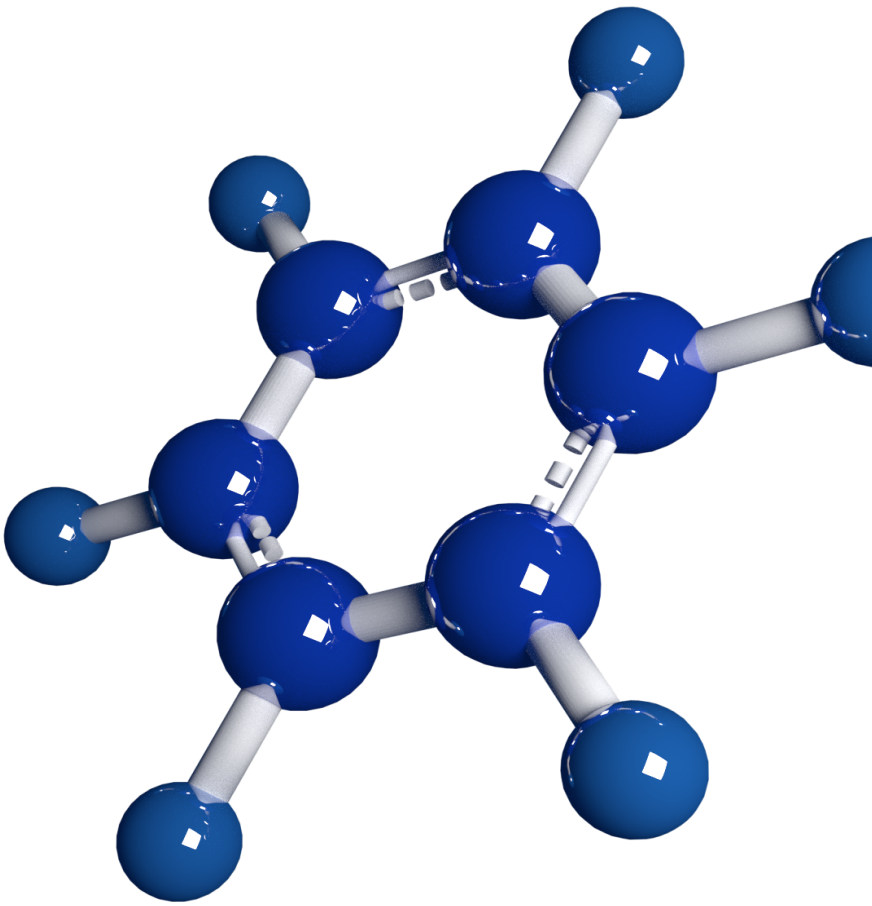
The Basics of Benzene

Properties : Exposure : Detection

"Human exposure to benzene has been associated with a range of acute and long-term adverse health effects and diseases, including cancer and aplastic anaemia. Public health actions are needed to reduce the exposure of both workers and the general population to benzene."

The World Health Organisation



Protecting both people and the environment whilst meeting the operational needs of your business is a very important role and, if you have operations in the UK you will be well aware of the requirements of the Control of Substances Hazardous to Health (CoSHH) Regulations and likewise the Code of Federal Regulations (CFR) in the US1. Similar legislation exists worldwide, the common theme being an onus on hazard identification, risk assessment and the provision of appropriate control measures (bearing in mind the hierarchy of controls) as well as health surveillance in some cases.

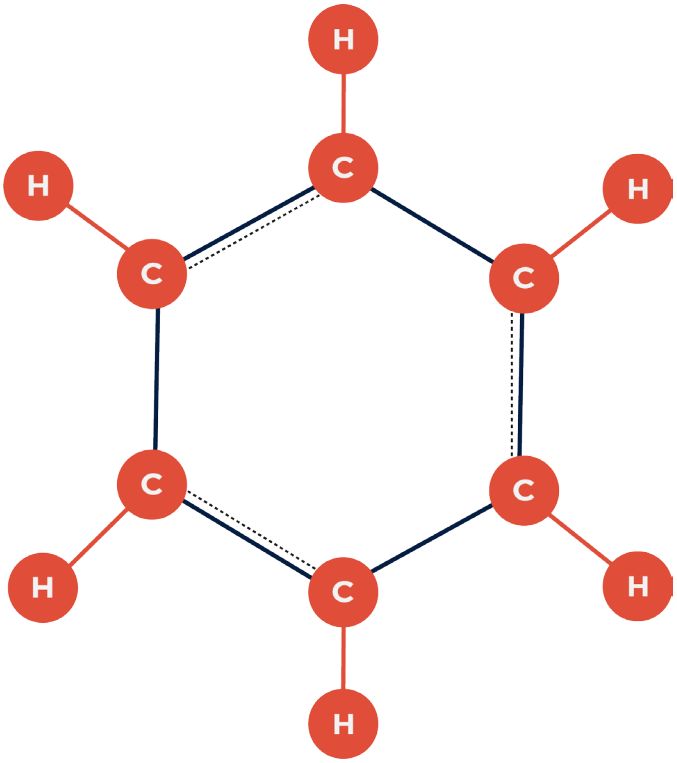
Whilst toxic gasses such as hydrogen sulphide and carbon monoxide are a major concern because they pose an immediate (acute) danger to life, long term exposure to relatively low level concentrations of other gasses or vapours such as volatile organic compounds (VOCs) are of equal importance because of the chronic illnesses that can result from that ongoing exposure.

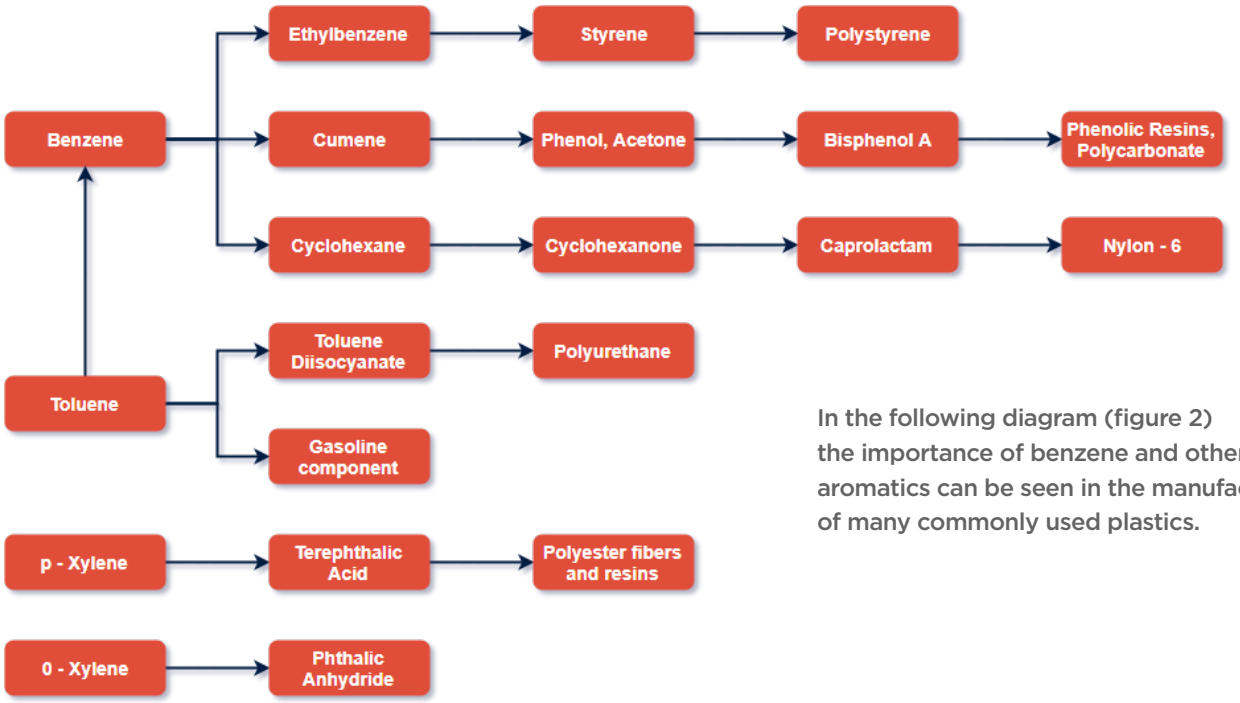
Thinking back to your school days and science, organic means the chemistry of carbon based compounds, which are substances that results from a combination of two or more different chemical elements. The atoms of the different elements are held together by chemical bonds that are difficult to break. These bonds form as a result of the sharing or exchange of electrons among the atoms.

Some VOCs are hydrocarbons but not all hydrocarbons are VOCs. The latter have a significant vapour pressure at normal ambient temperature which means they evaporate (volatilise) at low temperatures so they can easily enter the body through normal breathing.

The Benzene Ring

- Benzene, also known as benzol, is one such common VOC, identified by its unique numerical CAS2 number 71-42-2.
- It is also a hydrocarbon as you can see from its chemical formula C6H6 represented diagrammatically as a ring.
- It belongs to the BTEX family (Benzene, Toluene, Ethylbenzene, Xylene) of so called aromatics because of their sweet, pleasant smell.
- Benzene is the simplest such aromatic hydrocarbon and it was the first one named as such, the nature of its bonding was first recognised in the 19th century.





In the following diagram (figure 2) the importance of benzene and other aromatics can be seen in the manufacture of many commonly used plastics.

Figure 2: The chain of petrochemicals derived from the BTEX aromatics (source: Wikipedia)

Workers might be exposed to benzene during certain jobs, for example, in :

- Oil refineries
- Chemical and petrochemical plants
- Coke works
- Foundries
- The storage, distribution and use of petrol or benzene itself

Benzene is :

- A highly flammable, colourless to light yellow liquid
- Occurs naturally in crude oil, natural gas and some ground waters
- Found in ambient air as a result of burning fuels, such as coal, petrol and wood and is common in unleaded fuel, where it is added as a substitute for lead, allowing smoother running
- Present in cigarette smoke

Benzene Exposure

Benzene evaporates easily and most people can just detect its distinctive smell at concentrations between 2.5 and 5 parts per million (ppm) in air.

As well as inhalation, benzene can be absorbed into the body through the skin or by swallowing material containing it. The effects on worker's health depends upon how much benzene they are exposed to and for how long and as with other organic solvents, the immediate effects of a single exposure to a high concentration (hundreds of ppm) e.g. from a fugitive process leak, include headache, tiredness, nausea, dizziness and even unconsciousness if the exposure is very high (thousands of ppm) meaning an acute safety incident.

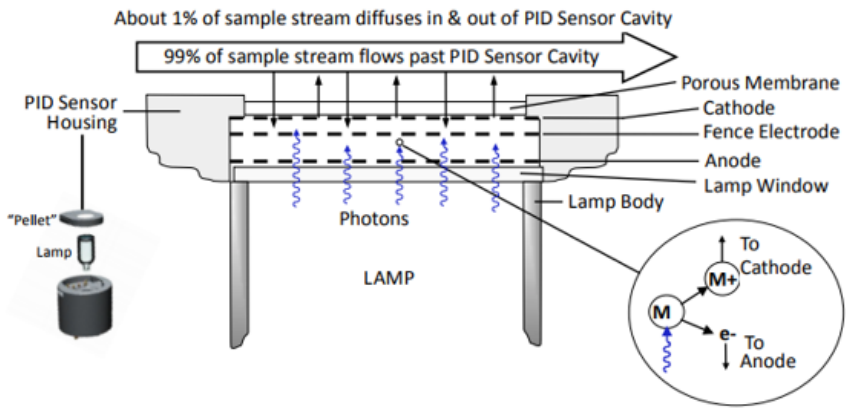
From a long term (chronic) health perspective, the World Health Organisation (WHO) and International Agency for Research on Cancer (IARC) classify benzene as a group one carcinogen. Prolonged exposure to high concentrations of benzene causes leukaemia and impacts red and white blood cells. The WHO has not set a standard for ambient benzene concentrations, stating that there is no safe level of exposure but many countries use an annual average standard of 3.6g m-3 which is equivalent to 1 part per billion (ppb) or 0.001 ppm.

Benzene Detection

Rather than having to rely on human senses in a workplace setting it is advisable to use an appropriate form of quantitative monitoring; indeed the onus is on the employer to do the risk assessment. Remembering the old adage attributed to Lord Kelvin that you can't manage what you don't measure, there are methods published by the Health and safety Executive in the UK4 and NIOSH in the US5 that can be used to capture air samples for later analysis but by definition this occurs after exposure could have taken place. Therefore real-time methods are preferable which can range from fixed, permanent systems for fence line applications, hand-held devices for area measurements or confined space entry and most recently developed, personal monitors that can alert a worker of an immediate hazard.

Collectively these devices are known as photoionization detectors (PID) which gives a clue to their theory of operation. Figure 3 below is a schematic of an Ion Science Ltd PID sensor system.

A UV lamp generates high-energy photons, which pass through the lamp window and a mesh electrode into the sensor chamber. Sample gas is pumped over the sensor and about 1% of it diffuses through a porous membrane filter into the other side of the sensor chamber. The inset on the lower right shows what happens on a molecular level. When a photon with enough energy strikes a molecule M, an electron (e-) is ejected. The M+ ion travels to the cathode and the electron travels to the anode, resulting in a current proportional to the gas concentration. The electrical current is amplified and displayed as a ppm or ppb concentration. Not all molecules can be ionized, thus, the major components of clean air, i.e., nitrogen, oxygen, carbon dioxide, argon, etc., do not cause a response, but most VOCs do give a response.



Three PID lamps are available with maximum photon energies, measured in electron-volts (eV), of 10.0 eV, 10.6 eV, and 11.7 eV.

Figure 3: Ion Science Ltd PID sensor design

Figure 4 below illustrates that a lamp can only detect those compounds with ionization energies (IE) equal to or below that of the lamp photons. Thus, a 10.6 eV lamp can measure hydrogen sulphide with an IE of 10.5 eV and all compounds with lower ionization energy, but cannot detect methanol or compounds with higher IE.

The choice of lamp therefore depends on the application. When only one compound is present, one can use any lamp with enough photon energy, often the standard 10.6 eV lamp which is the lowest cost and has a long working life of up to a few years. Conversely the 11.7 eV lamp has a short life of only a few months so in the case of compound mixtures, use the lowest energy lamp possible.

Benzene has a low IE value as shown in Figure 4 and it is often present in a cocktail of other chemicals including aromatics. Using a proprietary 10.0eV lamp means that only the aromatics are detected and should the total aromatic compounds (TAC) be above the regulatory limit a benzene pre-filter tube can be used to provide an accurate reading. It is important that your PID is maintained due to the potential for contamination of the lamp due to dirty, humid environments plus, the PID requires calibration every time it is used using a reference gas.

With a seemingly inexorable rise in the production and release of benzene into the environment it is vitally important that the health dangers and legislative provision are understood which will be covered in greater detail in future whitepapers. This will ensure that you go beyond compliance in the safety, health and wellbeing of your most valuable asset, your workforce.

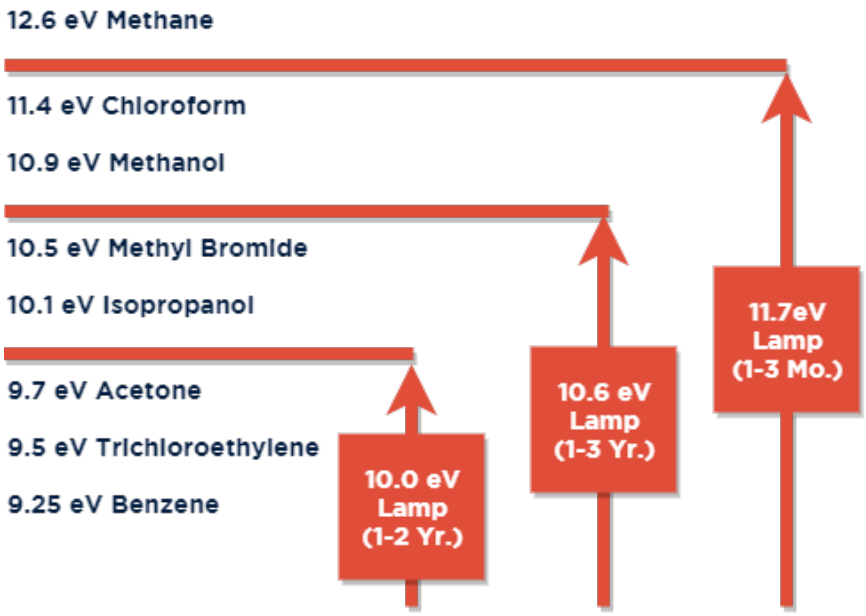


Figure 4: PID lamp energy thresholds

REFERENCES

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2. Chemical Abstracts Service (CAS), www.cas.org
3. https://en.wikipedia.org/wiki/BTX_(chemistry)
4. MDHS 88 Volatile Organic Compounds in Air - Laboratory method using diffusive samplers, solvent desorption and gas chromatography
5. NIOSH Manual of analytical methods: 1500 hydrocarbons

About ION Science

Ion Science provide a portfolio of handheld, fixed and portable photoionisation (PID) detection instruments for the rapid, accurate detection of volatile organic compounds (VOCs). Find out more about our industry leading range of Benzene detection solutions by clicking on the links below.

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