can occur.

Assessing the risk

Different processing methods have a significant effect on the amount of styrene evaporating from the resin surface. The rate of styrene evaporation depends on many factors, such as the type of resin, application process, application equipment used, tool design and configuration.

As a guide, the table below indicates the typical percentage of styrene loss for different processing techniques.

Process	Styrene loss %
Gelcoat spray	10-14
Spray-up, non-LSE resin	7-10
Gelcoat, brush	6-8
Filament winding	5-7
Hand lay-up, non-LSE resin	4-6
Spray-up, LSE/LSC resin	4-6
Topcoat, spray	4-5
Topcoat, brush	3-4
Hand lay-up, LSE/LSC resin	3-4
Pultrusion	1-3
Continuous lamination	1-2
SMC/BMC manufacturing	1-2
SMC/BMC processing	1-2
Closed processes (RTM, infusion etc)	<1

Table 1: Typical % loss of styrene for common processing techniques

Thus, the measures needed to control vapour levels are dependent on the scale of the manufacturing process and the nature of the components being produced. It is essential that workplace styrene levels are regularly assessed.

There are many ways to keep exposure levels down. Some relate to the proper choice of the raw materials, some to the process or the equipment used, and some to the awareness and vigilance of the worker. These are some key basic ways of reducing exposure levels:

- Use LSE (low styrene emission) resins wherever possible, and always use a resin with the lowest styrene content (LSC) – they may help reduce the total emission by 30-50% depending on application used.
- Avoid open resin/gelcoat buckets and pails
- Keep workshop temperatures down
- Use personal protection equipment when necessary
- Switch to closed mould processing where possible

Where a component can only be produced using an open mould process then HSE has developed an effective scoring system to determine the level of control needed to meet WEL.
Ref: HSE Plastics Processing Sheet No 14: Styrene Control in FRP Contact Moulding

Once control measures are in place then maintenance and continued monitoring is critical to ensure their effectiveness.

Assessing workplace exposure levels

Most legislation stipulates that the responsibility for measuring and monitoring workplace concentration of dangerous substances lies with the employer. This can be carried out by the employer or by a third-party agency. Workplace exposure levels can be measured using commercially available equipment. This will enable FRP manufacturers to take any appropriate measures to reduce exposure and ensure compliance.
The European standards that outline the requirements for measuring workplace atmospheres and worker exposure are:

- EN 838 1996: Workplace Atmospheres. Diffusive samplers for the determination of gases and vapours. Requirements and test methods.
- EN 689 1996: Workplace atmospheres. Guidance for the assessment f exposure by inhalation to chemical agents for comparison with limit values and measurement strategy.

Methods for monitoring styrene levels:

- Spot measurements – glass tubes with a discolouring medium (gies a quick estimate)
- Checks against legal exposure limits – carbon badges or Tenax tubes over an 8-hour period
- Biological monitoring – measures styrene breakdown products in urine samples taken from the worker at the end of a shift

Workplace Ventilation

The bulk of the styrene vapour is generated closest to the moulding operation and so it should preferably be removed from the air as close to the source as possible. If styrene vapour is allowed to diffuse through the workshop then the ventilation requirements are greater. The ventilation system should therefore be designed with this in mind, although there is no blueprint for a polyester workshop as the volume of resin used and the processing technique are all contributory factors.

There are three different methods of ventilation, each with advantages and disadvantages:

General workshop ventilation

- Total air volume of the workshop is replaced several times per hour.
- Relatively simple and allows flexibility in the movement of materials and products in the workshop
- Can lead to excessive heating costs in cold periods
- Not always sufficient for large mouldings

Local ventilation

- Styrene vapour is removed through ventilation hoods installed as close as possible to the source of styrene generation
- Offers flexibility in positioning of ventilation hoods
- Hoods can hamper the freedom of movement around the mould
- Effective method for small parts made in a fixed place

Zonal ventilation

- Combines general ventilation with local ventilation – styrene is removed before it is diluted into the air of the total workshop
- Needs good balance between supply of fresh air into the compartment and the removal of contaminated air
- Spray booths are a good example of zonal ventilation

Personal Protective Equipment

The use of Personal Protective Equipment (PPE) should be considered after process-related measures and engineering controls like workplace ventilation have been properly assessed and implemented. However, to maximise safety at work, the use of PPE is often necessary:

- Gloves prevent contact with the skin. Polyvinyl alcohol (PVA) and laminated film gloves are recommended. Gloves should be inspected before each used for any signs of degradation.
- Coveralls to prevent contact with the sin and protect clothing.
- Googles to prevent contact with the eyes
- Respirator to reduce exposure to styrene vapour and other VOCs (volatile organic compounds).
- The most commonly used are air-purifying respirators with replaceable Type A (activated carbon) cartridges for organic vapours. Type P filters are used for articulate such as resin dust and fibres. Combination filters are available.

- Each respirator type is categorised by an Assigned Protection Factor (APF) which is a numerical rating indicating the level of protection. For guidance on type of masks recommended for different processes see the CEFIC Safe Handling Guide No 2: Occupational Exposure to Styrene,
- Emergency eye wash stations must be provided in areas where employees may be exposed to accidental splashes from corrosive materials.

Abatement techniques

The most effective abatement technique is to prevent the escape of VOCs into the workplace and subsequently the atmosphere. The use of low styrene emission and low styrene content resins will help in this respect in open moulding applications. It reduces the level of VOC emitted compared with conventional resins. Even more effective are the use of closed mould techniques such as vacuum bagging, resin transfer moulding (RTM), RTM light and hot and cold press moulding.

When styrene emission has to be controlled, a number of abatement techniques exist. These are described in detail in CEFC Safe Handling Guide no 2: Occupational Exposure to Styrene. The two systems most relevant to the FRP industry are:

- Removal of styrene vapour by incineration – gives high efficiency with energy recycling
- Bio-filtration systems – bacterial oxidation of organic matter; good at removing low concentrations.

General recommendations

- Keep the workshop closed so as not to disturb air streams.
- Use personal respiratory protection if necessary.
- Wear appropriate safety clothing such as gloves, coveralls and googles to prevent resin coming into contact with skin and eyes.
- Decant and mix resins in a separate well-ventilated room to reduce the spread of styrene vapours.
- Always follow manufacturers' instructions when mixing and blending additives, accelerators, fillers and peroxides to avoid unwanted reactions.

Further information:

- EH40-2005 Workplace exposure limits
- Control of substances hazardous to health
- Working with substances hazardous to health
- Exposure measurement - air sampling
- Styrene Control in FRP contact moulding
- Resin safe handling guides
- CLP Regulations Advisory note
- Changes to the Classification Legislation for Styrene - Advisory note
- Clearing the air - a guide to buying and using LEV
- Controlling airborne contaminants at work - a guide to LEV
- Time to clear the air - a workers guide to LEV