Information on performing a risk assessment for the operation of incubators with CO\textsubscript{2} and N\textsubscript{2}

This information sheet contains suggestions and example calculations for safety measures when handling carbon dioxide (CO\textsubscript{2}) and nitrogen (N\textsubscript{2}) in the laboratory. It does not replace local applicable regulations or Material Safety Data Sheets issued by the gas supplier.

1 CO\textsubscript{2} and N\textsubscript{2} in the incubator laboratory: Dangers, measures, thresholds

1.1 Standards and regulations in Germany

- Observe the national guidelines on handling gases and on the equipment and operation of laboratories.

Performing a risk assessment is strongly recommended, independent of the existing national guidelines, if incubators are operated with gases.

This document describes as an example a possible approach to performing a risk assessment on the basis of German legislation and resulting recommendations.

In Germany, thresholds for the gas concentration and specifications for the handling of technical gases are listed in the Technical Rules of the Federal Institute for Occupational Safety and Health (Technische Regeln der Bundesanstalt für Arbeitsschutz und Arbeitsmedizin) and in DIN standards. The following list does not claim to be exhaustive; it is provided as a starting point for researching the relevant national guidelines.

- Ratgeber zur Gefährdungsbeurteilung (Guide to determining risk-related occupational safety and health measures at the workplace)
- Technische Regel für Gefahrenstoffe – Schutzmaßnahmen (TRGS 500) (Technical Rule for Hazardous Substances – Protective Measures)
- Technische Regel für Gefahrenstoffe – Laboratorien (TRGS 526) (Technical Rule for Hazardous Substances – Laboratories)
- Technische Regel für Gefahrenstoffe – Arbeitsplatzgrenzwerte (TRGS 900) (Technical Rule for Hazardous Substances – Occupational Exposure Limit Value)
- Technische Regel für Betriebssicherheit – Befähigte Personen (TRBS 1203) (Technical Rule for Hazardous Substances – Qualified Persons)

1.2 Dangers when handling CO\textsubscript{2} and N\textsubscript{2}

Working with incubators requires the use of the technical gases CO\textsubscript{2} or N\textsubscript{2}.

Risks to health
- The CO\textsubscript{2} concentration in the air is too high: Risk of suffocation
- N\textsubscript{2}: Risk of suffocation due to the displacement of O\textsubscript{2}
1.3 CO₂ and O₂ thresholds in the breathing air

Thresholds for the gas concentration according to the *Guide to determining risk-related occupational safety and health measures at the workplace* (Ratgeber zur Gefährdungsbeurteilung, ed.: Federal Institute for Occupational Safety and Health (Bundesanstalt für Arbeitsschutz und Arbeitsmedizin)):

- CO₂ threshold: A maximum of 0.5%
- O₂ threshold: A minimum of 17%

1.4 Measures: Reduction of dangers from technical gases

- Observe the national guidelines on handling gases and on the equipment and operation of laboratories.
- Perform a risk assessment for the laboratory. Implement measures against the identified dangers, for instance:
  - Measures that issue an alert when a critical gas concentration is reached in the laboratory (gas detectors).
  - Measures that ensure air exchange (ventilation systems) both during normal operation and when a critical gas concentration is reached in the laboratory.

2 Notes on the use of gas detectors

- Observe the applicable regulations when using a gas detector.

Possible results of a risk assessment

- It must be possible to recognize whether the gas detector has failed from outside the laboratory.
- The gas detector must be connected to an emergency power supply.
- The gas detector issues an alert if the CO₂ concentration is too high.
- The gas detector issues an alert if the O₂ concentration is too low.
3 Example calculations for ventilation measures

The risk assessment assumes that gas will escape in the event of an accident. The following calculations make a distinction between the use of gas cylinders (a limited quantity of gas) and a permanently installed gas network (a potentially unlimited quantity of gas/a quantity of gas escaping over a period of time).

The following example calculations were developed on the basis of German thresholds for the gas concentration. All numerical values are examples.

3.1 Calculating the quantity of escaping gas: Gas cylinders

The following example calculations are based on the complete emptying of a gas cylinder in a room with a surface of 5 m × 6 m and a height of 3 m.

Room volume: 5 m × 6 m × 3 m = 90 m³

3.1.1 Calculating the CO₂ concentration

Example: CO₂ gas cylinder

• Threshold: A maximum of 0.5 % CO₂
• CO₂ gas volume: 0.55 m³/kg*
• Gas cylinder filling factor: 0.75 kg/L*
  * Example values. Observe the specifications of the gas supplier.

The CO₂ concentration in the room air (in percent) after the complete emptying of a gas cylinder is calculated approximately using the following formula:

\[
\text{CO}_2 \text{ concentration in percent} = \left( \frac{\text{Cylinder filling weight in kg} \times 0.55 \text{ m}^3/\text{kg}}{\text{Room volume in m}^3}\right) \times 100 \%
\]

CO₂ concentration in percent with a room air of 90 m³ and a 6 kg gas cylinder:

\[
\frac{6 \text{ kg} \times 0.55 \text{ m}^3/\text{kg}}{90 \text{ m}^3} \times 100 \% = 3.7 \%
\]

CO₂ concentration in the room air after the complete emptying of the gas cylinder: 3.7 %. The threshold has been exceeded.
3.1.2 Calculating the displacement of O\(_2\) by N\(_2\)

Example: N\(_2\) gas cylinder

- O\(_2\) concentration threshold: A minimum of 17% 
- Simplified value for the O\(_2\) concentration in the room air: 20% 
- N\(_2\) gas volume: 0.85 m\(^3\)/kg \(\triangleq\) 0.2 m\(^3\)/L with an internal cylinder pressure: 200 bar* 
  * Example values. Observe the specifications of the gas supplier.

The displacement of O\(_2\) in the room air after the complete emptying of a N\(_2\) gas cylinder is calculated approximately using the following formula:

\[
20\% \times (1 - \frac{\text{Cylinder filling volume in L} \times 0.2 \text{ m}^3/\text{L}}{\text{Room volume in m}^3})
\]

O\(_2\) concentration in percent with a room air of 90 m\(^3\) and the emptying of a N\(_2\) gas cylinder with a capacity of 10L:

\[
20 \% \times (1 - \frac{10 \text{ L} \times 0.2 \text{ m}^3/\text{L}}{90 \text{ m}^3}) = 19.5\%
\]

O\(_2\) concentration in the room air after the complete emptying of the N\(_2\) gas cylinder: Approx. 19.5%. 
The value has not yet fallen below the threshold.
3.2 Calculating the quantity of escaping gas: Gas network

In the event of a failure in a stationary gas supply (gas network), the escaping volume of gas within a certain period of time is important.

3.2.1 Calculating the CO₂ concentration

Example: Stationary CO₂ gas supply

- The gas supply delivers 50 L/min
- Gas volume per hour: 3000 L/h = 3 m³/h

The CO₂ concentration in the room air (in percent) in conjunction with an inflow from the gas supply is calculated approximately using the following formula:

\[
\text{CO}_2 \text{ concentration in percent} = \frac{\text{Gas inflow in m}^3/\text{h}}{\text{Room volume in m}^3} \times 100 \%
\]

CO₂ concentration in percent with a room air of 90 m³ and a CO₂ inflow of 3 m³/h:

\[
\frac{3 \text{ m}^3/\text{h}}{90 \text{ m}^3} \times 100 \% = 3.3 \%/\text{h}
\]

CO₂ concentration after 1 h: 3.3%. The threshold has been significantly exceeded.

3.2.2 Calculating the displacement of O₂ by N₂

Example: Stationary N₂ gas supply

- The gas supply delivers 166 L/min
- Gas volume per hour: 10000 L/h = 10 m³/h
- Simplified value for the O₂ concentration in the room air: 20%

The reduction of O₂ in the room air through the inflow of N₂ is calculated approximately using the following formula:

\[
\text{Reduction in the O}_2 \text{ concentration in percent} = \frac{\text{Gas inflow in m}^3/\text{h}}{\text{Room volume in m}^3} \times 20 \%
\]

Reduction in the O₂ concentration in the room air with a room air of 90 m³ and a N₂ inflow of 10 m³/h:

\[
\frac{10 \text{ m}^3/\text{h}}{90 \text{ m}^3} \times 20 \% = 2.2 \%/\text{h}
\]

- Reduction in the O₂ concentration after 1 h: 2.2% Δ 17.8% O₂ in the room air: The value has not yet fallen below the threshold.
- Reduction in the O₂ concentration after 2 h: 4.4% Δ 15.6% O₂ in the room air: The value is significantly below the threshold.
3.3 **Ventilation system: Calculating the air exchange rate**

A ventilation system is designed to prevent the gas concentration (CO$_2$, N$_2$) from increasing. The required air exchange rate can be determined based on the previous example calculations for stationary gas supply.

The air exchange rate that is actually required may be significantly higher than the example calculations due to other constraints in the laboratory. These constraints must be considered in the risk assessment.

### 3.3.1 Calculating the air exchange rate for the inflow of CO$_2$

The required air exchange rate for the inflow of CO$_2$ is calculated from the increase in the CO$_2$ concentration per hour in relation to the threshold.

\[
\text{Increase in CO}_2\text{ concentration in relation to room volume in } \%/h = \frac{\text{CO}_2\text{ concentration threshold}}{\text{Increase in the CO}_2\text{ concentration}}
\]

**Example: Air exchange rate for the inflow of CO$_2$**

- CO$_2$ inflow: 3 m$^3$/h
- Room volume: 90 m$^3$
- Increase in the CO$_2$ concentration: 3.3%\(h\)
- CO$_2$ threshold: A maximum of 0.5%

\[
\frac{3.3 \ %/h}{0.5 \ %} = 6.6/h
\]

The required air exchange rate is 6.6/h.

The supply air flow of the ventilation system must be 6.6 times the room volume per hour. A room volume of 90 m$^3$ requires a supply air flow of 594 m$^3$/h.
3.3.2 Calculating the air exchange rate for the inflow of N₂ (displacement of O₂)

The required air exchange rate for the inflow of N₂ is calculated from the reduction in the O₂ concentration per hour in relation to the maximum O₂ reduction (O₂ concentration of 20% minus the threshold of 17%).

\[
\text{Reduction in O}_2 \text{ concentration in relation to room volume in } \% / h \\
\frac{\text{O}_2 \text{ concentration reduction threshold}}{3 \%} = 0.7 / h
\]

Example: Air exchange rate for the inflow of N₂
- N₂ inflow: 10 m³/h
- Room volume: 90 m³
- Reduction in the O₂ concentration: 2.2% /h
- Maximum O₂ reduction: 3% (a reduction in the O₂ concentration from 20% to the threshold of 17%)

\[
\frac{2.2 \% / h}{3 \%} = 0.7 / h
\]

The required air exchange rate is 0.7/h.

The supply air flow of the ventilation system must be 0.7 times the room volume per hour. A room volume of 90 m³ requires a supply air flow of 63 m³/h.
Information
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English (EN)