

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

Overview of the expert analysis, US edition

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1. The facts

High temperature insulation contains basic oxides, above all calcium oxide 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 components to form calcium chromate and sodium chromate; sodium chromate already from about 200 °C. The reaction needs a chromium source, a basic oxide, oxygen and temperature. All four conditions are present in an insulated hot plant during normal operation. In the delivered state no chromate is present; it forms at the interface between insulation and component and forms again after every start up. It is released during maintenance, removal, cleaning, overhaul and dismantling, as dust that leaves the work area on tools, clothing, gloves and removed components.

2. What is documented

The formation pathway has been described in patent form since 1939. United States patent 2,176,687 expressly claims the production of calcium chromate and sodium chromate from a chromium source, lime or soda and oxygen. It is confirmed experimentally at the metal to insulation interface: in 2015 CaCrO_4 was identified on calcium silicate insulation and Na_2CrO_4 on sodium bearing insulation, with 160 mg Cr(VI) per square meter of contact area after 1,000 hours and 940 mg/m² after 5,000 hours. A barrier layer 3 to 4 µm thick prevented formation almost completely. The earliest manufacturer warning dates from April 1990 and was expressly extended to insulation and textiles in 1994. Operator and service documents from the years 2019 to 2025 describe the same process, with the temperature window and the calcium source. Added to this are our own site inspections and wipe and material samples taken since 2019 on engines, power plants, incineration plants, ships, vehicles and construction machinery.

Part of that record is American. The product service bulletin of April 1990 and its 1994 edition come from an American boiler manufacturer and are addressed to American operators. A Californian air quality authority had hexavalent chromium emissions from industrial heat treating furnaces measured in a report of September 2021, which records the highest formation rates for fixtures of 304 and 310 stainless steel and states that the speciation depends on the availability of oxygen and of other alkali earth metals. One insulation manufacturer warns on the American market: Frenzelit publishes its technical information sheet 28, "Chromium(VI)-Formation at High Temperature", in English in the download area of its United States region pages, version V2 of August 2025, naming the four conditions that must all be met and adding that its own insulation materials also contain calcium oxide in varying proportions. The North American safety data sheets of the other suppliers state no chromium compound under hazardous decomposition products, and the association that organizes those manufacturers in North America has published nothing on the subject.

3. Why it is overlooked

The collective term Chromium(VI) states the hazard correctly and conceals the cause. Behind every solid finding there is a salt, and the prefix of that salt names the reaction partner. Anyone who finds calcium chromate sees where the compound came from; where only Chromium(VI) is mentioned, that information stays unused.

The design of the documents adds to this. The safety data sheet describes the delivered state and carries no meaning for the assessment of a maintenance operation. In the data sheets of the fiber products calcium does not appear as a line of its own, although it is contained in the substance definition behind the CAS number. The third cause lies in the analysis. For thermal insulation there is no standardized method, the matrix is itself the reaction partner, and methods transferred from other matrices give results that are too low, down to almost zero. A negative result without a stated recovery rate for the same matrix says nothing about the content.

4. Incineration residues

With thermal insulation the formation can be prevented through the choice of material. With incineration residues that option does not exist, because the reaction partner is in the feed material and the feed material cannot be chosen. Calcium oxide is present in household waste at about 3 percent. Calcium chromate forms between 500 and 850 °C where the oxygen partial pressure is sufficient, and above 850 °C it is reduced again.

The critical phase is therefore not full load operation but shutting down for maintenance. Ash residues remain on the grate and on chromium alloyed hot components, the temperature passes through the formation window from above, and opening the plant admits additional oxygen. During the internal overhaul scaffolding is erected and grate components are walked on, surface treated, removed and replaced. Where the plant uses direct desulfurization, calcium bearing sorbent is also injected into the furnace at about 900 °C or into the boiler passes at about 350 °C. For this field only the protective regime remains.

5. The duties in the United States, with the German benchmark

German regulation is the reference in this analysis because it describes the case treated here expressly. The German TRGS 561 covers it under 5.9.3 and applies the protective regime as soon as a Chromium(VI) burden cannot be excluded. The German Hazardous Substances Ordinance requires in Section 6 paragraphs 2a to 2c the examination of whether hazardous substances can be released from the plant during the work, the use of external expertise where the employer lacks the knowledge and, where a technical investigation is needed, that investigation as a precondition for the work. Section 7 paragraph 1 prohibits starting the work before the risk assessment and the protective measures are in place. European law sets the frame for every member state and, for anyone exporting into it, for the product as well: Directive 2004/37/EC has required for more than twenty years that the nature, degree and duration of exposure be determined and that absorption through the skin be taken into account, and since 17 January 2025 a binding limit value of 0.005 mg/m³ applies.

In the United States 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, the same figure as the European limit value, with an action level of 2.5 µg/m³. The scope is not conditional on anyone having named the source: the standard applies to occupational exposures to chromium (VI) in all forms and compounds, and the only material way out is objective data showing that a material or a process cannot release chromium(VI) at or above 0.5 µg/m³ as an eight hour average under any expected conditions of use. Paragraph (d) requires the eight hour average to be determined for each exposed employee, by personal sampling or on the basis of air monitoring, historical or objective data. Regulated areas, the duty to keep surfaces free of accumulations and the prohibition on blowing down with compressed air exist only in general industry; the shipyard and construction standards contain no counterpart to either paragraph.

There is no duty to substitute. The standards require engineering and work practice controls before respiratory protection and prohibit job rotation to achieve compliance, and the word substitution occurs in none of the three. Section 7 paragraphs 3 and 4 of the German Hazardous Substances Ordinance, Article 4 of Directive 2004/37/EC, Regulation 7(2) of the British COSHH Regulations and Section 5.57(I) 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.

Two further instruments bear on the case. The Hazard Communication Standard requires the manufacturer's hazard classification to include the chemical reaction products associated with known or reasonably anticipated uses, while the duty to develop a safety data sheet attaches to what a manufacturer produces or imports; a compound that comes into being at the customer's plant therefore has no supplier and no sheet, and the classification duty that would reach it sits with the manufacturer of the material from which it forms. In waste law the toxicity characteristic under 40 CFR 261.24 has a single chromium row, hazardous waste number D007 at 5.0 mg/L in the leaching procedure extract, and the section distinguishes no oxidation state; the question of valence on which the occupational hazard turns is not asked. The determination rests with the generator and may be made on process knowledge.

How much procedural depth American law gives a named substance is shown by the asbestos standard for construction. It 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 covers repair and maintenance operations, requires a trained competent person, and obliges building and facility owners to determine the presence, location and quantity of the material before the work begins. For chromium(VI) there is no presumption rule, no class system, no competent person and no duty of the plant owner.

California applies four instruments side by side. Hexavalent chromium compounds have been on the Proposition 65 list as a carcinogen since 27 February 1987 and as a developmental and reproductive toxicant since 19 December 2008; Section 25249.6 of the Health and Safety Code forbids knowingly and intentionally exposing an individual without a clear and reasonable warning, the No Significant Risk Level is 0.001 micrograms per day by inhalation, the penalty is up to 2,500 US dollars per day for each violation, and an action may be brought by any person in the public interest. The Californian occupational standard carries the federal limit value and adds a report of use in writing to the Chief, which the federal standard does not have. In drinking water a maximum contaminant level of 10 micrograms per liter has applied since 1 October 2024, with compliance dates beginning on 1 October 2026 for the largest systems.

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 is to be reduced to a minimum even where it stays within the value. Ontario reaches 0.01 and 0.05 mg/m³ by reference to the table of the American Conference of Governmental Industrial Hygienists. British Columbia requires the employer to replace a substance carrying the ACGIH A1 or A2 or the IARC 1, 2A or 2B notation, if practicable, with a material that reduces the risk to workers, and both chromium(VI) entries in its table carry A1 and 1.

The other systems treated in the full analysis point the same way. In the United Kingdom Regulation 6(1) of the COSHH Regulations 2002 prohibits work liable to expose employees to a substance hazardous to health without a suitable and sufficient prior assessment, with a limit value of 0.01 mg/m³ under EH40 in its fourth edition 2020 and a duty to reduce carcinogens to the lowest level reasonably practicable. France sets 0.001 mg/m³, has compliance verified at least once a year by an accredited body, stops the work where the value is exceeded, and requires a pre-work asbestos investigation in six domains, among them rolling stock, ships, aircraft and industrial installations. The Netherlands set 0.001 mg/m³ expressed as chromium. None of these systems recognizes a threshold below which the protective regime would cease to apply, and in all of them the sanction attaches to the duty that was not performed rather than to the harm that occurred. Australia shows the direction of travel: from 1 December 2026 Safe Work Australia no longer issues workplace exposure limits for non threshold genotoxic carcinogens, Chromium(VI) compounds included.

6. Limits of subsequent treatment

The reduction of Chromium(VI) to Chromium(III) is chemically possible and requires a suitable reducing agent, a suitable pH range, sufficient contact time and proof of effectiveness. The work instructions available do not state the conditions that the certificate of the testing laboratory expressly names, and proof of effectiveness for the insulation matrix does not exist. Verification of success rests on the colorimetric spot test, whose negative result the same testing body declares in writing to be unreliable; a field study found 869 ng Cr(VI) at the turbocharger while the spot test at the same point gave a negative result.

Penetrating oil does not reduce Chromium(VI); the chromate passes into the oil phase and is withdrawn from the measurement. Chromium(III) is moreover not an end state. The soluble Chromium(III) compounds carry the sensitization marking Sh in the German MAK and BAT list 2026, which compounds are actually present after a treatment is determined nowhere, and with the reinstalled material the reaction partner returns to the hot component.

7. Order of magnitude

The expert analysis contains a projection of the occasions, not of the findings. Public manufacturer statements, fleet statistics and plant registers give, among others, 190,000 engines of a single series in the field, more than 100,000 engines sold from two further series, an active installed base of 44 GW at one gas engine manufacturer, more than 7,000 gas turbines from one manufacturer with a stated share of about half of the global base, around 7,300 coal fired units, around 109,000 ships, 6.16 million trucks above 3.5 tonnes in the European Union and 2,539 waste incineration plants in Europe, the United States, China and Japan.

With the maintenance and overhaul intervals applied here, this gives about 58,000 to 61,000 occasions per year in the industrial segments alone, plus millions of workshop visits whose relevant share is not quantified. What stands for assessment is therefore not an isolated event.

8. 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.

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.

9. 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.

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.

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.

10. 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 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.

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.

11. 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.

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.

12. 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.

Material and trade form	Documented content of basic oxides
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 %
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
AES wool, substance definition of the manufacturers	calcium oxide and magnesium oxide together 18 to 43 %, silicon dioxide 50 to 82 %
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
Calcium silicate, board and molded part	CaO 38 to 43 %
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
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 %
Assembly paste for hot components, containing calcium	calcium hydroxide 10 to below 20 percent by mass

Field of application	Temperature
Yachts and superyachts	surface below 220 °C required; components in the engine compartment up to 750 °C
Container ships and merchant ships, two-stroke engine	not stated in the document
Container ships and merchant ships, four-stroke engine	turbine outlet 390 °C in normal operation, 450 °C in the design, 554 °C in emergency operation
Cruise ships	as for the four-stroke engine
Locomotives and rail vehicles	molded part up to 650 °C; mat types up to 816 °C and up to 1,149 °C
Construction machines and mobile working machines	components up to 750 °C, surface reduced to below 220 °C

Field of application	Temperature
Combined heat and power plants and cogeneration	exhaust gas 421 °C at full load, 476 °C at half load
Standby and emergency power installations, including in data centers	371 °C to almost 538 °C
Gas and steam turbines	casing above 500 °C, exhaust duct above 480 °C, heat recovery steam generator up to 1,093 °C
Road vehicles, trucks and passenger cars	heat shield up to 1,100 °C depending on the material; peak manifold temperature 1,000 °C
Industrial furnaces, boilers, waste incineration and biomass plants	up to 640 °C, heavy version up to 649 °C
Chemical plants and refineries	up to 640 °C, pipe sections up to 650 °C

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

13. What is to be done

Where the formation can be prevented, it is to be prevented. Outside the United States that follows from an express duty: Section 7 paragraphs 3 and 4 of the German Hazardous Substances Ordinance, Article 4 of Directive 2004/37/EC, Articles R. 4412-66 and R. 4412-67 of the French Code du travail, Article 4.17 of the Dutch Arbeidsomstandighedenbesluit, the state of the art under Article 82 paragraph 1 of the Swiss Federal Act on Accident Insurance, and Section 5.57(1) of the Occupational Health and Safety Regulation of British Columbia. American federal rules contain no such duty. What remains there is the requirement to use engineering and work practice controls to reduce exposure to the lowest levels achievable, the duty under Section 5(a)(1) of the Occupational Safety and Health Act to furnish a place of employment free from recognized hazards, and the fact that substitute materials without alkali and alkaline earth metal oxides are available, so that the examination can be carried out with a result.

Where the formation cannot be prevented, the work is to be organized as work with a carcinogenic substance, with investigation before work begins, a documented risk assessment, low dust working, extraction, zoning, separate changing and washing facilities, personal protective equipment and controlled disposal.

Cleaning and decontamination work for the single operation and do not remove the material cause. Where the calcium bearing insulation stays on the chromium alloyed hot component, the chromate forms again at the next thermal load.

Version 1.4, October 2026, United States edition. The British limit is corrected to 0.01 mg/m³ under EH40 in its fourth edition 2020, and the section on the duties in the United Kingdom takes in the hazard statements. This overview reflects the state of the expert analysis and the summary in the United States edition, version 1.4, which follows the German benchmark edition in version 1.10. The evidence, the references and the list of sources are given there.