Duvas Technologies
Real-time air quality

Guide to benzene

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Benzene abounds

Benzene is all around us, present in practically every organic compound on earth and one of the most widely-used chemicals worldwide. And yet, the World Health Organisation tells us that 'there is no safe concentration of benzene'.

The sweet smelling, colourless liquid evaporates into air and partially dissolves in water. While only present in microscopic amounts in organic compounds, benzene is found in large quantities in gas emissions from volcanoes and smoke from forest fires, as well as in crude oil reserves, rivers, oceans and soil.

For industrial applications, the chemical was first isolated by the petrochemical industry from coal tar in the 1800s. As nations rushed to industrialise, benzene levels in the atmosphere began to rise as coal and oil were more widely burnt.

THE
CANCER-CAUSING
EFFECTS OF BENZENE
have been widely-reported
since 1897

Traditionally, benzene was manufactured from the distillation of light oils produced during the manufacture of coking coal. Today, the main sources are from catalytic reforming of naphtha *(in the US)* **or steam cracking of liquid petroleum feedstocks** *(in Europe)*.

Benzene now ranks among the top 20 chemicals produced in the US by volume, while Asia Pacific is set to consume 45% of all produced benzene in 2018.

Benzene is used as a raw material in the production of ethylbenzene, cyclohexane, synthetic fibres and polystyrene. The chemical is also used in the manufacture of dyes, detergent, pesticides, rubbers, lubricants and pharmaceuticals.

238,000 PEOPLE MAY BE OCCUPATIONALLY **EXPOSED TO BENZENE** IN THE UNITED STATES ALONE

TOP 20 CHEMICALS PRODUCED IN USA

	SUBSTANCE	FREQUENCY
1	Ammonia	365
2	Sulfur Dioxide	342
3	Sulfuric Acid	150
4	Hydrochloric Acid	147
5	Butadiene	132
6	Sodium Hydroxide	130
7	Chlorine	115
8	Paint or Coating	111
9	Ethylene	109
10	**Benzene**	**105**
11	Polychlorinated Biphenyls	87
12	Carbon Monoxide	86
13	Ethylene Glycol	82
14	Mercury	77
15	Freon 22	59
16	Hydrogen Sulfide	55
17	Sodium Hypochlorite	53
18	Mixture: Hydrogen Sulfide/ Sulfur Dioxide	50
19	Propylene	49
20	Nitrogen Fertilizer	48

Health implications

These effects can cause a decrease in red blood cells resulting in anaemia, excessive bleeding, damage to the immune system and ultimately leukaemia, a cancer of the blood.

Everyone is exposed to benzene, particularly when breathing air containing benzene gas particles. While high levels come from service stations, vehicle exhausts and industrial emissions, domestic sources include tobacco smoke and solvents such as detergents, paints and glue.

Once in the bloodstream, benzene travels throughout the body and is metabolised in the liver and bone marrow. The metabolites created by this process are usually quickly flushed out in urine within 48 hours of exposure, however when metabolites are stored in the body they may cause harm.

Air pollution
is responsible for
1 in 6
DEATHS
WORLDWIDE

At high levels in air (10,000–20,000 ppm) exposure to benzene can be fatal. At lower levels (700–3,000 ppm), it can cause dizziness, headaches and unconsciousness. If high levels of benzene are ingested in food or drink, this can lead to vomiting, convulsions, rapid heart rate, coma and even death.

Benzene can be smelled in the air at approximately 60 ppm* and tasted in water at 5ppm**. However, levels much lower than this cause irreversible damage. For example, long term exposure to benzene levels as low as 1 ppm can lead to harmful effects in the tissues that form blood cells, especially the bone marrow.

**4.68 - 60 ppm*
***0.5 - 4.5/5 ppm*

NO ANTIDOTE
EXISTS FOR
BENZENE POISONING

Female Fertility

Long term exposure has been shown to directly affect female fertility. Research suggests that women exposed to high levels over several months had irregular periods and decreased ovary size. It is not known what effects exposure to benzene may have in men.

Until recently, benzene's ability to cause leukaemia was best established among adults exposed to the chemical at work. Previous studies had established a link between childhood leukaemia and exposure in the home to benzene-containing paints and solvents. Smaller studies hinted that expectant mothers' exposure at work might be a factor in the condition. A recent study has now confirmed that children whose mothers were occupationally exposed to benzene during pregnancy face a higher risk of leukaemia.

EXPOSURE TO BENZENE

REDUCES THE PRODUCTION OF BOTH

RED & WHITE

BLOOD CELLS

People employed in industries that make or use benzene may be exposed to the highest levels of benzene. These industries include petrochemicals, refining, coke and coal chemical manufacturing, rubber tyre manufacturing and transportation of petroleum products.

In total, the Department of Health and Human Services estimates more than 238,000 Americans are exposed to benzene at work every day.

MORE THAN
65%
OF WORKERS

think they face
NO RISK
from benzene

No safe levels

The EPA estimates that if someone spends their lifetime breathing benzene at concentrations of only 0.4 ppb, they raise their risk of cancer by 1 in 100,000.

TIMELINE OF BENZENE

1825
Michael Faraday isolates benzene from oil gas.

1849
First industrial-scale production of benzene begins in Germany.

1897
Swedish researchers, observing high rates of aplastic anemia in young women working in a bicycle tyre factory, conclude that benzene is a powerful poison to bone marrow.

1920s
Benzene used as after-shave lotion and douche due to its pleasant smell.

1928
Italian researchers Dolore and Borgomano publish first case study of leukaemia caused by benzene.

1939
Several investigators recommend other solvents to replace benzene, but this is not implemented.

1946
American Conference of Governmental Industrial Hygienists (ACGIH) suggests maximum level of exposure to benzene of 100 ppm, although some cases of benzene poisoning occur at levels of 25 ppm and 10 ppm. Some investigators recommend substitution of other solvents to replace benzene, but again—no implementation.

1947
Maximum level of exposure to benzene reduced to 50 ppm.

1948
Maximum level of exposure to benzene further reduced to 35 ppm. American Petroleum Institute (API) recommends maximum level of exposure to benzene of 50 ppm or less.

1957
CGIH lowers recommended maximum level of exposure to benzene of 25 ppm.

1961
Benzene first used in Turkish shoe industry; 15 years later, there is an epidemic of anemia and leukaemia (benzene exposure symptoms) among Turkish shoe workers.

1967
About 800 million gallons of benzene produced in United States. Within two years, it will be up to 1,185 million gallons.

Early 1970s
Researchers at University of North Carolina publish studies showing chronic leukaemia among people exposed to low levels of benzene.

1974
Passage of Safe Drinking Water Act requires EPA to determine safe levels of chemicals (including benzene) in drinking water.

1977
U.S. Department of Labor seeks to reduce maximum level of exposure to benzene to 1 ppm, but this is challenged in the courts by API.

1978
Benzene voluntarily withdrawn from consumer products in United States

1980

U.S. Supreme Court issues the "Benzene Decision." This ruling overturns recent policy of Occupational Health and Safety Administration, severely limiting regulatory actions.

1993

12 billion pounds of benzene produced, up from 9.9 billion in 1984.

1996

Studies show benzene-related diseases even at 1 ppm level of exposure.

2001

In wake of September 11 terrorist attacks, benzene levels at Ground Zero are 58 times higher than OSHA's permissible limit.

2005

Water supply to Harbin, China (population 9 million) cut off when benzene leaks into Songhua River.

2006

Suit filed against Coca-Cola over presence of benzene in soft drinks; smaller companies voluntarily eliminate ingredients that cause it.

2007

Four senators from Washington and Oregon demand that EPA tighten regulations on benzene; residents in Pacific northwest have some of highest levels of benzene exposure in country.

Feb 2007

Under legal pressure, EPA imposes tougher rules on benzene fuel limits.

Global legislation

While classified as a carcinogen in 1967, regulation of benzene remains disjointed. Some governments have introduced strict guidelines to protect against over-exposure, while others have little or no legislation at all.

USA

In the USA, benzene is covered by section 112d of the Clean Air Act. This requires the EPA to set emission standards for hazardous air pollutants based on performance of the maximum achievable control technology (MACT).

The US chemical engineering industry is the most strictly regulated in the country: production site fence line monitoring in California requires levels to remain just under 3 ppb (9 µg/m3). Concentration guidelines for eight other air/water pollution regulations vary from 1 to 10 ppm.

In the workplace, the Occupational Safety and Health Administration has set a permissible exposure limit of 1 ppm in the workplace during an 8-hour workday, 40-hour workweek. OSHA also recommends workers wear special breathing equipment when exposed to benzene at levels exceeding 0.1 ppm.

EUROPE

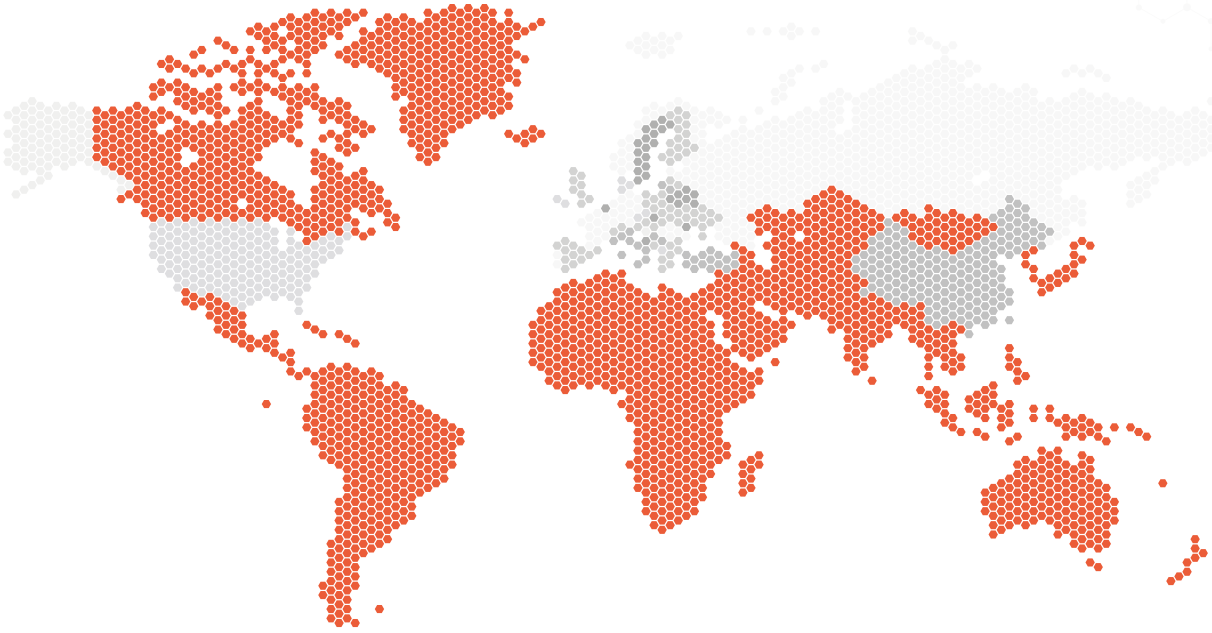
Although the EU sets safe concentration for benzene at an annual average of 5 µg/m3, European legislation classifies benzene within other chemical compounds. The UK has the same exposure limit for workers as the US.

CHINA

In China, the Air Pollution and Control Law mentions benzene, but devolves responsibility for air quality management to the local authority level. The limit for worker exposure is also higher than the US at 1.878 ppm.

REST OF WORLD

Many developing countries, such as Egypt, Ethiopia, Iran, do not legislate to keep benzene within safe levels. A 2017 study of benzene exposure in an oil refinery in Egypt found benzene risk management is low, with more than 65% of workers thinking they faced little to no risk.



Monitoring Concentrations

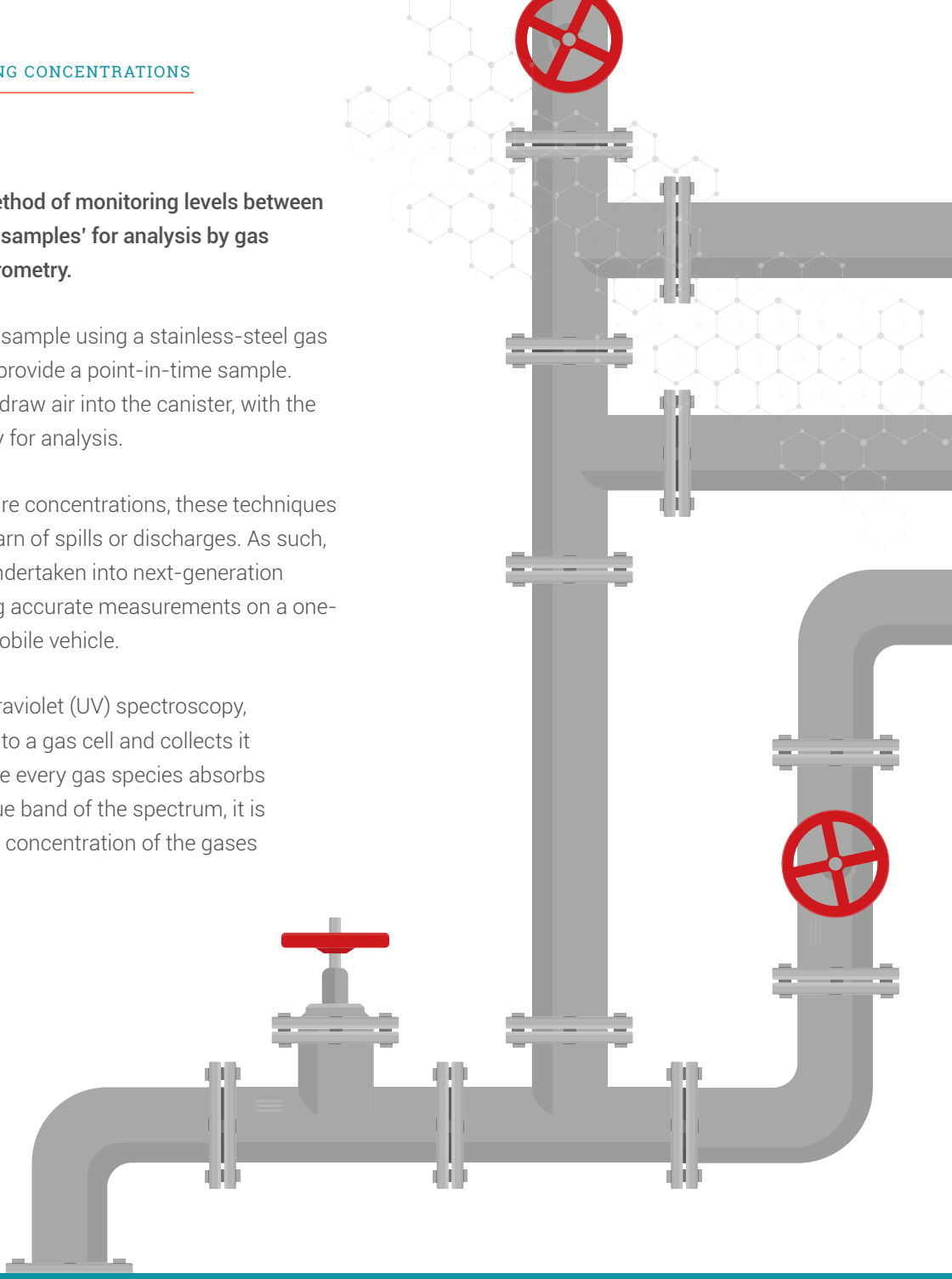
Accurately quantifying benzene in air has always been challenging. In fact, traditional products could only monitor to within ppm boundaries.

Until recently, the only viable method of monitoring levels between 10 - 50 ppb was by taking 'grab samples' for analysis by gas chromatography or mass spectrometry.

This approach involves taking a sample using a stainless-steel gas canister over a short interval to provide a point-in-time sample. The canister vacuum is used to draw air into the canister, with the sample then sent to a laboratory for analysis.

While an effective way to measure concentrations, these techniques are not responsive enough to warn of spills or discharges. As such, significant research has been undertaken into next-generation technology, capable of delivering accurate measurements on a one-second response time from a mobile vehicle.

This technology is known as ultraviolet (UV) spectroscopy, a process that shines UV light into a gas cell and collects it with a UV spectrometer. Because every gas species absorbs UV radiation along its own unique band of the spectrum, it is possible to precisely identify the concentration of the gases present.



World-Leading Technology

Duvas Technologies is at the forefront of benzene monitoring, using UV spectroscopy technology to quickly and accurately analyse levels of benzene to within ppb ranges.

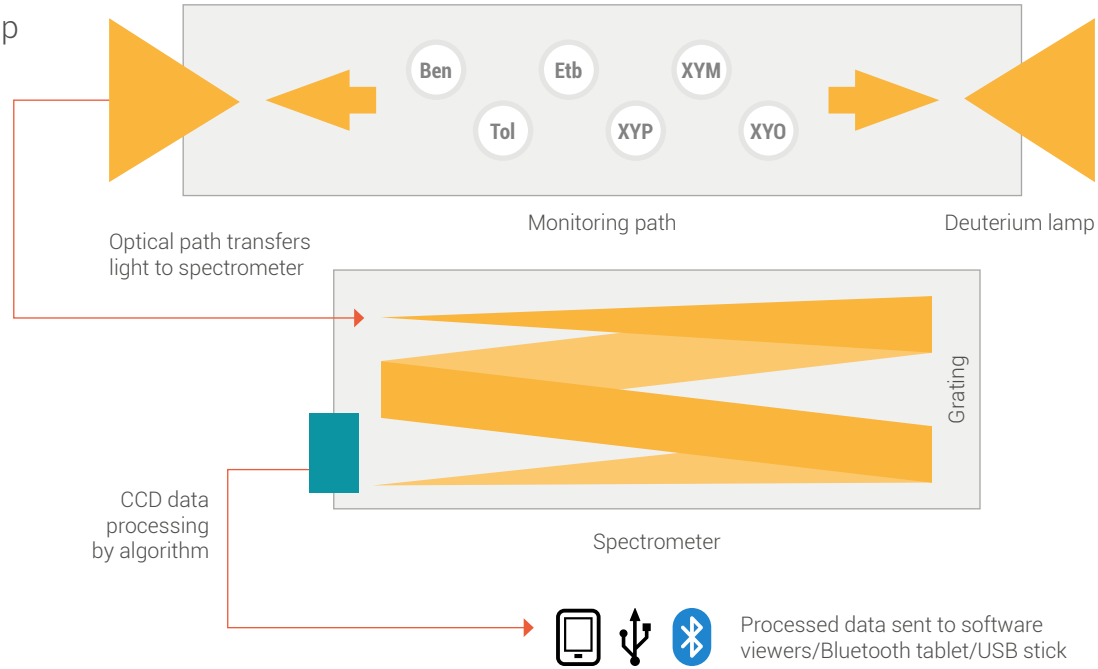
Its DV3000 system is patent protected and uses proprietary software and algorithms to analyse the readings and generate ppb concentration levels, typically every second per species.

The instrument is powered in the portable mode by battery packs, which supply power for six hours. These packs can easily be swapped during analysis for uninterrupted operation and prolonged field deployment. Easy operation ensures accurate analysis without the need for expert training.

These features make the DV3000 robust, reliable, and highly mobile. The unit is capable of undertaking perimeter fenceline reports for fracking, petrochemical and other manufacturing facilities that use or create high levels of benzene gas.

DV3000
Real-time air quality monitoring

Gas Analyser Set Up

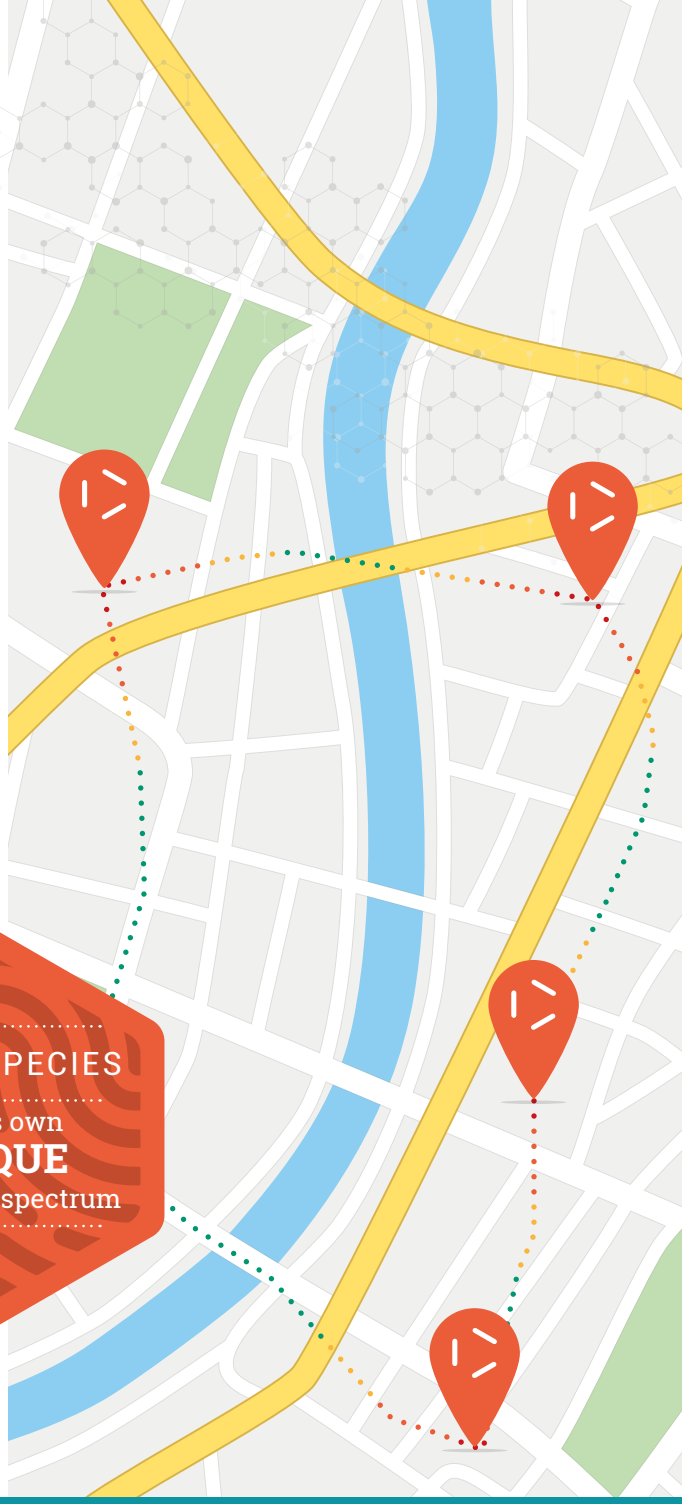


For companies which must report on pollutant levels entering the nearby environment, the system can be fixed to a specially-designed testing vehicle. This allows results to be viewed in real time and means that businesses can precisely analyse their impacts, review processes and improve air quality.

Local authorities, transport planners and fleet operators can also use the technology to map and monitor street pollutants, not only for benzene but for up to 14 gases.

- Benzene
- Toluene
- Xylene Ortho (O)
- Nitric Oxide
- Ozone
- 1,3 – Butadiene
- Ammonia
- Ethylbenzene
- Xylene Meta (M)
- Xylene Para (P)
- Nitrogen Dioxide
- Sulphur Dioxide
- Formaldehyde
- Styrene

Analysis of these gases is simultaneous to low ppb levels. Every species has its own unique absorption spectrum, like a fingerprint, making it possible to identify each individual species present at its concentration.

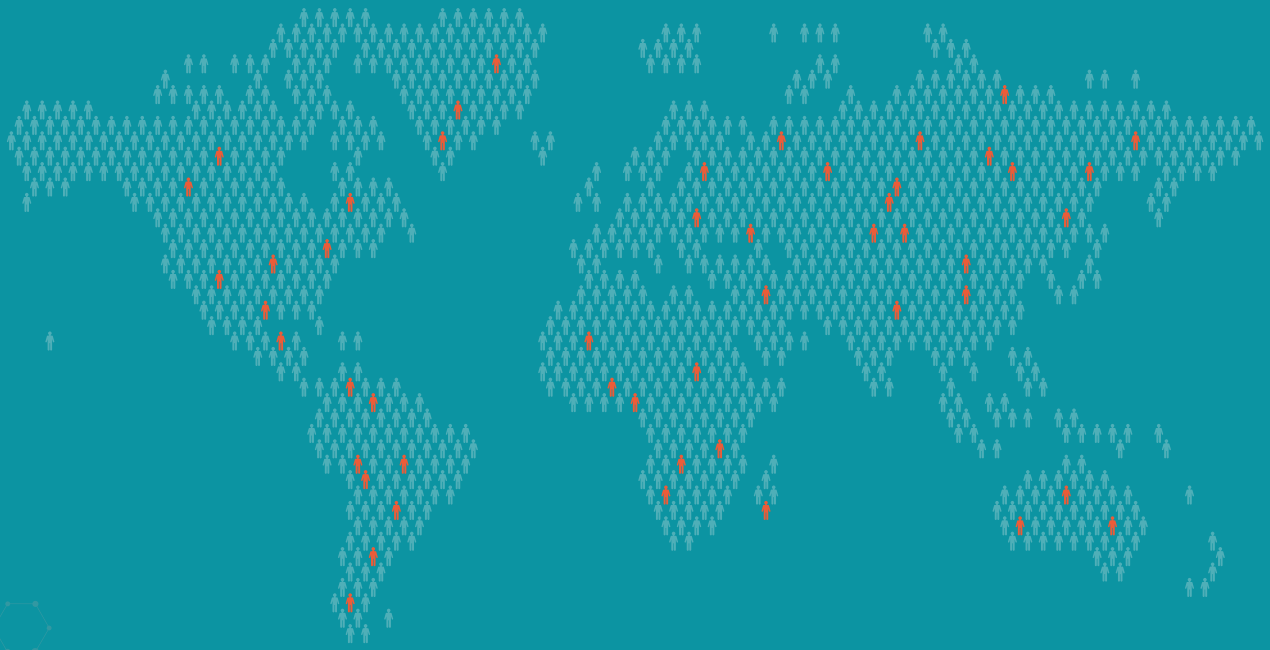


The requirement for change

Although an essential chemical, the negative aspects of benzene are severe.

Even when the legislated limit is complied with, it is estimated that continued exposure over a working lifetime could mean millions of workers around the world are dying or at risk as a result of benzene exposure every year.

Benzene in the workplace not only risks the health of adults, but can also increase the risk of leukaemia among children. Such research reinforces the essential role of research into safe levels plays in safeguarding our communities and the environment.



International Alignment

There is a notable lack of homogenous legislation guiding safe levels of benzene exposure. Until tighter legislative controls are introduced, the increasing prevalence of the chemical within industrial applications means the situation will not improve.

At Duvas, we believe tighter and more binding air and water pollution legislation is essential to reduce such risks. While international guidelines apply to carbon dioxide, nitrogen oxides and methane, this is not the case for benzene.

Governments around the world must draw up a clear structure for the regulation of benzene. The dangers are paramount – we must agree on best practice approaches and implement regulation guiding acceptable levels.

Monitoring Responsibility

Until the regulatory environment improves, it is the responsibility of everyone who uses or produces benzene to carry out routine monitoring. This not only helps individual companies take action on air pollution, but also provides an effective way to report findings to legislators and help prevent pollution in the first place.

Duvas' real-time, mobile capability provides accurate and detailed insight to businesses worldwide. By taking advantage of these advances in monitoring technology, it is possible to alert workers about high concentrations of benzene and take the necessary steps to reduce the risks to themselves and their families.

EARLY DETECTION IS ESSENTIAL

NO ABSOLUTE SAFE LEVEL OF EXPOSURE CAN BE RECOMMENDED

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