

Don't Give Chromium(VI) a Chance

Detecting | Mastering | Preventing

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The Overlooked Ingredient

How an inconspicuous metal oxide triggers a worldwide turning point in occupational and environmental protection

Summary of the expert analysis, US edition

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High temperature insulation materials contain alkaline oxides, above all calcium and sodium oxide. Neither is classified as carcinogenic, and neither appears in any assessment of chromium(VI). Above about 300 °C they react with the chromium oxide layer of chromium-alloyed hot parts to form calcium and sodium chromate. Carcinogenic compounds arise that nobody manufactured, ordered or installed.

Asbestos was never simply asbestos. In everyday speech it was distinguished by color; behind that stand chrysotile, amosite, crocidolite and three further minerals. For the protective regime this made little difference: the substance was bought in, its origin was known, and all types were handled in the same way.

With "chromium(VI)" the position is different. The collective term captures the hazard correctly, since the European classification treats chromium(VI) compounds as a group. But it hides the cause. Behind every solid finding stands a salt, and the prefix of that salt names the reaction partner: lead chromate, zinc chromate, strontium chromate, sodium chromate, calcium chromate. Whoever finds calcium chromate sees where the chromium(VI) compound came from. If only "chromium(VI)" is spoken of, the information about the process that caused it goes unused, the question of origin is not asked, and the calcium remains the overlooked ingredient (section 3).

A further difference from asbestos lies in the point at which the danger arises. The asbestos fiber was already a dangerous product in its as-delivered condition. The chromium(VI) compounds treated here (chromates) arise in situ, that is, during use. Such formation is often presented as a contamination or as an unavoidable consequence of operation. With calcium chromate, however, the reaction partner can be named. It is a constituent of a second product, the thermal insulation, which was selected and installed. A calcium-bearing insulation material, a calcium-bearing gasket or a calcium-bearing assembly paste can lead to the formation of calcium chromate on a chromium-alloyed hot part. An insulation material, a gasket or an assembly paste without alkali and alkaline earth metal oxides cannot form these compounds in situ, because the reaction partner is absent. The formation is therefore a property of the material pairing and not an unavoidable consequence of operation. The risk assessment has to cover this material pairing, and the substitution check under section 7 paragraph 3 of the German Hazardous Substances Ordinance and under sections 4.1 and 4.2 of the German TRGS 561 has to be carried out with an available substitute.

This summary gives the content of the full expert analysis and names, for every point, the section in which it is evidenced. It is the way into the full document and does not replace it.

1. The formation path

The reaction needs four conditions, and all four are met in an insulated hot installation in normal operation. First a chromium source: as a rule the passive chromium oxide layer of chromium-alloyed steel, that is, precisely the layer that makes the steel corrosion resistant. Second an alkaline oxide as reaction partner, mostly calcium oxide, alongside sodium, potassium and magnesium oxide. Third oxygen. Fourth raised temperature. Sodium chromate forms from about 200 °C, calcium chromate from about 300 to 350 °C (sections 9 and 12).

The reaction partner does not come from an additive that could be left out. It comes from calcium silicate, mineral and rock wool, E-glass fabric, AES wools, refractory masses, assembly pastes or combustion residues. Alkaline oxides are constitutive parts of the glass melt from which most high temperature fibers are drawn. They enter the formulation inevitably through recycled glass, limestone and dolomite, and there they serve a technical purpose: they lower the melting temperature and make the fiber drawable at all. Fewer alkaline oxides mean a higher melting temperature and therefore different plant technology. The subject is thus tied neither to a product nor to a manufacturer; it is tied to a class of materials. Fibers without any appreciable alkaline oxides have nevertheless existed for decades (section 13).

Decisive for understanding the whole process is the difference between the as-delivered condition and the condition in use. In the as-delivered condition no chromate is present. It arises in intended operation, at the interface between insulation and hot part, and it arises there continuously for as long as the conditions exist. It is released not during operation but during maintenance, removal, cleaning, overhaul and dismantling, and it is released as dust. The dust leaves the work area on tools, clothing, gloves and removed components. A safety data sheet describing the as-delivered condition is therefore formally correct and says nothing for the risk assessment of the maintenance operation.

The reaction is also not a one-off. It is cyclical. If a component is cleaned and the calcium-bearing insulation is fitted again, all four conditions are met once more after the next start-up. Every operating cycle produces new chromate. The 1,000 and 5,000 hour values from the interface study describe exactly this accumulation.

2. The body of evidence

The formation path has not been newly discovered; it has been described in patent form since 1939. Udy roasted chromium-bearing ferrochrome with lime in air and expressly claimed, in claims 22 to 26, mixtures of calcium chromite and calcium chromate as well as sodium chromate. There the reaction was not an unwanted side effect but the purpose of the process. Whoever disputes the chemical basis disputes a granted process patent whose entire purpose consists in this reaction (sections 7 and 8).

Four experimental works confirm the path at different levels and with different methods. Paoletti in 2002 at the Karlsruhe Research Centre detected CaCrO_4 by X-ray diffraction after one hour at 850 °C in air, but in an inert atmosphere only trivalent $\text{Ca}(\text{CrO}_2)_2$. Oxygen is thereby experimentally established as a necessary condition. Verbinnen et al. in 2013 reached 83 percent Cr(VI) leaching with NaOH after 60 minutes at 500 °C and 89 percent at 700 °C. Mao et al. in 2015 showed the direct reaction of Cr(III) with CaO between 500 and 900 °C (section 10).

The work closest to the application comes from Sayano et al. in the same year. What was examined was not a powder mixture in a furnace but the direct contact of chromium-bearing steels with commercially available insulation materials, that is, the geometry of the real installation. On calcium silicate insulation, X-ray diffraction identified CaCrO_4 , on sodium-bearing insulation Na_2CrO_4 . After 1,000 hours at 873 K, 160 mg Cr(VI) per square meter of contact area were measured, after 5,000 hours 940 mg/m². A barrier layer of Al_2O_3 only 3 to 4 µm thick stopped the chromium diffusion and prevented the formation almost completely. That barrier layer is the factual proof that the mechanism is understood: whoever can stop a reaction on purpose knows its path (section 10).

Toshiba described the same process as early as 2010 and 2011 in two patent applications, including the reaction equation, and proposed a ceramic separating layer and a nickel foil as prevention. The application-related problem was thus publicly available before the 2015 study, and in the form in which industrial companies document knowledge when they consider it commercially significant (section 11).

Alongside this there is a second path. Volatile chromium species from a hot source can deposit on cooler fibers. This gas phase transport does not replace the interface reaction; both can occur in the same installation, and both lead to chromate on the insulation (section 14).

3. What the industry knew and how it worded it

The earliest manufacturer warning does not date only from recent years. In April 1990 Babcock & Wilcox issued Plant Service Bulletin PSB-43 to owners and operators of boilers; the version PSB-43A of March 1994 expressly extended it to "plastics, insulation, and textiles". It states that chromium compounds can convert into hexavalent chromium during operation and that the dust created during removal carries it. The extension to insulation and textiles thus lies thirty-two years before the first official description in Germany (section 16).

Year	Source	Content
1939	US patent 2,176,687 (Udy)	Deliberate production of calcium and sodium chromate from a chromium source, lime or soda and oxygen
1990/1994	Babcock & Wilcox PSB-43 and PSB-43A	Conversion during operation, dust transport on removal, extension to insulation and textiles
2002	Paoletti, Karlsruhe Research Centre	CaCrO ₄ from Cr ₂ O ₃ and CaO between 500 and 850 °C, oxygen as a precondition
2010/2011	Toshiba, two patent applications	Interface of stainless steel and calcium-bearing insulation, approaches to prevention
2015	Sayano et al.	Direct detection of CaCrO ₄ and Na ₂ CrO ₄ at the interface
2019	Manufacturer correspondence	Calcium from the insulation named as the cause, all engine types affected
2019	Energy UK, industry bulletin	The three formation conditions named correctly, WD-40 recommended in the same document for picking up the residue
2020 to 2025	Service bulletins and technical instructions	Findings on engines, vehicles, turbines and insulation, in part naming calcium chromate
2024	Dissertation, Montana State University	Research at the request of the European manufacturers association ECFA, part-funded by its industry partners
2026	The German TRGS 561 and the BG ETEM	Alkali and alkaline earth oxides from insulation and assembly pastes as a factor

The conclusion drawn in 1990 was obvious and had no consequences: the product contained chromium, so chromium-bearing products were deselected. The formulations themselves remained unchanged. The safety data sheet for Ceraform 130 still states chromium(III) oxide at up to 3 percent in the version of 23 December 2020. The yellow powder continued to appear, and since the chromium seemed to have been removed from the insulation, the hot part remained as the explanation. What was not recognized was which compounds were involved. The alkaline reaction partner was never removed (section 16).

Between the manufacturer groups there is a striking difference in the manner of documentation. The refractory manufacturer HarbisonWalker names the conversion expressly in its safety data sheets: chromium(III) can convert into chromium(VI) during use. The sentence sits, however, in section 13, disposal, that is, in that part of the data sheet which the American rule OSHA 29 CFR 1910.1200 Appendix D designates as not mandatory. The same information has a different legal effect in section 2, hazards, than in section 13 (section 16).

With the fiber manufacturers such a statement is missing altogether. In the safety data sheets of the high temperature wools examined there is no calcium line, although calcium oxide is contained in the substance definition of aluminosilicate wool behind CAS number 142844-00-6 and is permitted there at up to 18 percent under EIGA document 207. Alkaline earth silicate wool is listed by the manufacturers under CAS number 436083-99-7; its substance definition gives calcium oxide and magnesium oxide at 18 to 43 percent. Whoever reads the data sheet does not learn that he is holding the reaction partner in his hand. Two presentations thus stand side by side: one that knows the conversion and writes it into the non-mandatory part, and one that does not declare the reaction partner (section 16).

4. The myths, one by one and with the counter-evidence

The subject is not primarily disputed; it is placed in the wrong category. In seven years of field work the same assumptions have been put forward again and again as grounds. Every one of them can be checked, and every one of them fails the check.

Assumption	Finding
"We do not use any chromium(VI), so it does not concern us."	The substance is not used, it is formed in the operator's own plant. The risk assessment attaches to the occurrence and not to the purchase.
"Chromium(VI) is chromic acid and dichromate, not this here."	Calcium and sodium chromate are chromium(VI) compounds and are classified as carcinogenic. In animal studies calcium chromate is the most potent of the chromates compared.
"The insulation material is chromium free, so it is harmless."	The chromium comes from the steel. Chromium free only means that the second ingredient is missing; the first is supplied by the installation itself.
"The safety data sheet declares nothing."	The data sheet describes the as-delivered condition. The compound arises only during use.
"Calcium oxide is harmless, it is not classified as carcinogenic."	Its harmonised classification is Skin Irrit. 2 (H315), Eye Dam. 1 (H318) and STOT SE 3 (H335); it carries no cancer category. That is precisely why it slips through every grid of a chromium(VI) assessment, although it is the reaction partner there.
"Asbestos free is safe."	The asbestos substitution removed the fiber, not the material system. The basic oxides remained in the formulation.
"There is nothing yellow to be seen."	The visible yellow deposit is the extreme case, not the detection threshold. Amounts relevant to exposure are invisible.
"The spot test was negative."	In a field study on diesel and marine engines the laboratory analysis detected 869 ng Cr(VI) at the turbocharger, while the colorimetric spot test at the same place came out negative.
"The laboratory found nothing."	Without a stated recovery on the same matrix that is not a statement about the content. In a round robin test the recovery was 0.2, 6.5 and 35.3 percent depending on the method.
"We wiped it down with WD-40."	Penetrating oil does not reduce chromium(VI). The chromate passes into the non-polar phase and is withdrawn from the measurement; measured recovery 5.8 percent.
"The mechanism has not been finally clarified."	What is open are the quantitative boundary conditions, not the existence of the reaction. Open kinetics is no reason to leave an established formation out of account.
"We have cleaned it, so the matter is settled."	Cleaning works for the individual operation. If the calcium-bearing insulation stays on the hot part, the chromate forms again at the next start-up.

5. How the warnings are worded

That warnings exist is not the point. The point is how they are built. They appear mostly in places and in wordings that do not put the recipient in a position to judge his own installation.

First the placement. At HarbisonWalker the conversion statement sits in section 13 and not in section 2. Under OSHA Appendix D, sections 12 to 15 are not mandatory. The information is present and at the same time sits where it has the least legal effect.

Second the omission of the reaction partner. The data sheets of the fiber products do not name the oxide constituents individually. Calcium oxide sits in the substance definition behind a CAS number that no user looks up. The ECHA registration dossier expressly names calcium, magnesium, sodium and potassium oxide for this substance group, but nobody installing an insulation mat looks there (sections 3 and 12).

Third the link to visible features. In service instructions, protective measures are tied to yellow deposits and to positive spot tests. Both features are unreliable, and both postpone the measure to the moment when the contamination is already high enough to be noticed.

Fourth the recommendation of an ineffective measure in the same document that describes the chemistry correctly. The industry bulletin of Energy UK from September 2019 names the three formation conditions correctly and recommends, a few pages later, binding and picking up chromium(VI) residue with WD-40. An independent laboratory report of September 2026 refutes any reducing effect: with complete extraction there was no dose-response relationship, the recovery was 96.8 percent in solution, and the apparent drop to 5.8 percent on the solid proved to be a solubility artefact. The recommendation therefore produces not less chromate but less measurement result (section 26).

Fifth the origin of the research. The 2024 dissertation at Montana State University was produced at the request of the European manufacturers association ECFIA and was part-funded by its industry partners. That does not devalue the work. It places it: the industry had the question investigated, so it knew the question.

Sixth the timing. The first official description in Germany is in the German TRGS 561 of 4 May 2026. The first manufacturer warning dates from April 1990. Between the two lie thirty-six years in which maintenance, removal, cleaning and reuse took place.

6. Why a negative result proves nothing

Determining chromium(VI) is species analysis. What is measured is not an element but an oxidation state, and that state can change in both directions during sample preparation. The American method EPA 3060A names both directions of error expressly and requires spiked samples with an acceptance range for recovery of 75 to 125 percent. That figure is part of the result, not additional information (section 17).

For thermal insulation materials no standardized method exists. That is not a formal defect but the core difficulty: the matrix is itself the reaction partner. It is rich in calcium, alkaline and, in the condition in use, laced with soot, oil and corrosion products, that is, with exactly those substances that reduce chromium(VI). Transferred methods therefore give under-findings down to near zero. The round robin test for the Dutch NEN 5617 shows the order of magnitude: in a matrix containing 16 percent zinc the recovery was 0.2, 6.5 and 35.3 percent depending on the method. The same material, three methods, results differing by more than two orders of magnitude.

An analytical result without a stated recovery on the same matrix is therefore not a statement about the content. The same applies all the more to spot tests. In a French field study on diesel and marine engines the laboratory analysis detected 869 ng Cr(VI) at the turbocharger, while the colorimetric spot test at the same place came out negative (section 19).

A second route leads to the same result. If a surface is treated with a penetrating oil before sampling, the chromate passes into the non-polar phase and is withdrawn from the measurement. For WD-40 a recovery of 5.8 percent was measured. Whoever treats a surface in this way and then has it measured obtains a negative result that describes the sample preparation and nothing else (section 17).

The same field study also shows that air measurement does not represent the dermal route. The hands of the employees were sampled as well: before removal the value lay below the limit of quantification of 40 ng, after removal at 45.4 ng, and the authors expressly record the contamination of the hands despite the disposable nitrile gloves worn. Half masks FFP3 and a type 5 working coverall were worn in addition. In the same run the air values remained low, and the urine values of the eleven mechanics examined averaged 0.26 µg per gram of creatinine and thus lay below the biological reference value of 0.54. The weak point here is not the glove but the sleeve end and the moment of taking the gloves off; in practice the transitions to the suit and to the footwear are therefore taped (section 31).

From this follows the position on proof. A positive result shows contamination. A negative result shows nothing as long as the recovery on the same matrix is not stated. This is not a strict reading but the consequence of the methodology, and it is the reason why the German TRGS 561 does not tie the protective measures to a measurement.

7. "Neutralisation" and the question of who may be assigned to it

In practice there is increasing talk of neutralization, decontamination or reduction, and such work is regularly assigned to the maintenance and cleaning staff already on site. This assignment is the weakest point of present practice, and for three reasons at once.

First, the term is factually indeterminate. Reduction of chromium(VI) to chromium(III) is chemically possible, but it presupposes a suitable reducing agent, a suitable pH range, sufficient contact time and proof of effectiveness. The conditions named in the certificate of the testing body do not appear in the work instructions, and proof of effectiveness for the insulation material matrix is missing from all the documents available. What is called neutralization in practice is mostly wiping, vacuuming or treatment with a product whose effect is not established. In the case of the penetrating oil the opposite is established.

Second, success cannot be checked by the staff. Whether a reduction has taken place can only be established analytically, and with the same matrix problem as above. An employee who has treated a surface has no way of establishing whether he has removed the danger or only changed its measurability. A measure whose effectiveness the person carrying it out cannot judge creates a feeling of safety without safety.

Third, and decisive in law, the ranking of measures is prescribed. The German Hazardous Substances Ordinance provides in section 7 paragraph 3 that for work with carcinogenic substances "vorrangig eine Substitution durchzuführen" is required, that is, substitution has to be carried out as a matter of priority. Paragraph 4 orders the further measures in a fixed sequence: design of processes and installations, technical protective measures, organizational measures, personal protective equipment last. A downstream treatment of the compound that has already formed is in this ranking neither substitution nor a technical protective measure; it is aftercare.

To this come two duties regularly overlooked in practice. Section 7 paragraph 7 requires that the function and the effectiveness of the technical protective measures be checked regularly, at least every third year. Paragraph 9 requires that, where no limit values exist, the effectiveness of the measures be checked by suitable methods. For the chromates formed in situ there is neither a standardized method for the matrix nor a substance-specific limit value for the compound. Whoever runs a neutralization as a protective measure must therefore be able to prove its effectiveness, and that is precisely what the present state of analysis for this matrix does not allow without considerable effort.

What practice looks like is shown by the documents available. The work instruction "Instructie voorkomen blootstelling aan Chroom(VI)" of Vattenfall Generation NL, first version 18 February 2019, last updated on 29 April 2024, describes the formation path correctly and provides a converter spray and a self-mixed ascorbic acid solution for the treatment. The check on success hangs entirely on the colorimetric spot test: if it comes out negative, then according to the wording no further measures and no protective equipment are required, tools and used full face masks go back to the store, and the misted insulation mattresses are put back into service. With that the reaction partner returns to the hot part together with the material (section 26).

The certificate which the testing body SEEF B.V. drew up in August 2025 for such a product is correct in its approach, because it claims no more than what was tested. It ties the effectiveness to the solubility of the compounds in the solution, names the aging of the product, requires a contact time of at least 15 minutes on a sufficiently cooled substrate and repetition if the test is positive, and it records for the check that a negative swab result is not reliable; the product is an aid within a safety strategy and not a solution that removes all risks on its own. On the supplier's pitch slide of 6 November 2025 four advertising points of this appear. The solubility condition, the aging, the repetition if the test is positive and the sentence on the unreliability of the negative result are missing there (section 26).

Three suppliers and one German statutory accident insurance institution make the same statement about the reaction product. The page of the German BG BAU speaks of uncritical chromium(III) compounds, the German language product page of Eco-Point of harmless chromium-3, the product page of MATinspired of non-toxic chromium-3. The same questions and answers from MATinspired expressly rule out complete removal and refer, for the check, to a test kit from the same supplier, which in the Vattenfall instruction is the release criterion. The selection of the protective measures is passed by the manufacturer to the user (sections 26 and 27).

The operating instruction of the same German statutory accident insurance institution under section 14 of the German Hazardous Substances Ordinance sets out a complete protective regime for the same activity: demarcation of the work area, low-dust procedures, extraction, dust extractors of dust class H, fresh air supply, separate changing and washing areas, continuous respiratory protection with P3 or FFP3, disposable protective suit type 5 and the ban on reusing removed mineral wool products. On the publicly accessible information page of the same accident insurance institution not one point of this catalogue appears; there only the chromate-reducing fiber binder appears, with the statement that it reduces the chromate to uncritical chromium(III) compounds and thereby lowers the exposure (section 26).

How an established reduction is organized is shown by cement. Entry 47 of Annex XVII of the REACH Regulation limits soluble chromium(VI) in cement to 2 ppm of the dry mass. This is achieved by a homogeneously mixed-in reducing agent in an eight to twentyfold excess, with a reaction that begins only with the mixing water, and tested in accordance with EN 196-10. What is carried over from this is the spraying of a solution onto an oily surface in the engine room, without dosage control, without a standardized test method and with a spot test as acceptance (section 26).

The same gap is shown by the comparison with asbestos. Both substances are carcinogenic, and with both the danger arises only when dust is released during maintenance or removal. For asbestos the German TRGS 519 requires notification of the work at least seven days before it begins, a responsible person with proven expertise, a supervisor and, for weakly bound products, containment with personnel and material locks. For the chromates formed in situ none of this exists. They are not perceived as a hazardous substance but as dirt, and are treated accordingly with rags, vacuum cleaners and spray products by the staff already on site. Nobody would spray and wipe an asbestos-bearing board by hand; with a chromate-loaded hot part that is the usual practice (section 25).

With skin contact the relationship is even reversed. The MAK and BAT value list 2026 of the German Research Foundation lists chromium(VI) compounds with the skin absorption marking "H" and the sensitization marking "Sh", together with carcinogenicity category 1; calcium and sodium chromate are not covered by the exceptions for barium, lead, strontium and zinc chromate. A substance that is absorbed through the skin and at the same time carcinogenic falls under table 2 of the German TRGS 401 into the high hazard grade for every type of contact, with no threshold for duration or area. For asbestos no such skin assessment exists, because its harmonised classification contains no skin-related hazard statement. Sodium chromate carries three of them (H312, H314, H317), and calcium and sodium chromate are in addition classified as very toxic to aquatic life with long lasting effects (H400, H410), which does not apply to asbestos (section 25).

The answer to the opening question is therefore not primarily a question of the qualification of the staff. It is a question of the measure: as long as the substitution check under section 7 paragraph 3 has not been carried out and as long as proof of effectiveness under paragraph 9 is missing, assigning a neutralization is not performance of the duties but their transfer to the person carrying out the work. Where the formation can be prevented by changing the material, that is the measure of the right rank. Where it cannot be prevented, the work has to be organized as work with a carcinogenic substance, with minimization of exposure, personal protective equipment, low-dust working, separate changing and washing areas and documentation, and not as a cleaning operation (sections 6, 18 and 26).

8. Rules and duties

Germany sets the benchmark. The German TRGS 561 in the version of 4 May 2026 deals expressly with the formation on chromium-alloyed hot parts. Section 3.3.4 describes the subject, section 5.9.3 names alkali and alkaline earth metal oxides from insulation materials or assembly pastes as a factor. The protective measures under 4.1 and 4.2, among them personal protective equipment, low-dust working and the substitution check, already apply where chromium(VI) exposure cannot be ruled out. No prior measurement is required. Given the state of the analysis, that is the only workable construction (sections 6 and 18).

Before work begins there are duties of their own, and they are for the most part framed without naming a specific substance. The German Hazardous Substances Ordinance requires in section 6 paragraphs 2a to 2c the examination of whether hazardous substances can be released from the installation during the activities, the involvement of external expertise where expertise is lacking and, if a technical investigation is necessary, its performance as a precondition of the activity. Section 7 paragraph 1 prohibits taking up the activity before the risk assessment and the protective measures, section 6 paragraph 8 sentence 1 requires the documentation before the activity is taken up. The year of construction entry under section 5a paragraph 2 is asbestos-related and has no significance for chromates formed in situ, because the compound arises only in operation (section 25).

In the Netherlands article 4.2 of the Arbeidsomstandighedenbesluit requires the assessment of the nature, degree and duration of the exposure, even where such activities are not currently carried out; the express ban on starting beforehand stands, asbestos-related, in article 4.54a. In the United Kingdom it stands, without naming a specific substance, in Regulation 6(1) of the COSHH Regulations 2002, under which an employer may not carry out work which can expose employees to a substance hazardous to health without a suitable and sufficient prior assessment. In the United States 29 CFR 1926.1126(d) obliges every covered employer to determine the eight hour shift average values for each exposed employee; the presumption rule for thermal insulation with a year of construction up to 1980 stands there in the asbestos standard. The German TRGS 561 ties the protective regime, in section 5.9.3 paragraph 5, to activities in which a chromium(VI) exposure is present or cannot be ruled out. The duty therefore arises before the finding (section 25).

Above this stands European Directive 2004/37/EC with a binding limit value of 0.005 mg/m³ since 17 January 2025. The Netherlands set 0.001 mg/m³ as chromium, the United Kingdom 0.01 mg/m³ under EH40 in its fourth edition 2020, but for carcinogens the COSHH Regulations at the same time require reduction to the lowest level reasonably practicable. The United States set, under OSHA 29 CFR 1910.1026, a PEL of 5 µg/m³ and an action level of 2.5 µg/m³ and prescribe protective clothing, changing and washing areas, in general industry also a ban on blowing down with compressed air. Within North America, Quebec sets 0.001 mg/m³ for water-insoluble and 0.005 mg/m³ for water-soluble chromium(VI) compounds, Ontario 0.01 and 0.05 mg/m³, British Columbia 0.01 and 0.025 mg/m³ (section 9). All these values refer to the chromium content and not to the compound. For Australia the limit value falls away from 1 December 2026 in favor of a duty to minimize (section 18).

In the United States procurement law is added. Since 2011 the clause DFARS 252.223-7008 has prohibited the delivery of items and construction products containing chromium(VI) above 0.1 percent by weight in a homogeneous material, and likewise the delivery of items for which chromium(VI) would have to be removed or reapplied in later sustainment phases. Under the definition the reference mass is the individual layer and not the component, and the exception applies only to by-products of manufacturing processes. The flow-down duty also covers subcontracts for maintenance and repair services (section 18).

That German rules are frequently cited in this account has two reasons. The work is carried out from Germany, and the German TRGS 561 describes the case of application expressly. This edition keeps those regulations as the benchmark and sets out the American, Californian and Canadian duties in sections 9 and 10. It does not thereby set stricter standards than European law; it spells out the approach of Directive 2004/37/EC for this case. For more than twenty years the Directive has required the nature, degree and duration of the exposure to be determined and the further routes of exposure, including absorption through the skin, to be taken into account, and it applies in all member states. With chromium(VI) compounds four levels of assessment stand side by side, inhalation, dermal, oral and environmental; asbestos carries neither a skin-related hazard statement nor a hazard to waters (section 31).

For the risk assessment it is irrelevant whether the chromate was used deliberately or arose in situ. What also matters is the broad concept of use in the REACH Regulation, which includes storing, keeping and treating. If contaminated insulation or a contaminated component is removed, stored and reused, this can be a use subject to authorisation. It is precisely at this point that a future EU-wide ban on use touches the whole of present maintenance practice. The ECHA restriction proposal of April 2025 would narrow this frame further (sections 2 and 25).

9. The duties in the United States

Section 5(a) of the Occupational Safety and Health Act of 1970 contains two duties: the employer “shall furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees”, and he “shall comply with occupational safety and health standards promulgated under this Act”. For chromium(VI) the second is the operative one, because a standard exists; the Field Operations Manual of the Occupational Safety and Health Administration states that the general duty clause is to be used “only where there is no standard that applies to the particular hazard”. What matters here is the term recognized hazard: the same manual names, among the means of establishing industry recognition, “Manufacturers’ warnings on equipment or in literature that are relevant to the hazard”. The documents evaluated in section 5 of this summary are warnings of precisely that class (section 33).

Hexavalent chromium was regulated by a single final rule of 28 February 2006, which created three standards: 29 CFR 1910.1026 for general industry, 29 CFR 1915.1026 for shipyard employment, marine terminals and longshoring, and 29 CFR 1926.1126 for construction. All three set a permissible exposure limit of 5 µg/m³ as an eight hour average and an action level of 2.5 µg/m³. That is the same figure as the European limit value of 0.005 mg/m³ and five times the French, Dutch and Quebec value for insoluble compounds of 0.001 mg/m³ (section 33).

The scope is not conditional on anyone having named the source. Paragraph (a)(1) applies the standard “to occupational exposures to chromium (VI) in all forms and compounds”, and the only material way out is paragraph (a)(4), where the employer holds objective data showing that a material or a process “cannot release dusts, fumes, or mists of chromium (VI) in concentrations at or above 0.5 µg/m³ as an 8-hour time-weighted average (TWA) under any expected conditions of use”. Chromate formed at the interface is chromium(VI) in a form and a compound. An employer who has never asked whether it forms on his insulated hot components is therefore not outside the standard; he is inside it without having determined his exposures (section 33).

Paragraph (d) requires the determination of the eight hour average for each exposed employee, either by personal breathing zone sampling or, under the performance-oriented option, “on the basis of any combination of air monitoring data, historical monitoring data, or objective data”. For the insulation material matrix there is no standardized method, and a result without a statement of the recovery rate says nothing about the content (section 6). Historical and objective data obtained that way carry the same defect, which is where the analytical problem becomes a compliance problem (sections 17 and 33).

Three provisions exist only in general industry. Paragraph (e)(1) requires a regulated area wherever exposure is or can reasonably be expected to be above the limit value; paragraph (j)(1) requires that all surfaces be maintained “as free as practicable of accumulations of chromium (VI)”; paragraph (j)(2)(iii) prohibits the use of compressed air to remove chromium(VI) unless it is used with a capture ventilation system or no other method is feasible. Neither the shipyard standard nor the construction standard contains a counterpart to either paragraph. For ship engines, for insulation work on board and for construction sites, zoning, housekeeping and the compressed air prohibition therefore do not apply, although the carry-over out of the working area is the same (section 33).

There is no duty to substitute. Paragraph (f)(1)(i) requires engineering and work practice controls before respiratory protection, and paragraph (f)(2) prohibits job rotation to achieve compliance. The word substitution occurs in none of the three standards. Section 7 paragraphs 3 and 4 of the German Hazardous Substances Ordinance, article 4 of Directive 2004/37/EC, article 4.17 of the Dutch Arbeidsomstandighedenbesluit, Regulation 7(2) of the British COSHH Regulations and section 5.57(1) of the Occupational Health and Safety Regulation of British Columbia all contain one. Under American federal rules the formation may therefore continue indefinitely and lawfully as long as the exposure is held below the limit value: the order of measures addresses the exposure, and the material cause is left untouched (section 33).

Hazard communication points the other way. Paragraph (d)(1) of 29 CFR 1910.1200 requires the manufacturer's hazard classification to include "Chemical reaction products associated with known or reasonably anticipated uses or applications". The formation of calcium and sodium chromate at the interface with a chromium-alloyed hot component is a reaction product of an anticipated use of a high-temperature insulation material. At the same time paragraph (g)(1) divides the duties: manufacturers and importers develop the safety data sheet for what they produce or import, and employers have one for each hazardous chemical which they use. A compound that comes into being at the customer's plant has no supplier and no sheet, while the classification duty that would reach it sits with the manufacturer of the material from which it forms. What the North American sheets of those manufacturers say is set out in section 10 (section 33).

Waste classification does not ask the question this analysis turns on. Under 40 CFR 261.24 a waste exhibits the toxicity characteristic if the extract obtained by the Toxicity Characteristic Leaching Procedure, Method 1311, reaches the value in Table 1; that table has a single chromium row, hazardous waste number D007 at 5.0 mg/L, and the words hexavalent and trivalent do not occur in the section. Removed insulation bearing chromate can pass or fail on leachable total chromium irrespective of which compound is present. The determination itself rests with the generator under 40 CFR 262.11 and may be made on process knowledge, including "knowledge of products, by-products, and intermediates produced by the manufacturing process" (section 33).

How much procedural depth American law gives a named substance is shown by the asbestos standard for construction. 29 CFR 1926.1101 presumes thermal system insulation and surfacing material in buildings constructed no later than 1980 to contain asbestos, grades the work into four classes of which Class III is "repair and maintenance operations", requires a trained competent person, and obliges building and facility owners, before the work begins, to determine the presence, location and quantity of the material. For chromium(VI) there is no presumption rule, no class system, no competent person and no duty of the plant owner. Two things the asbestos standard also lacks should be said: it requires no notification of an authority before the work and no license for the contracting undertaking as such (section 33).

10. California, Canada and the North American warnings

California applies four instruments side by side. Section 25249.6 of the Health and Safety Code, Proposition 65, provides that "No person in the course of doing business shall knowingly and intentionally expose any individual to a chemical known to the state to cause cancer or reproductive toxicity without first giving clear and reasonable warning to such individual". Hexavalent chromium compounds have been on the list as a carcinogen since 27 February 1987 and as a developmental and reproductive toxicant since 19 December 2008. The No Significant Risk Level is 0.001 micrograms per day by inhalation, the Maximum Allowable Dose Level 8.2 micrograms per day by the oral route (section 34).

Enforcement does not wait for an authority. The civil penalty is up to 2,500 US dollars per day for each violation, and an action may be brought “by a person in the public interest” once notice has been given and a certificate of merit accompanies it. The instrument does not ask where the compound came from, whether anyone placed it on the market or whether an air limit value was exceeded. It attaches to the exposure (section 34).

The Californian occupational standard, section 5206 of Title 8 of the California Code of Regulations, carries the same limit value and action level as the federal one and sits in the article on regulated carcinogens. It adds one duty that the federal standard does not have: a report of use. Under section 5203 “All employers who use a regulated carcinogen shall report that use in writing to the Chief”. That turns on the same question as the European concept of use, namely whether handling, storing and reinstalling a chromate-bearing component is a use of the substance (sections 25 and 34).

In drinking water California has had a maximum contaminant level for hexavalent chromium of 10 micrograms per liter since 1 October 2024, with compliance dates beginning on 1 October 2026 for the largest systems; before that the substance was covered by the total chromium limit of 50 micrograms per liter. A limit value of the same figure adopted in 2014 was invalidated by a court on 31 May 2017 on the ground that the economic feasibility of compliance had not been properly considered, the court making no finding on health protection. Ten micrograms per liter in water, next to 0.001 micrograms per day by inhalation and 5 micrograms per cubic meter in air, shows how far the regulatory quantities for one substance lie apart once the pathway changes (section 34).

In Canada occupational safety is provincial. Quebec sets the strictest values in North America, 0.001 mg/m³ for water-insoluble and 0.005 mg/m³ for water-soluble inorganic chromium(VI) compounds, both marked as human carcinogens and as substances whose exposure “shall be reduced to a minimum, even when it remains within the standards”. Ontario reaches 0.01 and 0.05 mg/m³ by reference to the table of the American Conference of Governmental Industrial Hygienists. British Columbia has the provision the American standards lack: where a substance carries the ACGIH A1 or A2 or the IARC 1, 2A or 2B notation, the employer “must replace it, if practicable, with a material which reduces the risk to workers”, and both chromium(VI) entries in its table carry A1 and 1. Canadian safety data sheets follow the Hazardous Products Regulations, whose Schedule 1 requires item 10 to state the “hazardous decomposition products” (section 35).

One manufacturer warns on the American market. Frenzelit publishes its TechInfo 28 in English as “Chromium(VI)-Formation at High Temperature”, version V2 of August 2025, listed in the download area of its United States region pages. It names the four conditions that must all be met, among them the “Presence of alkali or alkaline earth metal oxides (especially calcium oxide)” and “High temperatures (> 350 °C)”, gives calcium oxide-containing thermal insulation of hot components as an example, and adds: “Please note that Frenzelit insulation materials also contain calcium oxide in varying proportions.” (sections 5 and 36).

The other North American sheets do not mention it. The two Morgan sheets for Cerachrome, Z-Blok CR Grade and Ceraform 130 state “Hazardous decomposition products: None”, and the further North American sheets of the same manufacturer, the Alkegen sheets for Insulfrax and the Fiberfrax papers, the ROCKWOOL Safe Use Instruction Sheet of 14 April 2026 covering ProRox, the Promat sheets for PROMATECT H and Microtherm, the Johns Manville sheet for calcium silicate pipe, block and board insulation, the 3M Canadian sheet for the Interam mats and the CertainTeed sheet for mechanical glass wool name no chromium compound at all. In none of them does chromium, chromate or hexavalent chromium occur (section 36).

The interface itself is not absent from the North American literature. Johns Manville publishes technical bulletin IND-TB009 of 21 February 2020 on the stress corrosion cracking of austenitic stainless steel under insulation, which attributes the damage to chloride and offers an inhibitor, and in which chromium, chromate, calcium oxide and alkali do not appear. The association that organizes the same manufacturers in North America has published nothing on the subject, while the European association issued a position paper on chromium(VI) residues in mineral wool products in January 2024. Two North American documents do describe the formation: a report commissioned by a Californian air quality authority in September 2021 on hexavalent chromium from industrial heat treating furnaces, and the product service bulletin of an American boiler manufacturer of April 1990, extended to insulation materials and textiles in 1994 (sections 5 and 36).

The record in the United States is therefore long, and much of it is American: the patent of 1939, the bulletin of 1990, the interface evidence of 2015, the measurement of 2021, a Proposition 65 listing since 1987 and one of the best known environmental cases in the country. My question is why the formation of chromates on insulated chromium-alloyed hot components has not been taken up in a legal system that has worked through asbestos over five decades. The answer does not lie in the evidence and does not lie in the instruments. The industrially manufactured compound has a manufacturer, a supplier, a label and a safety data sheet. The compound that forms in situ is met as a deposit on a surface, has none of these, and therefore falls out of the category of hazardous substance and into the category of dirt. What has no product has no addressee, and what has no addressee is not taken up (sections 25 and 37).

11. Where it occurs

Affected are gas and diesel engines, locomotive and marine engines, gas and steam turbines, biogas plants, combined heat and power units, emergency power supplies in hospitals and public buildings, data centers with their own power generation, vehicles, construction machinery and exhaust after-treatment, and waste incineration plants (section 4). The bulletins of the German statutory accident insurance institutions, in particular BG BAU, BG ETEM and BG Verkehr, name these areas expressly.

With vehicles the finding concerns maintenance, handling, the reuse of components and the cost of a lasting remedy. Claims for defects under sales law and manufacturer duties under product safety law open up their own routes of examination in the EU (section 20).

The basis, alongside patents, studies and manufacturer documents, is my own site inspections and wipe and material samples since 2019 at engines, power plants, incineration plants, ships, vehicles and construction machinery. For none of the areas named can an absence of contamination be established after seven years of field work (section 28).

On the order of magnitude the expert analysis contains an extrapolation of the occasions and not of the findings. It rests on public manufacturer data, fleet statistics and plant registers: 190,000 engines of the 3500 series from Caterpillar in the field, more than 100,000 engines of the mtu series 2000 and 4000 sold, an active installed base of 44 GW at INNIO, more than 7,000 gas turbines at GE Vernova with a stated share of about half the worldwide base, around 7,300 coal fired power plant units, around 109,000 ships of 100 gross register tons and above, 6.16 million trucks over 3.5 tonnes in the European Union and 2,539 waste incineration plants in Europe, the United States, China and Japan (section 32).

With the maintenance and overhaul intervals applied, this gives about 58,000 to 61,000 events a year in the four industrial segments alone, together with around 6.9 million workshop visits for commercial vehicles and around 90 million car repairs in the European Union, whose relevant share is not quantified. What is to be assessed is therefore not an isolated process. The release takes place daily, in engine compartments, on vehicles, on turbines, in power plants and in incineration plants, in a number that cannot be quantified, and for the most part unnoticed (section 32).

12. Combustion ashes: the same process with no possibility of substitution

With thermal insulation the formation can be prevented by using an insulation material without alkali and alkaline earth metal oxides. With combustion ashes that is not possible. The reaction partner sits in the material being burned, and that material cannot be chosen. Calcium oxide is present in household waste at about 3 percent. The measure of the first rank therefore falls away, and what remains is the protective regime for work with a carcinogenic substance.

The evidence comes from waste incineration itself. In 2002 Paoletti investigated at the German Karlsruhe Research Centre the behavior of oxyanion-forming heavy metals in household waste incineration. Calcium chromate forms between 500 and 850 °C and is reduced again to trivalent chromium above 850 °C; the precondition is a sufficient oxygen partial pressure in the combustion chamber. The work expects corresponding reactions with sodium, potassium, magnesium, strontium and barium as well. Vehlow, Paoletti, Seifert and Sirini presented the results in 2004 at the WTER Fall Meeting at Columbia University (section 21).

What is critical is not full load operation but shutting down for maintenance. Ash residues remain on the grate and on chromium-alloyed hot parts, the temperature passes through the formation window from above, and opening the plant admits additional oxygen. These ashes are stirred up and released at the next overhaul. Further works support the connection: Hu et al. describe in 2013 and 2015 the oxidation of chromium during the thermal after-treatment of fly ashes and emphasise the availability of free calcium oxide, Gong et al. measure in 2017 an increasing chromium leaching after thermal treatment, and a Japanese work of 2006 on bottom ashes from two grate-fired plants shows the dependence on temperature and oxygen concentration (section 21).

The counter-test is provided by a wood ash process after Brill, cited in the 2019 report of the German Federal Environment Agency: there contact with oxygen is deliberately allowed only below 200 °C in order to prevent the formation of chromium(VI). Whoever stops a reaction by controlling the cooling atmosphere knows its conditions (section 21).

The European environmental literature names the substance too. The European BAT reference document on waste incineration of 2019 lists chromium(VI) in respect of leaching from grate ash. From the United Kingdom, Cr(VI)-positive deposits in boiler passes 2 to 6 and the exposure during maintenance and overhaul are described. What is missing are direct comparative measurements at waste incineration plants before and after shutdown. That gap concerns the order of magnitude, not the mechanism (section 22).

In both fields of application the chromate hazard is not understood, or it is not taken note of. In that they are alike. The starting position differs, since with the insulation material the cause can be chosen and with the ash it cannot. The formation path has stood in a manufacturer warning since 1990 and in the technical literature of waste incineration since 2002. That raises the question whether it was overlooked or whether it was not meant to be taken note of. What also has to be examined is whether the risk assessments cover overhaul, opening the boiler, removal of deposits, cleaning, handling of ash and carry-over. Total chromium measurement, leaching tests and personal dust measurement answer different questions here (section 22).

13. Health significance

Water-soluble chromates have the same structure as sulfate and phosphate ions and enter the cell through their transport routes. There chromium(VI) is reduced via reactive intermediates to chromium(III), which forms DNA adducts and cross-links. The reduction additionally produces oxidative stress. That chromium(VI) becomes chromium(III) in the body is therefore not a reason for reassurance; it is the mechanism of action (section 24).

The International Agency for Research on Cancer classifies chromium(VI) compounds as carcinogenic to humans, group 1, with established effect on the lung and observed links with cancer of the nose and the paranasal sinuses. The American occupational safety authority OSHA based its 2006 limit value above all on two cohorts from chromate production, Baltimore after Gibb et al. 2000 with 2,357 men from 1950 to 1992 and Painesville after Luippold et al. 2003 (section 24).

Not every chromate acts in the same way. In a comparative study on the rat lung, calcium chromate as positive control caused lung tumours in 25 of 100 animals, zinc chromate by contrast in 5 and 3 of 100 respectively. Calcium chromate, the main product of in situ formation, is thus among the most potent chromates in animal studies. An assessment that records only "chromium(VI)" hides this difference, and hides it in the unfavourable direction.

Skin contact has to be assessed in its own right. Contaminated components, insulation materials, tools and gloves remain a danger even when the air measurement is unremarkable. Calcium and sodium chromate are at the same time classified as very toxic to aquatic life with long lasting effects, which brings the process within environmental law as well.

14. Chromium(III): the assumed final state

All the treatment methods named rest on the same assumption: that with the conversion of chromium(VI) into chromium(III) the dangerous part of the process is at an end. The technical instruction of an engine manufacturer of 31 May 2023 sets this out in full. Chromium-3 occurs in many foodstuffs, the daily intake quantities in Europe lie in a range with no health risk to be expected, whether chromium-3 is an essential trace element for humans at all has not been conclusively clarified, and since the possible concentration after application of the reduction solution lies far below the applicable limit values, a health hazard from chromium-3 can be ruled out. Then follows, highlighted, the sentence that chromium-3, unlike chromium-6, is not carcinogenic. The question of essentiality is answered: in 2014 the European Food Safety Authority found no evidence for chromium(III) being essential (section 27).

The conversion is not a single step reaction to a defined end product. The MAK documentation on the chromium(VI) compounds describes the reduction as a course via chromium(V) and chromium(IV) to chromium(III), with radical oxygen and sulfur compounds arising. Which intermediate stage occurs depends on the reducing agent. On a plant surface there is in addition whatever lies there: oils, greases, insulation material residues and assembly pastes. Chromium(III) forms soluble complexes with organic acids and their oxidation products. Chromium(III) oxide, which is what the product statements mean, is formed thermally and not by spraying on and wiping off (section 27).

Which chromium(III) compounds are actually present after a treatment is stated in none of the documents available. The colorimetric rapid test indicates chromium(VI) or it does not, the laboratory methods determine chromium(VI) or total chromium. A species analysis of the chromium(III) compounds formed is provided for in no method and is required in none of the documents (section 27).

This matters, because the classification depends on this distinction. The MAK and BAT value list 2026 lists the chromium(III) compounds with the sensitization marking Sh and the addition that this does not apply to chromium(III) oxide and comparably sparingly soluble chromium(III) compounds. The marking therefore covers the soluble compounds, that is, precisely the group of substances that a wet treatment produces. For chromium(III) oxide a workplace limit value of 2 mg/m³ in the inhalable fraction applies in Germany; a harmonised classification under the European CLP Regulation does not exist for this substance. In its opinion of 28 July 2021 the French agency Anses considers a classification of chromium(III) oxide as a skin sensitizer of category 1 to be indicated, regards this as relevant for other chromium(III) compounds as well, recommends examining a classification as STOT RE 2 for the inhalation route together with the harmonised classification as Aquatic Acute 1 and Aquatic Chronic 1; it regards the criteria for germ cell mutagenicity as not met on overall assessment (section 27).

That chromium(III) is not a final state is documented in another field of application. The same MAK documentation states on chromium tanning that the tanning is indeed carried out with chromium(III) compounds, but that small quantities of chromium(VI) compounds can arise from these with unsuitable processing or storage methods, and that where the chromium(III) is formed in situ by reduction of chromium(VI) compounds, soluble chromium(VI) can likewise remain in the leather if the reduction is incomplete. Both statements concern the process dealt with here (section 27).

To this comes the return to the hot component. In the alloy the chromium is bound. After a reduction, chromium(III) compounds are present finely distributed and unbound on the surface and in the adhering material, that is, in the state that forms the starting material in chromate production. If the treated material is fitted again and the installation is brought up to temperature, all the conditions for formation are met once more. Since the complete conversion is not guaranteed and the release procedure is not dependable when the result is negative, the liquid arising has to be handled as hazardous substance waste and the work has to be carried out with no run-off (section 27).

The lower toxicity of the chromium(III) compounds compared with the chromium(VI) compounds is beyond question; they carry neither a category for carcinogenicity nor one for germ cell mutagenicity. The statements that the reaction product is uncritical, harmless or non-toxic go beyond that. They make a statement about substances that are not determined, and they presuppose a completeness of the conversion that no supplier guarantees (section 27).

15. Legal consequences of non-compliance

The German Hazardous Substances Ordinance provides in section 22 paragraph 1 that anyone who intentionally or negligently fails to document the risk assessment (number 1a), has an activity started contrary to section 7 paragraph 1 without a prior assessment and protective measures (number 3) or fails to check the effectiveness of the technical protective measures, or fails to check it in good time (number 5), commits an administrative offense within the meaning of section 26 paragraph 1 number 8 letter b of the German Chemicals Act. Under section 26 paragraph 3 of the German Chemicals Act the fine runs to up to 50,000 euros. Section 22 paragraph 2 of the Hazardous Substances Ordinance goes further: anyone who endangers the life or health of another by such an act is liable to punishment under section 27 paragraphs 2 to 4 of the German Chemicals Act, with imprisonment of up to five years where intentional and up to two years where negligent. What is punishable is the endangerment and not only the damage that has occurred (section 30).

To this comes recourse: under section 110 of the German Social Code Book VII, persons whose liability is limited under sections 104 to 107 are liable to the social insurance institutions for their expenditure where they have brought about the insured event "intentionally or through gross negligence". On the environmental side, section 326 paragraph 1 of the German Criminal Code covers the unauthorised handling of wastes which "are carcinogenic, toxic to reproduction or mutagenic for humans", with imprisonment of up to five years, and up to three years where negligent (section 30).

In the Netherlands, Article 4.17 of the Arbeidsomstandighedenbesluit requires the replacement of carcinogenic substances and processes as a matter of priority, as far as technically feasible. Non-compliance is an overtreding under Article 33 of the Arbeidsomstandighedenwet; under Article 34 paragraph 3 the bestuurlijke boete amounts at most to the sum of the fifth category under Article 23 paragraph 4 of the Dutch Criminal Code, since 1 January 2026 110,000 euros, increased by 100 or 200 percent in the case of repetition. Article 32 of the same Wet prohibits the employer from any act or omission contrary to the Act where, as he knows or must reasonably know, danger to life or serious damage to health arises from it or is to be expected. Through Article 1 number 1 of the Wet op de economische delicten this is an economic offense, and where intentional a misdrijf with imprisonment of up to six years (section 30).

In the United Kingdom, Regulation 7 of the Control of Substances Hazardous to Health Regulations 2002 requires the prevention of exposure, as a matter of priority through substitution, and for carcinogens in addition enclosure, cleaning, labeling and safe disposal. A breach is a criminal offense under Section 33(1)(c) of the Health and Safety at Work etc. Act 1974; Schedule 3A provides, on indictment, for imprisonment of up to two years and a fine with no statutory upper limit. In the United States the civil penalties under Section 17 of the Occupational Safety and Health Act are, for assessments after 15 January 2026, up to 16,550 US dollars per violation, up to 16,550 US dollars per day for failure to abate and up to 165,514 US dollars for willful or repeated violations; Section 17(e) additionally makes an intentional standard violation causing death a criminal offense (section 30).

In all four legal systems the sanction attaches to the duty left undone and not to the health injury that has occurred. Since the protective measures under the German TRGS 561 already apply where exposure cannot be ruled out, and since a negative result without a recovery shows nothing, what decides is the documentation: risk assessment, substitution check and proof of effectiveness. A missing or incorrect assessment of a chromium(VI) exposure is therefore not a marginal question of works organization.

16. What is established and what is open

Established are the formation path, the compounds involved, the temperature ranges and the state of knowledge among manufacturers and operators. What is unknown is the extent of the affected stock, because it has never been recorded under this question.

What is open are the quantitative boundary conditions: the exact temperature thresholds in the individual case, the influence of the chromium content of the alloy, the content of calcium or sodium oxide required, kinetics, moisture and number of cycles. These questions concern the extent of the reaction and not its existence. In statements, the mechanism not being conclusively clarified is occasionally cited in order to postpone further consequences. This distinction does not hold up against the body of evidence: the risk assessment starts from the possible occurrence and not from full knowledge of the kinetics (section 29).

17. The duties in Germany

Section 31 names the reasons why this analysis cites predominantly German rules. This section brings together the German provisions in force in one place and gives the source for every statement. In doing so it repeats points that stand in their own context elsewhere, so that a company in Germany does not have to assemble the duties from the whole of the analysis.

The term hazardous substance also covers what only arises later

The German Hazardous Substances Ordinance does not attach to the purchase. Section 2 paragraph 1 number 3 counts among the hazardous substances "substances, mixtures and articles from which substances within the meaning of number 1 or number 2 arise or are released during manufacture or use". Number 4 additionally covers substances and mixtures which, because of their properties and the manner in which they are present or used at the workplace, can endanger the health and the safety of the employees. A chromate that forms at the interface between insulation material and hot component is therefore covered, although nobody bought it and nobody wanted to manufacture it.

Substitution and the ranking of the measures

Section 7 paragraph 3 requires that, on the basis of the result of the substitution check, "substitution be carried out as a matter of priority", namely by substances, mixtures, articles or processes which, under the respective conditions of use, are not hazardous or are less hazardous. Section 7 paragraph 4 orders the further steps: the design of the processes and low emission forms of use according to the state of the art, after that collective technical measures at the source of the hazard and organizational measures, and only then individual measures including personal protective equipment. Section 7 paragraph 5 sentence 2 provides that the use of burdensome personal protective equipment may not be a permanent measure.

The value of 1 µg/m³ and what it does not achieve

For chromium(VI) compounds there is no workplace limit value in Germany. The German TRGS 910 carries in table 1 a tolerance concentration of 1 µg/m³ for the inhalable fraction with an excursion factor of 8 and the note "see TRGS 561"; an acceptance concentration is not laid down for this entry. The concentration relates to the element content of the metal and is defined as a shift average over eight hours.

Exposure register

Since the amendment of 2 December 2024 the exposure register has stood in a provision of its own. Section 10a paragraph 1 sentence 1 requires a register of the employees who carry out activities with carcinogenic, germ cell mutagenic or reproductive toxic hazardous substances of category 1A or 1B "for whom the risk assessment shows a hazard to their health", stating the activity and the level and the duration of the exposure. Under paragraph 2 it is to be kept, for carcinogenic or germ cell mutagenic hazardous substances, for 40 years after the end of the exposure; on termination of the employment relationship the employee receives an extract. Under paragraph 3 the employer may discharge these duties by transmitting the data to the competent accident insurance institution or its association.

Supervision and sanctions

Supervision is a task of the state. Section 21 paragraph 1 of the German Occupational Safety and Health Act (Arbeitsschutzgesetz, ArbSchG) assigns it to the competent authorities of the Länder; since the calendar year 2026, under section 21 paragraph 1a at least 5 percent of the establishments present in the Land are to be inspected each year, and this minimum inspection quota may not be departed from by Land law. Section 22 paragraph 2 confers the power to examine working procedures and to carry out measurements, section 22 paragraph 3 the power to issue orders and, where they are not carried out, to prohibit the work concerned.

The distance from the asbestos regime

For asbestos there is a procedure of its own in Germany. The German TRGS 519 requires in section 2.7 proof of expertise through successful participation in a course recognized by the authorities with an examination; the proof is valid for six years. The German Hazardous Substances Ordinance requires in section 11a paragraph 3 an official approval for activities in the area of high risk, since 20 December 2025 in section 11a paragraph 4a a permit for demolition work in the area of low and medium risk, and in section 11a paragraph 4 notification at the latest one week before the activities begin. Section 14.5 of the German TRGS 519 allows the protective measures to be lifted only where a visual check shows no visible residual contamination and a measurement gives a fiber concentration below 500 fibers per cubic meter.

What the German body of rules names

Germany is the only one of the legal systems considered here in which the case of application has a section of its own in the sub-statutory body of rules. The German TRGS 561 describes in section 5.9.3 that chromium(VI) compounds can form on thermally loaded chromium-alloyed industrial components, that these can be deposited in insulation materials or assembly pastes and that exposure can follow during dismantling and maintenance work. As influencing factors it names the steel temperature, the chromium content of the alloy, the reaction time, the presence of alkali and alkaline earth metal oxides from insulation materials or assembly pastes, and oxygen and air humidity close to the surface. On the mechanism it records that it is at present not yet clarified.

What follows from this for a company in Germany

From the provisions named there follows a set of documents that can be examined. These include the documented risk assessment, drawn up by a competent person, for the material pairing of chromium-alloyed hot component and basic insulation material, and the substitution check carried out and reasoned under section 7 paragraph 3. They include the information from the party commissioning the work under section 5a and the technical investigation under section 6 paragraph 2c. They include the operating instruction and the annual instruction under section 14. They include the entry in the exposure register or its reasoning under section 10a in conjunction with the German TRGS 410, the arranging of the mandatory occupational health care and the classification of the waste according to its content.

18. The duties in the European Union

The national bodies of rules of the Member States transpose Union law. This section brings together what Union law itself requires, and in doing so separates occupational safety and health law from chemicals law and from waste law. Implementation is a matter for the Member States; for a company the duties arise from the respective national law.

Scope of Directive 2004/37/EC

Under Article 3 paragraph 1 the Directive applies "to activities in which workers are or may be exposed to carcinogens, mutagens or reprotoxic substances as a result of their work". It thus attaches to the exposure during an activity. Article 2 letter a point i defines the carcinogen through the classification criteria of Annex I of Regulation (EC) No 1272/2008 and contains no restriction to substances that are bought, placed on the market or deliberately used. Calcium chromate and sodium chromate are classified in harmonised form as carcinogenic category 1B in Annex VI Part 3 of that Regulation.

Replacement, closed system, minimization

Article 4 paragraph 1 requires the employer to reduce the use, "in particular by replacing it, in so far as is technically possible, by substances, mixtures or processes which, in the conditions of their use, are not or are less dangerous". Article 5 paragraph 2 requires, for the case that substitution is not technically possible, manufacture and use in a closed system. Article 5 paragraph 3 requires, for the case that this too is not technically possible, that the exposure is "reduced to as low a level as is technically possible".

The binding limit value

Annex III Part A of Directive 2004/37/EC carries the entry "chromium(VI) compounds which are carcinogens within the meaning of Article 2 letter a point i (as chromium)" with a limit value of 0.005 mg/m³ as a time weighted average over eight hours. A short term value is not laid down, and the notes column is empty. The transitional column names 0.010 mg/m³ until 17 January 2025 and 0.025 mg/m³ until the same date for welding and plasma cutting work and similar fume generating processes.

Register, health surveillance and forty years

The list of exposed workers is set out in Article 12 letter c. Under it the employer keeps an up to date list of the workers employed in activities for which the assessment reveals a risk, "indicating the exposure to which they may have been subjected", in so far as this information is available. Article 15 paragraph 1 requires, for carcinogens and mutagens, that this list and the health record be kept for at least 40 years after the end of the exposure.

Chemicals law: classification, authorisation, restriction

The harmonised classification is set out in Annex VI Part 3 of Regulation (EC) No 1272/2008. Calcium chromate carries the Index number 024-008-00-9 and is classified as carcinogenic category 1B with H350. Sodium chromate carries the Index number 024-018-00-3 and is classified as carcinogenic, germ cell mutagenic and toxic for reproduction, in each case of category 1B. The collective entry 024-017-00-8 covers "chromium(VI) compounds, with the exception of barium chromate and of those specified elsewhere in this Annex" with H350i.

The distance from the Asbestos Directive

Directive 2009/148/EC lays down duties for asbestos that Directive 2004/37/EC does not contain for carcinogens generally. Article 11 requires, before demolition, maintenance or renovation work begins, all necessary steps to identify materials presumed to contain asbestos, by obtaining information from the owner and from relevant registers. Article 4 requires a notification to the competent authority before the work begins, stating among other things the number of workers involved and their training certificates. Article 13 requires a plan of work before the work begins and, after its completion, verification that there is no longer any hazard. Article 14 with Annex Ia lays down minimum requirements for the content, the duration and the frequency of the training, and Article 15 an authorisation of the undertaking.

What follows from this

For a company in a Member State the duty arises from the national transposing law. The test applied by Union law is at three points stricter than the question of a measurement. The assessment under Article 3 paragraph 2 is activity-related and is to be repeated on any change in the conditions. Absorption through the skin is expressly to be included under Article 3 paragraph 3. The reduction under Article 5 paragraph 3 is tied to no threshold; it applies as soon as a closed system is not technically possible. A Member State may provide for stricter provisions; the Directive lays down minimum requirements.

19. The duties in the Netherlands

The Netherlands is a Member State of the European Union and has transposed Directive 2004/37/EC into the Arbeidsomstandighedenbesluit. The case of application dealt with here is not named as such there either. This section brings together the Dutch provisions in force and gives the source for every statement.

The term substance is neutral as to origin

Article 1.1 paragraph 5 letter b of the Dutch Arbeidsomstandighedenbesluit defines hazardous substances as "stoffen of mengsels waaraan werknemers bij de arbeid worden of kunnen worden blootgesteld die vanwege de eigenschappen van of de omstandigheden waaronder die stoffen of mengsels voorkomen gevaar voor de veiligheid of gezondheid kunnen opleveren". The definition attaches to the exposure at work and to the circumstances in which they occur. Purchase, placing on the market and intended use do not appear in it.

The additional duties for carcinogenic substances

Under Article 4.12, section 2 of chapter 4 applies in addition as soon as workers are or may be exposed to carcinogenic, mutagenic or reprotoxic substances "of aan stoffen die vrijkomen bij kankerverwekkende of mutagene processen". The definition in Article 4.11 letter b attaches in point 1 to the classification criteria of Regulation (EC) No 1272/2008. Chromium(VI) compounds are thus covered.

The limit value of 0.001 mg/m³

The statutory limit value is set out in Bijlage XIII Part B2 of the Arbeidsomstandighedenregeling, the list of limit values laid down for carcinogenic substances according to the risk approach. The entry reads "Chroom (VI)-verbindingen (als Cr)" with 0.001 mg/m³ as a time weighted average over eight hours. A CAS number, a fifteen minute value and a skin notation are not entered. According to the explanatory note on Bijlage XIII, for substances which can occur as particles the value relates to the fraction sampled as inhalable dust.

Supervision, fine and economic offense

Under Article 27 of the Arbeidsomstandighedenwet the Nederlandse Arbeidsinspectie may issue an eis tot naleving, that is determine with binding effect the manner in which a provision is to be complied with, together with a time limit. Article 9.22 of the Arbeidsomstandighedenbesluit allows this instrument for the articles of chapter 4 relevant here. Under Article 28 a supervisory officer may order that certain work be stopped or may not be started where in his reasonable judgment it constitutes a serious danger to persons; the power includes the sealing of work equipment and workplaces.

Waste

The Regeling Europese afvalstoffenlijst declares the list in the Annex to Decision 2000/532/EC to be authoritative. For insulation material other than asbestos, 17 06 03* "overig isolatiemateriaal dat uit gevaarlijke stoffen bestaat of dergelijke stoffen bevat" comes into consideration, for furnace debris 16 11 03* and 16 11 05*, and for chromates as a substance 16 09 02*. Article 4 paragraph 1 assigns the waste to the entry marked with an asterisk where it is established that it has one of the properties of Annex III of the Waste Framework Directive. Paragraph 2 provides that the effects of evaporation, dilution, mixing or leaching are left out of account.

The distance from the asbestos regime

Section 5 of chapter 4 governs asbestos separately. Article 4.54a paragraph 1 requires the presence of asbestos to be fully inventoried before the demolition or dismantling of structures or objects in which asbestos may reasonably be expected to have been used is begun; under paragraph 4 the inventory and the report are reserved to a certified company. Article 4.54d paragraph 1 requires for the removal from risk class 2 upwards a company with a certificate, and paragraphs 5 and 7 the competence certificates of the persons deployed. Article 4.47c paragraph 1 requires notification to the supervisory authority at the latest two days before the work begins. Article 4.51a requires, before the hazard zone is lifted, a final assessment with a visual inspection and a measurement against the value of 10,000 fibers per cubic meter.

What follows from this for a company in the Netherlands

From the provisions named there follows a set of documents that can be examined. These include the written assessment under Article 4.2 paragraph 1 for the material pairing of chromium-alloyed hot component and basic insulation material, and the seven items under Article 4.13 including the reasoning why a substitution is not technically feasible. They include the limit value laid down by the employer under Article 4.16 paragraph 2, in so far as no statutory value applies. They include the list under Article 4.15 with its forty year retention, the annual instruction under Article 4.19 letter a and the description of the waste under Article 10.39 of the Wet milieubeheer.

20. The duties in the United Kingdom

This section brings together the British body of rules in one place, as the three preceding sections do for Germany, the European Union and the Netherlands. Since 1 January 2021 the United Kingdom has no longer been bound by Directive 2004/37/EC. The governing provision, the Control of Substances Hazardous to Health Regulations 2002, is older than that Directive and continues to apply unchanged.

The territorial scope is divided. The COSHH Regulations 2002 and the Control of Asbestos Regulations 2012 carry the note "E+W+S" and therefore apply in England, Wales and Scotland; Northern Ireland has provisions of its own, built up with the same content, in the Control of Substances Hazardous to Health Regulations (Northern Ireland) 2003 and the Control of Asbestos Regulations (Northern Ireland) 2012. In waste law the four parts of the country go their own ways, each with its own regulations for England, Wales, Scotland and Northern Ireland. Unless stated otherwise, the information in this section relates to England and Wales.

The term substance does not attach to the classification

Regulation 2(1) determines what a “substance hazardous to health” is. Letter a covers every substance which meets the criteria for classification in a health hazard class under the CLP Regulation, and does so expressly “whether or not the substance is classified under that Regulation”. Letter b covers substances with a workplace limit value approved by the British authority HSE, letter d dust of any kind above the concentration named there. A chromate that forms at the interface between insulation material and hot component meets the criteria of letters a and b, without there having to be a supplier, a safety data sheet or a formal classification.

Prevention, replacement and what is reasonably practicable

Regulation 7(1) requires the exposure to be prevented or, so far as that is not reasonably practicable, to be adequately controlled. Regulation 7(2) makes the priority of replacement clear; Regulation 7(3) orders the further stages from the design of the processes through control at source to personal protective equipment. Regulation 7(4) letter b expressly requires “the adoption of suitable maintenance procedures”, letter c the reduction of the number of exposed employees, of the level and the duration of the exposure and of the quantity present at the workplace to the minimum required for the work. Section 30 reproduces the wording of paragraphs 1, 2 and 5.

The limit value of 0.01 mg/m³ and the state of the HSE publications

EH40/2005 in its fourth edition 2020 carries in Table 1 the entry “Chromium (VI) compounds (as Cr)” with 0.01 mg/m³ as a time weighted average over eight hours and a value of 0.025 mg/m³ for process generated exposure, with the notes Carc, sen and BMGV. The footnote to this entry provides: “‘Process generated’ refers to exposures to Chromium (VI) Compounds generated as a result of a work process, such as fumes from welding.” The lowered value has applied since 17 January 2020; the introductory note of the edition lists chromium(VI) compounds among the substances with a lowered limit value.

The hazard statements trigger the duties

In British law the classification statements are the point of attachment. Regulation 2(1) determines the substance hazardous to health through the criteria of the CLP Regulation and defines that Regulation in the same provision as Regulation (EC) No 1272/2008, whose Articles 6 paragraph 5, 11 paragraph 3, 12, 14, 18 paragraph 3 letter b, 23, 25 to 29 and 35 paragraph 2 as well as Annexes I to VII “are to be read as amended from time to time”. Regulation 7(7) letter c then names individual hazard statements in their wording. Point i covers a substance with “the hazard statement H340, H350 or H350i” or a substance or process listed in Schedule 1, point ii a substance with “the hazard statement H334”.

Measurement, health surveillance and forty years

Regulation 10(1) makes the measurement dependent on a precondition. Measurement takes place where the risk assessment shows that the measurement is “requisite” in order to maintain adequate control or to protect the health of the employees. Regulation 10(2) allows it to be dispensed with where the employer can demonstrate by other means that the requirements of Regulation 7(1) are met. There is no duty to measure as such.

Supervision, criminal offense and duty to report

Supervision works with two types of notice. Under Section 21 an inspector may serve an improvement notice where a provision is being breached, with a time limit for remedying it. Under Section 22 he may serve a prohibition notice where an activity involves a risk of serious personal injury; the notice may take effect immediately and prohibits the activity until the defects have been remedied. British law contains no notification to the authority of work with carcinogens before it begins.

The distance from the asbestos regime

The Control of Asbestos Regulations 2012 show what a legal system prescribes for a recognized process risk. Regulation 5 requires, before demolition, maintenance and similar work, the determination of the presence, the type and the condition of the asbestos and provides for cases of doubt that its presence is to be assumed. Regulation 6 requires the recording of the significant findings irrespective of the size of the company. Regulation 7 requires a written plan of work with a prescribed minimum content.

What the British body of rules names

No British legal act names the formation of chromate on insulated chromium-alloyed hot components. The only chromium entry in the measurement intervals of the COSHH Regulations concerns electrolytic chromium plating, the only chromium entry in the health surveillance the manufacture of potassium and sodium chromate. Insulation, high temperature and hot components do not appear in the Regulations. The list of waste covers the matter only through the mirror entry for insulation material, without naming chromium.

What follows from this for a company in the United Kingdom

The duties begin before the work. Regulation 6(1) prohibits the start without a suitable and sufficient assessment, and Regulation 6(2) letter e names maintenance with the potential for a high level of exposure as a subject of assessment in its own right. An assessment that does not consider the formation pathway on insulated chromium-alloyed hot components, although the component materials and the operating temperatures are known, does not meet this requirement.

21. Appendix: insulation materials with basic oxides and where they are installed

The following commercially available insulation materials contain the basic oxides described, which can trigger thermochemical in-situ formation of the chromium(VI) compounds described. These are not assumptions, but conclusions drawn from manufacturer information, warning notices from users and my own field observations.

The evidence column names the origin of the information. H stands for information from a manufacturer or from a standard, W for a warning notice or a user report, F for my own field observation. Where a manufacturer publishes no figures, this is stated expressly in the table.

Insulation materials containing calcium, sodium and other basic oxides

Material and trade form	Documented content of basic oxides	Evidence
E-glass, yarn and fabric for printed circuit boards and aviation	CaO 16 to 25 %, MgO 0 to 5 %, Na ₂ O and K ₂ O 0 to 2 %	H

Material and trade form	Documented content of basic oxides	Evidence
Mineral wool, rock and glass wool: mat, wire mesh mat, board, pipe section	Na ₂ O, K ₂ O, CaO, MgO and BaO together more than 18 percent by weight; the value is part of the substance identity under Annex VI index 650-016-00-2 and not a batch property	H
AES wool, substance definition of the manufacturers	calcium oxide and magnesium oxide together 18 to 43 %, silicon dioxide 50 to 82 %	H
AES wool, blanket (Superwool Plus Blanket)	CaO 26 to 32 %, MgO 3 to 7 %	H
AES wool, blanket (Insulfrax LT)	CaO 27 to 33 %, MgO 2.5 to 6.5 %	H
Aluminum silicate wool and ceramic fiber (ASW, RCF): blanket, board, paper, module	Na ₂ O, K ₂ O, CaO, MgO and BaO together less than or equal to 18 percent by weight; dividing value in relation to index 650-016-00-2. The manufacturers' data sheets do not quantify alkali and alkaline earth oxides	H
Calcium silicate, board and molded part	CaO 38 to 43 %	H
Perlite, expanded: loose fill and molded part	Na ₂ O 3.7 %, K ₂ O 5.3 %, CaO 0.5 %, MgO 0.1 %. The analysis comes from a filter perlite; for pipe and tank insulation materials the manufacturers publish no oxide analysis	H
Vermiculite, expanded: loose fill and board	MgO 21.5 to 25.5 %, K ₂ O 3 to 6 %, CaO 2.0 to 6.0 %; the data sheet additionally lists Cr ₂ O ₃ at 0.01 to 0.15 %	H
Aerogel blanket	no calcium compound and no sodium compound declared; more than 50 % textile glass without chemical specification	H
Assembly paste for hot components, containing calcium	calcium hydroxide 10 to below 20 percent by mass	H

Applications using these insulation materials

Field of application	Insulated components, insulation material and trade form	Temperature	Evidence
Yachts and superyachts	Exhaust line, exhaust manifold, dry turbocharger and indicator valves; insulation mat with riveted-on sheet metal cladding, metallic insulation cladding of cassette design, removable textile insulation shells. Removable sections are expressly provided for maintenance	surface below 220 °C required; components in the engine compartment up to 750 °C	H
Container ships and merchant ships, two-stroke engine	Exhaust manifold and exhaust lines; insulation with a cover of galvanised sheet metal	not stated in the document	H

Field of application	Insulated components, insulation material and trade form	Temperature	Evidence
Container ships and merchant ships, four-stroke engine	Exhaust line from the turbocharger outlet via the exhaust gas boiler and the silencer to the funnel, plus the SCR unit; insulation pads on the turbocharger, continuous insulation from 30 mm thickness with cover sheet, SCR insulation designed to be demountable	turbine outlet 390 °C in normal operation, 450 °C in the design, 554 °C in emergency operation	H
Cruise ships	Auxiliary diesel engines, exhaust lines and exhaust gas cleaning; same engine series and same insulation design as in four-stroke operation in merchant shipping, removable mattresses on valves and fittings	as for the four-stroke engine	F
Locomotives and rail vehicles	Exhaust gas turbocharger, exhaust manifold, complete exhaust runs and exhaust gas aftertreatment; textile molded insulation part to the fire protection standard EN 45545, integral insulation with an outer shell of stainless steel foil or thin sheet, stitched insulation mats with alkaline earth silicate, E-glass or silica as insulation material and stainless steel foil or nickel-base foil on the hot side, expressly removable and reusable	molded part up to 650 °C; mat types up to 816 °C and up to 1,149 °C	H
Construction machines and mobile working machines	Turbocharger, manifold, exhaust system, particulate filter and SCR modules, underbody insulation and engine compartment heat protection; three-dimensional molded fiber parts with outer shells of stainless steel foil or thin sheet	components up to 750 °C, surface reduced to below 220 °C	H
Combined heat and power plants and cogeneration	Exhaust system and exhaust gas turbocharger of the gas engine; metallic insulation cladding as completely removable modules	exhaust gas 421 °C at full load, 476 °C at half load	H
Standby and emergency power installations, including in data centers	Exhaust line of the diesel generator set; calcium silicate or mineral wool pipe sections, laid in two layers, with jacket, banding and tie wire of stainless steel 304. For this case the manufacturer expressly recommends calcium silicate, because the organic binder of the mineral wool burns out from about 177 °C	371 °C to almost 538 °C	H
Gas and steam turbines	Exhaust duct, transition piece, turbine casing, heat recovery steam generator, silencer and stack; internal insulation behind liner sheets of 304 or 409 steel, flexible insulation pillows, fiber insulation mats and fiber modules in the heat recovery steam generator, insulation mattresses on the casing, removable and reusable	casing above 500 °C, exhaust duct above 480 °C, heat recovery steam generator up to 1,093 °C	H, W
Road vehicles, trucks and passenger cars	Heat shields, cast manifolds, exhaust system, particulate filter, SCR and mounting mats in the catalytic converter; heat shield of cassette design with cover sheet or foil of stainless steel or aluminum and an insulation insert inside, needled mat as mounting mat	heat shield up to 1,100 °C depending on the material; peak manifold temperature 1,000 °C	H

Field of application	Insulated components, insulation material and trade form	Temperature	Evidence
Industrial furnaces, boilers, waste incineration and biomass plants	Boiler walls, flue gas ducts and pipework; rock wool wire mesh mats with galvanised or stainless steel wire mesh	up to 640 °C, heavy version up to 649 °C	H
Chemical plants and refineries	Pipework on austenitic steels, valves and flanges; wire mesh mats, pipe sections and removable covers	up to 640 °C, pipe sections up to 650 °C	H

The complete tables, with the source given for each row, are in the appendix to the expert analysis.

22. Consequence

Where the formation can be prevented, it has to be prevented. That is not a recommendation but the ranking of section 7 paragraphs 3 and 4 of the German Hazardous Substances Ordinance. In France the same follows from Articles R. 4412-66 and R. 4412-67 of the Code du travail, in Switzerland from the state of the art under Article 82 paragraph 1 of the Federal Act on Accident Insurance and from the minimization requirement with substitution in first place. In high temperature insulation there are substitute materials available that exclude the formation path, because they contain no alkali and alkaline earth metal oxides. The substitution check can therefore not be carried out without a result.

Where it cannot be prevented, as in waste incineration, what remains is to acknowledge the process and to direct occupational and environmental protection accordingly: minimization of exposure, low-dust working, separate areas, documentation.

Cleaning and decontamination work for the individual operation. They do not remove the material cause: if the calcium-bearing insulation stays on the chromium-alloyed hot part, the chromate forms again at the next thermal load (section 26).

WD-40 does not reduce chromium(VI). Picking up residue with a cloth and penetrating oil removes material from the surface, and to that extent the impression gained in practice is understandable. The chromate thereby remains chemically unchanged and is afterwards present in the cleaning material and in the waste; at the same time it passes into the oil phase and is no longer captured by the measurement (section 26).

Wherever a chromium-alloyed hot part comes into contact with an alkaline oxide, the formation of chromates has to be reckoned with. The question whether this should not have been seen arises for every one of the areas treated here, and it has arisen since April 1990.

Version history

Version	Date	Change
1.0 US	October 2026	First edition of the United States edition of the summary. It follows the German benchmark edition in version 1.7. Section 9 on the duties in France and section 10 on the duties in Switzerland are replaced by section 9 on the duties in the United States and section 10 on California, Canada and the North American warnings; section 8 extended by the Canadian limit values; American spelling throughout.
1.1 US	October 2026	New appendix with two tables: commercially available insulation materials with their documented content of basic oxides, and the application fields in which they sit on chromium-alloyed hot components. The complete tables with their sources are in the expert analysis.
1.2 US	October 2026	Three new sections on the duties in Germany, in the European Union and in the Netherlands, condensed from the sections of the same name in the expert analysis. The complete sections with all their references are there.
1.3 US	October 2026	One new section on the duties in the United Kingdom, condensed from the section of the same name in the expert analysis. The complete section with all its references is there.
1.4 US	October 2026	The British limit is corrected to 0.01 mg/m ³ under EH40 in its fourth edition 2020. The condensed section on the United Kingdom takes in the new subsection on the hazard statements. The complete section with all its references is in the expert analysis.