FOLLOW-UP STUDY 20250101.02 CHROMATES IN THE WORKPLACE – PRACTICAL TEST OF INSULATION MATERIALS

Measurements and Analyses in the Handling of Contaminated Thermal Insulation – Chromates in the Workplace

Gesundheitsrisiken durch Chrom (VI)-Expositionen bei Arbeiten mit (erd-) alkalimetallhaltigen Hochtemperaturisolierungen und -systemen in der gängigen Praxis unter Anwendung anerkannter Mess- und (labortechnischen) Analysemethoden (Gesamtstaub und Hintergrundkonzentration (E-Staub) untersucht

5. Februar 2025

Revision: 1.0

Exposure to dust generated during handling of used insulation materials

Summary

This follow-up study **extends the findings** of the **main study 20250101** and the **side study 20250101.01** with **specific investigations on chromium (VI) exposure** through dust generation **during** the **normal handling of used insulation materials**. The measurements carried out simulate **realistic working conditions** that **typically occur during maintenance and disassembly work on engines and turbines**.

The results show a significant chromium (VI) contamination of the ambient air through the mere manipulation of contaminated insulation elements.

With a measured concentration of about 1.0 µg/m³, the tolerance concentration according to TRGS 910 (1.0 µg/m³) is reached or exceeded.

These findings underline the need for comprehensive protective measures even for seemingly non-critical activities such as interim storage (Fig. 2) or sorting of used insulation materials at the workplace. Insulation elements such as those shown in Fig. 3 are usually intended for further use, also because the contamination is not or only insufficiently known and is only indicated by a rapid test procedure.

In the course of these investigations, it was also possible to make the fiber flight with contaminated dusts a little visible (Fig.1)

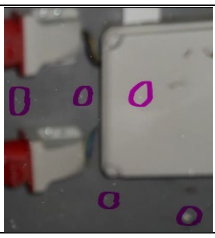


Fig.1 Fiber flight	Fig.2 Storage	Fig. 3 Reuse

1. Introduction

1.1 Background

The previous studies (20250101 and 20250101.01) have documented the fundamental problem of chromate formation through the use of high-temperature insulation containing (earth) alkali metals on hot parts containing chromium. One aspect that has received little attention so far is the potential hazard of handling already contaminated insulation materials after they have been dismantled.

1.2 Objective

This follow-up study specifically investigates the exposure to chromium (VI) compounds during typical manipulations of used insulation elements, as they are routinely carried out in the context of maintenance and service work. Of particular interest is the quantification of the background pollution caused by swirled fibrous dusts that are potentially contaminated with chromates.

The aim of this follow-up study is to point out, based on the main and secondary study, hidden and unexpected hazards from hexavalent chromium compounds in contact with the skin, but also to **the exposure of carcinogenic and chronically harmful substances during work with insulating parts** , and shows once again that both the personnel entrusted with this work and persons entrusted with other work, some of whom happen to be in the work environment described, are exposed to dangerous health risks.

Normally, the components stacked close to the engine after uninstallation would be treated without special protective clothing and pre-sorted after dismantling and thus deposited in the work area to promote dust, and would also be placed as a potential health risk or as a potential environmental risk. This practice has been practiced for decades, without anyone being aware of the double risk to humans and the environment.

Natural draught or artificial ventilation can then also lead to inhalable chromium (VI) compounds being released and inhaled.

It should also be noted that the service technicians who carry out such work are not insulators and carry out the processing of the insulation elements rather as a necessary non-binding activity.

Service technicians for engines of combined heat and power plants or emergency power generators, as they can also be found in public buildings such as hospitals and other facilities, are more likely to be mechanics, electricians, but by no means personnel entrusted with insulation technology.

On the basis of these findings**, a package of measures is now to be developed** that **protects people and the environment in accordance with existing occupational safety regulations** and creates a **reliable and reliable recommendation for action to correctly assess the hazard posed by CMR substances**.

1.3 Reaction mechanism and chemical basis of chromium (VI) compounds

[no change compared to main study (1.2)]
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: $CaO + H_2O \rightarrow Ca(OH)_2$
- 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:

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

1.3.1 Problem

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 chromates due to the presence of (earth) alkali metal-containing compounds in high-temperature contact with chromium-containing hot parts was not the focus of companies and developers.

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

[...] – see main study

The scope of service work resulting from the main study would inevitably lead to the need to store some of the insulation elements described, as the elements are normally intended for reuse.

This scope of work was simulated by storing several insulation elements separately that could no longer be used for different applications and due to structural changes on site or that had to be replaced in principle.

It is quite common for used insulation elements to be stored on construction sites or in stationary engine houses, provided they are still reasonably intact, in order to reuse them for temporary structures as temporary thermal insulation.

In this work, too, it is the service technician for engine maintenance rather than the insulator, although it should be noted that even trained insulators with many years of professional experience are not aware of the dangers that can arise from insulation materials containing alkali and/or alkaline earth metals if they have had contact with hot parts containing chromium over a longer period of time.

The following illustrations show more than clearly how carelessly insulation material is handled, because hardly anyone knows the potential danger posed by chromium (VI) compounds that have formed:

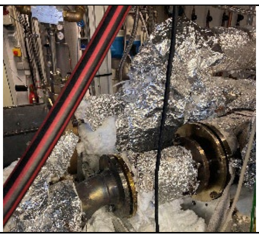


Fig.4 Cr6 hazard	Fig.5 Cr6 hazard	Fig.6 Cr6 hazard

Fig.4: Modern test bench system of the TU BerlinFig.5: Insulation residues from dismantled boilersFig.6: Old engine insulation (contaminated) in a greenhouse for houseplants

1.4 Health and environmental risks [from main study 20250101]

1.4.1 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.

1.4.2 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.

1.4.3 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.**

1.5 Regulatory framework [from main study 20250101]

1.5.1 Germany (TRGS 910)

Tolerance value: 1 µg/m³ | Acceptance value: 0.1 µg/m³
Between acceptance and tolerance value:

- 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

1.5.2 Netherlands (SER standard)

Tolerance limit: 1 µg/m³
Below tolerance limit:

- 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

1.5.3 Great Britain (COSHH)

Limit value: 5 µg/m³
Recommendations from 1 µg/m³:

- Principle of ALARP (As Low As Reasonably Practicable) for CMR substances

1.5.4 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.7 Filter pump SG 10-2	Fig.8 Cr6 Test Kit TK01	Fig.9 Filter membrane after test

2.1 Experimental set-up and framework conditions

The investigations were carried out under controlled conditions that simulate typical construction site situations. Used insulation elements of various degrees of contamination were handled as usual maintenance work.

2.1.1 Work situation:

Room temperature: 22°C ± 2°C
Relative humidity: 45% ± 5%Effective working time: 1 hourStaff: 1 service technician, 1 measurement technician

2.1.2 Materials examined:

Various used insulation elements from previous maintenance projectsDifferent levels of contamination (verified by previous quick and wipe tests) (Fig.8)Material variants: textile insulation in the form of insulating mattresses and fibre mats

2.2 Measurement Methodology

2.2.1 Metrological Recording

Sampling device: SG 10-2 (GSA) (Fig. 7)Volume flow: 10 l/min (maximum)
Measurement time: 60 minutesEstimated pump efficiency: 95-98%Theoretical total volume: 600 litersEffective sample volume (at 95% efficiency): 570 liters

2.2.2 Positioning of the measurement technology

Pump head placed above the material storeHeight: approx. 1.5 m above ground levelPosition: centrally above the handling areaDistance to active handling zones: approx. 0.5 m

2.3 Workflow

The simulation included typical handling scenarios:

Sorting of dismantled elements | Stacking by Material Type and SizeNormal Manual Movements and Stock Transfers | No targeted dust-promoting activities

These activities correspond to the usual handling of dismantled insulation parts on construction sites and thus represent realistic exposure scenarios.

2.4 Measuring instruments and analytical methods

2.4.1 Sampling device SG 10-2 (GSA)

The sampling device SG 10-2 was specially developed for the measurement of hazardous substances and is designed for the personal and stationary sampling of hazardous substances up to 12 l/min in accordance with EN 481.

Technical specifications:
Volume flow range: 1-12 l/min
Preset volume flow rate for Cr(VI): 10 l/min
IFA-licensed sampling heads
Measurement of inhalable dust (E-dust, total dust)

Quality assurance:

Regular maintenance in accordance with DGUV Information 213-505Validated calibration in accordance with EN ISO/IEC 17025
Documented functional test before each useContinuous volume flow measurement during sampling

2.4.2 Rapid test procedure SEEF ST01

The SEEF ST01 rapid test procedure is used for the qualitative on-site detection of chromium (VI) compounds.
Functional principle:
Colorimetric detection with 1,5-diphenylcarbazide (DPC)Color reaction: violet to pink with Cr(VI) presenceColor intensity proportional to Cr(VI) concentrationVisual or colorimetric evaluation possible

Features:
"True positive" hit rate: >99% | "False negative" rate: <50%Detection limit: about 0.1 µg Cr(VI) | Immediate results on siteSpecial development for chromate-contaminated thermal insulation

2.4.3 Mobile Chromium(VI) Laboratory SEEF TK01

The TK01 enables advanced on-site analysis of Cr(VI) compounds with laboratory-like precision.
Analysis principle:
Patented method for Cr (VI) determinationMinimization of interference by zinc and aluminumPrevention of Cr (VI) reduction during analysisColorimetric evaluation after defined reaction time

Technical details:
Analysis time: 45 minutesSimultaneous analysis of up to 6 samplesTemperature-controlled sample preparationMeasurement range: 0.1-100 µg Cr(VI)Reproducibility: ±5%

2.4.4 Laboratory analytical methods

The final quantification is carried out by accredited laboratory analysis.

- Filter extraction according to a standardised procedurePreparation in 10 ml analytical solutionpH value control and matrix adjustmentConsideration of blank values

Method of analysis:

UV/VIS spectrophotometry at 540 nmCalibration with certified standardsQuality assurance through proficiency testsMeasurement uncertainty: ±10%

3. Results

3.1 Measurement results

3.1.1 Filter occupancy and air concentration

- Measured amount of chromium (VI) in the filter: 0.6 µg
- Effective sample volume (at 95% pump efficiency): 0.57 m³
- **Calculated air concentration: 1.05 µg/m³**

The calculation is made according to the formula:

c [µg/m³] = m [µg] / V [m³]
c = 0.6 µg / 0.57 m³
c = 1.05 µg/m³

3.1.2 Assessment in the context of limit values

- **Tolerance concentration (TRGS 910): 1.0 µg/m³**
- **Acceptance concentration (TRGS 910): 0.1 µg/m³**
- **Measured concentration: 1.05 µg/m³**

The determined concentration is thus:

- **above the tolerance concentration (!) and**
- **significantly (factor 10) above the acceptance concentration**

3.2 Factors influencing the measurement results

3.2.1 Workplace-specific factors

- Limited air movement in the measuring range
- No additional forced ventilation
- Normal handling intensity with no special dust-bearing activities

3.2.2 Potential increase in exposure from:

- Draught with open doors/windows
- More intensive material movements/longer handling time
- Parallel activities of several employees

3.4 Assessment of carryover risks

3.4.1 Direct working environment

The immediate working environment is the main exposure area where the highest concentrations of chromium (VI) occur in the form of background exposures through mechanical processing and manipulation of the insulating elements.

The release takes place both through direct work processes and **through secondary whirling**, whereby **the handling of the components in particular represent critical moments**.

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

Primary dust release:

- Handling of the insulation cassettes
- 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

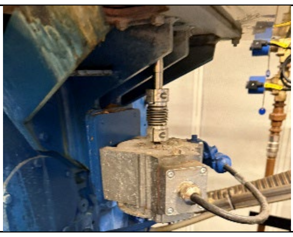


Fig.10 Fiber dust environment	Fig.11 Fiber dust environment	Fig.12 Fiber dust environment

3.4.2 Extended Workspace

The spread of chromium (VI) contamination beyond the immediate working area occurs through various carry-over mechanisms, with **personal transmissions and technical propagation routes (Figs. 10-12) playing a central role in particular**.

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

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. 23)**
- **Contaminated insulation residues due to other contaminated insulation parts (Fig. 27)**
- **Contaminated tools and aids**
- **Contaminated packaging materials**
- **Soil dust**

		
Fig.13 Contaminated PPE	Fig.14 Insulation remnants	Fig. 15 Tool contamination

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:

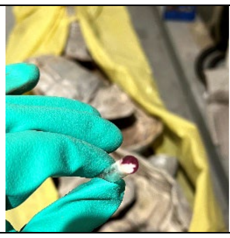
- Increased cleaning effort (Fig. 16)
- Additional PPE Requirements
- Special disposal (Fig. 18)
- Decontamination measures (Fig. 17)

Indirect costs:

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

Long-term costs:

- Remedial | Liability
- Image damage | Insurance aspects

		
Fig.16 Decontamination	Fig.17 Decontamination	Fig.18 Disposal

4. Discussion

4.1 Evaluation of the measurement results [from main study 20250101]

4.1.1.1 Total dust analysis (see main study; here: exposure due to disinstallation)

- 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

4.1.1.2 Background exposure (see main study; here: passive exposure due to disinstallation)

- The measured background concentrations (0.526-0.556 µg/m³) are above the acceptable value
- 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

4.1.1.3 Consequential exposure (from this study; here: inhalation exposure through handling/positioning)

- The measured chromium (VI) load (1.05 µg/m³) exceeds the tolerance value
- Uninvolved persons are also exposed to relevant exposure
- The vertical distribution shows a spread of dust throughout the entire work area
- The risk can extend to the entire container area
- Risk of carryover

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.

Insulation fiber products, however, naturally react by "fraying"; this exposes the base core (glass core) of the insulation products, which then leads to the release of the (earth) alkaline metal oxides, which are responsible for the high oxidation of the chromium (III) compounds to hexavalent chromium compounds; Figures 32-34 show a global problem with calcium-containing insulation materials from different sectors.

Fig.19 Cr6-positive - mineral wool

Fig.20 Cr6-positive "Microtherm"

Fig.21 Cr6-positive "Superwool"

5. Recommendations for action [in addition to the main study 20250101]

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 Guidelines 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 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 Technical measures

- **Closed containers for dismantled insulation**
- **Extraction devices for material handling**
- **Dust-minimized working processes**
- **Separate storage areas**

5.2 Organisational measures

- **Access restrictions for storage areas**
- **Documentation of material movements**
- **Staff training**
- **Regular exposure measurements**

5.3 Personal protective equipment

- **Respiratory protection at least FFP3**
- **Protective suits category III**
- **Gloves according to EN 374**
- **Eye and face protection**

6. Conclusions [complementary to the main study 20250101]

The present study clearly shows that the hazard posed by chromium (VI) compounds is not limited to active dismantling work. Even the normal handling of contaminated insulation materials leads to exposures in the tolerance concentration range. This requires a fundamental re-evaluation of occupational health and safety measures for all activities involving used insulation materials.

Particularly noteworthy:

- Exceeding the tolerance concentration, even under normal handling
- The risk for non-directly involved persons
- The need for closed systems
- The need for substitution solutions

6.1 Exposure risks

The measured values determined from a mix of different insulation materials and systems prove a systematic and significant exceedance of the applicable occupational exposure limits:

- **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 the background pollution (0.526-0.556 µg/m³) is above the acceptable values**
- **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 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 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 all study results, the following recommendations are made:

7.1 Need for further research

- Long-term measurements under different working conditions
- Investigation of carryover effects
- Development of improved measurement strategies
- Evaluation of protective measures
- Optimisation of handling procedures
- Further development of measurement technology
- Improvement of protection concepts
- Integration into existing workflows

7.2 Technical Innovation | Strategic orientation

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**

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**

7.3 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

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.

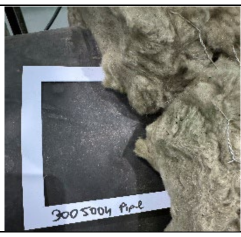
In practice, further tests according to this procedure could, for example, heavily dust-covered or otherwise soiled areas be detected as positive and thus chromate-containing despite a negative rapid test.

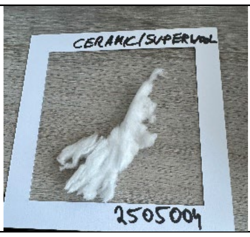
9.3 Laboratory analysis (wipe test | Material samples) (SEEF B.V.)

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.

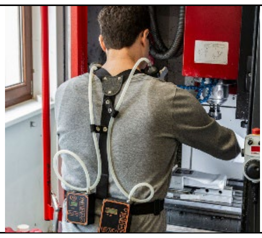
Subsequently, if the cloth is not examined using the mobile laboratory method, it is sent to the laboratory for analysis of the chromium (VI) load for the tested area. A few days later, the exact contamination in ppm | mg/kg in writing; the wipe sample is also tested for other heavy metals.

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

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.

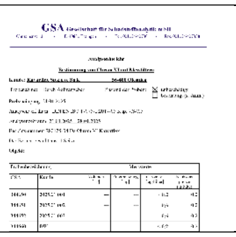
The SG10-2 offers a volume flow of 1-12 l/min and thus enables significantly shorter measurement times.

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 study

This follow-up study builds on the findings from the basic reference study (20250101 plus side studies) on the chromium (VI) problem in high-temperature insulation. It forms the scientific and methodological basis for all further investigations. The observations from this side study 20250101.01 broaden the observation perspective. Future and past measurements and empirical values are used as a supplementary data collection, with the established methods and parameters of the main study serving as standard.

11.2 Representativeness and transferability

The studies and locations of the analyses form an extract from average workplaces, as they can be found in industry worldwide and tens of thousands of times. It should be expressly pointed out that the MWM engine examined in the main study happened to be the first genset 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. The insulation cassettes examined are professional and of high quality, but do not take into account the formation of chromates. Many other engine manufacturers use significantly more textile insulation technology and significantly inferior cassettes, which could potentially lead to even higher loads.

11.3 Extended findings

The significant chromium (VI) concentrations detected in removable metal cassettes are produced according to the clear thermochemical pattern in areas where calcium-containing insulation materials with air supply ("oxygen-open") have been installed. This observation once again supports the theoretical considerations on the formation mechanism of chromates in a practical way.

11.4 Automotive sector

Initial preliminary investigations have also 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 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.