SHEET N° 05

GOBIERNO DE ESPAÑA | MINISTERIO DE TRABAJO Y ECONOMÍA SOCIAL | insst Instituto Nacional de Seguridad y Salud en el Trabajo

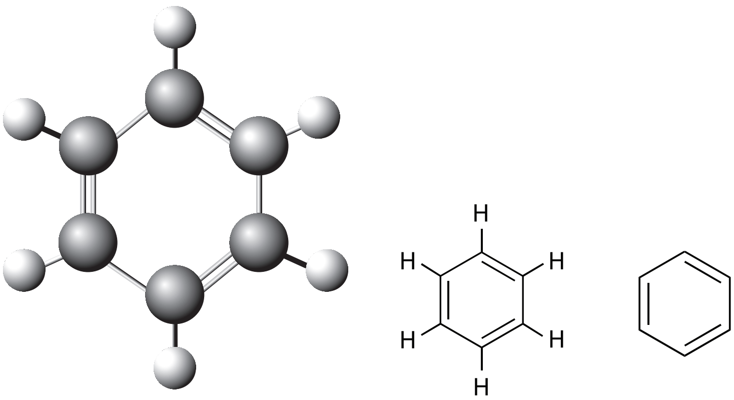
Benzene

CARCINOGENS AT WORK:
Know to prevent

Information about the substance and where it can be found

Benzene is a colourless, volatile, sweet-smelling, highly flammable liquid obtained by petroleum distillation processes. It is less dense than water and is slightly soluble in it.

It is an aromatic hydrocarbon and, because of the type of chemical bonds it has, it is a very stable molecule, requiring catalysts to make it react chemically. It is used in the chemical industry to obtain intermediate compounds to manufacture various products, such as plastics, resins, synthetic fibres, pesticides, medicines and dyes, mainly.



Molecular structure of benzene

According to the OECD, the volume of this chemical agent produced in the world is high, at around 40 million tonnes per year. Currently, 90% of total benzene consumption is used for the production of ethylbenzene (to produce styrene, a component of plastics and resins), cumene (to produce phenol), cyclohexane (raw material for polyamides, monomers of nylon) and nitrobenzene (an intermediate in the production of dyes). (IARC 2018, Sanz Tejedor).

Benzene occurs naturally in petroleum products, including gasoline, to which it is also added as an additive, since it increases its octane rating and has

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anti-knock properties. In the European Union, the maximum concentration of benzene allowed in petrol for sale is 1%. There are other EU regulations for this agent, such as the prohibition on marketing it as a substance, either pure or as a component of a mixture (in concentrations equal to or greater than 0.1% by weight), as well as its presence in the formulation of cosmetics and food contact materials, among others.

It also occurs naturally in the environment as a result of forest fires and volcanoes, although major sources of benzene are anthropogenic, such as burning of coal and oil and motor vehicle exhaust. It is also a component of tobacco smoke. A 2008 study in 12 European cities measured average ambient concentrations ranging from 2 μg/m^3 to 9.8 μg/m^3. There is EU legislation that sets maximum allowable concentrations in both air and water.

Table 1
Other areas where benzene is regulated in the EU

Scope	Legislation
Gasoline content	Directive 98/70/EC
Cosmetic products	EC Regulation No° 1223/2009
Air quality	Directive 2008/50/EC
Water quality	Directive 2008/105/EC

Restrictions set out in Annex XVII of Regulation (EC) No 1907/2006, on Registration, Evaluation, Authorisation and Restriction of Chemical Substances and Mixtures (REACH)as regards mixtures:

- It is prohibited to place it on the market and use it in mixtures in concentrations equal to or greater than 0.1% by weight, except in:

- Motor fuels under Directive 98/70/EC.
- Substances and mixtures used in industrial processes which do not permit the emission of benzene in quantities greater than those set out in current legislation.
- Natural gas placed on the market for consumer use, provided that the concentration of benzene is less than 0.1% volume/volume.

Health effects

Benzene is a carcinogenic agent that can cause serious effects on human health, the most prominent of which is acute myeloid leukaemia. Positive associations have also been observed for non-Hodgkin lymphoma, chronic lymphoid and myeloid leukaemia, multiple myeloma and lung cancer, although experts disagree on the latter type of cancer. It is also recognised as having mutagenic potential, including the ability to cause heritable mutations, in germ cells of humans (IARC 2018).

Besides its carcinogenic effects on the haematopoietic system, benzene can cause other acute and chronic health effects. Brief exposure to high concentrations can cause irritation, dizziness, nausea, headache, convulsions, unconsciousness, cardiac disturbances and even death if exposure levels are very high (ATSDR 2016).

As for chronic effects, the most prominent is alteration of the bone marrow tissues where blood cells are produced. This alteration can lead to anaemias, haemorrhages and the leukaemia mentioned above. Harmful effects on the immune and reproductive systems, including disruption of menstrual cycles, have also been reported.

Benzene is classified as a Group 1 carcinogen (carcinogenic to humans) by IARC and as a 1A carcinogen under the harmonised classification of Regulation (EC) No 1272/2008 on Classification, Packaging and Labelling of Substances and Mixtures (CLP Regulation). In the same EU regulation, it is also assigned the health hazard categories mutagen 1B, as there is evidence that it causes heritable mutations in the germ cells of humans, it is a category 2 irritating to skin and eyes, a category 1 aspiration toxic and a category 1 systemic toxic after prolonged or repeated exposure.

Where the exposure can take place

Occupational exposure to benzene has decreased considerably over the years. Historically it was used as a metal degreaser and as a solvent; however, as knowledge of its carcinogenicity progressed, its use was restricted and limited, especially in higher income countries, so that fewer people are now exposed at work and then at lower concentrations.

Exposure to this agent can currently occur in a variety of industries and occupations, including oil and gas production and refining, distribution, sale and use of petroleum products, coke production, manufacture and use of chemicals (including some lubricants, dyes, detergents, medicines and pesticides), automotive repair, footwear production, firefighting, and various occupations involving exposure to exhaust fumes from combustion engines (IARC 2018). Other occupations that may involve exposure are steel workers, printing workers, laboratory technicians and workers in solar thermal power plants, since it is generated by the degradation of the heat transfer fluid.

Table 2
Harmonised hazard classification of benzene under Regulation (EC) 1272/2008 on Classification, Labelling and Packaging of substances and mixtures (CLP)

Benzene N° CAS 71-43-2

Hazard Statement Code	Hazard Statement
H225	Highly flammable liquid and vapour
H315	Causes skin irritation
H319	Causes serious eye irritation
H304	May be fatal if swallowed and enters airways
H340	May cause genetic defects
H350	May cause cancer
H372	Causes damage to organs through prolonged or repeated exposure

Hazard pictograms



The IARC (iarc.who.int) is an autonomous agency of the World Health Organization of the United Nations. It seeks to promote international collaboration in cancer research. It runs studies that are widely recognised for their quality and independence.

In Europe, benzene ceased to be used as a solvent and ink cleaner in printing houses in the mid-20th century. However, this use remains one of the greatest sources of exposure in other countries, for example, China and Canada (Canada 2021, IARC 2018).

The main route of entry into the body is via inhalation, although dermal exposures may also occur, the level of which depends on the use and manner of handling.

Table 3
Some examples of benzene exposure levels in different productive sectors. Source: IARC 2018

Productive sector	Approximate average exposure	Observations
Primary industry (extraction)	< 1ppm	Per shift (12 hours), except cleaning, maintenance and hydraulic fracturing, where it is greater
Secondary industry (refineries)	< 1ppm	Exposure higher than in primary industry
Secondary industry (distribution)	Up to 2 ppm (closed loading) Up to 10 ppm (open loading)	
Petrol Station	0.059 mg/m^3	In countries with restrictions on the concentration of benzene and with a gas recovery system at discharge
Due to vehicle exhausts (police, taxi drivers, etc.)	Examples: Italy: 6.1 µg/m^3 Thailand: 38.2 µg/m^3	Varies by region
Automobile repair	< 1 ppm	
Coke Production	0.5 ppm	
Rubber industry	1.42 ppm (rubber) 0.34 ppm (tyres)	
Shoemaking	21 ppm (small factory) 3.5 ppm (large factory)	China data (EU and US exposure is no longer so important)
Firefighting	<0.5 ppm	Higher in forest fires than in urban fires. Short exposures may exceed 1 ppm.
Handling of jet fuels		The notified values indicate that the OEL (8 hours) of 1 ppm could be exceeded

Exposure assessment

Work involving exposure to benzene falls within the scope of Royal Decree 665/1997 on the protection of workers from the risks related to exposure to carcinogens at work and, therefore, the risk assessment and prevention measures to be applied must take into account the requirements of this regulation.

Once the risk from exposure to this agent has been identified, it shall be eliminated or exposure avoided, as a priority, in the activity's conception and design phases. Where elimination is not possible, a risk assessment shall be performed to determine the nature, degree and duration of workers' exposure. This assessment will provide information about the preventive measures to be implemented to reduce the exposure to a level as low as technically possible.

Benzene has an occupational exposure limit value (8-hour OEL) of 1 ppm (3.25 mg/m^3). These exposure values may not be exceeded on any working day, weighted at 8 hours.

For those carcinogens or mutagens for which an OEL has been established, the assessment of inhalation exposure is based on measuring the concentration of the chemical agent in the worker's breathing area and weighting the result according to the reference period, in this case 8 hours, since these are 8-hour OEL.

To determine the concentration of benzene in air, active sampling is usually performed by pumping air through activated carbon tubes or other suitable adsorbents. Another alternative is the use of passive or diffusion samplers. In the laboratory benzene is desorbed using solvents such as carbon disulphide (NIOSH methods 1501 and MTA/MA-030/A92) or high-temperature thermal desorption (NIOSH methods 2549 and MTA/MA-066/A19) and analysed by gas chromatography equipped with a flame ionisation detector (NIOSH Methods 1501, MTA/MA-030/A92 and MTA/MA-066/A19) or with a mass spectrometer (NIOSH Method 2549).

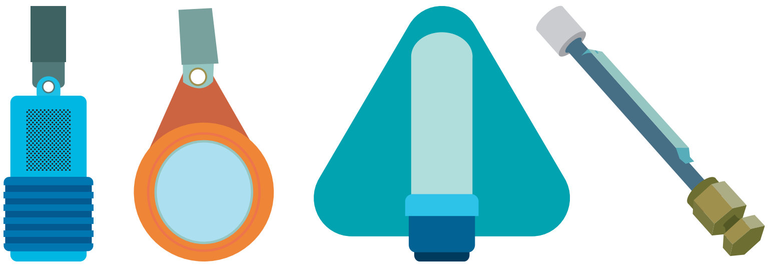
Regulatory references

Benzene was the first carcinogen to be assigned an occupational exposure limit (OEL) in Annex III of Royal Decree 665/1997, as amended by Royal Decree 1124/2000 of 16 June 2000. Since then, this value has remained constant. However, in the Commission's proposal for the fourth amendment of the Carcinogens or Mutagens Directive, a proposal is made to reduce this value to 0.2 ppm (0.66 mg/m^3), with a transitional period of 5 years, and to assign a binding biological limit value (BBLV) to this agent, among other revisions for other chemical agents.

Table 4
Limit value for benzene

	ppm	mg/m^3
8 hour-OEL	1	3,25
Notes	**C1A**, **M1B**, skin, BLV, v, r	

INSST has two validated methods for determining occupational exposure to benzene. The first to be published was MTA/MA-030/A92, which is based on active sampling in activated carbon tubes, solvent desorption and gas chromatographic analysis; MTA/MA-066/A19, which is based on sampling by passive diffusers, thermal desorption and gas chromatography, was later validated for laboratory analysis.



Examples of passive samplers

Benzene has established biological limit values for two indicators related to benzene exposure. BLVs represent the most likely levels of biological indicators in healthy workers subjected to an overall exposure to chemical agents, which is equivalent, in terms of absorbed dose, to an inhalation exposure of the order of the 8 hour-OEL.

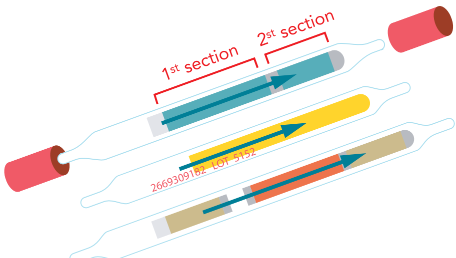
Biological monitoring can be used to complete the assessment, as a complement to the environmental assessment, to test the effectiveness of personal protective equipment or to detect possible dermal and/or gastrointestinal absorption. Where dermal contribution may be significant for the total body burden, it is advisable to use biological monitoring to quantify the overall quantity of contaminant absorbed.

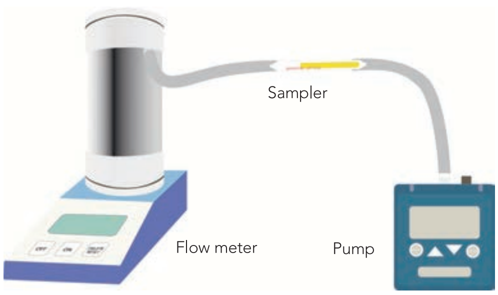
Table 5
Biological Limit Values for benzene

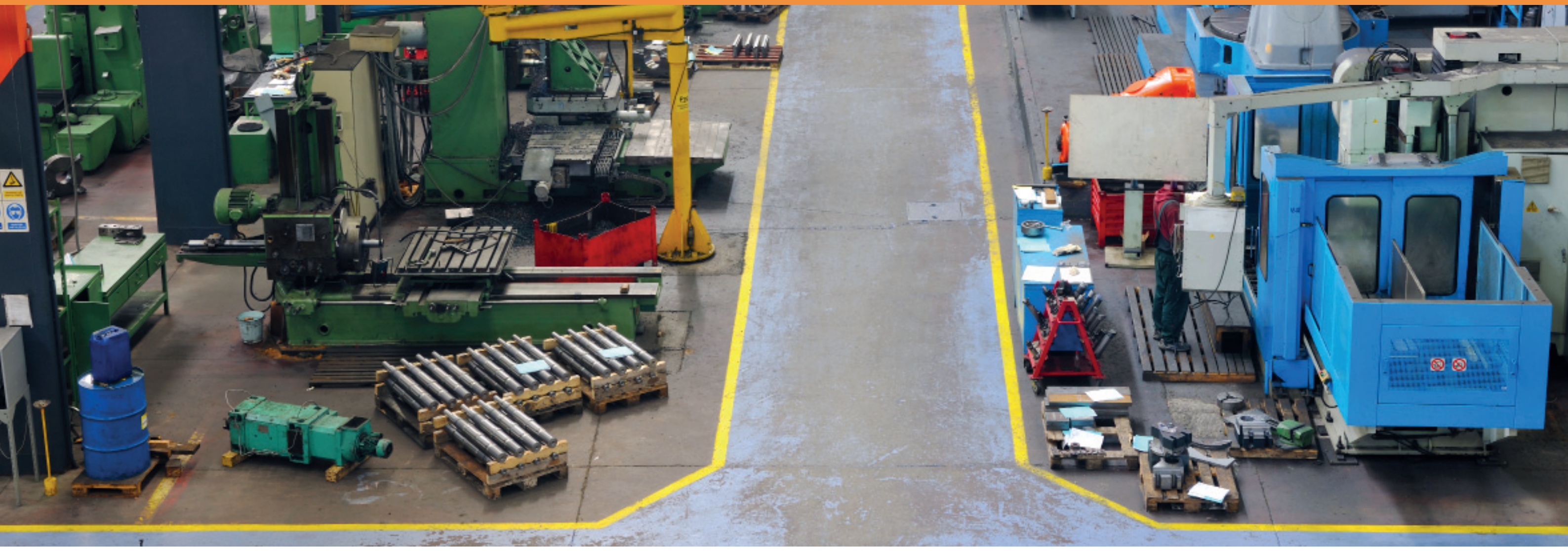
Biological indicator	BLV	Sampling time
S-Phenylmer Capturic Acid in Urine	0,045 mg/g creatinine	End of the working day
T,t-Muconic Acid in Urine	2 mg/l	

Representativeness of the samples

Whenever a quantitative assessment of inhalation exposure to a hazardous chemical agent is performed, a sampling strategy must be adopted to ensure the representativeness of the data obtained. The standard UNE-EN 689:2019+AC:2019, *Workplace exposure. Measurement of exposure by inhalation of chemical agents. Strategy for testing compliance with the occupational exposure limit values*, provides a possible strategy for comparing daily exposure with the occupational exposure limit values.







Controlling exposure

Exposure control or prevention measures should be prioritised according to their effectiveness. The first option should always be substitution; where this is not possible, the possibility of working in a closed system should be explored; where this is also not possible, it should be ensured that the level of exposure of workers is reduced to as low a level as is technically possible. Finally, where the above measures are not sufficient, personal protective equipment (PPE) must be used.

1. Substitution

The priority measure, and mandatory whenever it is possible, when working with carcinogens or mutagens, is always substitution with another agent or process not dangerous or is less dangerous. This measure is the most difficult to implement, especially when a production process is already in place, and many variables must be taken into account, but it must be planned and implemented whenever feasible, even if it is more costly, and it is necessary to keep up to date with technological advances in each sector.

In the past, benzene was used in many more processes than it is today, mainly as a metal degreaser and as a solvent. However, as its carcinogenic potential has become known, its use has been restricted and it has replaced by other agents that are less hazardous to health.

Further progress can now be made towards replacing or eliminating this agent in the workplace. For example, a Danish forestry school replaced conventional petrol with alkylate petrol in all two-stroke engines (chain saws, strimmers, etc.). Alkylate gasoline is obtained from gaseous fractions of the oil refining process and has a much lower content of benzene, polycyclic aromatic hydrocarbons, sulphur and lead.

As a result, exposure to benzene and other hazardous chemicals contained in exhaust fumes from two-stroke engines decreased significantly, although it did not disappear, and pupils and teachers reported much less irritation when exposed to these fumes (Subsportplus 2012).

Another example of substitution can be found in the footwear industry. A Spanish company had problems with intoxication of some workers due to exposure to benzene, toluene and other hazardous chemicals present in the

Prioritisation of preventive measures for carcinogens:

1. Substitution
2. Closed system
3. Reduction of exposure to as low a level as is technically possible.
4. Personal protective equipment

Resources for substitution:

More practical experiences of risk substitution or elimination can be found in the following links:

- Solutions, examples of substitution and good practice for carcinogens, from the Roadmap on carcinogens initiative.

https://roadmaponcarcinogens.eu/solutions/good-practices/

- SUBSPORT Substitution Support Portal.

https://www.subsportplus.eu/

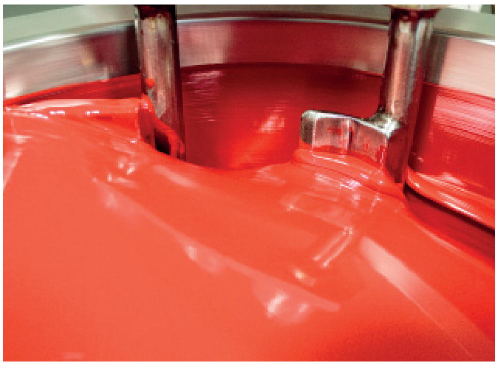
- OECD Substitution Toolkit Portal.

http://www.oecdsaatoolbox.org/

- INRS Substitution Fact Sheets.

http://www.inrs.fr/actualites/nouvelles-far-fas.html

leather tanning process. After receiving advice from a substitution expert, they changed the hazardous solvent to acetone, thus meeting the process's quality requirements and they started using a much less hazardous chemical agent, although it also presents risks (Subsportplus 2008).



2. Closed system

It consists of preventing the dispersion of the agent into the air breathed by the worker by placing the process in which it is generated within a closed system with air evacuation, and a system of the treatment and evacuation to a safe environment to prevent the agents from harming the environment or public health.

This measure will be more easily applicable in the chemical industry, where reactions can be performed in closed tanks and chemical agents can be transported through pipelines. In these cases, special attention must be paid to the cleaning and maintenance of reactors and other equipment, since much higher exposures can occur in these situations than during normal operation.

3. Reduction of exposure to as low a level as is technically possible

The aim is to implement technical and organizational measures so that exposure is reduced as much as technically possible. This obligation implies that it is not sufficient to achieve exposure levels below the established occupational exposure limit, but rather that it is necessary to go beyond it by applying all available measures.

Royal Decree 665/1997 lays down the obligation to adopt all necessary measures as set out in article 5.5. In general, these requirements are in line with the requirements of *Royal Decree 374/2001 on the protection of the health and safety of workers from the risks related to chemical agents at work*, adding the express mention of installing detection and warning devices in the event of situations that could generate abnormally high exposures. This can be achieved by installing leak detectors (continuous meters) associated with an alarm system.

A good example of exposure reduction is the use of vapour recovery systems during the unloading of gasoline from tanker trucks at service stations (Stage I vapour recovery). This measure significantly reduces the exposure of drivers who perform unloading (Saarinen, Hakkola and Kangas 2000). These systems can also be applied to dispensers for refuelling (Stage II vapour recovery), thus also significantly reducing the exposure of attendants and customers.

When benzene is to be handled in processes that are not fully closed, local exhaust ventilation measures, such as use inside fume cupboards or cabinets, must be applied to avoid dispersal into the environment. For this measure to be effective, the extraction system must be located as close as possible to the point of emission, be fitted with filters suitable for this pollutant and follow a regular maintenance programme to ensure it is properly maintained. It is important to have good general ventilation to complement this local exhaust ventilation system and to not generate draughts that could impede its proper functioning. Moreover, the worker's position in relation to the extraction system during the handling of benzene must be taken into account.

4. Personal protective equipment

Personal protective equipment must not be used as the only preventive measure. All of the foregoing technical and organizational measures possible must have been implemented beforehand.

The results of the risk assessment will be the basis for determining the need for personal protective equipment and for the selection of the most appropriate equipment. Moreover, when selecting equipment, the anatomy of the workers who will be using it should be taken into account and, in the case of respiratory protective equipment, it is highly recommended that a fit test be performed on each individual.

If personal respiratory protection is required and filtering equipment is suitable, the filters to be used are type A: Gases and vapours of organic compounds with boiling point > 65°C. Consideration must be given to whether there are other hazardous chemicals in the environment, whether aerosols are generated, and the quantity of oxygen in the air.

Regulatory references

The recovery of petrol vapours emitted into the atmosphere in phase I, that is, during storage and distribution to service stations, is regulated in our country by Royal Decree 2102/1996 of 20 September 1996 on the control of volatile organic compound (VOC) emissions resulting from the storage and distribution of petrol from petrol stations to service stations. Subsequently, Royal Decree 1437/2002 of 27 December 2002 was approved, bringing petrol tanks into line with Royal Decree 2102/1996 of 20 September 1996 on the control of volatile organic compound (VOC) emissions.

Stage II of petrol vapour recovery covers vehicle refuelling operations at service stations and is regulated in Spain by Royal Decree 455/2012 of 5 March, setting out measures to reduce the quantity of petrol vapour emitted into the atmosphere during the refuelling of motor vehicles at service stations. This regulation obliges service stations with an effective flow of more than 500 m^3/year to incorporate these systems, so that the recovered vapours pass into a tank or return to the pump itself during the refuelling operation, to prevent hazards to the environment and public health.

If there is a risk of splashing, PPE must protect exposed parts from dermal contact in the form of gloves, aprons, goggles or face shields. For gloves, the protection offered must be supported by the information provided by the manufacturer through the pictogram and marking. In general, when there is prolonged contact with benzene, certain materials such as natural rubber, butyl, nitrile or PVC must be avoided. Polyvinyl alcohol, Viton® or Barrier® are recommended in this case.

The choice of protective clothing, if necessary, is also determined by the physical state of the substance (INRS 2019) and, in the case of liquids, whether it is splashes, sprays or larger liquid splashes.

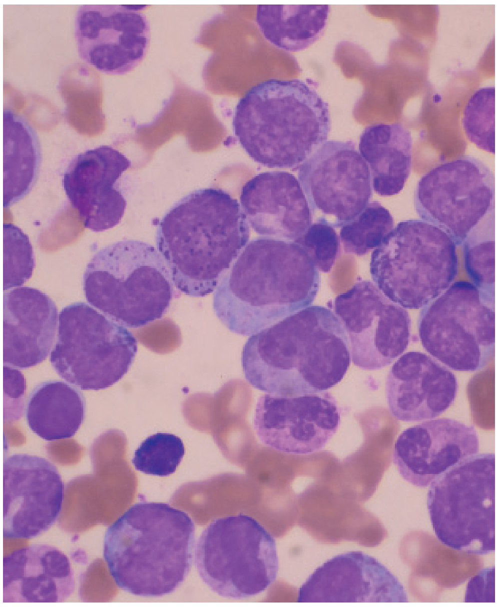
In the case of benzene, due to its high flammability, where there is a risk of fire or explosion, all PPE used must also be antistatic to prevent the generation of sparks which could be a source of ignition.

PPE removal, cleaning and maintenance procedures are as important as its correct selection and use. Manufacturers' recommendations must be strictly followed and workers must be trained to be aware of them and to apply them properly. Reusable PPE must be provided with a suitable place for storage after decontamination and disposed of as hazardous waste, when necessary, as with disposable PPE.

To select, use and maintain personal protective equipment, the requirements set out in Royal Decree 773/1997 on the minimum health and safety requirements for the use by workers of personal protective equipment must be complied with.

Further information can be found in the Technical Guide for the use of personal protective equipment by workers, developed by the INSST to clarify the technical aspects set out in the Royal Decree.

Health surveillance



Cancerous processes related to exposure to carcinogens or mutagens are generally characterised by long latency periods. Thus, Royal Decree 665/1997 establishes the right for workers who have been exposed to these agents to the extension of health surveillance beyond the end of the exposure or of the employment relationship.

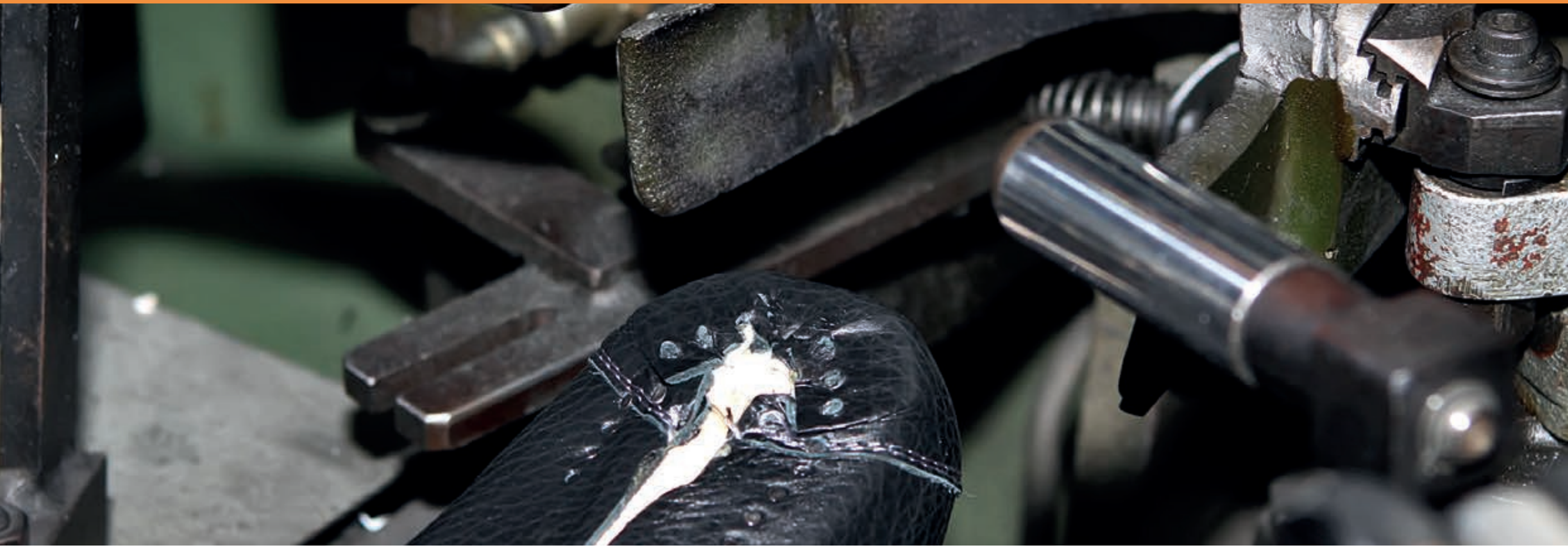
In order for the health surveillance programme to be adjusted to the risks arising from the presence of chemical agents in the workplace, the employer must provide information about these risks and safety data sheets to the basic health unit (BHU) responsible for health surveillance. In the absence of specific guidelines and action protocols, this UBS, based on the risk assessment and the health effects of benzene, will draw up a protocol and document the method and criteria used for the aforementioned health surveillance.

Clinical examination should look for signs of irritation and neurological signs. Exposure of workers with haematological disorders and pregnant or breastfeeding workers must be prevented. Workers exposed to this substance must be informed of the hazards to fertility and pregnancy.

Other preventive measures

At works involving the risk of exposure to benzene, other series of preventive measures established in Royal Decree 665/1997 must be complied with, such as the following:

- Personal hygiene measures (article 6).
- Measures to be taken in the event of accidental and non-regular exposures (article 7).
- Obligation with regard to documentation (article 9).
- Information for the competent authorities (article 10).
- Consulting, informing and training workers (articles 11 and 12).



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