Influence of calcium chromate and other chromates on health: inhalation and skin contact, also taking into account the release of chromium (VI) compounds, through service work with contact with contaminated high-temperature insulation

1. Introduction

This study investigates the health risks arising from inhalation and skin contact with chromates, in particular calcium chromate ($CaCrO_4$). The focus is on the potential hazards posed by the use of high-temperature insulation containing alkaline and/or alkaline earth metals.
These risks can occur especially during maintenance operations, but it is also possible for chromates to be released during regular operation by engines and turbines equipped with insulation containing calcium or sodium in particular. The aim of this study is to identify the toxicological mechanisms and recommend preventive measures to minimize exposure.

The focus should be on preventing the hazard instead of relying on the mere damage limitation of personal protective equipment (PPE), which is always wrongly regarded as the first supposedly sufficient protective measure, but does not comply with the minimization requirement of EU Regulation 2004/37/EC and thus the German Hazardous Substances Ordinance (GefStoffV).

Date:

2024-09-05

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Case group:

Fibers and dusts

Authors:

Florian Sommer
Markus Sommer

2. Chemical properties of chromates

2.1 Calcium Chromate ($CaCrO_4$)

Chemical structure and properties: Calcium chromate is a moderately water-soluble, yellowish powder that decomposes at high temperatures, releasing reactive Cr(VI) compounds. It is widely used as an anti-corrosion agent and in pigments.

Classification according to CLP Regulation: Calcium chromate is classified as **H350** (can cause cancer) and **H410** (very toxic to aquatic organisms with long-term effects). This makes it clear that this substance is extremely dangerous to both human health and the environment.

2.2 Comparison with other chromates:

Sodium Chromate (Na_2CrO_4):
This compound is more water-soluble than calcium chromate and is used in the chemical industry and in the production of paints and pigments. Due to its high solubility and reactivity, it is particularly dangerous, as it can easily enter the body and cause damage there.

Classification according to CLP Regulation:
In addition to the H350 **and** H410 **classifications, sodium chromate also carries** the **H360FD** classification (can affect fertility, can harm the child in the womb). Due to this classification, it must be checked whether the workplace may be released for women when sodium chromate is released.

3. Health effects of inhalation of chromates

3.1 Lung cancer and DNA damage

3.1.1 Double-strand breaks and DNA damage

mechanism:
When chromium (VI) compounds enter the body, especially through inhalation, they are reduced in the cells. This reduction process, which leads from chromium (VI) to chromium (III), produces highly reactive intermediates, including reactive oxygen species (ROS) and unstable chromium(IV) and chromium(V) intermediates. These highly reactive molecules can penetrate directly into DNA and cause severe damage there.

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Double strand breaks:
One of the most serious forms of DNA damage that can be caused by these reactions is double-strand breaks . These are breaks in which both strands of DNA are cut at the same time. Such damage is extremely difficult to repair and can lead to cell death or, if repaired incorrectly, cancer. Double-strand breaks are considered particularly dangerous because they make the genome unstable and drastically increase the likelihood of mutations.

Consequences:
The development of double-strand breaks can lead to uncontrolled cell growth, which is the basic mechanism for the development of cancer. In the case of chromium (VI) exposure, this often leads to lung cancer, one of the most common and deadly cancers in workers exposed to these substances.

3.1.2 Reduction process in the body

Reduction of chromium (VI) to chromium (III):
In the body, chromium (VI) is reduced by various cellular mechanisms after its absorption. This produces chromium (III), which is less reactive, but during the reduction process aggressive intermediates are produced that can cause significant damage to cell structures, especially DNA.

Oxidative stress:
The reduction of chromium (VI) leads to the formation of reactive oxygen species (ROS). These free radicals cause oxidative stress in the cells, which attacks proteins and lipids in addition to DNA. Oxidative stress leads to a cascade of cell damage that can ultimately lead to apoptosis (programmed cell death) or, worse, the transformation of cells into a cancer-causing form.

Dangers for the repair mechanisms:
During DNA damage caused by these aggressive intermediates, the cell's own repair mechanisms are often overwhelmed or work incorrectly. Faulty repair processes can lead to chromosomal aberrations, in which parts of chromosomes are incorrectly assembled or lost, further increasing the risk of cancer.

Attack on the genetic material:
It is important to understand that this damage is not limited to the lung cells. Chromium (VI) compounds can travel through the bloodstream to other organs and cause similar damage there. Organs such as the kidneys and liver are particularly at risk, but the central nervous system can also be affected.

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3.1.3 Long-term consequences and risks

Cancers:
The mechanisms described make it clear why chromium (VI) compounds are so highly carcinogenic. What is particularly insidious is that the damage often does not break out until years after exposure, which makes early diagnosis and prevention difficult.

Irreversible damages:
Once DNA damage has occurred, especially double-strand breaks, it is often not possible to completely repair it. Even if the cell survives, this can lead to mutations that contribute to the development of cancer in the long term.

Increased risk even with small amounts:
It is important to emphasize that even small amounts of chromium (VI) are capable of causing such serious damage. Since there is no safe threshold for exposure, any possible source of chromium (VI) compounds must be taken seriously and eliminated as completely as possible.

3.2 Chronic obstructive pulmonary disease (COPD)

Mechanism:
Long-term exposure to chromates can cause chronic inflammation of the airways, leading to COPD. The inflammation and damage to the airways lead to a progressive narrowing of the airways, which makes breathing increasingly difficult.

Symptoms:
Symptoms include shortness of breath, chronic cough and impaired lung function. These symptoms worsen over time and can significantly affect the quality of life.

3.3 Asthma and bronchitis

Mechanism:
Chromates can cause irritation of the respiratory tract, leading to asthma and chronic bronchitis. The inflammatory reactions in the bronchi lead to a narrowing of the airways, which triggers asthma attacks and chronic inflammation (bronchitis).

Symptoms:
Typical symptoms include coughing, shortness of breath and wheezing sounds. These conditions can become chronic and are often difficult to treat, especially if exposure to chromates persists.

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3.4 Allergic reactions and sensitization

Mechanism:
Chromates can lead to immunological reactions and sensitization, leading to severe allergic reactions. Repeated contact can lead to sensitization, which means that even small amounts of chromates can trigger an allergic reaction.

Symptoms:
Respiratory diseases, skin reactions, and systemic allergic reactions are common symptoms. These can worsen over time and lead to serious health problems.

3.5 Kidney failure and kidney disease

Mechanism:
Chromates can enter the bloodstream through the lungs and damage the kidneys. The toxic effect of chromium (VI) can lead to acute or chronic kidney damage, which manifests itself in kidney failure or chronic kidney disease. –

Follow:
Kidney failure, chronic kidney disease and the need for dialysis can be the result. These conditions are often irreversible and require lifelong medical care.

3.6 Liver diseases

Mechanism:
Chromates have a hepatotoxic effect and can damage liver cells. The liver, as the central detoxification organ, can be significantly damaged by the ingestion of chromium (VI), leading to liver dysfunction. –

Follow:
Liver damage, cirrhosis or even liver cancer can result. These conditions are difficult to treat and have long-term effects on health.

3.7 Damage to the immune system

Mechanism:
Chromates can weaken the immune system by causing oxidative damage and disrupting the production of immune cells. Chronic exposure can weaken the body's immune defenses in the long term, leading to increased susceptibility to infections and other diseases.

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Symptoms:
Frequent infections and an increased susceptibility to cancer are possible consequences. A weakened immune system can slow the healing of injuries and diseases and increase the risk of serious health complications.

3.8 Cardiovascular diseases

Mechanism:
Chromates can cause systemic inflammatory reactions that increase the risk of cardiovascular disease. The inflammation caused by chromium (VI) can damage blood vessels and contribute to the development of cardiovascular disease.

Follow:
High blood pressure, cardiac arrhythmias and heart failure can occur. These conditions are often chronic and can increase the risk of heart attacks and strokes.

3.9 Neurological disorders

Mechanism:
Chronic exposure to chromates can have neurotoxic effects leading to neurological disorders. The neurotoxic effects of chromium (VI) can damage the central nervous system, leading to a variety of neurological problems.

Symptoms:
Memory problems, concentration disorders and headaches are possible symptoms. In the long term, these neurological disorders can lead to a significant impairment of quality of life.

4. Prevention and minimization of risks

4.1 Minimization Requirement and S-T-O-P Principle

Protection through prevention:
It is crucial that minimizing exposure to chromates is a priority. Instead of relying on PPE, substitution and technical measures should be prioritized. The goal should be to eliminate the hazard as much as possible before resorting to personal protective equipment.

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Independence from AGW:
The minimisation requirement applies regardless of whether the occupational exposure limit value (OEL) is complied with. There is no safe threshold for carcinogenic substances, so all measures must be taken to reduce exposure as much as possible. The focus should be on preventing dangers instead of merely mitigating them.

CMR substances and skin absorption:
Chromates, especially the compounds discussed in this study, such as calcium chromate and sodium chromate, are **skin-resorptive.** This means that they can enter the body through the skin. Therefore, there is a permanent risk of skin contact, even in the vicinity of the chromate-producing sources, as exposures can be widely distributed.

4.2 Exposure-risk relationship (ERB)

ERB for Chromium (VI):
TRGS 910 specifies an exposure-risk ratio of **1 µg/m³** for chromium (VI) compounds , where the risk is estimated at 4 additional cancer cases per 1,000 exposed persons.

No threshold:

There is no set threshold for chromium (VI) compounds, i.e. no exposure density that could be described as safe and tolerable. The minimisation requirement requires a constant reduction in exposure; if the acceptance value is exceeded (0.0001 mg/m³), immediate safety measures must be initiated (medium risk, TRGS 910).

5. Protective measures and legal regulations

5.1 Legal basis and minimization requirement

EU Regulation 2004/37/EC and Hazardous Substances Ordinance:
These regulations establish a strict principle of minimization that applies regardless of compliance with limit values. Companies are obliged to reduce exposure to carcinogenic substances as much as possible, even if the measured values are below the accepted risk relationship.

Prefer substitution:
Wherever possible, chromates should be replaced with less hazardous substances to minimize the risk at the source. Technical measures, such as closed systems or extractions, should be implemented before personal protective measures are considered.

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5.2 Implementation of the S-T-O-P principle

Technical and organizational measures:
Technical and organisational protective measures should be taken before PPE is introduced to minimise exposure. This includes the use of safe technologies, improved workflows and training of employees to ensure the safe handling of hazardous substances.

PPE as a last option:
Personal protective equipment should only be used when all other measures have been exhausted. The use of PPE should always be understood as a final barrier, not as a primary protective measure.

6. Conclusions and recommendations

Prevention instead of panic:

This study aims to provide sound information that helps to prioritize preventive measures and minimize exposure to chromates through effective substitution and technical measures. The point is not to spread panic, but to emphasize the need for effective prevention strategies. –

Focus on minimization:

It is crucial that the minimisation requirement is taken seriously and that employers proactively take steps to reduce exposure, rather than relying on compliance with limit values or the use of PPE. The protection of workers' health must be achieved through a combination of substitution, technical and organisational measures.

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