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| **Technical Rules for Hazardous Substances** | **Activities involving carcinogenic metals and their compounds** | **TRGS 561** |
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The Technical Rules for Hazardous Substances (*TRGS*) reflect the state of the art, the state of occupational health and occupational hygiene as well as other sound work-scientific knowledge relating to activities involving hazardous substances including their classification and labelling. The

**Committee on Hazardous Substances (AGS)**

compiles and/or adapts these rules in cooperation with the Occupational Medicine Committee (AfAMed). They are published by the Federal Ministry of Labour and Social Affairs in the Joint Ministerial Gazette (*GMBl*).

This *TRGS* specifies, within its scope of application, the requirements of the German Hazardous Substances Ordinance (*GefStoffV*) and the Ordinance on Occupational Health Care (*ArbMedVV*). By complying with these Technical Rules, the employer may therefore assume that the corresponding requirements of the Ordinance have been fulfilled. Should the employer choose a different solution, he must then achieve at least the same level of safety and the same health protection for his employees.

**Contents**

## 1 Scope of Application

(1) The present *TRGS* applies to activities which may involve a high risk according to *TRGS* 910 “Risk-related concept of measures for activities involving carcinogenic hazardous substances” due to an exposure to carcinogenic metals and their inorganic compounds of category 1A or 1B. This applies to substances with an exposure above the tolerable concentration. Without prejudice to the provisions of *TRGS* 910, the main objective of these *TRGS* is to achieve an exposure level below the tolerable concentration. The higher the concentration of a carcinogenic substance at the workplace, the higher the risk of contracting illness, and, accordingly, the more urgent the requirement for additional risk mitigation measures. The present *TRGS* provide guidelines for employers regarding the reduction to levels below the tolerable concentration. It is to be striven for reaching level below the acceptable concentration. This is why information regarding the measures to be taken for a medium and minor risk is also provided. This *TRGS* is therefore intended to implement the risk minimising obligation stipulated in Sec. 7 *GefStoffV*. Additional industry-specific information can be found in industry rules and guidelines by the accident insurers[1] as well as the required measures (combination model).

(2) This *TRGS* also applies to activities involving the exposure to carcinogenic metals and their inorganic compounds of category 1A or 1B with occupational exposure limit (OEL) or risk-based assessment criterion (BM).

(3) This *TRGS* concretises the special protective measures according to Sec. 10 *GefStoffV* and the concept of measures as well as the requirements of *TRGS* 910 regarding activities involving carcinogenic metals and their inorganic compounds.

(4) This *TRGS* particularly concerns the following industries and areas:

1. non-ferrous metal production,
2. cemented carbide production,
3. pig iron and steel production,
4. electroplating and chromate coating,
5. battery production,
6. recycling,
7. production and use of catalysts and pigments.

(5) In practice, there will be comparable activities with exposure to carcinogenic metals and their inorganic compounds which cannot be assigned to one of the above-mentioned industries. The TRGS is equally applicable for these areas.

(6) Without prejudice to the provisions of this *TRGS*, the REACH regulation (EC) No. 1907/2006 and Sec. 16 Para. 2 *GefStoffV* (restrictions for production and use) are to be observed. It is to be checked, in particular, whether the activities within the meaning of this *TRGS* are subject to authorisation or to any restrictions for production and use.

(7) This *TRGS* does not apply to welding-related activities such as welding, cutting and similar processes involving metals during which hazardous substances in the form of gases or particles may be released. *TRGS* 528 “Welding work” apply in this case. If information on

[1] See number 5 and references.

the exposure to carcinogenic metals during welding is given in the present *TRGS*, *TRGS* 528 shall apply accordingly.

(8) The present *TRGS* does not apply to laboratory activities involving the amounts usually used in laboratories in accordance with the requirements of *TRGS* 526 “Laboratories”. *TRGS* 526 shall apply in this case.

## 2 Definition of terms

(1) The terms in this *TRGS* are used in accordance with the definitions in the “*Begriffsglossar zu den Regelwerken der Betriebssicherheitsverordnung (BetrSichV), Biostoffverordnung (BioStoffV) und GefStoffV des ABAS, ABS und AGS*” [Glossary of terms for the rules of the German Ordinance on Industrial Safety and Health (*BetrSichV*), German Ordinance on Biological Agents (*BioStoffV*) and *GefStoffV* by the ABAS, ABS and AGS]”[2].

(2) A low risk refers to levels below the acceptable concentration, a medium risk to levels between the acceptable and the tolerable concentration. A high risk refers to levels above the tolerable concentration, the OEL or the assessment criterion (BM).

(3) Apart from that, the terms used in this *TRGS* have the following meaning: Carcinogenic metals and inorganic compounds are:

1. Carcinogenic metals of category 1A or 1B and their inorganic compounds for which an exposure-risk-relationship (ERR), including tolerable concentration and acceptable concentration in accordance with the risk concept as per *TRGS* 910, a risk-related assessment criterion[3] or an OEL according to *TRGS* 900 have been derived.
2. Metals and their inorganic compounds without an ERR which have been classified as carcinogens (cancer-causing substances) of category 1A or 1B according to the CLP Regulation (EC) No. 1272/2008 or according to *TRGS* 905 “List of carcinogenic activities or procedures according to Sec. 3 secPara. 2 No. 3 *GefStoffV*”.[4]
3. Metals which are not specified in the CLP Regulation or in *TRGS* 905 but are available on the market and their inorganic compounds which were classified as carcinogens of category 1A or 1B by the manufacturer and/or importer (according to the safety data sheet).
4. Alloys and mixtures which are classified as carcinogens of category 1A or 1B due to their content of carcinogenic metals and their inorganic compounds (≥0.1% w/w or special concentration limit in annex VI, table 3 of the CLP Regulation). Alloys can generally be considered as homogeneous mixtures of the metals they are comprised of.

(4) Substances, ores/mixtures/alloys and products which are not classified can also produce or release carcinogenic metals and their inorganic compounds during certain activities, e. g. thermal or mechanical processing.

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[2] *https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Regelwerk/Glossar/Glossar_node.html.*

[3] *https://www.baua.de/DE/Aufgaben/Geschaeftsfuehrung-von-Ausschuessen/AGS/Beurteilungsmassstaebe.html.*

[4] *https://www.baua.de/DE/Angebote/Rechtstexte-und-Technische-Regeln/Regelwerk/TRGS/TRGS-905.html.*

(5) In the following sections of these *TRGS*, carcinogenic metals and their inorganic compounds will be referred to as “carcinogenic metals”.

(6) The criterion for the inclusion as a process or an activity with relevant exposure in the present *TRGS* is the availability of data which allow for an evaluation of the compliance with the relevant assessment criteria (tolerable concentration, OEL, assessment criterion (BM)).

## 3 Information collection and risk assessment

### 3.1 General information on the hazards of activities involving carcinogenic metals

(1) The employer is required to carry out and document a risk assessment in accordance with Secs. 5 and 6 of the German Occupational Safety and Health Act and Sec. 6 *GefStoffV*. The procedures described in *TRGS* 400 “Risk assessment for activities involving hazardous substances”, TRGS 401 “Risks resulting from skin contact - identification, assessment, measures”, *TRGS* 402 “Identification and assessment of the risks from activities involving hazardous substances: inhalation exposure” and *TRBA/TRGS* 406 “Sensitising substances for the respiratory system” are to be observed. Prior to starting the activities, the employer must determine whether carcinogenic metals or metal compounds can be produced or released. In this context, the enrichment effects in thermal processes, e. g. with filter dusts, are to be taken into account as well. The employer may authorise the start of an activity only after the risk assessment has been performed and the required protective measures have been taken.

(2) It must be checked and documented whether it is possible to avoid the use of carcinogenic metals or whether a change of the procedure or work equipment would lead to reduced release of these substances. If there are suitable alternatives, these are to be used (see Sec. 6 *GefStoffV* and *TRGS* 600 “Substitution”).

(3) For activities involving non-carcinogenic hazardous substances, health-related occupational exposure limits (OEL) are defined as the maximum admissible concentration to which employees may be exposed at the workplace. OEL are derived for some carcinogenic substances as well; for these, Sec. 10 *GefStoffV* must be also observed.

(4) For carcinogenic metals with ERR, tolerable and acceptable concentrations can be found in *TRGS* 910.

(5) If it is not possible to specify a tolerable concentration, risk-related evaluation criteria within the meaning of the publication by the *BMAS* [Federal Ministry of Labour and Social Affairs] can be used as an alternative.

(6) As part of the risk assessment, the employer shall prepare an action plan in which they precisely describe which measures will be taken to further minimise exposure and to what extent the exposure will be minimised. If there is a high risk, the employer must explain in the action plan how they plan to reduce the levels in the air to below the tolerable concentration/the evaluation criterion. The measures described in the present *TRGS* are to be implemented in the process.

(7) According to the current state of knowledge, it will not be possible in some areas to reach values below the OEL, the tolerable concentration or the assessment criterion even if the system- and process-related measures in this *TRGS* are implemented. In these cases, the employees must be sufficiently protected by a suitable combination of measures includ-

ing technical, organisational and ultimately also personal protective measures (see also number 4.1, para. 8, personal protective equipment).

(8) The goal of the risk-related concept of measures is to achieve exposure levels below the acceptable concentration. According to this concept, the employer must prioritise the measures which are to be taken. The higher the concentration, the more urgent the implementation of additional operational mitigation measures.

(9) The measures of this *TRGS* are based on the carcinogenic properties of the metals. In addition, other possible specific hazards posed by these substances (e.g. sensitising effects or physio-chemical hazards such as explosion hazards) are to be considered in the risk assessment.

(10) The protective measures which are mentioned in this *TRGS* are based on evaluations of working areas, in particular from IFA's exposure database "Measurement data relating to workplace exposure to hazardous substances" (MEGA database) and from the industry. The selected activities are representative for areas with high and medium risks of exposure to carcinogenic metals. This includes areas in which it is known that such metals are produced or released during the applied procedure.

(11) The inhalation exposure at the actual workplace is to be determined and evaluated according to *TRGS* 402.

(12) If the concentration of carcinogenic metals in a mixture is known (e.g. if the dust composition in the air is identical to the composition of the processed mixture), the concentration of the metal can be calculated based on the concentration of the measured E dust or A dust (E = inhalable dust, A = alveolar dust) in some cases. This is, for example, often the case in the area of powder processing. If the calculated value is below the acceptable concentration, no further additional protective measures need to be taken to reduce the inhalation exposure for these work areas.

(13) Regarding activities involving carcinogenic metals, it is to be noted that only part of the exposure of the employee is caused by the inhalation of carcinogenic metals. Oral intake (e.g. by hand-to-mouth contact) is possible and is to be minimised by the implementation of suitable hygiene measures (see no. 4.1 of this *TRGS*). The risk of dermal exposure must also be evaluated in the risk assessment (see *TRGS* 401).

(14) The determination of the exposure to carcinogenic metals through biomonitoring in the framework of preventive occupational medical care, including possible examinations, may play a decisive role, irrespective of the concentration in the air at the workplace. Experience shows that, with various metals, the levels in blood or urine depend greatly on operational and personal hygiene as well as personal behaviour. Findings from biomonitoring are therefore an important additional tool in monitoring the effectiveness of protective measures (see also number 6 and Occupational Safety and Health Rule *AMR* 6.2). Biomonitoring procedures require the approval of the employee. If exposure equivalents for carcinogenic agents are used (*EKA* correlation), the air concentrations must be within the scope of the *EKA* correlation. In particular regarding the acceptable concentration, this is usually not the case.

(15) According to Sec. 15 *GefStoffV*, the employer is obliged to inform contractors about hazards for employees and specific rules of conduct, if an exposure to carcinogenic metals cannot be ruled out with certainty. This refers in particular to the following activities:

1. servicing,
2. building cleaning,
3. street cleaning,
4. transport and washing of dirty work clothes,
5. cleaning of respiratory devices and other personal protective equipment.

### 3.2 Measurement information

(1) In measurements which have been available up to now, mainly the I-fraction (inhalable dust) was determined. It must therefore be checked in the risk assessment whether the available measured values for E dust can be compared using the assessment criteria for metals, which often refer to the A fraction (alveolar dust). Information on particle size at the actual workplaces should also be considered. If no information is available regarding the proportion of A dust in the measured E dust, the entire E dust should be evaluated as if it was A dust as a conservative assessment. Instead of such an assumption, it is recommended to carry out new measurements. The fraction to which the relevant assessment criterion refers is to be evaluated.

(2) Due to further methodological developments, significantly lower limits of quantitation have recently emerged for some substances. This applies in particular to chromium(VI) compounds. This must be taking into account in the evaluation of older measurements. If older measurement results with limits of determination above the assessment criterion are available, it is recommended to perform at least indicative measurements using new, more sensitive measurement methods to evaluate the exposure situation. The AGS publishes suitable measurement methods, primarily of carcinogenic substances, in the form of a list[5].

(3) If several carcinogenic metals are present at the same time, a key component may be measured in justified cases, e.g if the composition of the substances in the air at the workplace is known. The key component is the metal with the highest substance index according to *TRGS* 402. The dust fraction which is to be assessed must be taken into account in this case. The reasons for this course of action are to be documented in the risk assessment. In addition, known interaction and combination effects are to be considered[6].

(4) A differentiation of individual compounds or oxidation stages is problematic regarding the classification of metals, in particular with the low concentrations which are to be assessed. For the evaluation of the measured results, it must therefore be kept in mind that although very low metal concentrations in the air at the workplace can be detected quantitatively using the described methods, but that the quantification refers to the overall content of the metal in the compound. In general, it is to be assumed in the exposure evaluation that metal compounds are present unless the risk assessment proves otherwise. In analyses, the

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[5] *http://www.baua.de/dok/8667860.*

[6] According to current information, none of these effects have been found or are specified in *TRGS* 900 or *TRGS* 910 for the scope of application of this *TRGS*.

overall metal content is usually determined. Chromium is an exception; here, the specific detection of chromium(VI) compounds is possible.

### 3.3 Substance-specific information and notes

(1) The assessment criteria for all metals which are relevant for the present *TRGS* are compiled in table 1.

(2) The level of inhalative exposure must be determined by the employer in measurements at the workplace or by other suitable methods. Measurement results of comparable workplaces and activities can be used for the risk assessment, if the measurements were performed and documented according to the provisions of *TRGS* 402.

(3) In addition, substance-specific information is required for the risk assessment and the selection of protective measures relating to the exposure to carcinogenic metals. This e.g. refers to the scope of application of the assessment criteria, possible classifications based on non-carcinogenic effects and information on the importance of biomonitoring.

(4) Restrictions and prohibitions of use are regulated uniformly in Europe by Regulation (EC) No. 1907/2006 of the European Parliament and of the Council concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH Regulation). The use restrictions for metals are listed in annex XVII, numbers 19, 23 and 27; substances subject to authorisation are listed in annex XIV. In addition, the German regulations regarding production and use restrictions according to Sec. 16 *GefStoffV* in conjunction with annex II no. 6 (“Particularly Dangerous Carcinogenic Substances”) are to be observed.

**Table 1:** Assessment criteria for carcinogenic metals

| Substance | Assessment criterion | | Exceedance factor | Source |
|---|---|---|---|---|
| Arsenic compounds, classified as carc. 1A, carc. 1B | TC<br>AC | 8.3 µg/m³ (E)<br>0.83 µg/m³ (E) | 8 | *TRGS* 910 |
| Beryllium and beryllium compounds | OEL<br>OEL | 0.14 µg/m³ (E)<br>0.06 µg/m³ (A) | 1 | *TRGS* 900 |
| Cadmium and inorganic cadmium compounds, classified as carc. 1A, carc. 1B | TC<br>AC | 1.0 µg/m³ (E)<br>0.16 µg/m³ (A) | 8 | *TRGS* 910 |
| Chromium(VI) compounds | BM | 1.0 µg/m³ (E) | 8 | *TRGS* 910 |
| Cobalt and cobalt compounds, classified as carc. 1A, carc. 1B | TC<br>AC | 5.0 µg/m³ (A)<br>0.5 µg/m³ (A) | 8 | *TRGS* 910 |
| Nickel compounds, classified as carc. 1A, carc. 1B | TC<br>AC | 6.0 µg/m³ (A)*<br>6.0 µg/m³ (A) | 8 | *TRGS* 910 |

**Key:**
TC Tolerable concentration
AC Acceptable concentration
OEL Occupational exposure limit
BM Assessment criterion, risk-related
(A) Alveolar fraction
(E) Inhalable fraction

* The tolerable concentration was defined based on the non-carcinogenic effect. In this case, the value corresponds to the acceptable concentration. Therefore, there is no medium risk range.

### 3.3.1 Arsenic compounds

(1) The ERR derivation for arsenic compounds applies to all arsenic compounds which have been classified as carcinogens of category 1A or 1B. It does not apply to arsenic trisulphide (virtually insoluble in water), gallium arsenide (effect of other inorganic arsenic compounds cannot be transferred) and for arsenic metal (not classified as carcinogenic).

(2) The ERR applies to the inhalable fraction.

(3) At the workplace, inhalation is most relevant. Possible oral exposure by hand-to-mouth contact, however, should also be considered. Dermal intake, by contrast, is of subordinate importance.

(4) Since they are chemically related to zinc and copper, arsenic compounds are found in raw materials for zinc, lead and copper production. Arsenic compounds are used, for example, in glass and zinc production as well as in electronic components.

(5) Biomonitoring is of importance for arsenic compounds (see 6.3). The correlation with workplace-related exposure is, however, often affected by external factors (in particular eating habits). When the examination is performed, it is therefore particularly important to ensure that the employee does not eat fish or seafood (for 48 hours before sampling)[7].

(6) For arsenic trioxide, (preliminary) exposure equivalents for carcinogenic substances (*EKA* correlation) between air pollution and urine excretion were derived. 10 µg/m³ of arsenic in the air correspond to 51 µg/l arsenic concentration in the urine. According to the ERR, the biological guidance value would be associated with a risk of approximately 5:1000.

(7) In further processing, exposure to arsenic compounds mainly involves arsenic trioxide. In the area of glass production, arsenic trioxide is used to produce special glasses. The TWA concentrations are typically below the tolerance concentration. The exposure situation in zinc production is similar.

### 3.3.2 Beryllium and beryllium compounds

(1) OELs were derived for beryllium and its inorganic compounds. Beryllium is classified as carcinogenic in the category 1B. The carcinogenic effects, however, are overshadowed by the effects on respiratory organs (chronic beryllium disease). For activities involving beryllium, however, Sec. 10 *GefStoffV* must be additionally observed. Beryllium and beryllium oxide are mainly responsible for causing the effects associated with beryllium.

(2) For beryllium, an E as well as an A value were derived as an OEL. Regarding the condensation of metal vapour or activities involving liquid beryllium-containing alloys, the A fraction was found to be predominant so that compliance with the A value is sufficient in this case. Dusts from other sources contain beryllium mainly in their E fraction so that compliance with the E value is sufficient. If the OEL is exceeded, measures from the medium and/or high

[7] Publication by the Federal Environment Agency, Bundesgesundheitsbl - Gesundheitsforsch - Gesundheitsschutz 2009 · 59:77–982.

risk area according to 4.1, Para. 7 or 8 of the present *TRGS* may be suitable to reduce the levels to below the limit value.

(3) Due to the sensitising effect of beryllium, special protective measures are required in case of skin contact with beryllium-containing solutions or salts (see also *TRGS* 401). This applies in particular to wounds or injuries to ensure that no beryllium-containing particles can enter the body. No special protective measures are required for skin contact with solid beryllium-containing alloys,.

(4) Workplaces where an exposure to beryllium above the OEL is to be expected are found in industrial areas where beryllium-containing alloys (in particular Be/Cu alloys) are produced and processed, the ceramics industry, cutting mills and Al and Mg melting plants.

(5) Recommendations for occupational physicians regarding activities and the prevention of chronic beryllium disease can also be found in the S3 guideline "*Gesundheitsüberwachung bei Beryllium-Exposition und diagnostisches Vorgehen bei Beryllium-assoziierter Erkrankung*" [Health monitoring in case of beryllium exposure and diagnostics for diseases associated with beryllium][8].

(6) For an overview of the exposure situation in the years 2000 to 2011 including measurements for 49 industries and 103 working areas with an exposure duration of more than six hours, please refer to the MEGA analysis from 2013 for creating exposure scenarios for beryllium and its compounds[9]. In the analysis, the majority of the measurement results is below the analytical limit of quantitation which was then above the currently applicable OEL for the E fraction.

### 3.3.3 Cadmium and cadmium compounds

(1) The ERR derivation for cadmium and its compounds applies to the metal and all compounds which are classified as carcinogenic. The most relevant of these are cadmium, cadmium oxide, cadmium hydroxide and cadmium carbonate. Some low-solubility cadmium compounds are not classified as carcinogenic (e.g. CdTe, xCdS·yCdSe and xCdS·yZnS). Cadmium chloride is not included in the scope of application of this *TRGS*. Sec. 16 Para. 2 *GefStoffV* applies to this in conjunction with annex II no. 6 which specifies that this substance may only be produced or used in closed systems.

(2) The carcinogenic effects were used to derive the A dust value (acceptable concentration); the nephrotoxic effects were used to derive the E dust value (tolerable concentration). In general, a high proportion of A dust is to be expected in places where a large part of the dust is generated by the condensation of cadmium vapour. When liquid metallic cadmium is used at a workplace, it can also be expected that the dust would mainly consist of A dust which means that A dust is to be primarily used for the assessment. The same applies to aerosols from solutions which contain soluble cadmium compounds, e.g. $CdSO_4$ and activities involving cadmium-containing filter dusts. Dusts from other sources contain cadmium mainly in the E dust.

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[8] S3 guideline "Gesundheitsüberwachung bei Beryllium-Exposition und diagnostisches Vorgehen bei Beryllium assoziierter Erkrankung": *http://www.awmf.org/leitlinien/detail/ll/002-032.html*.

[9] MEGA analyses for the preparation of REACH exposure scenarios for beryllium and its compounds: *http://www.dguv.de/medien/ifa/de/fac/reach/mega_auswertungen/beryllium_und_seine_verbindungen-2.pdf.*

(3) At the workplace, cadmium enters the body primarily by inhalation. Possible oral exposure by hand-to-mouth contact, however, should also be considered. Dermal intake, by contrast, is of subordinate importance.

(4) Cadmium is part of the raw materials for the primary production of zinc. It is mainly used in the area of battery production and semi-conductor production. In the aerospace industry, defence technology and in nuclear facilities, parts may also be manufactured in which cadmium is used for coating or other purposes. Cadmium can also be found in the recycling of plastic windows (Cd stabilisers), in electronic waste and in the production of solar panels.

(5) Cadmium is stored in the liver and in the kidneys. The discharge of resorbed cadmium with urine and stool is very delayed. The biological half-life is ten to 20 years. In addition to the carcinogenic effect, damage to the kidneys is the main consequence of a chronic exposure to cadmium. The Scientific Committee on Occupational Exposure Limit Values (SCOEL) proposed a biological limit value (BLV) of 2 µg/g creatinine in urine.[10, 11]

(6) A publication from the year 2011 provides an overview of the work-related exposure to cadmium[12]. Exposure to cadmium at the workplace occurs in zinc production, the recycling of electric and electronic devices, the removal of cadmium-containing paints or the welding of cadmium-containing alloys.

### 3.3.4 Chromium(VI) compounds

(1) With the exception of barium chromate and the compounds which are listed in annex VI of the CLP regulation, chromium(VI) compounds are classified as carcinogens of category 1B and as skin sensitizers and in some cases as respiratory sensitizers of category 1. The most important chromium(VI) compounds are chromium(VI) oxide ($CrO_3$), chromates ($CrO_4^{2-}$) and dichromats ($Cr_2O_7^{2-}$).

(2) No ERR could be derived for chromium(VI) compounds,. The risk-related assessment criterion of 1 µg/m³ is to be used for the inhalable fraction. With an exposure of 1 µg/m³ over the entire working life, there is an additional statistical lung cancer risk of approx. 4:1000. A concentration above 1 µg/m³ means a high risk, a concentration below 1 µg/m³ means a non-quantifiable low risk[13]. Compliance with the assessment criterion is therefore ensured according to DIN EN 689:1995-04 at levels below 0.1 µg/m³ (10% of the assessment criterion). A suitable measurement method is currently not available since the limit of quantitation is above 0.1 µg/m³ at the moment.[14] A reduction of the exposure to values below the current limit of quantitation is to be aimed for.

(3) Due to the skin sensitising properties, special protective measures are required for skin contact with chromium(VI) compounds (see *TRGS* 401). In the risk assessment, the respiratory system sensitising properties of chromium(VI) compounds are to be considered as well (see *TRBA/TRGS* 406).

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[10] SCOEL, List of recommended health-based biological limit values (BLVs) and biological guidance values (BGVs), June 2014, *http://ec.europa.eu/social/BlobServlet?docId=12629&langId=en*.

[11] See number 6.3.

[12] Work-related exposure to carcinogenic, mutagenic and reprotoxic substances in Germany – Part 1: cadmium and its compounds. Gefahrstoffe - Reinhalt. Luft 71 (2011) no. 1/2, p. 47-56.

[13] See reason for the assessment criterion for chromium(VI): “An increased cancer risk cannot be excluded for low exposure levels but it is not proven by epidemiological data.”

[14] *https://www.baua.de/dok/8667860*.

(4) The largest area of application of chromium(VI) compounds is the functional and decorative coating of surfaces. Numerous technologies are used here which affect a variety of industries. Most of the coatings are applied using galvanic methods (hard chromium plating and high-gloss chromium plating). Coating materials which contain chromate are also used in the aerospace industry, defence technology and in nuclear facilities. In addition, the coatings of rail vehicles also contain some strontium chromate. For further information on the substitution of chromate-containing coating materials, refer to *TRGS* 602 “Substitutes and restrictions for use – zinc chromate and strontium chromate as pigments for corrosion protection – coating materials”.

(5) For an overview of the exposure situation in the years 2000 to 2009 including over 4500 measured values, please refer to the MEGA analysis for the preparation of exposure scenarios for chromium(VI) compounds[15]. Almost 3000 of the measured values were below the analytical limit of quantitation which was sufficient in the data period.[16] An exposure to chromium(VI) compounds is particularly relevant in electroplating and the thermal processing of chromium-containing steels. For workplaces involving cemented carbide, the *DGUV* [German Social Accident Insurance] Information 213-724 (recommendations for risk identification by accident insurers (EGU) according to *GefStoffV*)[17] also provided information on the exposure to chromium and its compounds. According to this information, exposure to chromium(VI) compounds does not play a role for workplaces involving cemented carbine.

### 3.3.5 Cobalt and cobalt compounds

(1) The ERR derivation applies to cobalt metal, inorganic cobalt compounds and cobalt-containing cemented carbide. Due the classification of cobalt as a carcinogen of category 1B in *TRGS* 905, cemented carbide is also classified accordingly, if the cobalt content in the mixture is ≥ 0,1 %.

(2) The ERR applies to the alveolar fraction.

(3) Due to the skin sensitising properties, special protective measures are required for skin contact with cobalt and cobalt compounds (see *TRGS* 401). In the risk assessment, the respiratory system sensitising properties of cobalt and its compounds are to be considered as well (see *TRBA/TRGS* 406).

(4) Cobalt and cobalt compounds are used in the catalyst industry, in electroplating, for the production and use of chemicals, in cemented carbides, in magnets, in non-ferrous metal alloys, sintered alloys and other heat- or corrosion-resistant alloys and parts, in inorganic pigments, paints, glass, ceramics, in battery production and thermal spraying. In addition, cobalt is used for the production of plastics and dental alloys. Cobalt-containing particulates can be generated in particular during the use of powders, during welding and during the surface treatment and machining of cobalt-containing workpieces/alloys. In these cases, higher dust concentrations are also found during maintenance and servicing work at air filter systems. Cobalt sulphate is also used in biogas plants in trace element mixtures. For additional information, please refer to *TRGS* 529 “Activities during the production of biogas”.

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[15] MEGA analyses for the preparation of exposure scenarios for chromium(VI) compounds (2000 to 2009) in Germany (*http://www.dguv.de/medien/ifa/de/fac/reach/mega_auswertungen/chrom-VI-Verbindungen_d.pdf*).

[16] For personal measurements, the limit of quantitation was 5 µg/m³ in 2010.

[17] *http://publikationen.dguv.de/dguv/pdf/10002/i_790-024.pdf*.

(5) For cobalt, *EKA* values are available (in urine; 6 µg/l ≙ 10 µg/m³; 60 µg/l ≙ 100 µg/m³, linear correlation), which can be used for the people-oriented assessment of the exposure at the workplace by the occupational physician. Regarding the consultation of the employer on the risk assessment, it must be noted that the correlation of the *EKA* value refers to E dust and not to A dust. In addition, it must be considered that the urine value is already below the *EKA* correlation at the tolerable concentration and is only twice the reference value of 1.5 µg/l for cobalt in urine (3 µg/l for 5 µg/m³). With linear extrapolation, the acceptable concentration would be significantly lower than the standard value for cobalt[18].

(6) For an overview of the exposure situation at workplaces involving cemented carbide from the years 2007 to 2009 with a focus, among other things, on cobalt and its compounds, please refer to the *DGUV* Information 213-724 (recommendations for risk identification by accident insurers (EGU) according to *GefStoffV*). The exposure description "*Verarbeitung von Nichtedelmetall-Legierungen in Dentallaboratorien*" [Processing of base metal alloys in dental laboratories][19] by BG ETEM from 2015, lists the exposure data for cobalt and chromium in the E fraction.

### 3.3.6 Nickel compounds

(1) The ERR derivation for nickel compounds applies to all nickel compounds which have been classified as carcinogens of category 1A or 1B. It does not apply to nickel metal (carcinogenic, category 2). The tolerable concentration was defined based on the non-carcinogenic effect. In this case, the value corresponds to the acceptable concentration; therefore, there is no medium risk range. Activities involving the exposure to nickel metal are not included in the scope of application of this *TRGS*. The OEL of 6 µg/m³ (A) applies in accordance with *TRGS* 900 "Occupational exposure limits". An assessment based on the OEL for nickel metal can be performed if only nickel metal is present. If activities lead to the release of nickel-containing dusts for which only surface oxidation is to be expected, these dusts are to be treated as mixtures containing nickel metal. If thermal processes are used in the presence of atmospheric oxygen, a formation of oxidic nickel compounds is to be assumed. This is the case, for example, in welding (electrode or wire) and thermal cutting with or of alloys, metal spraying of alloys, melting and casting of alloys and grinding and cutting of alloys involving "spark formation". Further recommendations and examples of work procedures for which OEL or ERR values can be used in the assessment can be found in the IFA work folder (number 0537[20]).

(2) OEL and ERR apply to the alveolar fraction. The OEL for nickel and the tolerance concentration for nickel compounds were determined based on the inflammatory effects on the lungs.

(3) Due to the skin sensitising properties of many nickel compounds, special protective measures are required for skin contact with nickel compounds (see *TRGS* 401). In the risk

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[18] In accordance with the ERR justification which says in regard to the daily cobalt intake through food: "The values for the derived acceptable risks correspond to the general background level."

[19] *https://www.bgetem.de/redaktion/arbeitssicherheit-gesundheitsschutz/dokumente-und-dateien/themen-von-a-z/gefahrstoffe/expositionsbeschreibungen/expositionsbeschreibung-verarbeitung-von-nichtedelmetall-legierungen-in-dentallaboratorien.*

[20] *http://www.dguv.de/ifa%3b/publikationen/ifa-arbeitsmappe-messung-von-gefahrstoffen/index.jsp.*

assessment, the respiratory system sensitising properties of nickel and its compounds are to be considered as well (see *TRBA/TRGS* 406).

(4) Nickel compounds are used in electroplating for the separation of metallic corrosion protection layers, in the catalyst industry (e. g. for the hydration of unsaturated fatty acids), in the production of chemicals and pigments and in battery production. Nickel compounds can also be released during the thermal or mechanical processing of nickel-containing alloys, e. g. stainless steels and heat- and corrosion-resistant alloys, and during the thermal processing of nickel powder, e. g. thermal spraying.

(5) For an overview of the exposure situation at workplaces involving cemented carbide from the years 2007 to 2009 with a focus, among other things, on nickel and its compounds, please refer to the *DGUV* Information 213-724 (recommendations for risk identification by accident insurers (EGU) according to GefStoffV)[21] During the production and use of cemented carbide, exposure to nickel is to be expected rather than exposure to nickel compounds. This is why the OEL for nickel metal is to be primarily used for the assessment.

(6) The occupational diseases report “Nickel” (*DGUV*[22]) contains analyses of approx. 33,000 measured values for nickel and its compounds in E dust from the years 1975 to 2016, with a focus on welding, machine construction and equipment manufacturing, electroplating and foundries. In another publication (*DGUV* 2017[23]), approximately 1,200 measurement results for nickel and its compounds in A dust are presented.

## 4 General protective measures

### 4.1 Cross-industry protective measures

(1) The employer must regularly consider the possibility of substitution with substances or mixtures with a lower health hazard level and make the substitution a priority (see *TRGS* 600). In particular, they must check whether materials in powder form can be replaced by materials which generate less dust. Examples are the substitution of finely powdered or “floury” material by e.g. coarse-grained or chunky material. It must also be checked whether pellets, granules, wax, pastes or slurry can be used.

(2) If the employer cannot exclude hazards to the employees during activities involving carcinogenic substances, they must reduce these hazards to a minimum, irrespective of the actual exposure level and the corresponding risk level. Technical measures have priority over organisational and personal protective measures or occupational health monitoring (see *TRGS* 500 “Protective measures”).

(3) If there is a possibility that carcinogenic substances are released due to operational disruption, all measures for high exposure must be taken. In particular, sufficient amounts of suitable respiratory protection (e. g.respiratory protective equipment) and, if applicable, protective gloves must be available.

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[21] *http://publikationen.dguv.de/dguv/pdf/10002/i_790-024.pdf.*
[22] In preparation.
[23] In preparation.

(4) For chromium(VI) compounds, an assessment criterion was derived. Since the substance is classified as carcinogenic, the general protective measures listed below are to be implemented in any case. Levels must remain below the assessment criterion. For surface treatment by electroplating, this can be achieved by the processes and operating modes which are usually used in the industry as described in number 5.4.4, or protective measures according to the state-of-the-art in technology. With a chromium(VI) concentration below the assessment criterion, no further technical protective measures are required for surface treatment by electroplating if these measures are not expected to lead to a significant reduction of the exposure. The minimisation goal for chromium(VI) compounds is to be the lower limit of quantitation.

(5) For beryllium and its inorganic compounds OEL were derived. Since the substance is classified as carcinogenic, the general protective measures listed below are to be implemented in any case. The OEL are to be complied with according to the provisions of *GefStoffV*.

(6) The following protective measures are to be generally observed for activities involving carcinogenic substances:

1. Technical measures

   The goal of the spatial separation of a working area, if applicable, in combination with ventilation/air conditioning or construction measures, is to prevent the exposure of employees in other working areas to released carcinogenic substances. This can also be achieved by reducing the use of substances which are relevant for the exposure. Regular inspections of the function and effectiveness of the technical protective measures must be conducted to ensure that the exposure status does not deteriorate.

2. Organisational measures

a) The employer must ensure that activities involving carcinogenic metals are only performed by experts or persons who have been properly instructed. Affected Working areas must be marked and may only be accessible for employees who work there. In there is a possible inhalation hazard, carcinogenic metals and alloys are to be stored in a way that ensures that only trained experts and trustworthy persons have access to them.

b) The duration of exposure and the number of exposed people must be minimised as far as possible. Company agreements may be made in this regard.

c) The special organisational provisions of *TRGS* 500 regarding shift work, rest break regulations and night work are to be observed.

d) The employer must ensure that the employees have access to written operating instructions. The operating instructions must be updated based on the risk assessment if there are significant changes.

e) During an instruction, the employer must inform the employees about the exposure level and the assigned risk level. The instruction is to be performed by experts based on the risk assessment and the operating instructions. This includes a general occupational health and toxicological consultation in the presence of the company doctor (see also number 6.2 of this *TRGS*).

f) As a result of the risk assessment, warning and safety signs, including the prohibition signs “No Admittance Without Authorization” and “No Smoking” are to be installed according to Sec. 10 *GefStoffV* (see also *ASR* A1.3 *Sicherheits- und Gesundheitsschutzkennzeichnung* [Safety and health protection marking]).

g) In case of an unforeseen increased exposure, the employees and, if applicable, the works council, are to be notified.

h) Affected work areas are to be cleaned regularly and professionally.

3. Hygiene measures

a) Since personal behaviour and personal hygiene have a significant influence on the intake of carcinogenic metals, individual provisions regarding personal protective equipment and personal hygiene (personal hygiene plans) are to be defined. The employer must provide a sufficient amount of time for hygiene measures and monitor their implementation (see *TRGS* 500).

b) The special organisational provisions of *TRGS* 500 regarding the separate storage of street and work clothes must be observed.

c) Employees who perform activities involving carcinogenic metals are not allowed to consume foodstuffs, drinks and tobacco (e.g. eating, drinking, chewing gum, smoking, snuffing tobacco) in the workspace or at their work stations. For these employees, areas are to be provided where they can consume foodstuffs, drinks and tobacco without endangering their health due to hazardous substances (see also *TRGS* 500 and *ASR* A4.2 “*Pausen- und Bereitschaftsräume*” [Rest break and stand-by rooms]). Only for activities with increased fluid requirements (e.g. at hot workplaces), the consumption of beverages near the working area may be made possible provided that suitable hygiene measures are observed (e.g. use of drinking bottles with mouthpiece and a protective cap for the mouthpiece).

d) Work clothes which are contaminated by dusts may not be shaken out or blown clear. The employer must ensure that employees do not carry their contaminated work clothes off to other areas. Contaminated work clothes shall remain at the company and be professionally cleaned at the employer’s request.

4. Personal protective equipment

a) The employer must choose, provide and ensure the care and maintenance of suitable personal protective equipment (PPE) according to Sec. 9 Paras. 3, 4 and 5 *GefStoffV* (*DGUV Regel* 112-189 et seq., formerly BGR 189 et seq.[24]). The obligation to wear the equipment as well as the storage and use of the PPE by the employee is to be regulated in the operating instructions. Suitable storage facilities for the PPE are to be provided in the operation area.

b) Suitable respiratory protection is to be selected according to *DGUV Regel* 112-190[25] (“*Benutzung von Atemschutzgeräten*” [Use of respiratory devices]). Respiratory protec-

[24] *http://publikationen.dguv.de/dguv/pdf/10002/bgr189.pdf*.
[25] *http://publikationen.dguv.de/dguv/pdf/10002/R-190.pdf*.

tion which is not cumbersome is to be preferred in the selection. Filters are to be chosen depending on the exposure situation; however, a P2 filter must be used as a minimum.

Technical, organisational and personal protective measures must be regularly checked for functionality and effectiveness.

(7) The following additional protective measures are to be observed for activities involving carcinogenic metals with medium risk level:

1. Technical measures

a) If an exposure in other working areas is not yet sufficiently prevented by the implemented measures, spatial separation is required.

b) In specific individual situations, the employer must take technical measures according to the state of the art in technology taking the level of exposure with regard to the risk according to the ERR, costs and benefits into account. This is to be documented in the risk assessment.

2. Organisational measures

According to Sec. 14 Para. 3 numbers 3 and 4 *GefStoffV*, the employer must maintain a list of the employees who are exposed to health risks due to activities involving carcinogenic substances. This applies to medium risk levels. Specific information on this is provided in *TRGS* 410 "*Expositionsverzeichnis bei Gefährdung gegenüber krebserzeugenden oder keimzellmutagenen Gefahrstoffen der Kategorien 1A oder 1B*" [Exposure list for hazards due to carcinogenic substances or germ cell mutagens of categories 1A or 1B].

3. Hygiene measures

a) Objects for personal and private use (mobile phones, bags, etc.) should not be brought into the workplace.

b) The employer must provide suitable protective clothes and clean it. In addition, it is recommended that the employer provides the work clothes. It must then be determined in the risk assessment, whether there is a possibility that the work clothes become contaminated by hazardous substances. If this is the case, the employer must also clean the work clothes.

c) Prior to eating, drinking, chewing gum, smoking and snuffing tobacco, the hands and, if applicable, the face must be washed in the areas intended for this purpose.

d) Personal protective equipment may not be taken along to break rooms.

e) In the area below the tolerable concentration or assessment criterion, it may be required to construct a spatial separation between the contaminated and the clean area in the form of two changing rooms which are connected to a wash room or in the form of an air lock system which is connected to the working area and used for putting on and taking off the work and protective clothing. Detailed provisions for the specific areas can be found in number 5 of this *TRGS*.

4. Personal protective equipment

a) In case of activities with exposure peaks, it must be checked whether respiratory protection must be worn during the period of increased exposure.

b) The wear time limit of respiratory protection according to *DGUV Regel* 112-190 and the above-mentioned hygiene measures for PPE must be observed. The timely replacement of respiratory device filters and the selection of suitable protective gloves must be ensured.

(8) The following additional protective measures are to be observed for activities involving carcinogenic substances with high risk level:

1. Technical measures

a) If an exposure in other working areas is not yet sufficiently prevented by the implemented measures, spatial separation is required. Construction measures should be preferred.

b) The employer is obliged to take technical measures (e.g. reduction of the amount, extraction and room ventilation, closed systems) according to the current state of the art in technology. The protection targets can also be achieved on the basis of the processes and operating modes which are usually used in the industry with added protective measures according to the current state of the art in technology.

2. Organisational measures

a) According to Sec. 14 Para. 3 numbers 3 and 4 *GefStoffV*, the employer must maintain a list of the employees who are exposed to health risks due to activities involving carcinogenic substances. This is the case in areas exceeding the tolerable concentration/assessment criterion. Specific information on this is provided in *TRGS* 410 "*Expositionsverzeichnis bei Gefährdung gegenüber krebserzeugenden oder keimzellmutagenen Gefahrstoffen der Kategorien 1A oder 1B*" [Exposure list for hazards due to carcinogenic substances or germ cell mutagens of categories 1A or 1B].

b) In case of activities during which a significant increase in the exposure of employees to carcinogenic metals is to be expected according to Sec. 10 Para. 4 *GefStoffV* and for which any possibility of utilising additional technical protective measures to limit exposure have already been exhausted, the employer must take measures to reduce the exposure period as far as possible and to ensure the protection of the employees during these activities after consultation with the employees or with their representative.

c) According to *TRGS* 910, table 1, it is urgently recommended to inform the competent supervisory authority and submit the action plan, if the tolerable concentration will be predictably exceeded for more than three months. A deviation from the recommendation is to be documented including the reasons.

3. Hygiene measures

a) Items for personal and private use (mobile phones, bags, etc.) are not permitted. The employer shall provide a suitable possibility to store these items.

b) Protective clothing must always be worn in areas with a high risk. The clothing must be provided and cleaned by the employer.

c) Clean protective clothing and other PPE must be stored outside the exposure area, free from dust and dry but separate from used protective clothing and used PPE. Alternatively, the protective clothing and the PPE is to be cleaned or exchanged after exposure.

d) If it is foreseeable that the tolerable concentration, occupational exposure limit or assessment criterion will be exceeded for an extended period, a spatial separation between the contaminated and the clean area in the form of two changing rooms which are connected to a wash room or in the form of an air lock system which is connected to the working area and used for putting on and taking off the work and protective clothing is to be considered and, if applicable, implemented. Detailed provisions for the specific areas can be found in number 5 of this *TRGS*.

e) When the shift/work ends, the body and hair must be washed in the shower. The employees must be granted a sufficient amount of time for hygiene measures.

4. Personal protective equipment

a) Employees must wear respiratory protection (in accordance with *DGUV Regel* 112-190, at least of class P 2). For activities during which the respiratory protection must be worn permanently, an exception for a limited period is to be requested from the competent authority according to Sec. 7 Para. 5 *GefStoffV* in conjunction with Sec. 19 Para. 1 GefStoffV, if the respiratory protection is cumbersome.

b) All respiratory protective equipment which are suitable for carcinogenic substances are considered as cumbersome with the exception of fan-assisted filtering devices and fresh air or compressed air hose units including a hood or helmet (see also *AMR* 14.2 "*Einteilung von Atemschutzgeräten in Gruppen*" [Classification of respiratory protective equipment in groups]. Cumbersome respiratory protection may not be a permanent measure. It is recommended to use respiratory protection which is not cumbersome.

c) After finishing the activity, first the contaminated work clothes and then the respiratory protective equipment must be taken off. It must be ensured that the PPE is not taken off in contaminated areas.

### 4.2 Prevention of dust

(1) The employer must select appropriate materials, working methods, machines and devices to ensure that as little dust as possible is released. Basic information on this topic is also included in *TRGS* 504 "*Tätigkeiten mit Exposition gegenüber A- und E-Staub*" [Activities involving exposure to A and E dust].

(2) Due to the effects of the materials in question, the measures for dust prevention/reduction are urgently required in the scope of application of this *TRGS*.

(3) Explosion protection measures are to be taken if metal dusts are present in the work atmosphere in explosive concentrations. This is, however, not to be expected in the area of the tolerable concentration.

(4) Appropriate work methods are to be selected and implemented which ensure that as little dust as possible is released. During activities involving an exposure to dust, the spread-

ing of the dust to other working areas is to be avoided. This can be achieved, for example, by the following measures:

1. The open handling of powdery materials is to be avoided. This can be achieved by working with completely encapsulated machines/systems and by storing and transporting raw materials, products and waste which release a lot of dust in closed systems, e.g. storage in closed silos, closed bags, big-bags, covered containers, conveying in closed pipelines, use of dissolvable packaging/non-returnable containers.
2. Wetting the material, if this is does not have a negative impact on processing.
3. If possible, closed systems with aspiration are to be used for the transfer and filling of powdery materials, for example special filling and/or discharge stations for barrels, big-bags, bags, etc. If closed systems are not feasible or suitable, encapsulation and effective extraction in line with the current state of the art in technology are to be provided.

(5) Appropriate machines and devices are to be selected and operated in such a way so as to ensure that as little dust as possible is released. Systems, machines and devices which emit dust must be equipped with effective an extraction system according to the state of the art in technology, if dust release is not prevented by other measures. This can e.g. be achieved by using machines and devices

1. with encapsulated dust sources,
2. with cladding,
3. which are operated at negative pressure,
4. for which the dust is removed by suction from working ports, transfer locations, generation or leakage locations,
5. for which sufficient dust reduction is achieved by wetting or the addition of water,
6. which are equipped with sealed operator cabins and a suitable filter for the cleaning of external air (this is not automatically the case with air-conditioned cabins) or
7. which are controlled by separate and force-ventilated control rooms.

(6) Carcinogenic metals and alloys must always be stored in their packaging or in designated containers or rooms if there is an inhalation hazard. The regulations for hazardous substances which are classified as carcinogens of category 1A or 1B as described in *TRGS* 509 “Storage of hazardous substances in stationary containers” and *TRGS* 510 “Storage of hazardous substances in non-stationary containers” are to be observed. Transport routes are to be kept as short as possible. If dust release is possible, continuous transport methods in closed systems are to be preferred. Where this is not possible or not suitable, closed or covered containers are to be used. It must be ensured that the outside of containers is free from adhesions. If required, they must be cleaned before transport.

(7) If possible, working areas in which dust may be present are to be designed and maintained in a way that ensures that

1. walls and ceilings are smooth to prevent dust adhesion,
2. surfaces where dust can accumulate are avoided,
3. floors, work surfaces and other surfaces are easy to clean,
4. Working rooms with different dust concentration are separated by construction measures.

Surfaces where dust could accumulate can e. g. be avoided by sloping or cladding.

(8) If the release of dust cannot be sufficiently minimised, the dust is to be collected as completely as possible at the place of leakage or release and safely disposed of. If sufficient dust collection is not possible, additional ventilation measures such as workplace ventilation are required. In this case, the air is to be directed away so that as little dust as possible gets into the breathing air of the employees.

(9) Facilities for the collecting, condensation and separation of dust and ventilation measures must be in line with the state of the art in technology. Sufficient effectiveness is to be verified prior to initial commissioning and in recurring tests of these facilities. See e.g. *TRGS* 402 “Identification and assessment of the risks from activities involving hazardous substances: Inhalation exposure”.

(10) Regarding extraction, it must be ensured that the extracted air is only recycled if it has been sufficiently cleaned using methods or devices which are approved by the official authorities or the providers of the statutory accident insurance. See also *TRGS* 560 “*Luftrückführung bei Tätigkeiten mit krebserzeugenden, erbgutverändernden und fruchtbarkeitsgefährdenden Stäuben*” [Air return in activities involving carcinogenic, mutagenic and reprotoxic substances].

(11) Facilities for the collection, condensation and separation of dusts and ventilation systems are to be checked for functionality and effectiveness, maintained and, if required, serviced according to the results of the risk assessment taking the time intervals specified by the manufacturer into account. The tests and the result are to be documented.

(12) If direct contact with carcinogenic metals is possible during repair work, the corresponding systems and machines should be emptied and cleaned beforehand, if possible. Suitable personal protective equipment as specified in the risk assessment is to be worn for this work.

(13) Aggregates, measuring devices or other system parts which are removed from the working area – e.g. for maintenance or repair - are to be cleaned beforehand. If this is not or only partly possible, the these are to be marked accordingly. In this case, it must also be ensured that no hazardous substances are released during transport.

(14) If possible, dust deposits are to be avoided. Work areas, work stations, break areas, traffic routes, operational facilities, machines and devices are to be cleaned at regular intervals. The cleaning intervals are to be determined based on the risk assessment. During cleaning, the release and stirring up of dust is to be avoided, e.g. using damp and wet procedures or suitable vacuum cleaners or dust extractors. This is achieved e.g. by

1. permanently installed vacuum cleaning systems, dust-removing machines or devices which comply with the requirements of the following paragraph 15,
2. wiping with a damp cloth or wet cleaning,
3. sweeping fixedly installed routes using (vacuum) sweepers which comply with the requirements of the following paragraph 15 and collecting the swept material.

(15) Machines or devices which remove dust must correspond to the state of the art in technology. For dust extractors and industrial vacuum cleaners, this means a design according to dust class H. A positive list of tested machines for dust removal is regularly published in the IFA manual, number 510210/1 “*Maschinen zur Beseitigung gesundheitsgefährlicher Stäube - Positivliste*” [Machines for the removal of hazardous dusts - positive list] [26]. Suitable

[26] *http://www.dguv.de/ifa/publikationen/ifa-handbuch/index.jsp*.

vacuum sweepers are those which were tested for dust filtration according to DIN EN 60335-2-69, annex AA, and comply with the requirements of dust class M.

(16) Cleaning by sweeping without dust collection measures or blowing off dust deposits using compressed air is not permitted.

(17) Routes and ways in outdoor areas which cannot be cleaned for technical reasons should be wetted regularly and, if possible, without pressure to prevent stirring up dust. Wetting is not required if no persons are present in dust atmospheres of routes and the drivers in the cabin are protected against the influence of dust.

(18) Workplaces are to be equipped with the required means for cleaning. Depending on the workplace this may be equipment for wet cleaning (water hose and cleaning brush) or for dry cleaning (vacuum cleaner, (vacuum) sweeper).

## 5 Extra protective measures for special areas

### 5.1 Production and processing of non-ferrous metals (NF)

(1) The term non-ferrous metals (NF metals) refers to all metals and alloys with a pure iron content of less than 50%. Typical non-ferrous metals are aluminium, copper, zinc, lead or magnesium but also beryllium, cadmium, chromium, cobalt and nickel, precious metals and high-fusing (refractory) metals. In a wider sense, metalloid arsenic can also be included.

(2) The production of non-ferrous metals refers to the fabrication of NF metals from primary raw materials (ores and slags from upstream processes) in primary smelters and from master alloys in secondary smelters or smelting plants and metal recovery from recycled materials (e. g. scrap metal, batteries, electronic waste, electroplating sludge, filter dusts, slags, etc.).

(3) The production of alloys by the sintering of powdery raw materials (e. g. in the area of magnet production) is also included in the production of NF metals. This also applies to the production of cemented carbide which is covered in a different section (number 5.2 of this *TRGS*).

(4) In the *DGUV-Regel* "*Branche Metallhütten*" [Smelting industry][27], additional and more concrete protective measures are listed than in this *TRGS*.

#### 5.1.1 Processes and activities involving relevant exposure

(1) In Germany, aluminium, copper, zinc, lead and refractory metals are extracted from ores or recycled from secondary raw materials in primary smelters. Arsenic, cobalt, nickel and cadmium are possible by-products.

(2) In general, arsenic, beryllium, chromium, cobalt, cadmium and nickel are added as alloy elements in the production of special alloys to achieve certain properties. In the process, the corresponding metal compounds can be released e.g. in fumes, dusts and skimmings.

[27] In preparation.

(3) During the production and processing of metal powders (production, filtering, bagging), dusts may be released. These dusts usually consist of the metals themselves which may be coated with a thin oxide layer. Carcinogenic metals are either present in the pure form or as part of an alloy.

(4) In the production of aluminium and precious metals, the occurrence of carcinogenic metals in concentrations above the acceptable concentration is generally improbable. This also applies to the recycling of lead batteries and zinc recycling. In NF metal production, a chromium(VI) exposure above the assessment criterion is generally not likely.

(5) When ores are roasted or when ores, slags and skimmings or ashes are ground or shredded, dusts and fumes are released which may, among other things, contain arsenic compounds and cadmium.

(6) Arsenic compounds and cadmium accumulate in filter dusts in the primary production of copper and zinc.

(7) Depending on the composition of the metals, the production of NF metals and the use of NF scrap metal may result in dusts and fumes which may contain carcinogenic metals. These then also accumulate in the filter dusts.

(8) In the leaching step of zinc electrolysis, arsenic trioxide is used as a reactant.

(9) During the electrolytic refining of copper (wet chemical procedure), aerosols containing arsenic and nickel, among other things, may be released by the electrolyte solution. Nickel compounds are typically discharged together with the electrolyte slurry.

(10) The scrap from lead refining contains arsenic compounds.

(11) When raw copper is refined by melting metallurgy (fire refining, pyrometallurgy), arsenic oxides is released in the flue gas. There is also a slagging of the oxides of cobalt and nickel.

(12) To improve the mechanical properties of aluminium, magnesium and some copper and nickel alloys and to reduce oxidation hazards, beryllium-containing master alloys are used. In this case, beryllium-containing dusts and fumes may be released.

(13) During the production of high-purity metals for electronic and optoelectronic applications and for the photovoltaic industry, a short-term exposure to carcinogenic metals, in particular arsenic compounds and cadmium, above the tolerable concentration may occur.

(14) During the dry processing of alloys which contain nickel, cobalt, chromium and/or beryllium, e.g. by sawing, drilling, grinding, abrasive blasting or polishing, an exposure to carcinogenic metals is to be expected.

(15) During wet chemical treatment (e. g. pickling), the resulting gases and/or aerosols may contain carcinogenic metals.

### 5.1.2 Exposure situation

(1) In the MEGA database of the *DGUV*, only a few datasets are available regarding the exposure to carcinogenic metals in the areas of the NF metal industry. These mainly come from the analysis of the E dust fraction. A conversion to the exposure situation in the A dust fraction is not easily possible.

(2) The exposure situation in various working areas based on the information by companies and from the MEGA database is summarised in table 2. To the extent possible, a key component was indicated (see number 3.2 of this *TRGS*).

**Table 2:** Exposure situation in various working areas of NF metal production and processing

| Process | Working area | Metals | Key component | Exposure tendency relating to the key component |
|---|---|---|---|---|
| Cu production | Raw material storage, mixture preparation | As, Cd, Ni | As | > TC |
| | Concentrate melting | As, Cd, Ni | As | > TC |
| | Converter | As, Cd, Ni | As | > TC |
| | Anode furnace | As, Cd, Ni | As | > AC< TC |
| | Anode casting | As, Cd, Ni | As | > AC< TC |
| | Electrolytic refining | As, Ni | As | > AC< TC |
| | Electrolyte processing | As, Ni | Ni | < AC |
| | Anode slurry processing | As, Ni | As | > TC |
| | Secondary material processing | As, Cd, Ni, Be | As, Cd | > TC |
| | | | | |
| Zn production | Raw material storage, mixture preparation | As, Cd, Ni, Co | Cd | > TC |
| | Roasting | As, Cd, Ni, Co | Cd | > AC< TC |
| | Leaching | As, Cd, Ni, Co | Cd | > AC< TC |
| | Filtration | Cd | Cd | > AC< TC |
| | Leaching purification | As, Cd, Ni, Co | Cd | > AC< TC |
| | Copper concentrate production | As, Cd, Ni, Co | Cd | > AC< TC |
| | Preparation station for arsenic acid | As | | < AC |
| | Cadmium hydrometallurgy | Cd | | > AC< TC |
| | Cadmium refining | Cd, Ni | Cd | > TC |
| | | | | |
| Pb production | Raw material storage, mixture preparation | As, Cd | The protective measures which are required due to the lead concentration cover the additional hazards caused by the carcinogenic metals (see *TRGS* 505). | |
| | Melting furnace | As, Cd | | |
| | Refining | As | | |
| | | | | |
| Al production | Electrolysis | Be | Be | < OEL |

(3) In the MEGA database of the *DGUV*, only a few datasets are available from the years 2012–2015 regarding the exposure to carcinogenic metals in the area of NF metal foundries. In the A dust fraction from aluminium and magnesium foundries, the following tendencies were found:

1. Arsenic compounds: An exposure to arsenic compounds cannot be excluded in the area of aluminium gravity die casting.
2. Beryllium: A large portion of the measurements could not be analysed since the detection limits of the measurement methods were above the occupational exposure limits. In some of the measurements that could be analysed, the occupational exposure limits were significantly exceeded.
3. Chromium VI: The available exposure values were < 1 µg/m³.
4. Nickel compounds: In the working areas of fettling, machine operator die casting, crane operator, smelter and casting station, the exposure values were < 1 µg/m³.

(4) For the production of technology metals such as indium, germanium, gallium or semiconductors such as GaAs, CdTe, etc., closed systems are usually used (often under vacuum or protective gas). Due to the high requirements to the purity of the products, a noteworthy exposure for an extended period is unlikely. An exposure to the metals or their compounds may occur during the loading and unloading of furnaces or comparable units, during mechanical processing and during maintenance or cleaning activities. In these cases, suitable respiratory protection is to be worn. The wearing period is to be reduced to the required minimum.

(5) During the further processing of alloys which contain carcinogenic metals, these metals may be released into the air as dusts or fumes. In this case, the composition in the air may not correspond to the percentages found in the alloy composition. The boiling point of cadmium is e.g. 765 °C, the sublimation point of arsenic is 613 °C so that a higher proportion of these metals in the melting fume is to be expected during melting processes.

(6) During aluminium electrolysis, exposure to beryllium cannot be excluded if beryllium-containing raw materials are used.

### 5.1.3 Substitution possibilities

(1) If carcinogenic metals occur as impurities during production, substitution is only possible to a very limited extent. Raw materials without these impurities are difficult to obtain due to the chemical similarity of the metals.

(2) Depending on the material properties which are required in each individual case, substitution is usually not possible. When looking for a possible substitution, it must be checked whether application or processing methods which generate low emissions and dusts are available or whether workpieces without alloy additions made of carcinogenic metals can be used without compromising the quality.

### 5.1.4 Protective measures

(1) The main focus of protective measures is to be placed on avoiding fumes and dusts and avoiding dust deposits or stirring up deposited dusts. More information on the topic can be found in number 4.2 of this *TRGS*.

(2) In some areas of copper, zinc and lead production, the tolerable concentrations of arsenic or cadmium are exceeded. A spatial separation of contaminated and clean areas by two changing rooms which are connected to a wash room is to be provided.

(3) Crushing and grinding of ores, slurries and aggregates is to be performed mainly in closed systems or using effective dust reduction measures.

(4) Open roasting and smelting furnaces are to be connected to system-related extraction systems with effective suction power. Rim ventilation – if available - must also be effective during charging with open furnace lid.

(5) Charging openings of melting units (e.g. anode furnaces, induction furnaces or converters) are to be equipped with effective extraction systems. Respiratory protection is required for charging or casting.

(6) During the blending of NF scrap and aggregates in the mixing hall of NF metal smelters, wheel loaders with pressurised cabins and suitable filtration systems are to be used.

(7) Systems for the production of casting alloys which consist of carcinogenic metals are to be equipped with effective ventilation and extraction systems.

(8) Pouring zones, cooling zones and unpacking stations in the production of cast parts which may release dusts with carcinogenic metals are to be enclosed and/or equipped with extraction systems.

(9) Systems for the production of large cast parts can usually not be enclosed. In these areas, organisational and hygienic measures as well as suitable PPE, if applicable, are to be used depending on the exposure situation.

(10) Filter dusts from dedusting systems may contain carcinogenic metals. Filter dusts from primary smelters contain, in particular, cadmium and arsenic. When they are bagged, dust development must be kept to a minimum, e. g. by using systems that are closed and/or have extraction devices. To minimise dust exposure, the filter outlets and collection containers are to be connected in a dust-free manner.

(11) Solids which contain arsenic may not additionally come into contact with sulphuric acid and zinc-containing materials due to the risk of arsine formation.

(12) To prevent dust exposure during the grinding and crushing of dried sludges, slurries, skimmings and recycling materials of different grain sizes as well as during fettling and work at or in filter systems, fan-assisted respiratory protective equipment and disposable protective suits are to be preferably used.

(13) During zinc recycling, e.g. also from steel dust, a purged airflow may prevent the release of process gases and dusts when feeding the rotary kiln.

(14) For the production of magnets made of nickel- and/or cobalt-containing powders, the protective measures according to number 5.2 of this *TRGS* are to be observed accordingly.

## 5.2 Production and use of cemented carbide

(1) The production and use of cemented carbide is a subarea of NF metal production and processing.

(2) Cemented carbides are compound materials which may contain, among other things, 3 to 30% cobalt metal and/or up to 15% nickel metal. In the production of cemented carbides or carbide tools, a ready-to-mould powder, granulate or modelling clay is moulded into a semisolid green part by various moulding techniques. The green part is converted into the cemented carbide with final strength either directly or following mechanical processing in a sintering and/or hot pressing procedure. Sintered carbide tools are then processed by grinding, honing, lapping or polishing, electrical discharge machining or laser machining.

(3) The *DGUV* Information 213-724 „*Hartmetallarbeitsplätze – Empfehlungen Gefährdungsermittlung der Unfallversicherungsträger (EGU) nach der GefStoffV*“ [Workplaces involving cemented carbide– recommendations for risk identification by accident insurers (EGU) according to GefStoffV][28] provides exposure data and additional specific protective measures.

### 5.2.1 Processes and activities involving relevant exposure

Exposure to cobalt may occur during the entire production process. During the recycling of cemented carbide, employees may also be exposed to nickel compounds and possibly chromium. Prior to sintering, employees are exposured to the metal powder or granules. Af-

[28] *http://publikationen.dguv.de/dguv/pdf/10002/i_790-024.pdf*.

ter sintering and during finishing, exposure to an aerosol from the cutting fluid and the grinding swarf is often possible.

### 5.2.2 Exposure situation

(1) In the production of cemented carbide, an increased exposure to cobalt can occure specially when handling dusts in open systems. Particularly high concentrations are measured during weighing, pressing, green machining and dry grinding. During the abovementioned activities, an exposure above the tolerable concentration is likely. With wet grinding, the exposure is significantly reduced and is usually below the tolerable concentration. In the *DGUV* Information 213-724 „*Hartmetallarbeitsplätze - Empfehlungen Gefährdungsermittlung der Unfallversicherungsträger (EGU) nach der GefStoffV*“ [Workplaces involving cemented carbide– recommendations for risk identification by accident insurers (EGU) according to GefStoffV], 2,480 measured values were determined from 52 plants. 1,130 measured values came from the “cemented carbide production and processing” industry and 1,350 from the “grinding” industry. The results are representative for the stratum. The 90th percentile was significantly above the tolerable concentration, the 50th percentile in most cases. It must be noted, however, that only E dust measurements were performed.

(2) Nickel metal is also frequently used for the production of cemented carbide. Exposure to nickel compounds are generally not to be expected. The occupational exposure limit for nickel metal given in *TRGS* 900 “Occupational exposure limits” is to be observed.

(3) During the recycling of cemented carbide compounds and the production of cemented carbide powders from ores, exposure to cobalt as well as exposure to nickel compounds and - possibly – chromium(VI) compounds may occur. These exposures are particularly common in high-temperature processes and the processing of powdery materials.

### 5.2.3 Substitution possibilities

Cobalt is required for the binding phase of cemented carbide production. It is therefore not possible to refrain from its use. When looking for a possible substitution, it must be checked whether workpieces can be produced using cobalt-free alloys or alloys which only contain small proportions of this element without compromising the quality. In addition, it is to be checked whether a process with a lower overall risk can be used.

### 5.2.4 Protective measures

(1) The most important measure for exposure reduction is the use of closed systems with integrated extraction and filtration. Depending on the manufacturing process, it is to be checked whether other forms of the material (granules) with lower emission rates can be used instead of powders.

(2) When processing workpieces made of cemented carbide, “wet” grinding methods using water-mixed or oily cutting fluids should be used, if possible. Regarding the use of water-mixed cutting fluids, products which prevent cobalt from dissolving are particularly suitable, especially cutting fluids with non-ferrous metal inhibitors which are free of amine (e. g. benzotriazole). These cutting fluids convert dissolved metal (e.g. cobalt) into a complex compound which can then be filtered off. The inhibitors must be replenished at regular intervals in accordance with the manufacturer’s recommendation since they are consumed by the continuous addition of metal. If possible, these working steps should be performed in cabins with extraction systems. Due to aerosol formation, it must be ensured that after processing the cabins are only opened after the visible mist has been extracted.

(3) Dry use requires closed systems or open systems with highly effective extraction systems (see number 4.2 of this *TRGS*). If cobalt-containing cemented carbide powder is used openly (e.g. during filling/weighing of powder and granules, dry grinding, dry processing), personal protective equipment is to be worn according to *DGUV*-Regel 112-190 (preferably fan-assisted respiratory protection or full-face masks with particulate filter). PPE must be worn during the cleaning, maintenance and servicing of systems which are exposed to dust, as well. For cleaning work, devices of dust class H are to be used.

(4) A light colour scheme is recommended for the workplaces. In this way, contamination with metal powder is more easily noticeable.

(5) Exposed and non-exposed areas in changing rooms are to be separated so that a contamination of the street clothes is avoided (*Schwarz-Weiß-Prinzip* [black-white principle]) Separate changing rooms – separated by wash rooms – are recommended (see also *DGUV*-Information 213-724). Even before a short break (drinking, smoking, etc.), the employees must wash their hands and, if necessary, their face, vacuum their clothes and clean their shoes. Special air showers have proven useful for cleaning clothes. Changing, wash and break rooms (incl. furniture) are to be cleaned using wet cloths. Cleaning is to be monitored and documented.

### 5.3 Pig iron and steel production

(1) DIN EN 10020:2000-07 (2.1) defines steel as a “material which has a mass percentage of iron higher than that of any other element, a carbon content which is usually below 2% and which contains other elements.” The “other elements” are mainly non-ferrous metals. The directive differentiates between unalloyed, stainless and other alloyed steels.

(2) There are two commonly used methods for steel production: The blast furnace route where pig iron is produced by the reduction of iron ore and is then further processed into crude steel in the oxygen converter, and the electric arc process in which steel is directly recovered from scrap metal.

(3) Alloying agents are added to the melt in the framework of secondary metallurgy to fine-tune the steel composition. These alloys either have a solid form or are enclosed in a hollow wire. Powder injection via lances is also possible. The subsequent transition from the liquid to the solid phase takes place in continuous casting or ingot casting.

(4) *The DGUV-Regel* 109-601 “*Branche Erzeugung von Roheisen und Stahl*” [Pig iron and steel production industry][29] specifies further requirements for the occupational health and safety in this industry regarding activity-, workplace- and process-related situations.

#### 5.3.1 Processes and activities involving relevant exposure

This *TRGS* mainly focuses on the production of alloyed steels due to their chromium, nickel or cobalt content. During the processing of alloyed steels, chromium(VI), cobalt and nickel compounds may be released.

[29] *http://publikationen.dguv.de/dguv/pdf/10002/109-601.pdf*.

### 5.3.2 Exposure situation

(1) The relevant raw materials for iron and steel production (ores, concentrates, alloy elements or scrap metals) are usually bulk materials. After delivery, the raw materials are transported to interim storage facilities (bunker or stockpile) by mechanical systems. From there, they are transported to the place of use - also by mechanical transport equipment. Iron ores are used in the blast furnace, scrap metal in the steel mill and alloy elements in secondary metallurgy. These processes are mainly automated. A relevant exposure to carcinogenic metals is not expected during normal operation in this case due to the low proportion in the raw materials.

(2) Alloy additions may be available in the form of pellets, briquettes, bars, wires or in irregular, solid form. These additions are pure metals or ferro alloys. Certain alloy elements can also be inside hollow wires or packaged. They may also be added to the melt as high-alloyed scrap metals. During the handling of the alloy elements or scrap metals, dust may form depending on the dust content of the substances. In crude steel production, usually only low levels of exposure to carcinogenic metals are to be expected. Primary as well as secondary extraction are normally used. The furnaces are generally enclosed.

(3) Higher exposure levels are possible in the area of wire and bar mill. The reason for this is the technologically unavoidable generation of scales and rolling dusts. During the rolling of stainless and other alloyed steels, exposure with a high risk level is locally possible, in particular exposure to cobalt and possibly nickel compounds.

(4) Stainless and alloyed steels are usually produced in electric steel production processes. Here, an exposure to chromium(VI) compounds is to be expected. Due to contaminations of the raw materials, exposure to cobalt cannot be excluded either.

(5) During the production of special steels (e.g. high-temperature resistant, corrosion-resistant for plant construction, offshore applications, turbines, etc.), relevant exposure to nickel compounds is to be expected, in particular in the area of alloys with high nickel content.

### 5.3.3 Substitution possibilities

Depending on the material properties which are required in each individual case, substitution is usually not possible. When looking for a possible substitution, it must be checked whether application or processing methods which generate low emissions and little dusts are available.

### 5.3.4 Protective measures

(1) For the charging of chromium-, nickel- or cobalt-containing and other alloy additions, chunky, e.g. briquettes, or packaged materials should be preferred.

(2) Grinding systems should be operated in a wet grinding format.

(3) By keeping the working periods in close proximity to blasting systems or deseaming systems short, the possible exposure to carcinogenic metals can be reduced.

(4) By keeping the working periods in close proximity to hot rolling stands or during casting short, the possible exposure to carcinogenic metals can be reduced.

(5) In the area of rod and bar mills, in electric steel making and in the production of special steels, an exposure, in particular to cobalt and nickel compounds, above the tolerable concentration is possible. This is why clean work clothes and PPE are to be stored separate-

ly from used work clothes and used PPE (contaminated area – clean area). For workplaces at which it is foreseeable that the tolerable concentration, occupational exposure limit or assessment criterion will be permanently exceeded, a spatial separation of contaminated and clean areas, for example by two changing rooms which are connected to a wash room or suitable air lock systems are to be provided.

## 5.4 Electroplating and chemical surface treatment

(1) This refers to the galvanic (electro-chemical) and electroless (chemical) treatment of surfaces using an immersion process.

(2) The recommendation for risk identification (EGU) "*Galvanotechnik und Eloxieren*" [Electroplating and anodising] (*DGUV*-Information 213-716, IFA-Report 3/2013)[30] provides exposure data. In the *DGUV-Regel* "*Branche Galvanik*" [Electroplating industry], additional specific protective measures, in particular regarding the use of suitable PPE, are specified.

### 5.4.1 Processes and activities involving relevant exposure

(1) Processes with possible exposure to chromium(VI) compounds include in particular hard chromium plating, high-gloss chromium plating, black chromium plating as well as chromating and pickling using chromic acid.

(2) Exposure to nickel compounds occurs during chemical and galvanic nickel-plating.

(3) Exposure to cobalt cannot be excluded for blue passivation after zinc plating. Chromium(III) compounds (chromium sulphate) and cobalt sulphate are added in this case.

(4) The exposure of employees is mainly influenced by hydrogen formation, the concentration of raw materials in the process container, systems engineering including the use of wetting agents, process parameters, ventilation conditions and exposure time.

(5) In processes of subcontracted electroplating, rack and barrel systems are used which are manually operated, operated using lifting gear, a crane or a feed unit or automatically operated. The process containers are mainly open and equipped with rim extraction. In addition, some chrome electrolytes are equipped with an emission-reducing foam cover (wetting agent). In some areas, enclosed facilities with extraction systems and ventilation cabins are used for the feeding cart.

### 5.4.2 Exposure situation

(1) During hard chromium plating, the employees are exposed to chromium(VI) concentrations of up to approximately 25 µg/m³ (95% value).

(2) Lower chromium(VI) concentrations are usually measured for high-gloss and black chromium plating (< 2.5 µg/m³; 95% value) and for chromating (6.8 µg/m³; 95% value).

(3) During chemical nickel plating, the employees are exposed to concentrations of nickel compounds of up to 22 µg/m³ (95% value, E fraction) and 31 µg/m³ (95 % value, E fraction) for nickel electroplating.

(4) Cobalt exposure during blue passivating is < 1 µg/m³. For these processes, an exposure description "*Verzinken in galvanotechnischen Betrieben*" [Galvanising in electroplating

[30] *http://publikationen.dguv.de/dguv/pdf/10002/213-716.pdf*.

plants][31] by *BG ETEM* [employers' liability insurance association of the energy textile and electronics and media industries] is available.

### 5.4.3 Substitution possibilities

(1) The substitution possibilities are very different depending on the individual process. It is to be checked whether processes which are free of chromium(VI) are available for the area of application.

(2) Regarding high-gloss chromium plating and chromating or passivating, electrolytes with chromium(III) compounds are available for specific applications. These are to be applied if technically feasible and admissible based on the product requirements.

(3) If electrolytes which are free of chromium(VI) cannot be used, it is to be checked whether there are ways to reduce the emissions. The use of effective wetting agents and/or foam covers, for example, leads to a reduction of the chromium(VI) concentration in the air during hard, high gloss and black chromium plating.

### 5.4.4 Protective measures

(1) If all technical protective measures listed in table 3 below are implemented, the employer can assume that the assessment criterion for chromium(VI) compounds and the acceptable concentration for nickel and cobalt compounds are adhered to for the specified processes.

(2) Protective measures marked with X are to be generally used; they correspond to the processes and operating modes which are usually used in the industry.

(3) The measures marked with Q are additional protective measures beyond X according to the state of the art in technology. They are to be taken individually or in additionally combination to the measures marked with X until the exposure level is below the assessment criterion. The effectiveness of the additional protective measures is to be verified in each individual case by determining the exposure. In this way, the requirement to implement technical measures according to the state of the art in technology according to *TRGS* 910 is met. For new systems, *TRGS* 460 “Recommended course of action for determining the state of the art” includes a practical aid for determining the state of the art for the hard chromium plating process.

[31] *https://www.bgetem.de/redaktion/arbeitssicherheit-gesundheitsschutz/dokumente-und-dateien/themen-von-a-z/gefahrstoffe/expositionsbeschreibungen/verzinken-in-galvanotechnischen-betrieben*.

**Table 3:** Technical measures for the reduction of inhalation exposure in order to comply with the assessment criteria for chromium(VI) compounds and nickel and cobalt compounds

| Process | Emission reducing measure, e.g. use of wetting agents (foam cover) | Closed facility with extraction system | Rim extraction at the process container | Ventilation cabin at the feeding cart | Process container cover | Ventilation system |
|---|---|---|---|---|---|---|
| Hard chromium plating of standard parts (e. g. gravure printing) | | X | | | | X |
| Hard chromium plating of changing parts (e. g. subcontracted electroplating) | X | | X | Q | Q | Q |
| High-gloss and black chromium plating | X | | X | Q | Q | Q |
| Chromating | X | | X | | | Q |
| Chemical nickel plating | | | X | Q | Q | Q |
| Nickel electroplating | | | X | Q | Q | Q |
| Blue passivation | | | X | | | Q |

X = Processes and operating modes usually used in the industry
Q = Additional measures according to the state of the art, if the assessment criterion is not met (see also *DGUV Regel* “Branche Galvanik” [Electroplating industry] according to number 5.3, paragraph 2)

(4) If the processes are performed in closed systems with a mechanical process container cover and extraction by ventilation systems or in a virtually closed system (process container with mechanical process container cover and transport cart with extraction system), it can be assumed that exposure levels are reached which are below the assessment criterion for chromium(VI) compounds and the acceptable concentration for nickel compounds, cobalt and cobalt compounds. The effectiveness of the ventilation system must be ensured in this case.

(5) If the risk cannot be prevented through the implementation of the measures described in sections 2 and 3, it is to be reduced to a minimum through the application of suitable organisational measures alongside individual protective measures, which also include the use of personal protective equipment. This may be the case during the three-year period which is granted for the implementation of the action plan (see number 3.1, section 6 of this *TRGS*), in particular for hard chromium plating of changing parts.

### 5.5 Production, use and further processing of chromate-containing coatings

(1) Chromium(VI) compounds are no longer produced at a relevant scale in Germany.

(2) Hexavalent alkali dichromats, in particular sodium dichromate, are still used to produce chromium(III)oxide pigments. The concentration of chromium(VI) compounds is usually below the assessment criterion in this case.

(3) In the aerospace industry, defence technology and in nuclear facilities, parts are manufactured which require the use of chromate-containing coatings. The following information refers to the aerospace industry.

#### 5.5.1 Processes and activities involving relevant exposure

(1) The primary corrosion protection of a metallic plane consists, among other things, of chromium-containing paint/primer. This means that relevant exposure above the assessment criterion is to be expected, in particular regarding:

1. spray painting of air planes, large parts, components with chromate-containing primers,
2. paint repair work using chromating solutions, application of paint or corrosion protection to small surfaces (using pen, brush, dabber, roller, touch-up, etc.),
3. machining (manual drilling, reaming, counterboring, milling, grinding, drilling, abrasive blasting, roughening of the surface, etc.) of the above-mentioned workpieces with chromate-, nickel- or cadmium-containing coatings.

#### 5.5.2 Exposure situation

(1) The work is performed

1. in painting and blast rooms,
2. in paint booths,
3. to a small extent directly in or at the plane.

(2) With spray painting, the coatings are sprayed manually on the parts using spray guns of different designs which are operated by compressed air (cup guns, airless systems, electrostatic spraying). Around the spray cone, a spray mist (so-called overspray) is formed which may be significantly more than 10% of the processing volume. Chromate-containing primers contain 5-10% chromate-containing pigments. The concentration in the air in close proximity to the spray cone is above the assessment criterion for chromium(VI) compounds.

(3) Regarding the mechanical roughening/grinding of large surfaces, the dust measurements are incomplete. Concentrations of up to 5 µg/m³ can be found in the air. One hour after completion of the grinding process, chromium(VI) compounds are usually no longer found in the air of the hall.

(4) Manual drilling/reaming/counterboring is usually performed with integrated extractions. Dust measurements are incomplete and concentrations of 1 µg/m³ in the immediate surroundings are to be expected. No chromate is found outside the direct surroundings/workplace.

(5) Air-borne exposure to chromate is unlikely during repair works at small surfaces; exposure through skin contact must be checked in each individual case.

### 5.5.3 Substitution possibilities

In aviation, there are very high requirements to material properties, in particular regarding corrosion protection. Up to now, no suitable alternative for the chromate-containing coatings has been found which fulfils all requirements and passes the required tests. Even if carcinogenic metals can be replaced in new products, it will not be possible to avoid the machining of chromate-containing coatings during maintenance and servicing work of older aircraft with a service life of > 50 years in the coming decades.

### 5.5.4 Protective measures

(1) Spray painting and large-scale grinding must be performed in properly separated and equipped areas with controlled extraction and ventilation systems.

(2) The required PPE, in particular protective clothing (protective suit), respiratory protection and protective gloves must be worn. Respiratory protection is to be worn in the entire hall up to one hour after the painting/grinding process is completed.

(3) Parts and working areas are to be wet-cleaned to bind chromate-containing dusts.

(4) For manual drilling/reaming/counterboring, a suitable extraction system is to be used and it must be checked whether additional technical, organisational and personal protective measures are required.

## 5.6 Battery production

(1) Batteries are electrochemical storage systems for electrical energy. A distinction is made between non-rechargeable primary batteries and rechargeable secondary batteries (accumulators).

(2) The *DGUV* Information 203-082 "*Herstellung von Batterien – Handlungshilfe für Tätigkeiten mit krebserzeugenden Metallen und ihren Verbindungen*" [Production of batteries – Guide for activities involving carcinogenic metals and their compounds][32] provides exposure data and additional specific protective measures.

### 5.6.1 Processes and activities involving relevant exposure

(1) In the production of nickel-cadmium accumulators, nickel-metal hydride accumulators and lithium accumulators, activities are performed during which employees may be exposed to the carcinogenic metals cadmium, cobalt and/or nickel compounds.

(2) In general, the production process for batteries and accumulators can be described as follows:

1. Production of the energy-storing electrodes with positive or negative polarity. For this, solids are pressed or processed as paste.
2. If required, assembly of electrodes and separators to form electrode packs,
3. production of cell and battery cases,
4. insertion of the electrodes or electrode packs in the cases,

[32] *http://etf.bgetem.de/htdocs/r30/vc_shop/bilder/firma53/dguv_information_203-082_a08-2016.pdf*.

5. provision of or filling with electrolyte fluids,
6. sealing of the battery housings,
7. formation (initial charging) and electrical commissioning in the case of accumulators.

(3) For the production of batteries and accumulators, nickel-plated and cobalt-coated steels are used as well.

(4) In addition to the battery-specific or other processes, galvanic processes may be used (see also number 5.4 of this *TRGS*). The formation should not be considered as a galvanic process.

### 5.6.2 Exposure situation

(1) In workplace practice, the manufacturing processes cannot all be performed as closed systems with extraction.

(2) During manufacturing processes which are designed as open systems for technical reasons, there is exposure to cadmium, cobalt and nickel compounds above the tolerable concentrations. This applies in particular to the processing of powdery materials and the further processing of electrodes and plate sets.

(3) If completely covered systems (including extraction) are used in manufacturing processes, the employer can assume that the exposure levels are below the tolerable concentrations for cadmium, cobalt and nickel compounds.

### 5.6.3 Substitution possibilities

(1) The metals used are the main electrochemical element of the corresponding battery system. For the listed battery systems, it is not possible to avoid using the carcinogenic metals.

(2) When looking for a possible substitution, it must be checked whether a procedure with a lower overall risk can be used. This includes whether material types (pastes, gels) with lower emissions can be used.

### 5.6.4 Protective measures

(1) In areas with a medium or high risk level, it may be required to construct a spatial separation between the contaminated and the clean area in the form of two changing rooms which are connected to a wash room or in the form of an air lock system which is connected to the working area and used for putting on and taking off the work and protective clothing.

(2) For small batches, a corresponding master batch or preparation of the powders by the supplier is to be aimed for to reduce the number of mixing processes.

(3) For large batches, the filling process is to be performed in a closed system. If this is not possible, extraction systems according to the state of the art are to be used. Due to the process-technical, the increase of the extraction volume is limited (turbulence and fire hazard with hydrogen storage alloys).

(4) A suitable mobile extraction system must be available in the production area for unexpected contamination in working areas (e. g. uncontrolled release of dusts or pastes).

(5) In areas in which the tolerable concentrations are exceeded despite the implementation of technical and organisational measures, personal protective equipment (respirator mask with particulate filter, fan-assisted respiratory protection system) are to be used.

(6) Due to the possible exposure to other metals, it is generally recommended to verify the effectiveness of the protective measures by regular biomonitoring as part of the preventive occupational medical measures (see also number 6 of this *TRGS*).

## 5.7 Recycling of electronic waste, PVC profiles, batteries and solar panels

### 5.7.1 Processes and activities involving relevant exposure

(1) A relevant exposure to carcinogenic metals is not expected during the collection and sorting of solid scrap metal.

(2) During the recycling of electronic waste (cleaning and disassembly workplaces) which contains carcinogenic metals, there is a risk of exposure to carcinogenic metals and dusts which may be released during disassembly. Beryllium is used, among other things, as an alloy element (e.g. in collectors and mechanical parts). Cadmium is contained in accumulators, soft solder, circuit boards and in the form of cadmium sulphide in the light-emitting layer at the inside of the front glass of picture tubes. Cobalt could be found in pigments and paints. Nickel (not nickel compounds) is used, among other things, in printed circuit boards, thermocouples, accumulators and in the aperture mask of picture tubes.

(3) Cobalt and nickel compounds can be released from batteries in electronic waste in automated systems, if they are not removed beforehand. The concentration in the electronic waste is still very low at the moment but may increase in the future.

(4) Plastic profiles made of rigid PVC may contain cadmium stabilisers which lead to relevant exposure during recycling.

(5) Device batteries which contain more than 0.002 cadmium percent by weight, may not be marketed in the EU (regulated in Germany by the *Batteriegesetz* [Battery Act]) Today, this battery type is only used with special permissions in niche applications (medical equipment, emergency lighting). However, nickel-cadmium batteries are still being returned (5.7% of the batteries collected in Germany in 2014). Usually, cadmium is recovered in a vacuum or an inert atmosphere (reaction-inhibiting environment) by distillation since it has a significantly lower boiling point than the other components such as iron and nickel. The cadmium may be re-used to produce new NiCd batteries (1% of the marketed batteries, no longer allowed in the EU from 1 January 2017).

(6) The recycling of solar panels is regulated by the directive on waste electrical and electronic equipment (WEEE directive 2012/19/EU). An exposure to cadmium and arsenic compounds is to be expected, in particular with photovoltaic modules which are not silicon-based. The minimum requirements for the recycling of solar panels are regulated in European standards[33].

### 5.7.2 Exposure situation

(1) In electronic waste recycling, the level of exposure is influenced by various parameters (e.g. age and degree of contamination of the devices, throughput of devices at the workplace, type and design of protection technology, individual working method). If the technical, organisational, hygienic and personal protective measures described in the *BGIA* [Profes-

[33] Standard EN 50625-2-4 “Treatment requirements for photovoltaic panels” and the corresponding Technical Specification TS 50625-3-5 are in preparation.

sional Association for Occupational Safety] recommendation "*Manuelle Zerlegung von Bildschirm- und anderen Elektrogeräten*" [Manual disassembly of visual display units and other electronic devices][34] from the year 2001 are complied with, a relevant contribution to the exposure is to be expected by cadmium only. The measured values are partly above the tolerable concentration[35], in particular if the electronic waste which is to be disassembled is not pre-cleaned in closed cleaning cabins.

(2) During the extraction of the light-emitting layer of picture tubes, a very high exposure to cadmium (up to 140 µg/m³) has repeatedly been observed.

(3) In the recycling of PVC profiles, the time weighted average for cadmium[36] measured in the years 1996 to 2003 were 0.4 µg/m³ which means that the acceptable concentration was exceeded. These increased values are particularly due to mixing without effective extraction. If the work practices and protective measures which are indicated in the instruction manual are complied with, a higher concentration is not expected.

(4) In battery recycling, there is an exposure risk in all mechanical treatment steps which involve damaging or opening the cells. In particular, semi- or fully automatic WEEE systems are to be mentioned here, which reduce the size of electrical devices with batteries by using crushers or shredders. Cadmium or $Cd(OH)_2$ can then be released and carried off as fine dust. During a targeted extraction of cadmium from batteries by distillation, release of the metal into the air is only expected if the system's design does not ensure a hermetic separation between the distillation room and the employees' working room. In addition, exposure is possible during charging and discharging processes.

(5) Exposure data on the recycling of solar cells are not available yet. If a panel size of 1 m² is assumed, however, the panels may contain a significant amount of cadmium telluride and/or cadmium sulphide depending on their design and technology. In panels with a semiconductor layer made of cadmium telluride, the stoichiometric proportion of cadmium which is bound in the semi-conductor can be up to 9 g; for other thin-film technologies, the amount of cadmium from cadmium sulphide is up to 1 g. The amounts of the integrated cadmium telluride and/or cadmium sulphide can therefore theoretically present an actual source for exposure. In the recycling methods used today, none of these substances are released during mechanical reduction but dissolved in the encapsulated, wet chemical recycling process. In this step, the generation of carcinogenic cadmium compounds cannot be excluded.

### 5.7.3 Substitution possibilities

Looking for substances for substitution is not possible for recycling. In addition, the recycling in the areas which are covered by *this* TRGS is often subject to statutory regulations (e.g. WEEE (2002/96/EU) or the battery directive (2006/66/EC) for solar cells).

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[34] *http://www.dguv.de/medien/ifa/de/pra/bg_bgia_empfehlungen/1037-Manuelle_Zerlegung_von_Bildschirm-_und_anderen_Elektrogeraeten.pdf*.

[35] Regierungspräsidium Kassel *Handlungsanleitung zur guten Arbeitspraxis* "*Elektronikschrottrecycling – Tätigkeiten mit Gefahrstoffen bei der manuellen Zerlegung von Bildschirm- und anderen Elektrogeräten*" [Instruction manual for good working practice "Electronic waste recycling – Activities involving hazardous substances during the manual disassembly of visual display units and other electronic devices].

[36] LUBW *Handlungsanleitung zur guten Arbeitspraxis* "*Kunststoffverwertung – Tätigkeiten mit Gefahrstoffen und biologischen Arbeitsstoffen bei der werkstofflichen Verwertung von Kunststoffen*". [Instruction manual for good working practice "Plastic recycling – Activities involving hazardous substances and biological working materials in the mechanical recycling of plastics].

### 5.7.4 Protective measures

(1) In electronic waste recycling, stirring up dust is to be avoided during disassembly, e.g. by the appropriate selection of disassembly tools. For workplace cleaning, dust-free procedures are to be used and cleaning is not permitted without dust-binding measures. Employees must be trained regarding the disassembly so that they can recognise the parts which contain hazardous substances. Picture tube sets are to be disassembled in closed cleaning cabinets.

(2) Regarding the recycling of plastics and the potentially released hazardous substances (in particular cadmium), a process- and substance-specific criterion (*VSK*) was defined which, when applied, minimises the exposure and ensures safe handling[37].

(3) During battery recycling, appropriate respiratory protection is to be worn for charging and discharging processes (at least of class P 2).

(4) The possible exposure levels which may occur during the recycling of solar panels can currently not be reliably assessed. In general, it is therefore recommended to use the measures from the above-mentioned *VSK* for plastics recycling or the *BGIA* recommendation for the manual disassembly of visual display units and other electronic devices (see number 5.7.2 paragraph 1 of this *TRGS*) as a guideline.

## 5.8 Production and use of catalysts and pigments

(1) The production of catalysts includes the production of chemical catalysts which are based on carcinogenic metals and their compounds, in particular the elements nickel and cobalt.

(2) Chemical catalysts are used in their pure form and as metal oxides on substrates. These are fed to the reactors by metering units or the reactors are filled with the catalysts prior to commissioning.

(3) At the moment, no recommendations in the form of a *DGUV* Information are available.

### 5.8.1 Processes and activities involving relevant exposure

(1) In the production and use of catalysts, activities are performed during which employees may be exposed to carcinogenic metals.

(2) In general, the production process of catalysts can be described as follows:

1. production of metal solutions from carcinogenic metals,
2. production of metallic salt suspensions from metal solutions,
3. drying and, if applicable, shaping of the metallic salts,
4. calcination of the metallic salts to metal oxides,
5. reduction of the metallic salts to carcinogenic metals,
6. stabilising and, if applicable, shaping of the metallic catalysts and/or their oxides.

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[37] *LUBW Handlungsanleitung zur guten Arbeitspraxis „Kunststoffverwertung – Tätigkeiten mit Gefahrstoffen und biologischen Arbeitsstoffen bei der werkstofflichen Verwertung von Kunststoffen“.*

(3) If used for catalyst metering in reaction mixtures or as fixed-bed or other reactors, the main processes are the introduction process of the catalysts in the reactors and, at the end of life (loss of sufficient activity of the catalyst), the removal and passivation of the catalysts.

### 5.8.2 Exposure situation

(1) During the manufacturing processes, which are designed as open or not completely closed systems due to production-technical reasons, an exposure to carcinogenic metals above the tolerable concentrations occurs. This applies to the drying of the metal suspensions but in particular to the shaping and/or further processing of powdery materials and to the further processing of shaped catalysts. In addition, filling processes can cause exposure to carcinogenic metals and their compounds above the tolerable concentrations.

(2) During the preparation of the use and during the use of the catalysts, filling processes and disassembly and passivation processes of the catalysts can cause exposure to carcinogenic metals above the tolerable concentrations.

### 5.8.3 Substitution possibilities

(1) The metals used are the only usable reaction catalysts for the corresponding chemical reactions. it is not possible to avoid using the carcinogenic metals for the reaction systems.

(2) When looking for a possible substitution, it must be checked whether a procedure with a lower overall risk can be used. This includes whether material types (tablets, extrudates, etc.) with lower emissions can be used instead of powder.

### 5.8.4 Protective measures

(1) In workplace practice, the manufacturing processes and filling and discharging processes cannot all be designed as closed systems with extraction.

(2) If completely closed systems (including extraction) are used in the manufacturing processes, the employer can assume that the exposure levels are below the tolerable concentrations for cobalt and nickel compounds.

(3) If raw materials and catalyst interim products are introduced via big-bag batch loading, suitable big-bag stations with sealing connections (e.g. inflatable sleeves or clamping devices) are to be provided. Corresponding equipment should be used for drum filling (duct for the falling goods, etc.).

(4) The filling of substances from drums into big-bags is to be performed in an enclosed system which is equipped with appropriate sealing systems for the connection of the big-bag and, if possible, with localized extraction.

(5) The systems which are used for the transfer, bagging and further processing (e.g. compaction, shaping, screening, etc.) of powdery catalyst interim and/or end products should be designed as closed systems, if technically feasible. If this is not possible, effective extraction systems are to be used. Due to process-technical reasons, the increase of the extraction volume is limited (turbulence and fire hazard caused by pyrophorous catalyst interim and end products).

(6) In areas in which the tolerable concentrations are exceeded despite the implementation of technical and organisational measures, personal protective equipment (respirator mask with particulate filter, fan-assisted respiratory protection) is to be used.

(7) In areas with a high risk level, it may be required to construct a spatial separation between the contaminated and the clean area in the form of two changing rooms which are connected to a wash room or in the form of an air lock system which is connected to the working area and used for putting on and taking off the work and protective clothing.

(8) Due to the possible exposure to several metals, it is generally recommended to verify the effectiveness of the protective measures by regular biomonitoring (see also number 6 of this *TRGS*).

### 5.9 Other special areas

In this section, concise information is given on areas in which an exposure to carcinogenic metals is to be expected as well, but which are not comprehensively covered in this *TRGS*. This is for example the case if the exposure is typically below the tolerable concentration or other sets of rules have a higher priority. The list of the areas in this section is not to be considered as complete or final.

#### 5.9.1 Dental technology

(1) In dental laboratories, dental workpieces (e. g. crowns, bridges and model castings) are produced and machined. If they consist of non-ferrous metal alloys, cobalt is included in the alloy with a proportion between 30 and 70%.

(2) Alloys which contain nickel are used for orthodontic workpieces such as braces or wires. They are machined by cold forming without releasing nickel compounds or metallic nickel (OEL scope).

(3) The exposure description "*Verarbeitung von Nichtedelmetall-Legierungen in Dentallaboratorien*" [Processing of base metal alloys in dental laboratories][38] by *BG ETEM* from 2015 specifies the exposure data for cobalt in the E fraction.

(4) After casting and deflasking, the dental workpieces are separated from the sprue cone and then machined by milling, grinding and polishing. Machining is performed manually by holding the workpiece using the handpiece in which rotating milling, grinding or polishing tools are clamped. During this work, the employees are exposed to cobalt and its compounds up to a maximum of 2.4 µg/m³ (E dust, 95th percentile).

(5) For the production of crowns and bridges, precious metal alloys and oxide ceramics may also be used. The decision on the use of the materials is made by the dentist who is responsible for the treatment.

(6) In Germany, beryllium-containing alloys are no longer used. It can, however, not be ruled out that patients are wearing dental workpieces which were produced abroad, contain beryllium and therefore may cause an exposure to beryllium.

(7) If the following protective measures are implemented, the employer can assume that the tolerable concentration for cobalt and its compounds or for nickel compounds is not exceeded:

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[38] *https://www.bgetem.de/redaktion/arbeitssicherheit-gesundheitsschutz/dokumente-und-dateien/themen-von-a-z/gefahrstoffe/expositionsbeschreibungen/expositionsbeschreibung-verarbeitung-von-nichtedelmetall-legierungen-in-dentallaboratorien*.

1. use of tested dust collection systems and extraction systems which are equipped with the filters and additional features recommended by the manufacturer,
2. use of inspection glasses at the collection systems,
3. proper usage of the extraction systems,
4. regular cleaning, maintenance and testing of the effectiveness of the extraction technology according to the manufacturer's instructions as well as their documentation.

(8) Collection systems and extraction systems correspond to the state of the art in technology if they were successfully tested according to the *DGUV*- Test "*Grundsätze für die Prüfung und Zertifizierung von Erfassungseinrichtungen und Absaugsystemen für Dentallaboratorien* [Basic principles for the testing and certification of collection systems and extraction systems for dental laboratories]" GS-IFA-M 20, edition 12/2012.

### 5.9.2 Glass production

(1) Arsenic, in particular in the form of arsenic trioxide, does no longer play a relevant role in the flat and hollow glass industry. In the production of special glasses, it is still used to meet specific requirements.

(2) Most concentrations of arsenic compounds in glass production are below the acceptable concentration and in some cases between the acceptable and tolerable concentration.

(3) The measures described in number 4 of this *TRGS* are to be applied accordingly.

## 6 Preventative occupational medical care

Preventative occupational medical care for activities involving carcinogenic metals and their compounds usually includes the involvement of the company physician in the risk assessment, the general occupational health and toxicological consultation and the preventative occupational medical care.

### 6.1 Involvement of the company physician in the risk assessment and insights from preventative occupational medical care

(1) For activities involving carcinogenic metals, the company physician or the physician commissioned with the preventative occupational medical care is to participate in the preparation of the risk assessment. Depending on the situation, the involvement of the occupational physician can take various forms, from short written or oral statements to the preparation of the risk assessment on behalf of the employer. This applies without prejudice to the employer's responsibilities.

(2) The main reason for the involvement in the risk assessment are the carcinogenic and other chronically damaging effects of the metals and the strain caused by the wearing of personal protective equipment. The work intensity must be considered in the assessment of the inhalative exposure.

(3) For the risk assessment, the employer must take the findings from the preventative occupational medical care (including biomonitoring) and the generally accessible, published information on this topic into account.

(4) The physician commissioned with the preventative occupational medical care shall also give the employer advice on reports according to Sec. 6 Para. 4 *ArbMedVV* (see number 6.3 paragraph 9 of this *TRGS*). The consultation is subject to medical confidentiality.

### 6.2 General occupational health and toxicological consultation

(1) In the case of activities involving carcinogenic metals, the employer must ensure that the employees receive a general occupational health and toxicological consultation. The goal is to inform the employees who are exposed to hazards e.g. in the form of an instruction. The instruction is usually given in groups and must therefore be distinguished from the individual consultation which is part of the preventative occupational medical care.

(2) It shall be based on the risk assessment, involve the company physician, if applicable, and is mainly intended to explain the possible health consequences and their prevention, the possible carryover of hazardous substances and the employees' right to preventative occupational medical care in a way comprehensible for laypersons. It should also provide information about the benefit and extent of preventative occupational medical care and encourage active participation in it. The requirement to involve the company physician can be met e.g. by training managers or participating in the preparation of suitable instruction materials.

(3) In the general occupational health and toxicological consultation for activities involving carcinogenic metals, the following aspects are to be covered:

1. The main routes of exposure to metal-containing dusts are the inhalative and oral routes. Depending on the dose, inorganic, inhalable and alveolar metal dust can lead to permanent damage to the lungs which is difficult to treat. After a latency period of 20-30 years, severe damage of the respiratory system and cancer at different organs may occur. Generally speaking, the risk of developing cancer increases with the dose of carcinogenic metal dusts.
2. The implementation of the protective measures which are defined in the operating instructions, including personal protective equipment and occupational hygiene, can significantly reduce the health risks. It is to be pointed out that, among other things, insufficient hand hygiene, e.g. prior to eating, smoking, nail-biting, or the wearing of a beard increase the risk of ingesting carcinogenic metals.
3. The continued inhalative smoking of cigarettes can increase the negative effect of metal dusts since it permanently impairs the self-cleaning mechanism of the lungs. Stopping smoking can reduce the risk significantly.
4. Measures to prevent the carryover of contaminations are to be emphasised.
5. The medical aspects of the use of personal protective equipment (e.g. protective gloves, protective clothes, respiratory protection) including handling, maximum wear times and change cycle as well as the possible strain caused by personal protective equipment are to be explained.
6. If applicable, the problem of working in wet conditions including skin protection and skin care measures is to be pointed out.
7. For many carcinogenic metals, biomonitoring can be used within the scope of preventative occupational medical care to check whether the individual employee is exposed to the metal in his or her activity and to check the effectiveness of protective measures. Biomonitoring requires the employee's consent.

8. The list of occupational diseases (annex 1 of the German Occupational Diseases Ordinance[39]) specifies the diseases which may be caused by metal-containing dusts.

### 6.3 Individual preventative occupational medical care

(1) Preventative occupational medical care is regulated in the German Ordinance on Occupational Health Care (*ArbMedVV*) and the corresponding published Occupational Safety and Health Rules (*AMR*).

(2) Preventative occupational medical care is intended to assess the individual influence of work on physical and mental health, to detect work-related health problems early-on and to determine whether a certain activity involves an increased health risk (Sec. 2 Paragraph 1 Number 2 *ArbMedVV*). The main focus is the education and consultation of the employees regarding the activity involving carcinogenic metals and their compounds and the resulting hazards to their health. An important part of the preventative occupational medical care is biomonitoring, provided that analytical methods which are accepted in the field of occupational health and suitable values for the assessment are available. Mainly, the equivalent values in biological material are to be compared to the acceptable and tolerable concentrations according to *TRGS* 910 (table 4). Using biomonitoring, the overall individual exposure (as a result of a possible intake via lungs, skin or the digestive system) to one of the metals specified in table 4 is determined. To find out whether the employee has been exposed to the metal due to his or her activity, biomonitoring must be offered prior to and after the activity as part of preventative occupational medical care. If an exposure is detected, additional protective measures are to be considered, if applicable (see paragraph 9). If physical or clinical examinations are not required for information and consultation from the physician's point of view or are rejected by the employee, the preventative occupational medical care may be limited to a consultation session.

(3) The employer must arrange for preventative occupational medical care for the affected employees according to Sec. 4 Para. 1 in conjunction with annex part 1 para. 1 umber 1 letter b and/or c *ArbMedVV* prior to the start of the activity and then at regular intervals (see also *AMR* 2.1) (compulsory preventative medical care), if repeated exposure to arsenic compounds, beryllium, cadmium and cadmium compounds, chromium(VI) compounds or nickel compounds at the workplace cannot be excluded (arsenic compounds, beryllium, cadmium and cadmium compounds, chromium-VI compounds and nickel compounds are carcinogenic hazardous substances of category 1A or 1B according to *GefStoffV*). The employer may only allow the activity to be performed by the affected employees if they have participated in the compulsory preventative medical care (Sec. 4 Para. 2 *ArbMedVV*).

(4) Preventative occupational medical care is to be offered to the affected employees by the employer according to Sec. 5 Para. 1 in conjunction with annex part 1 para. 2 number 1 *ArbMedVV* prior to the start of the activity and afterwards at regular intervals (see also *AMR* 2.1) (optional preventative medical care), if preventative medical care is not compulsory and an exposure to arsenic compounds, beryllium, cadmium and cadmium compounds, chromium(VI) compounds or nickel compounds cannot be excluded. Preventative occupational medical care is to be offered to the affected employees by the employer according to Sec. 5 letter Para. 1 in conjunction with annex part 1 para. 2 number 2 d double letter aa *ArbMedVV* prior to the start of the activity and afterwards at regular intervals (see also *AMR* 2.1) (op-

[39] *http://www.baua.de/de/Themen-von-A-Z/Berufskrankheiten/Rechtsgrundlagen/Anlage-BKV.html*.

tional preventative medical care), if preventative medical care is not compulsory and a repeated exposure to cobalt cannot be excluded (cobalt is a carcinogenic hazardous substance of category 1B). The rejection of an offer does not release the employer from the obligation to regularly offer optional preventative medical care. *AMR* 5.1 specifies the way in which these offers are to be made.

(5) In addition to the activity involving carcinogenic metals and their compounds, additional reasons for compulsory or optional preventative medical care according to the annex of the *ArbMedVV* may arise based on the risk assessment. If the affected employees are required to wear respiratory protection, the related compulsory or optional preventative medical care (annex part 4 para. 1 number 1 or para. 2 number 2 *ArbMedVV*) is to be combined with the preventative care due to the activity involving carcinogenic metals and their compounds. The use of respiratory protective equipment does not affect the above-mentioned requirements for preventative occupational medical care.

(6) After completion of the activity involving arsenic compounds, beryllium, cadmium and cadmium compounds, chromium(VI) compounds, cobalt or nickel compounds, the employer must offer affected employees follow-up preventative medical care according to Sec. 5 Para. 3 Sentence 1 in conjunction with annex part 1 para. 3 number 1 *ArbMedVV* at regular intervals (see also *AMR* 2.1). The offer of preventative occupational medical care is intended for the early detection of diseases. Health problems which are caused by these metals or their compounds are to be expected in particular after extended latency periods. The rejection of an offer does not release the employer from the obligation to regularly offer optional preventative medical care in the form of follow-up preventative medical care. *AMR* 5.1 specifies the way in which these offers are to be made. If the employees give their consent, the employer may transfer the obligation to offer follow-up preventative medical care to the competent statutory accident insurer at the end of the employment relationship and submits copies of the required documents to them (see also Sec. 5 Para. 3 Sentence 2 *ArbMedVV*).

(7) The physician shall document the result and findings of the preventative occupational medical care including the examination, if applicable, in writing according to Sec 6 Para. 3 *ArbMedVV* and advises the employee accordingly. At the employee's request, the physician shall provide him or her with the result of the preventative medical care. The physician shall issue a confirmation of the performed preventative occupational medical care to the employee and the employer. The confirmation must include information on the time and reason for the current preventative medical care appointment and indicate when preventative occupational medical care will be required again from the physician's point of view (see also *AMR* 6.3). This confirmation shall neither contain diagnoses nor other information on the employee's state of health nor a medical assessment regarding the fitness for certain activities.

(8) The employer must maintain a preventative medical care file which includes information on when and why medical care was provided to each employee (Sec. 3 Para. 4 *ArbMedVV*).

(9) The physician shall analyse the findings from the preventative occupational medical care (Sec. 6 Para. 4 *ArbMedVV*). If there are any indications that the occupational protection measures are not sufficient, the physician must inform the employer and suggest (additional) protective measures for exposed employees. If the physician thinks that a change of tasks is necessary for medical reasons which exclusively refer to the employee, notification of the employer requires the employee's consent. More detailed information can be found in *AMR* 6.4. As a consequence of such a proposal by the physician, the employer must revise the risk assessment according to Sec. 8 Para. 1 *ArbMedVV* and immediately take the required occupational protection measures. If a change of tasks is recommended, the employer is to assign another job to the employee according to the regulations of employment law. The

works council or staff council and the competent authority are to be informed about the measures taken (Sec. 8 Para. 2 *ArbMedVV*).

**Table 4:** Biomonitoring: analytical methods which are accepted in the field of occupational health and suitable values for the assessment regarding carcinogenic metals

| Metal | Primarily affected organs | Matrix | Assessment values |
|---|---|---|---|
| Arsenic | Blood, kidneys, haematopoietic system | Urine [b, c] | BAR:0.5/2/10 µg/l *<br>BLW: 50 µg/l<br>*EKA* correlation |
| According to table 2 in annex 1 of *TRGS* 910 also:<br>Arsenic compounds, classified as carc. 1A, carc. 1B;<br>Parameters Σ arsenic(+III), arsenic(+V), monomethylarsonic acid and dimethylarsinic acid;<br>Matrix urine [b, c];<br>Assessment values equivalent value to tolerable concentration 40 µg/l, equivalent value to acceptable concentration 14 µg/l; | | | |
| Beryllium: | Lungs | Urine [b, c] | BAR: 0.05 µg/l<br>*EKA* correlation |
| Cadmium | Kidneys | Urine [a]<br>Blood [a]<br><br>Urine | BAR: 0.8 µg/l<br>BAR: 1.0 µg/l<br>*EKA* correlation<br>BLV: 2 µg/g Creatinine |
| Chromium(VI) | Lung, nose | Urine [b]<br>Blood [c] (erythrocyte [a]) | BAR: 0.6 µg/l<br>*EKA* correlation |
| Cobalt | Lungs | Urine [b,c] | *EKA* correlation |
| Nickel | Lungs, nasal cavities | Urine [c] | BAR: 3 µg/l<br>*EKA* correlation |

**Key:**
BAR Biological material reference value
BLV Biological Limit Value
BLW Biological guidance value
EKA Exposure equivalent for carcinogenic materials
* depending on the parameter

**Sampling time:**
a no limitation;
b end of exposure;
c after several shifts

**Literature**

DIN EN 60335-2-69 “Household and similar electrical appliances - Safety - Part 2-69: Particular requirements for wet and dry vacuum cleaners for commercial use”.

*DGUV-Regel “Branche Galvanik”.*

*DGUV-Regel “Branche Metallhütten”.*

*DGUV-Regel 109-601 “Branche Erzeugung von Roheisen und Stahl”.*

*DGUV-Regel 109-002 (BGR 121) “Arbeitsplatzlüftung – Lufttechnische Maßnahmen”.*

*DGUV-Regel 112-189 et seq. “Benutzung von Schutzkleidung”.*

*DGUV-Regel 112-190 “Benutzung von Atemschutzgeräen”.*

*BG/BIA-Empfehlung “Manuelle Zerlegung von Bildschirm- und anderen Elektrogeräten”.*

*DGUV-Information 213-716 Empfehlung zur Gefährdungsermittlung (EGU) “Galvanotechnik und Eloxieren” (IFA-Report 3/2013).*

*DGUV-Information 213-724 “Hartmetallarbeitsplätze, Empfehlungen Gefährdungsermittlung der Unfallversicherungsträger (EGU) nach der Gefahrstoffverordnung”.*

*DGUV-Information 203-082 “Herstellung von Batterien – Handlungshilfe für Tätigkeiten mit krebserzeugenden Metallen und ihren Verbindungen”.*

*DGUV-Test “Grundsätze für die Prüfung und Zertifizierung von Erfassungseinrichtungen und Absaugsystemen für Dentallaboratorien” GS-IFA-M 20, Ausgabe 12/2012.*

*BG ETEM Expositionsbeschreibung “Verarbeitung von Nichtedelmetall-Legierungen in Dentallaboratorien”, 2015.*

*“Leitfaden zur Auslegung von Abluftanlagen an Galvanikanlagen” Lenkungsgruppe Umwelt (LGU) im Zentralverband Oberflächentechnik e. V. (ZVO), Postfach 10 10 63, 40710 Hilden.*

*MEGA-Auswertungen zur Erstellung von REACH-Expositionsszenarien für Beryllium und seine Verbindungen.*

*MEGA-Auswertungen zur Erstellung von Expositionsszenarien für Chrom(VI)-Verbindungen (2000 bis 2009) in Deutschland.*

*Workrelated exposure to carcinogenic, mutagenic and reprotoxic substances in Germany - Part 1: Cadmium and its compounds Gefahrstoffe -- Reinhalt. Luft 71 (2011) no. 1/2, p. 47-56.*

*AMR 2.1 “Fristen für die Veranlassung/das Angebot von arbeitsmedizinischen Vorsorgeuntersuchungen”.*

*AMR 5.1 “Anforderungen an das Angebot von arbeitsmedizinischer Vorsorge”.*

*AMR 6.2 “Biomonitoring”.*

*AMR 6.3 “Vorsorgebescheinigung”.*

*AMR 6.4 “Mitteilungen an den Arbeitgeber nach § 6 Absatz 4 ArbMedVV”.*

*AMR 11.1 “Abweichungen nach Anhang Teil 1 Absatz 4 ArbMedVV bei Tätigkeiten mit krebserzeugenden oder keimzellmutagenen Gefahrstoffen der Kategorie 1A oder 1B”.*

*AMR 14.2 “Einteilung von Atemschutzgeräten in Gruppen”.*

*ASR A1.3 “Sicherheits- und Gesundheitsschutzkennzeichnung”.*

*ASR A3.6 “Lüftung”.*

*ASR A4.2 “Pausen-und Bereitschaftsräume”.*

*TRGS 400 “Risk assessment for activities involving hazardous substances”.*

*TRGS 401 “Risks resulting from skin contact - identification, assessment, measures”.*

*TRGS 402 “Identification and assessment of the risks from activities involving hazardous substances: Inhalation exposure”.*

*TRGS 410 “Expositionsverzeichnis bei Gefährdung gegenüber krebserzeugenden oder keimzellmutagenen Gefahrstoffen der Kategorien 1A oder 1B”.*

*TRGS 460 “Recommended course of action for determining the state of the art”.*

*TRGS 500 “Schutzmaßnahmen”.*

*TRGS 504 “Tätigkeiten mit Exposition gegenüber A- und E-Staub”.*

*TRGS 505 “Blei”.*

*TRGS 509 “Lagerung von Gefahrstoffen in ortsfesten Behältern”.*

*TRGS 510 “Storage of hazardous substances in non-stationary containers”.*

*TRGS 528 “Welding work”.*

*TRGS 529 “Tätigkeiten bei der Herstellung von Biogas”.*

*TRGS 560 “Luftrückführung bei Tätigkeiten mit krebserzeugenden, erbgutverändernden und fruchtbarkeitsgefährdenden Stäuben”.*

*TRGS 600 “Substitution”.*

*TRGS 602 “Substitutes and restrictions on use - zinc chromates and strontium chromate as pigments for anticorrosive coatings”.*

*TRGS 900 “Occupational exposure limits”.*

*TRGS 905 “Verzeichnis krebserzeugender, keimzellmutagener oder reproduktionstoxischer Stoffe”.*

*TRGS 910 “Risk-related concept of measures for activities involving carcinogenic hazardous substances”.*

*IFA-Handbuch, Kennzahl 510210/1 “Maschinen zur Beseitigung gesundheitsgefährlicher Stäube - Positivliste”.*

*IFA-Arbeitsmappe, Kennzahl 0537 “Anwendung der Luftgrenzwerte bei Herstellung, Be- und Verarbeitung von metallischem Nickel und Nickellegierungen”.*

*S3-Leitlinie “Gesundheitsüberwachung bei Beryllium-Exposition und diagnostisches Vorgehen bei Beryllium assoziierter Erkrankung”.*

*LUBW Handlungsanleitung zur guten Arbeitspraxis “Kunststoffverwertung – Tätigkeiten mit Gefahrstoffen und biologischen Arbeitsstoffen bei der werkstofflichen Verwertung von Kunststoffen”.*

*Regierungspräsidium Kassel Handlungsanleitung zur guten Arbeitspraxis “Elektronikschrottrecycling – Tätigkeiten mit Gefahrstoffen bei der manuellen Zerlegung von Bildschirm- und anderen Elektrogeräten”.*