Cancer is one of the most frequent causes of deaths due to occupational illness. There are industrial workplaces where it is impossible to prevent exposure to carcinogenic materials completely, despite all available technical and preventive measures. This paper discusses approaches to protecting workers used in the United States and Germany.
Monitoring carcinogenic substances: Comparison of U.S. and German approaches

Occupational exposure limits for carcinogenic materials are typically set very low, because contact with them can cause particularly severe health consequences. There is a general tendency to further reduce these exposure limits in light of the latest scientific research regarding the effects of carcinogens on the human body.

However, there is no standardized or global occupational safety model for evaluating the risk of carcinogenic substances in the workplace. On the contrary: Safety models differ greatly, which can be seen by comparing the approaches of occupational health and safety in the United States and Germany.

U.S.: NIOSH recommends, OSHA implements

The National Institute for Occupational Safety and Health (NIOSH) is responsible for determining occupational exposure limits in the United States. The institute provides the Occupational Safety and Health Administration (OSHA) with recommendations regarding the workplace exposure limits and occupational health measures, as well as monitoring and documentation mechanisms. OSHA is then tasked with establishing a practical consensus and creating a draft of the relevant legal provisions on the basis of these recommendations.¹

As a result, there is a difference between the maximum exposure limits permitted by OSHA and the exposure limits recommended by NIOSH. The permissible exposure limits (PELs) published by OSHA are often higher than the recommended exposure levels (RELs) published by NIOSH. Another important industry standard that is recognized in practice is the threshold limit value (TLV®), which is defined by the American Conference of Governmental Industrial Hygienists (ACGIH®).² The TLV describes the concentration of hazardous substances that a worker can be exposed to on a daily basis without experiencing negative effects throughout their working life. As with all threshold values, the TLV values are regularly updated according to new findings. In contrast to the OSHA-PELs, TLVs are only a recommendation.³

NIOSH revises its policies on carcinogenic substances

The NIOSH risk evaluation is based on NIOSH’s Carcinogen Classification and Target Risk Level Policy for Chemical Hazards in the Workplace, which was originally published by NIOSH in 1978. Since then, NIOSH’s understanding of the science of cancer and the ability to measure potential exposures in the workplace have advanced a great deal. The revised policy reflects these advancements. NIOSH foresees the revised policy as improving the relevance of the information on workplace exposure to carcinogens.⁴

Technological feasibility of exposure monitoring

In the future, NIOSH plans to orient itself to existing general classifications from the U.S. National Toxicology Program (NTP), the Environmental Protection Agency (EPA), and the International Agency for Research on Cancer (IARC). IARC has classified many substances as Group 1 in the last few years, thereby classifying them as proven to be “carcinogenic for humans”. In the future, NIOSH will focus on developing effective recommendations for workplace exposure limits (recommended exposure limits – REL),⁵ based on evaluation of case reports, studies on humans and animals, and technological feasibility of exposure monitoring in the workplace.⁶
Going forward, NIOSH will also set quantitative rather than qualitative risk evaluation benchmarks. Instead of answering the question of whether a substance is potentially carcinogenic as yes or no, the carcinogen will be quantified with a concrete value, which should reduce the risk to a minimum. This approach assumes a risk probability of 1:1,000, which means that one in 1,000 workers with a lifetime workplace exposure (45 years) to the substance-specific RELs may develop cancer.\(^{11}\)

**Germany: a significantly stricter approach to risk**

In Germany, there are different approaches for evaluating the risks of non-carcinogenic and carcinogenic substances. The differentiation is generally made between a health-related exposure limit value (Arbeitsplatzgrenzwert – AGW) for non-carcinogenic substances, stated in mg/m\(^3\) or ppm\(^{12}\), and a risk-based value for carcinogenic substances.

The AGW is a maximum value. It is assumed that there is no serious health risk when substance concentrations fall below this value. By contrast, the following applies for the risk-based value: Any contact with any concentration of this substance increases the risk of developing cancer. So the risk of cancer can only be completely ruled out if there is no contact with this substance. If working in the presence of this substance is unavoidable, then a particularly stringent protection measure applies, as do special, risk-related exposure limits based on the technical regulations for hazardous substances (TRGS), published by the Federal Institute for Occupational Health and Safety and Occupational medicine (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin - BAuA).\(^{13}\)

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<table>
<thead>
<tr>
<th>CARCINOGEN/ INSTITUTION</th>
<th>OSHA(^7) (PEL)</th>
<th>NIOSH(^8) (REL)</th>
<th>ACGIH(^9) (TLV(^{10}))</th>
<th>IARC-CLASSIFICATION(^{10}) (SINCE/YEAR)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Formaldehyde (CH(_2)O)</td>
<td>0.75 ppm (TWA)</td>
<td>0.016 ppm (TWA)</td>
<td>0.1 ppm (TWA)</td>
<td>Group 1 (2012)</td>
</tr>
<tr>
<td>Benzene (C(_6)H(_6))</td>
<td>1 ppm (TWA)</td>
<td>0.1 ppm (TWA)</td>
<td>0.5 ppm (TWA)</td>
<td>Group 1 (2012)</td>
</tr>
<tr>
<td>Chrome-(VI)-compounds</td>
<td>0.0002 mg/m(^3) (soluble; TWA)</td>
<td>0.005 mg/m(^3) (soluble; TWA)</td>
<td>0.01 mg/m(^3) (not soluble; TWA)</td>
<td>Group 1 (2012: Chrome-(VI)-compounds)</td>
</tr>
<tr>
<td>Trichloroethylene (C(_2)HCl(_3))</td>
<td>100 ppm (TWA)</td>
<td>25 ppm</td>
<td>10 ppm</td>
<td>Group 1 (2014)</td>
</tr>
<tr>
<td>Vinyl chloride (C(_2)ClH(_3))</td>
<td>1 ppm (TWA)</td>
<td>lowest possible; carcinogenic</td>
<td>1 ppm</td>
<td>Group 1 (2012)</td>
</tr>
</tbody>
</table>
Exposure-risk-relationship using benzene as an example

The exposure-risk-relationship (Expositions-Risiko-Beziehung – ERB) has been used as the model for category 1A¹⁴ carcinogenic substances – such as benzene – in Germany since 2008.¹⁵ It describes the relationship between the substance concentration in inhaled air and developing cancer. This means that it is possible to derive the statistical probability of developing cancer in the event of known exposure more than eight hours a day for a period of 40 years of work.

Preventive and protective measures are imperative

No level of exposure to benzene can be considered safe. However, because working with benzene is unavoidable, special protection measures apply. In Germany, the safety approach to benzene workplaces is derived from the so-called risk acceptance concept – a traffic light principle: It differentiates between high (red), medium (yellow) and low risk (green). The threshold between high and medium risk is defined as tolerance risk. The tolerance risk corresponds to a statistical and additional cancer risk of 4:1,000, the statistical probability that four in 1,000 persons exposed to the substance throughout their working life will develop cancer at this level of risk.
Goal: Decrease acceptance thresholds
The boundary between medium risk and low risk is defined as acceptance risk. Employers are obliged to undertake measures to reduce the remaining risk to the acceptance risk value within this zone. Until 2018, pursuant to work protection provision TRGS\textsuperscript{16} 910, an acceptance risk of 4:10,000 over a lifetime of work (Arbeitslebenszeit – Alz) applied to carcinogenic substances such as benzene.\textsuperscript{17} The value describes the theoretical acceptance of four cancer cases from 10,000 workers after constant, long-term exposure. This acceptance risk, which was valid until 2018, corresponds to an acceptance threshold of 0.06 ppm / 0.2 mg\textsuperscript{3} for benzene. In 2018, the acceptance risk became 4:100,000 – so the acceptance threshold for benzene has been reduced from 0.006 ppm or 0.02 mg/m\textsuperscript{3}. This value reflects the probability of developing cancer at the level of risk present in the general environment.\textsuperscript{18} That means that any person could develop cancer as a result of benzene present in the atmosphere.

The reference values for tolerance risk (4:1,000/Alz) remains the same, as does the tolerance threshold (benzene: 0.6 ppm).

Reducing cancer cases by means of strict prevention
Let’s look at a few facts: According to the German Social Accident Insurance (Deutsche Gesetzliche Unfallversicherung – DGUV) in Germany in 2010, there were 2,486 recognized occupational deaths, 1,385 of which (55.7\%).\textsuperscript{19} were due to cancer.

According to an estimate by the Center for Disease Control and Prevention in the US in 2012, there were between 45,872 and 91,745 certified new cases of cancer caused by workplace exposure.\textsuperscript{20}

The safety approach for working with carcinogenic substances in Germany was readjusted to consistently reduce the probability of developing cancer due to contact with a carcinogen. It is now much stricter – as shown by these statistics – than in the United States. The number of deaths and the latency period, which could amount to several decades between exposure and cancer onset, require a strict prevention principle at a global level, both today and in the future.
OCCUPATIONAL EXPOSURE LIMITS

SOURCES:


2 ACGIH® and TLV® are registered trademarks of the American Conference of Governmental Industrial Hygienists


12 ppm - parts per million


