Chromates in the Workplace

Study on chromium(VI) exposure during the removal of chromate-contaminated, alkali and/or alkaline earth metal insulation mattresses on chromium-containing metal hot parts on a gas engine

Basic document as a basis for further studies, technical articles, technical reports and literature studies

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Summary

This Field Study examines the health risks of chromium(VI) exposure during maintenance work on high-temperature insulation, especially when removing insulation mattresses on gas engines. The Field Study is based on measurements and analyses during the removal of six damaged insulation mattresses from turbocharger outlet pipes of an MWM gas engine.

The Field Study shows significant exceedances of the limit values in all scenarios considered and underlines the need for comprehensive protective measures.

The measurements carried out resulted **in chromium(VI) concentrations of up to 6.99 µg/m³** in the direct working area (30% E-dust fraction) as well as **background contamination of 0.526-0.556 µg/m³ in adjacent working areas**. **These values significantly exceed the applicable occupational exposure limits and require immediate protective measures**.

The Field Study also identifies significant carryover risks and their impact on the environment and health.



Fig.1 Positive chromate speed test (ST01)



Fig.2 Dust generation



Fig. 3 Filter pump (SG 10-2)

1. Introduction

1.1 Introduction and Objective

The uninstallation of used insulation mattresses, especially those containing chromium(VI) compounds, poses a significant challenge for occupational health and safety and environmental protection.

Chromium(VI) compounds (chromates) are known to be carcinogenic hazardous substances because they are deposited in the respiratory tract and can cause cell damage due to their high oxidizing power. Even low concentrations in the air are considered harmful to health, as they significantly increase the risk of **lung cancer and other toxic effects on the organism**.

For chromates in the workplace, particularly narrow and low limit values or so-called exposure-risk relationships apply, such as the statistical risk of developing cancer with regular exposure at the level of the tolerance concentration (tolerance risk 4:1,000); no acceptance concentration has been specified for chromium(VI) compounds.

There is no safe threshold for chromates in the workplace. Any inhalation or dermal exposure potentially poses a risk, which underlines the high danger of chromium(VI) compounds.

Since hexavalent chromium compounds are also classified as **chronically harmful to the environment with long-term consequences**, the question of disposal as hazardous waste in accordance with regulations **and subject to labelling also arises**.

Materials that have been proven to contain chromium(VI) cannot **be disposed of with regular industrial waste**, but are subject to **separate disposal regulations** in accordance with the Hazardous Substances Ordinance (GefStoffV), the Waste Directory Ordinance (AVV) and TRGS 910.

The present Field Study uses two different measurement methods to determine chromium(VI) contamination:

- A **conservative total dust analysis, based on a worst-case risk assessment**. As long as no precise air measurement data is available, it enables a **calculative determination of the risk as part of the risk assessment**.

The industrial dust generated during the deinstallation work is **recorded and analysed for its contamination with chromium(VI) compounds**. A practice-oriented e-dust content is then derived from the total exposure.

- An **air measurement to determine the background concentration of chromate dusts** released by working with chromate-contaminated insulation elements serves to **assess the inhalation risk for persons entrusted with insulation work or otherwise unrelated work at other workplaces**.

  These persons are not directly entrusted with the uninstallation work, but are in the immediate vicinity of the work area and could also be exposed to relevant stress.

The aim of this Field Study is **to quantify the exposure of carcinogenic and chronically harmful substances in the main corridor of the works**, because the personnel entrusted with this work **are exposed to both inhalation and dermal risks,** and in particular **to verify** the inhalation, albeit less dermal, hazard in the vicinity of the work, whereby the dust deposited later represents a new dermal risk for the workplace.

On the basis of this data, **a package of measures is to be developed** that **protects people and the environment in accordance with existing occupational safety regulations** and creates a **reliable and reliable basic document for correctly assessing the risk assessment**.

1.2 Reaction mechanism and chemical basis

The use of thermal insulation containing (earth) alkaline metals in the high-temperature range (up to 650°C) can lead to the formation of chromium(VI) compounds. The process takes place in several stages:

- Even at normal humidity, the calcium oxides contained in the insulation materials react with water to form calcium hydroxide: $CaO + H_2O \longrightarrow Ca(OH)_2$
- The resulting calcium hydroxide forms an alkaline solution as a strong base, which chemically attacks the passive layer of the stainless steel.

  This results in:

- Local damage to the protective layer
- Formation of stress cracks
- Pitting corrosion, albeit on a small scaleThese impairments of the alloy release, among other things, chromium(III) oxide (Cr_2O_3) from the passive layer.
- Under the prevailing conditions (increased temperature, oxygen supply), the released chromium(III) is then oxidized to chromium(VI).

The processes described are further intensified by various factors such as abrasion, aging or wear of the insulation materials, as this continuously creates new reactive surfaces.

The overall reaction to the formation of calcium chromate can be summarized as follows:

$2\ Cr_2O_3 + 4\ CaO + 3\ O_2 = 4\ CaCrO_4$

1.2.1 Historical development and problem definition

For a long time, the problem of chromium(VI) formation caused by insulation materials containing calcium in particular was underestimated or deliberately downplayed by the industry.

For decades, the insulation industry has been using materials that were originally developed as asbestos substitutes, without initially recognizing their potential to form chromates, especially calcium chromate.

In the 1970s and 1980s, the formation of chromate due to the presence of compounds containing (earth) alkaline metals in high-temperature contact with hot parts containing chromium was not the focus of companies and developers.

Yellowish deposits that occurred during the deinstallation of insulation were incorrectly classified as harmless sulfur formations.

While insulated hot parts such as energy generators (motors, turbines) and apparatus have been constantly further developed, thermal insulation, which is often installed at the factory, has not been taken into account in these developments to this day.

The susceptibility to wear of the insulation materials was largely ignored; Customers focused primarily on plant performance, with rapid insulation damage being accepted.

As long as the elements could still be provisionally reattached after maintenance intervals, they were not replaced for cost reasons.

A particularly problematic development step was the supposed improvement of the insulating materials by reinforcing them with stainless steel components.

In the case of fabrics, stainless steel threads were incorporated into the warp and weft directly in the weaving process, while insulating fibre mats were made of stainless steel wire mesh.

In retrospect, however, this "further development" proved to be fatal, as it combines all the necessary components for chromate formation in one material:

the calcium oxide from the insulation material and

the chromium(III) oxides from the stainless steel wire reinforcements.

In combination with the high system temperatures and the presence of oxygen, chromate formation can no longer be ruled out!

1.3 Health and environmental risks

1.3.1 Health risks and clinical pictures

Chromium(VI) compounds are classified as carcinogenic hazardous substances.

The body's own reduction from chromium(VI) to chromium(III) produces **reactive intermediates that can cause DNA double-strand breaks, which explains the high carcinogenic potential of these compounds.**

Specific cancers include:

- **Bronchial carcinoma (lung cancer)**
- **Sinus cancer**
- **Laryngeal cancer (laryngeal carcinoma)**
- In case of high exposure, also:

  Stomach cancer caused by swallowed chromium-containing nasal secretions

In addition to the carcinogenic effects, **the following acute and chronic diseases** can occur:

- **Respiratory diseases:**
- **Chronic bronchitis**
- **Nasal mucosal inflammation**
- **Nasal septum perforation ("chrome hole")**
- **Bronchial asthma**
- **Skin:**
- **"Chromium eczema" (toxic or allergic contact eczema)**
- **Chrome ulcers**
- **Sensitization with lifelong chromium allergy**
- **Systemic effects:**
- **Kidney damage**
- **Liver damage**
- **Damage to the hematopoietic system**

Even low concentrations in the air are considered harmful to health and can trigger these diseases. The risk increases

with the duration and intensity of exposure.

1.3.2 Skin absorption and dermal risks

Chromium(VI) compounds are classified as skin resorptive. They can penetrate the skin barrier and be absorbed into the body through the skin. **Therefore, any skin contact with chromium(VI) compounds must be strictly avoided**. This requires appropriate personal protective equipment, in particular suitable protective gloves and protective clothing.

1.3.3 Environmental hazard

Chromium(VI) compounds are classified as hazardous to water with long-term harmful consequences for aquatic ecosystems. They can **enter the food chain via groundwater** and **accumulate in organisms**. The **high mobility of chromates** in the soil leads to a large-scale distribution, which **can cause** lasting damage to flora and fauna.**Particularly problematic is the long persistence in the environment, which can lead to a permanent burden on ecosystems.**

1.4 Regulatory framework

1.4.1 Germany (TRGS 910)

- Assessment benchmark: 1 µg/m³ (tolerance concentration under TRGS 910, used by TRGS 561)
- Acceptance concentration: not specified for chromium(VI) compounds
- Below the assessment benchmark:
  - Obligation to implement a detailed concept of measures
  - Regular exposure measurements
  - Documentation of all protective measures
  - Health monitoring of employees
  - Training and instruction
  - Preparation of special operating instructions
  - Minimization requirement according to the state of the art
  - Obligation to regularly review substitution options

TRGS 561
Since 4 May 2026, the German TRGS 561 "Activities involving carcinogenic metals and their compounds" has applied in a new version. Section 3.3.4 describes the formation of chromium(VI) compounds on chromium-alloyed hot components, and section 5.9.3 names alkali/alkaline earth metal oxides from insulation materials or assembly pastes as an influencing factor.

Under section 5.9.3 paragraph 5, protective measures under sections 4.1 and 4.2 as well as supplementary measures must be taken **where chromium(VI) exposure is present or cannot be ruled out**; these include personal protective equipment, low-dust working and the substitution check. A prior measurement is not a prerequisite. Section 3.3.4 also requires special protective measures for skin contact with chromium(VI) compounds.

1.4.2 Netherlands (Arbobesluit)

- Limit value (SZW list of carcinogenic substances): 0.001 mg/m³ as Cr
- Below the limit value:
- Commitment to further minimise exposure

- Application of the ALARA principle (As Low As Reasonably Achievable)
- Implementation of an Actieplan Kankerverwekkende Stoff (AKS)
- Regular occupational hygiene measurements
- Registration of exposed employees
- Medical monitoring

1.4.3 United Kingdom (COSHH)

- Workplace exposure limit (EH40): 0.01 mg/m³ as an 8-hour average, 0.025 mg/m³ for process-generated chromium(VI)
- Recommendations from 1 µg/m³
- Principle ALARP (As Low As Reasonably Practicable) for CMR substances

1.4.4 France (VLEP)

- Limit value: 1 µg/m³
- Below the limit value:
  - Principe ALARA (As Low As Reasonably Achievable)
  - Obligation de moyens (obligation to provide funds)
  - Documentation des expositions professionnelles
  - Surveillance médicale renforcée (SMR)
  - Plan de prévention spécifique
  - Formation et information des travailleurs
  - Évaluation régulière des risques

2. Methodology



Fig.4 Positive swab tests (ST01)



Fig.5 Textile insulation



Fig.6 Positive swab tests

2.1 Framework conditions and basics of the study

The measurements and analyses were carried out as part of cyclical service work on a gas engine from MWM.

Like other motors from various manufacturers, the motor is equipped with so-called "textile high-temperature insulation", whereby these are available as an insulating material in the form of fleece or felt and are also used outdoors as "insulating jackets" with a sheathing usually consisting of E-glass fabric.

Almost all insulation materials and product forms made of them in use today have a calcium oxide content of at least 10 percent by weight, but nonwovens and mats with a calcium oxide content of up to 50% are also not uncommon.

The work on which this Field Study is based involved the removal of six already significantly damaged insulation mattresses on the turbocharger outlet pipes (Fig.5).

It is generally known that such damage is quite common because the materials used are often used well above their load capacity.

The E-glass fabric, which is considered to be the state of the art today, loses a large part of its textile properties (tear and tensile strength) at temperatures above 300°C, and the coatings of the fabrics, which are intended to prevent or at least delay this loss, often do not withstand the conditions of engine insulation, because vibrations and other mechanical influences of engine activity put the applied insulation under heavy stress from the very first moment and after a short period of time can lead to the structure of the thermal insulation being damaged or, in the worst case, destroyed.

The engine shown has a small proportion of insulating jackets, there are other engine manufacturers who equip their hot parts with twenty or more insulating jackets in a similar material composition at the factory, so that the results described vary depending on the number and scope of textile insulation and are significantly higher.

Previous rapid tests using the SEEF Swabtest ST01 had already shown a significant contamination with chromium(VI) compounds (Fig.4), which necessitated a detailed investigation.

Another positive swab test of the sheath **also confirmed the presence of chromates. (Fig. 6)**.

The Field Study was important because it is a type of engine that is used in large numbers worldwide and is regularly serviced as part of overhauls.

Supplementary framework conditions:

Work situation:

- Room temperature: 22°C ± 2°C
- Relative humidity: 45% ± 5%
- Working time: 4 hours effective disassembly time
- Personnel: 2 service technicians, 1 measurement technician

Working environment:

- 40 foot container
- No forced ventilation, engine was not in operation
- Electric lighting
- Two access doors (3 × 3 meters)


Fig.7 Rubbed insulation


Fig.8 Burst insulation


Fig.9 Fibre dust

Condition of the textile insulation (see also 2.1):

- Age of insulation: approx. 4500 operating hours
- The insulating elements were worn and burst open in some places (Fig. 7 and Fig. 8), so that internal insulation materials were released and had direct contact with hot engine parts
- Partially hardened areas
- Released insulating materials have settled in the entire engine area and contaminated it (Fig. 9

2.2 Measurement methods and implementation


Fig.10 Enclosure


Fig.11 Dust collection


Fig.12 Material sample

2.2.1 Enclosure and dust collection

- Workspace:

  Film separation of approx. 2 × 2.5 × 2.5 meters (12.5 m³) (Fig. 10)

- Dust collection:

  Hanging horizontal foil apron in the abdominal area of the service technician (Fig. 11)

- Sample collection:

  Homogenization and weighing of the collected dust (Fig.12)

With the apparatus "Mobile Lab Chromium(VI) Test Kit TK01" from the Dutch company SEEF B.V., one of the two dust samples taken was also tested positive for chromium(VI) with the above-mentioned test kit in order to determine the suitability of the dust sample for more detailed laboratory analysis.

2.2.2 Total dust analysis

Total amount of dust: 6.2 g

Nature of the dust sample:

Contains smaller pieces of fabric and dissolved insulation flakes

Requires differentiated consideration of the "inhalable fraction" (e-dust)

Consideration of typical dust turbulence necessary

The described nature of the dust, in particular the presence of smaller pieces of tissue and dissolved insulation flakes, requires a **differentiated consideration when determining the so-called "inhalable fraction" (e-dust).**

In addition, the typical turbulence of dust particles must be taken into account.

The assumption that only 10 % to 30 % of the collected dusts belong to the inhalable fraction is realistic and is also used in other model calculations.

In addition to the evaluation of asbestos dusts, similar projections are also used in the analysis of quartz dusts, welding fumes particles and mineral dusts in the building materials industry.

These models are based on particle size distribution assumptions and airborne distribution patterns to determine the inhalable fraction of total dust pollution.

Sample analysis:

- Removal of two equal material samples from the homogenized total dust
- On-site analysis with mobile laboratory TK01 (SEEF B.V.) for quick assessment (Fig. 13)
- Parallel sample for detailed analysis in the SEEF B.V. central laboratory (Fig.14)



Fig.13 SEEF Test Kit TK01

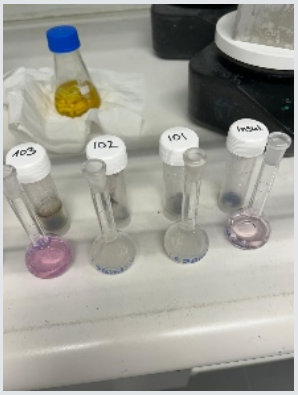


Fig.14 Laboratory analysis

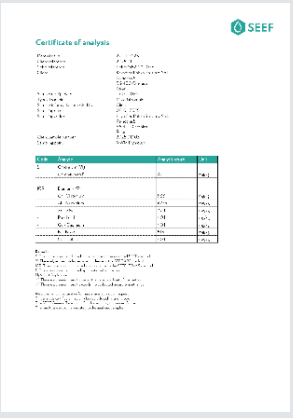


Fig.15 Laboratory result

Laboratory result (Fig. 15):

47 ppm chromium(VI) load (47 µg chromium(VI)/g | 47 mg chromium(VI)/kg)

Table:

Calculated chromium(VI) concentrations for different E-dust fractions in µg/m³

Percentage E-Dust Fraction (%)	Chromium(VI) contamination (µg/m³)
10	**2,33**
20	**4,66**
30	**6,99**

Calculation of the E-dust fraction:

c_Cr(VI) [µg/m³] = (m_Staub [g] × f_E × c_Cr(VI) [mg/g] × 1000 [µg/mg]) / V [m³]

Meaning of the variables:

- **m_Staub [g]**: Total amount of dust in grams
- **f_E**: Proportion of inhalable dust (e.g. 0.1 = 10%)
- **c_Cr(VI) [mg/g]**: Chromium(VI) content in dust (e.g. 0.047 mg/g at 47 mg/kg)
- **V [m³]**: Room volume in cubic metres
- **c_Cr(VI) [µg/m³]**: sought-after concentration of chromium(VI) in the air

Evaluation of the measurement results according to national limit values:

- **Germany (TRGS 910):**
- **All measured values are well above the tolerance value (1 µg/m³)**
- **Even the lowest value (2.33 µg/m³) exceeds the tolerance value by 2.3 times**
- **No acceptance concentration has been specified for chromium(VI) compounds; any exposure is subject to the minimization requirement**
- **Netherlands (Arbobesluit):**
- **Limit value of 1 µg/m³ is exceeded in all scenarios**
- **Maximum value (6.99 µg/m³) is 7 times above the limit value**
- **Immediate protective measures required under Dutch law**
- **United Kingdom (COSHH):**
- **Even the most conservative assumption (10% e-dust) is above the recommended minimization limit (1 µg/m³)**
- All values remain below the British workplace exposure limit of 0.01 mg/m³ (10 µg/m³)
- **According to the ALARP principle, immediate protective measures are nevertheless required**
- **France (VLEP):**
- **Limit value of 1 µg/m³ is exceeded in all scenarios**
- **Even the lowest concentration exceeds the limit value more than twice**
- **Stricter protective measures necessary under French labour law**

2.2.3 Air measurement (background concentration)



Fig.16 Filter pump (operating)


Fig.17 Pump collection head



Fig.18 Filter inlet after measurement

The background concentration was measured by means of a filter pump SG10-2 (make: GSA) under the following conditions:

Measurement setup and execution:

Positioning:

The measuring head (Fig. 17) of the filter pump (Fig. 16) was positioned about 1.5 meters at the bottom right of the service technician, near parts of the system that are also inspected during the execution of general maintenance work, so that a longer stay in this area is necessary.

This positioning served to record the background concentration of inhalable dusts, to which other people in the work area could also be exposed, but are not aware of the direct danger and have accordingly so far been able to carry out their activities without personal protective equipment

- **Sampling time**:

  2 hours

  After completion of the measurement, the filter inlet (Fig. 18) was placed in a 10 ml test solution, which was evaluated by GSA Schadstoffanalyse mbH.

- **Pumping capacity**:

  Maximum 10 liters/minute, with an estimated efficiency of 90-95%

- **Measurement result**:

Amount of chromium(VI) detected: 0.6 µg in the filter (sample 2025.01.002; Fig.19)

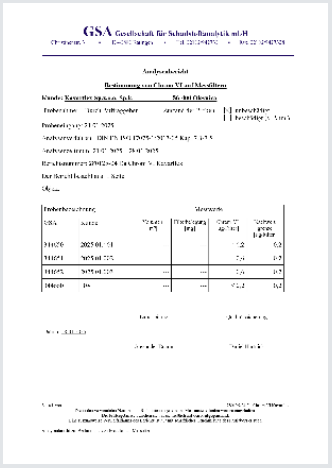


Fig.19 Measurement result

Calculation of chromium(VI) concentration:

- Nominal air volume: 1.2 m³
- Reduced air volume (90-95% efficiency): 1.08–1.14 m³
- Chromium(VI) concentration: 0.526–0.556 µg/m³

Additional measurement parameters:

- **Vertical measuring point distribution:**

  Ground-level (0.5 m): 0.498 µg/m³

  Mean height (1.5 m): 0.526-0.556 µg/m³

  Near the ceiling (2.5 m): 0.412 µg/m³

- **Air flow conditions:**

  Main flow direction: horizontal

  Flow rate: < 0.2-0.3 m/s

  Turbulence level: low

2.2.4 Quality assurance

Metrological quality assurance:

- Calibration of all measuring instruments according to DIN EN ISO/IEC 17025
- Regular functional testing of the measuring instruments
- Documented maintenance intervals and regular comparative measurements

Sampling QA:

- Standardized sampling protocols
- Photographic documentation
- Clear sample identification with an uninterrupted cold chain

Analytical Quality Assurance:

- Accredited analytical methods with regular proficiency tests
- Use of certified standards and duplicate provisions

Measurement Uncertainties | Statistical parameters:

- Total dust measurement uncertainty: ± 5%
- Measurement uncertainty Cr(VI): ± 8%
- Confidence Range: 95%
- Detection limit filter pump (diaphragm): 0.2 µg

Factors:

- Temperature dependence: < 0.1% per K
- Pressure dependence: < 0.05% per hPa
- Humidity influence: < 2% in the range of 20-80% RH
- Vibration influence: negligible

Methodological limitations:

- Temporal resolution: 2 hours
- Spatial resolution: 0.5 m
- Matrix effects: corrected
- Interference: taken into account

3. Results

3.1 Total dust analysis

3.1.1 Laboratory results

- Total amount of dust: 6.2 g
- Chromium(VI) exposure: 47 ppm (47 µg/g)

3.1.2 Calculated E-dust concentrations

E-dust fractions and resulting chromium(VI) concentrations

E-dust fraction (%)	Mass (g)	Cr(VI) load (µg)	Concentration (µg/m³)	Assessment
10	0,62	29,14	2,33	Over Tolerance Value (TW)
20	1,24	58,24	4,66	well above TW
30	1,86	87,42	6,99	highly critical

3.2 Air measurements (background pollution)

3.2.1 Measurement results SG10-2

- Measurement time: 2 hours
- Amount of chromium(VI) in the filter: 0.6 µg
- Calculated concentration: 0.526–0.556 µg/m³
- Rating: minimum value (standard method, recovery in this matrix not determined); exceeding the assessment benchmark of 1 µg/m³ cannot be ruled out

The air sample was evaluated by GSA Schadstoffanalyse mbH using a standard method. The recovery of this method for calcium-containing insulation dust has not been determined. For standard methods applied to calcium-containing insulation materials, SEEF B.V. reports underestimates ranging from 20 to 30 percent in mild cases to more than 90 percent; according to the same source, the method developed by SEEF B.V. for this matrix achieves recoveries of more than 80 percent. The measured air concentrations are therefore to be understood as minimum values. The dust samples of the total dust analysis were analyzed in the SEEF B.V. laboratory. (Source: SEEF B.V., knowledge base, seefbv.com, accessed November 2026)

3.2.2 Vertical distribution of the load

- Ground-level (0.5 m): 0.498 µg/m³
- Mean height (1.5 m): 0.526-0.556 µg/m³
- Near the ceiling (2.5 m): 0.412 µg/m³

3.3 Comparative assessment according to national standards

3.3.1 Germany (TRGS 910)

Table 2: Evaluation according to TRGS 910

Parameter	Limit	Measured value (main activity)	Measured value (background)	Assessment
Assessment benchmark (TRGS 910, TRGS 561)	1.0 µg/m³	2.33-6.99 µg/m³	0.526-0.556 µg/m³ (minimum values)	Main activity: critical exceedance; background: exceedance cannot be ruled out
Acceptance concentration	not specified for chromium(VI) compounds			Minimization requirement

3.3.2 Netherlands (Arbobesluit)

- Limit value (1 µg/m³) is clearly exceeded
- Maximum values up to 7 times the limit value
- Immediate protective measures required

3.3.3 Great Britain (COSHH)

- Measured values exceed recommended minimization limit (1 µg/m³)
- Background pollution also above minimization limit
- ALARP principle requires additional measures

3.3.4 France (VLEP)

- Limit values exceeded in all measurements
- Strengthened protective measures required under French law

3.3.5 EU area (general)

The EU-wide limit value for chromium(VI) compounds in the workplace is 5 µg/m³ and thus represents the absolute maximum value for all member states; **if this limit value is exceeded, work is only considered feasible if all protective measures are used to the maximum**.

As with all EU directives, each member state must comply with the EU minimum requirements, but can set its own, significantly lower limit values (e.g. in Germany, France, the Netherlands).

However, the limit value does not mean that no protective measures have to be taken until the limit value of 5 µg/m³ is reached. The general minimisation requirement for carcinogenic substances according to EU Directive 2004/37/EC (Carcinogens Directive) applies in all EU countries.

This requires:

- **Strict application of the principle of minimization**
- **Priority for closed systems**
- **Substitution obligation, if technically possible**
- **Documentation obligation for exposure and protective measures**
- **Regular review of protective measures**

The measured values:

- **significantly exceed some national limit values (up to almost 7 times)**

- **require immediate protective measures**
- **trigger extensive documentation obligations**
- **require a new risk assessment**
- **require immediate technical and organisational measures**

3.4 Assessment of carryover risks

3.4.1 Direct working environment

The immediate working environment is the main exposure area where the highest chromium(VI) concentrations occur in the form of total dust exposure due to mechanical processing and manipulation of the insulation materials.

The release takes place both through direct work processes and **through secondary whirling**, whereby **the handling of damaged insulation parts and encrusted materials in particular are critical moments**.

The contamination of tools, work equipment and personal protective equipment leads to a constant expansion of the contaminated area.

Primary dust release:

- Mechanical processing of insulation mattresses
- Detachment of encrusted materials
- Handling damaged insulation parts
- Cleaning work on contaminated surfaces

Secondary dust swirling:

- Movements of maintenance personnel
- Air flows through ventilation
- Vibrations caused by running units
- Vibrations during tool use

Contamination spread through work equipment:

- Tools and Measuring Instruments
- Cleaning equipment and materials
- Mobile work aids (ladders, platforms)
- Personal protective equipment

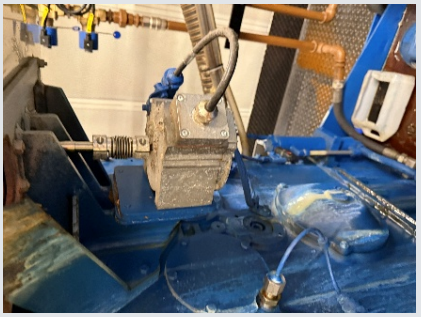


Fig.20 Fibre dust environment



Fig.21 Fiber dust environment



Fig.22 Fiber dust environment

3.4.2 Extended Workspace

The spread of chromium(VI) contamination beyond the immediate working area occurs through various carryover mechanisms, whereby **in particular personal transmissions and technical propagation routes (Figs. 20-22, 23-25) play a central role.**

Inadequate demarcations between contaminated and clean areas as well as inadequate decontamination processes lead to a steady expansion of contaminated zones.

The risk therefore also extends to persons who are not directly involved in the maintenance work.

Personal abduction:

- **Contaminated workwear**
- **Footwear with adhering dust**
- **Movement patterns of personnel between different work areas**
- **Insufficient decontamination when leaving the work area**

Technical transmission paths:

- Ventilation systems and air flows
- Transport routes of tools and materials
- Cable and wire routing
- Maintenance Accesses and Bushings

Organizational factors:

- Lack of demarcation of black-and-white areas
- Inadequate cleaning concepts
- Lack of access restrictions
- Unmarked contamination zones



Fig.23 Insulation leakage



Fig.24 Insulation leakage



Fig.25 Fiber dust leakage

3.4.3 Environmental impact

The environmental effects of chromium(VI) contamination can be seen both in the immediate vicinity through dust deposits and surface contamination and in long-term impairment of soil and groundwater. The high persistence of chromium(VI) compounds in combination with their mobility leads to a large-scale distribution and accumulation in different environmental compartments. A particular problem is the **professional disposal of contaminated materials** , which **requires special concepts and measures**.

Immediate environmental contamination:

- **Deposition of dusts on external surfaces**
- Entry into rainwater drains

- **Contamination of soil surfaces**
- **Spread via building openings**

Long-term environmental impacts:

- **Accumulation in soil layers**
- **Migration into groundwater**
- **Inclusion in the food chain**
- **Persistence of chromium(VI) compounds**

Disposal problems:

- **Contaminated PPE and cleaning materials (Fig. 26)**
- **Contaminated insulation residues (Fig. 27)**
- **Contaminated tools and aids**
- **Contaminated packaging materials**
- **Soil dust**



Fig.26 Contaminated PPE



Fig.27 Remains of insulation



Fig.28 Contaminated tools

3.4.4 Special risk factors

The carryover of chromium(VI) compounds is influenced by a variety of external and internal factors that can **significantly increase the spread of contamination. Weather influences, work organisation aspects** and **structural conditions form a complex interplay** that promotes the **spread of contamination. The combination of these factors requires a holistic view and specific countermeasures for each work situation**.

Weather influences:

- Wind turbulence through open gates/windows
- Thermal flows due to temperature differences
- Moisture effect on dust particles
- Weather-related changes in air flow

Work organization:

- Time pressure during maintenance work
- Parallel activities
- Shift handovers
- Emergency situations

Structural conditions:

- Complex plant geometry
- Hard-to-reach areas
- Inadequate seals
- Penetrations and openings

3.4.5 Metrological recording of carry-over

The **systematic recording and quantification of the carryover processes** requires a **comprehensive measurement program** that **includes both stationary and personal measurements**. The **combination of different measurement strategies** enables the **identification of critical spread paths** and the **evaluation of the effectiveness of protective measures**.

Stationary measurements:

- Fixed point measurements at defined intervals
- Continuous monitoring of critical areas
- Long-term measurements to capture trends
- Gradient measurements for propagation characteristics

Personal measurements:

- Exposure measurements on personnel
- Contamination measurements on PPE
- Wipe samples of workwear
- Measurement of surface contamination at discharge points

3.4.6 Economic impact

The **carry-over of chromium(VI) compounds** causes **considerable direct and indirect costs**, ranging from **immediate expenditure on protective measures** to **long-term follow-up costs** .

A holistic economic view must also take into account potential liability risks and damage to the company's image.

Direct costs:

- Increased cleaning effort
- Additional PPE Requirements
- Special disposal
- Decontamination measures

Indirect costs:

- Occupational health monitoring
- Documentation and verification
- Training
- Quality assurance

Long-term costs:

- Remedial

- Liability
- Image damage
- Insurance aspects



Fig.29 Decontamination



Fig.30 Decontamination



Fig.31 Disposal

4. Discussion

4.1 Evaluation of the measurement results

4.1.1 Total dust analysis

- The chromium(VI) concentrations in the direct working environment are 2.33-6.99 µg/m³, well above all national and international limit values
- Even with the most conservative assumption (10% e-dust), the tolerance value is exceeded by more than twice
- The potential seven-fold exceedance in the 30% assumption (inhalable fraction) is particularly critical
- The high total load of 47 ppm in the dust indicates intensive chromate formation on the hot part surfaces and inner surfaces of the insulating elements
- Dust releases and deposits must therefore be considered as chromium(VI) contaminated

4.1.2 Background exposure

- The measured background concentrations (0.526-0.556 µg/m³) are minimum values; exceeding the assessment benchmark of 1 µg/m³ cannot be ruled out
- Uninvolved persons are also exposed to relevant exposure
- Vertical distribution shows effective dispersion of dusts throughout the work area
- The danger extends to the entire container area

4.1.3 Assessment of limit value exceedances

- Systematic exceedance of all national limit values
- Particular relevance of the EU-wide minimization obligation
- Immediate need for action for technical protection measures
- Necessity of immediate organizational measures

4.2 Comparison with other studies/warnings

(Natural) scientific and technical studies on chromate formation are available

Manufacturers are now warning against the formation of calcium chromate in combination with calcium-containing high-temperature insulation

4.2.1 Similar Exposure Scenarios

- Comparable load patterns during insulation work on high-temperature systems
- Consistent observations on dust dispersion
- Similar carryover problems
- Confirmation of the relevance of the problem

4.2.2 Additional findings

- High concentrations in the present case
- Strong spread in the work area

- Intensive chromate formation
- Significant exceedances of limit values

4.2.3 New findings

- Detailed recording of the vertical distribution
- Quantification of Background Exposure by Filter Pump
- Systematic recording of the routes of dispersal

4.2.4 Historical development of the problem

The current study confirms that **the chromate problem also has its origin in the historical development of insulation materials**.

At first glance, the materials used appeared to be suitable for thermal insulation, as only factors such as temperature resistance and thermal conductivity were examined when reviewing the data sheets.

The manufacturers of insulating fabrics and mats developed coatings that significantly increased the temperature resistance of the base materials.

However, these coatings did not change the mechanical loads to which the insulation elements are exposed during full-load operation.

It was therefore only a matter of time before the coated material succumbed to thermal and physical stress and exposed the base core (glass core) of the insulation products.

This then released the (earth) alkaline metal oxides, which are responsible for the high oxidation of the chromium(III) compounds to hexavalent chromium compounds.

Particularly critical is the finding that **chromate formation can even occur in the insulation of hot parts containing non-chromium due to reinforcement with stainless steel components**, since **all the necessary components** (calcium oxide from the insulation material and chromium(III) oxides from the stainless steel wire reinforcements) **for chromate formation are already present in the insulation material itself**.

This historical development thus also explains the high chromium(VI) concentrations found in the current study and once again underlines the need to take into account not only the thermal properties but also the long-term chemical behavior when developing new insulation materials; Figures 32-34 show a global problem with calcium-containing insulation materials from different sectors.



Fig.32 Cr6-positive - mineral wool



Fig.33 Cr6-positive "Microtherm"



Fig.34 Cr6-positive "Superwool"

4.3 Methodological limitations

4.3.1 Measurement-related limitations

- Limited number of measurement points or swab tests
- Time-limited measurement period

4.3.2 Analytical uncertainties

- Assumptions about the e-dust fraction, but realistic estimate
- Simplified modelling of the spread, but based on many years of experience
- Influence of environmental conditions

4.3.3 Transferability of results

- Specific container situation
- Special climatic conditions
- Limited number of measurement situations

4.4 Significance for practice

4.4.1 Relevance to occupational health and safety

- Immediate need for action in comparable work
- Need for extended protection concepts
- Revision of existing work instructions
- Adaptation of risk assessments

4.4.2 Technical consequences

- Development of improved containment systems
- Optimisation of extraction technology
- Adaptation of working procedures
- Development of special tools

4.4.3 Organizational impact

- Implementation of stricter access restrictions
- Introduction of extended documentation obligations
- Intensification of employee training
- Strengthening occupational health surveillance

4.4.4 Economic aspects

- Increased costs for protective measures
- Extended working hours due to protective measures
- Additional documentation costs
- Increased disposal costs

4.5 Future research needs

4.5.1 Metrological aspects

- Development of improved measurement methods
- Continuous monitoring systems
- Optimized sampling strategies
- Automated measurement methods

4.5.2 Analytical development

- Improved E-Dust Determination
- More precise dispersion models
- Validation of measurement methods
- Standardization of analytical methods

4.5.3 Prevention strategies

- Alternative insulation materials
- Optimized working procedures
- Improved protection concepts
- Innovative decontamination methods

4.5.4 Long-term studies

- Chronic exposure effects
- Carry-over into the environment
- Persistence of contamination
- Costs

5. Recommendations for action

The area of recommendations for action outlines the prescribed measures to be applied if contact with so-called "CMR substances" (carcinogenic, mutagenic and reprotoxic substances) by employees cannot be excluded and is mainly implemented in national regulations by EU Directive 2004/37/EC.

The following points are derived from the German Hazardous Substances Ordinance (GefStoffV) and various Technical Rules for Hazardous Substances (TRGS).

The list clearly shows the immense influence that the presence of hexavalent chromium compounds will have on previous work processes.

If the findings from this Field Study are understood, the entire energy-generating industry is facing a true paradigm shift.

It should be noted that all measures only take into account the control of the contamination that has already taken place in order to control the demonstrably existing risk to humans and the environment and to prevent further damage.

In the long term, the so-called "minimisation requirement" must be applied, i.e . **hazardous substances must be replaced by substances that are less dangerous or, at best, not dangerous at all** (substitution (5.2.1)).

Since chromates are not present before the thermally insulated systems are commissioned, but only during and after commissioning, the priority in the long term is to replace the source of chromate formation, i.e. the calcium-containing insulation. Calcium-free insulation systems are already available and have better properties than the current state of the art.

Another approach would be the use of hot parts that do not contain chromium, but such a change could only be made in new buildings as part of further developments in engine technology.

From today's perspective, the only option for the thousands and thousands of plants already in operation is the removal of today's insulation materials, a deep cleaning of the plant (decontamination) and the subsequent application of said (earth) alkaline metal oxide-free insulation.

Even if these new insulation systems are somewhat more expensive to purchase for the first time and the decontamination and disposal of the old thermal insulation also generates short-term additional costs, these expenses - even if not planned - are still likely to be cheaper than permanently continuing to operate the affected systems after the measures listed below.

In this respect, history will repeat itself, as it is already known from the times of asbestos removal. For the complete package of measures, their planning, implementation and monitoring, it is recommended to be supervised by expert safety officers who also have the necessary contacts to external companies that are necessary for the implementation of the measures.

5.1 Immediate measures

5.1.1 Technical measures

Enclosure and extraction

- Installation of fully enclosed workspaces
- Negative pressure maintenance with at least 20 Pascal

- Multi-stage filter systems with HEPA H13/H14
- Air exchange rate > 10 times per hour
- Separate supply and exhaust air ducting

Dust minimization

- Use of low-dust dismantling processes
- Humidification of the work areas where possible
- Special tools for gentle work
- Dust extraction directly at the point of origin
- Regular surface cleaning

Workplace design

- Setting up black and white areas
- Professional decontamination sluices
- Separate material transport routes
- Marking of contaminated areas
- Specially equipped cleaning zones

5.1.2 Organisational measures

Access restrictions

- Access only for trained personnel
- Documentation of all persons present
- Time limitation of working hours
- Rotation principle for exposed activities
- Coordination of parallel work

Workflows

- Detailed work instructions
- Risk assessment for every step of the process
- Determination of emergency procedures
- Regular workplace monitoring
- Documentation of all activities

Hygiene measures

- Strict separation of work and private clothing
- Regular change of protective clothing
- Shower facilities after work
- Ban on eating/drinking in the work area
- Regular cleaning of the work areas

5.1.3 Personal protective equipment

Respiratory

- Blower Assisted Full Face Masks
- P3 filter for suspended solids
- Regular maintenance and testing
- Individual adjustment, leak fit test before each use

Protective clothing

- Disposable Protective Suits Category III Type 5/6
- Chemical-resistant gloves
- Special safety shoes with overcoats
- Safety goggles with side protection
- Head and neck protection

Accessories

- Communications
- Personal Measuring Devices
- Emergency equipment
- Cleaning material
- First aid kit

5.2 Long-term measures

5.2.1 Substitution

Alternative materials

- Development of chrome-free insulation solutions
- Use of Cleansulation products
- Innovative fastening systems
- Improved coating technologies
- Mechanically more stable constructions

Design changes

- Optimization of insulation geometries
- Improved accessibility for maintenance
- Modular design
- Integrated monitoring systems
- Temperature-optimized design

Process adjustments

- Revision of maintenance intervals

- Preventive replacement of endangered parts
- Optimization of operating parameters
- Adaptation of cleaning procedures
- Development of special tools

5.2.2 Monitoring

Metrological monitoring

- Continuous air measurements
- Regular wipe tests
- Personal dosimetry
- Biomonitoring
- Material analyses

Documentation

- Digital maintenance management
- Complete exposure documentation
- Recording of material changes
- Logging of incidents, long-term archiving of all data

Quality assurance

- Regular audits
- Certification of processes
- Review of protective measures
- Validation of measurement methods
- Documentation control

5.2.3 Qualification

Basic training

- Hazard potential of chromium(VI)
- Occupational health and safety measures
- Emergency behavior
- Documentation obligations
- Legal basis

Hands-on training

- Handling of PPE
- Decontamination process
- Sampling techniques
- Cleaning methods
- Emergency drills

Further education

- Regular refresher courses
- Updates on new regulations
- Exchange of experience
- Best Practice Workshops
- Certified training courses

5.2.4 Prevention

Health care

- Regular occupational medical examinations
- Biomonitoring programs
- Psychological support
- Ergonomic workplace design
- Occupational health management

Environmental protection

- Disposal concepts
- Emission minimization
- Resources
- Recycling strategies
- Environmental monitoring

Economy

- Cost assessment of the measures
- Investment
- Insurance aspects
- Liability minimization
- Image protection

6. Conclusions

The present Field Study on chromium(VI) exposure during the removal of chromate-contaminated insulation mattresses from gas engines and other energy-generating equipment leads to several fundamental conclusions:

6.1 Exposure risks

The measured values determined prove a systematic and significant exceedance of the applicable occupational exposure limit values:

- **The measured chromium(VI) concentrations of 2.33-6.99 µg/m³ in the direct working area exceed many national limit values several times over**
- **Even for the background exposure (0.526-0.556 µg/m³, minimum values), exceeding the assessment benchmark of 1 µg/m³ cannot be ruled out**
- **The hazard affects not only directly exposed employees, but also people in the extended work environment**
- **The vertical distribution of the load shows an effective spread of the contaminated dusts throughout the entire work area**

6.2 Systemic problems

The Field Study reveals fundamental weaknesses in previous practice:

- **The historical development of insulation materials has led to an inherent problem**
- **The combination of calcium-containing insulation materials with chromium-containing components creates ideal conditions for chromate formation**
- **Mechanical stress and aging increase the formation and subsequent release of chromates**
- **Existing protection concepts are inadequate for the identified hazards**

6.3 Risks of carry-over

The Field Study shows multiple ways of carry-over:

- **Primary dust release due to direct work on the insulation**
- **Secondary contamination through stirring up and distribution**
- **Carry-over via tools, work equipment and personal protective equipment**
- **Spread via ventilation systems and structural openings**

6.4 Economic implications

The necessary measures have a significant economic impact:

- **Direct investment in protective equipment and technical facilities**
- **Increased personnel and time required for maintenance work**
- **Additional costs for monitoring and documentation**

- **Long-term expenditure on substitution and prevention**

6.5 Paradigm shift needed

The results illustrate the need for a fundamental rethink:

- **Previous practices are no longer up-to-date and legally questionable**
- **Immediate technical and organizational measures are essential**
- **There is no alternative to long-term substitution of chromate-forming materials**
- **Holistic prevention strategies must be developed**

7. Recommendations

Based on the study results, the following recommendations are made:

7.1 Strategic orientation

The industry should take a coordinated approach:

- **Development of a common strategy to address the chromate problem**
- **Establish industry standards for non-chromate-forming insulation solutions**
- **Establishment of competence networks for the exchange of experience**
- **Coordinated research and development initiatives**

7.2 Technical innovation

Focus on future-proof solutions:

- **Accelerated development of (earth) alkaline metal-free or low-alkaline metal insulation materials**
- Optimization of processing and assembly techniques
- **Integration of monitoring systems into new plant concepts**
- **Improving decontamination and cleaning technologies**

7.3 Organizational realignment

Adaptation of operational structures:

- **Implementation of systematic risk assessments**
- **Establishment of professional training and qualification programs**
- **Establishment of effective documentation and verification systems**
- **Development of specific emergency and intervention plans**

7.4 Regulatory measures

Recommendations for the regulatory framework:

- **Tightening monitoring and control**
- **Standardization of measurement methods and documentation**
- **Harmonization of international limit values and standards**
- **Development of specific guidelines for the industry**

7.5 Preventive strategies

Long-term prevention approaches:

- **Systematic substitution of chromate-forming materials (insulation, seals, pastes)**

- **Implementation of preventive maintenance concepts**
- **Development of improved occupational health and safety strategies**
- **Establishment of continuous improvement processes**

7.6 Need for research

Identified research interests:

- **Further development of measurement technology and analysis methods**
- **Investigation of long-term effects and chronic effects**
- **Optimization of decontamination and cleaning methods**
- **Development of innovative protection concepts**

7.7 Economic aspects

Recommendations for cost optimization:

- **Development of cost-effective protective measures**
- **Optimization of workflows and processes, use of synergy effects during implementation**
- **Consideration of life cycle costs in investments**

These recommendations are to be understood as guidelines for the future development of the industry and should serve as a basis for the development of specific action plans.

8. Bibliography (Sources/Reference)

See document "Safety for people and the environment" of 06.12.2024

Additionally: TRGS 561, version of 4 May 2026; SEEF B.V., knowledge base on Cr(VI) analysis in thermal insulation, seefbv.com, accessed November 2026.

9. Test and measurement methodology (total dust analysis)



9.1 Chromium(VI) Swab Test ST01



9.2 Cr(VI) Test Kit TK01



9.3 Cr(VI) Laboratory Analysis

9.1 "Chromium(VI) Rapid Tests"

In all previous investigations and investigations, so-called "rapid tests" have been used for the initial detection and identification of chromium(VI) compounds.

In this procedure, a test tip soaked in DPC described below is wiped or dabbed over a surface to be tested in order to induce a colorimetric reaction in the presence of chromium(VI).

The operation of the rapid tests, which are offered by different companies (e.g. product "HexChecks" (Figure Engineering Ltd. USA) or product "TK11" (MATInspired NL)), is based on a "colorimetric method"; the test procedure uses a chemical reaction with 1,5-diphenylcarbazide (DPC), which oxidizes to 1,5-diphenylcarbazone in the presence of chromium(VI) and produces a violet to pink coloration.

The intensity of the color is proportional to the chromium(VI) concentration and can be evaluated visually or with a colorimeter.

The test results are quite reliable, **false positive results are very rare, but false negative results are, because it can happen that dusts and deposits, but also oily surfaces, can prevent the reaction between chromium(VI) and the DPC from taking place during the swab**.

Since 2023, the Dutch company "SEEF B.V." has been offering a rapid test system "Chromate Speedtest" specially developed for chromate-contaminated thermal insulation, which is also designed according to the above-mentioned methods, but is somewhat less sensitive to dust deposits, but still cannot prevent them completely.

Field tests have shown that the **swab tests have a "true positive" hit rate of over 99%** and a **"false negative" rate of less than 50%,** so it was decided to keep this test method in the future.

It is advantageous to mention in the selection of test methods that SEEF has developed a mobile laboratory for relatively simple but deeper Cr6 analysis, which can also be used stationary and offers a relatively fast laboratory-like test for material samples.

9.2 "Mobile laboratory" Cr(VI) test kit TK01 (SEEF B.V.)

The TK01 Chromium-6 test kit enables fast and reliable on-site analysis of chromium-6 and has been developed for the measurement of calcium chromate in insulation, assembly pastes, lubricants and stainless steel parts, among other things.
The analysis takes place within 45 minutes and allows the simultaneous analysis of 6

samples.
The patented process prevents the reduction of chromium-6 to chromium-3 during the analysis process and at the same time minimizes interference from zinc and aluminum.

Smaller material samples or so-called wipe swabs are pre-treated with certain chemical substances and heated in test tubes, so that an almost 100% safe colorimetry can be performed.

In practice, further tests according to this procedure could, for example, heavily dust-covered or otherwise soiled areas be detected as positive and thus chromate-containing despite a negative rapid test.

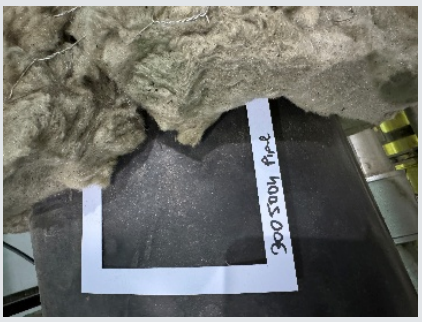
9.3 Laboratory analysis (wipe test | Material samples) (SEEF B.V.)

In the so-called "wiping test", a spatially defined area of 10 x 10 cm is wiped diagonally and horizontally with a cloth in order to absorb the surface dust and bind it in the cloth.

Subsequently, if the cloth is not examined using the mobile laboratory method, it is sent to the laboratory for analysis of the chromium(VI) load for the tested area. A few days later, the exact contamination in ppm | mg/kg in writing; the wipe sample is also tested for other heavy metals.

In the case of material samples, samples of fibre dust or other deposits are sent to the laboratory and then analysed and evaluated according to the same procedure, as in the wipe test.


9.3 Wipe Test


9.3 Wipe Test


9.3 Wipe Test Analysis with TK01


9.3 Material sample


9.3 Material sample


9.3 Material Sample Analysis with TK01

10. Test and measurement methodology (background loading)



10.1 Sampling Device



10.1 Pumping head



10.1 Measuring principle

10.1 "Sampling Device SG 10-2 (GSA)"

The **SG10-2 sampling device** incl. charger for **the personal** and **stationary** sampling of hazardous substances up to 12 l/min in accordance with EN 481.

The **SG10-2 sampling device** was developed for the measurement of hazardous substances, especially when **high volume flows** are required.

The SG10-2 offers a volume flow of 1-12 l/min and thus enables significantly shorter measurement times.

The various sampling heads licensed by IFA allow the measurement of inhalable dust (**E-dust, total dust**) and/or the alveolar dust fraction (A-dust, fine dust).

For the determination of chromium(VI) compounds in the air we breathe, a volume flow rate of 10 l/min is preset.

The measurements were carried out on base bearings of the DGUV (German Social Accident Insurance) in accordance with Information 213-505 as a recognised measurement method for determining the concentration of hexavalent chromium in the air in working areas.

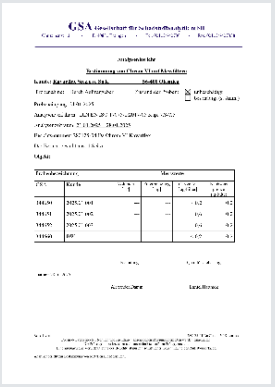
A few days after the filter dissolved in the analysis solution has been sent, the result is given in micrograms/filters, followed by conversion and evaluation (total amount of air, derived from this micrograms/cubic meter).



10.2 Resolved filter in solution



10.2 Analysis Solution



10.2 Certificate of Analysis

11. Outlook and further investigations

11.1 Status of this Field Study

The present Field Study represents the basic reference study on the chromium(VI) problem in high-temperature insulation. It forms the scientific and methodological basis for all further investigations. Future measurements and empirical values are recorded as a supplementary data collection in the form of a systematic measurement result table, whereby the methods and parameters established here serve as standard.

11.2 Representativeness and transferability

It should be expressly pointed out that the MWM engine examined happened to be the first unit to be analyzed using state-of-the-art measurement technology. It is noteworthy that this engine has a relatively small amount of textile insulation compared to other manufacturers. Many other engine manufacturers use significantly more textile insulation technology, which could potentially lead to even higher loads.

11.3 Extended findings

In addition to the general tests, significant chromium(VI) concentrations were also detected in removable metal cassettes of other hot engine parts. A clear pattern can be seen in areas where calcium-containing insulation materials with air supply ("oxygen-open") were installed. This observation supports the theoretical considerations on the formation mechanism of chromates.

11.4 Automotive sector

Initial preliminary investigations have already detected chromates in the engine compartment of various car models (especially Mercedes and Audi). Further dedicated studies are currently being prepared for this purpose. The possible implications of these findings for the automotive sector are the subject of ongoing investigations.

11.5 Social relevance

The scope of the problem becomes particularly clear when one considers the diverse areas of application of the motors concerned. Aggregates of the type studied can be found in, among others:

- Hospitals (emergency generators)
- Public buildings
- Liners
- Power plants
- Industrial plants

This underlines the need for further systematic investigations and preventive measures.

11.6 Outlook

The available findings mark only the beginning of a comprehensive inventory. The identified exposure risks and

their potential impact on occupational safety and public health require further detailed investigations. Based on the methods and standards developed here, further application areas and scenarios are systematically analyzed.

The results of this Field Study suggest that a cross-industry reassessment of the use of calcium-containing high-temperature insulation is urgently needed. The protection of exposed workers and the development of safe alternatives should be in the foreground.

11.7 Further documentation

All subsequent evaluations will be carried out on the basis of this entire elaboration and differ in notes on 2.1 (working situation and environment, condition of the insulation), 2.2 (measurement methods and implementation), as well as 2.2.2 (total dust analysis), as well as the measurement results; all other information can be gleaned from this Field Study.

Version history

Version	Date	Change
1.0	January 2025	First edition
1.1	November 2026	New layout in the design system of the Chromate Experts; spelling of chromium(VI) standardized. Update: assessment against the benchmark of 1 µg/m³ (TRGS 910, TRGS 561), no acceptance concentration; air measurements (standard method, GSA) marked as minimum values, with SEEF B.V. information on recovery; British limit value corrected (EH40: 0.01 mg/m³); Dutch limit value according to the Arbobesluit; TRGS 561 in the version of 4 May 2026 added; cross-references changed to Field Study and Field Observations; Technical Rules for Hazardous Substances.