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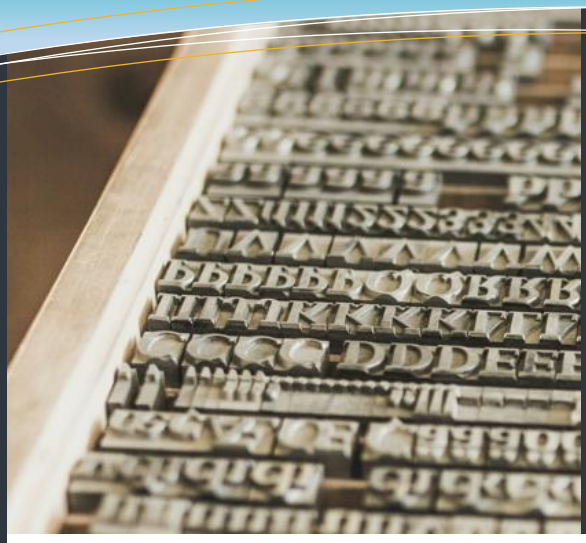
GERMAN SOCIETY OF
TOXICOLOGY

Poison of the month



...The proposal to select lead as the "Toxin of the Month" originated from the Working Group on Inhalation Toxicology

…because the inhalation of airborne lead particles remains a major yet often underestimated health risk. Few other metals illustrate so vividly how persistent air pollutants can exert complex systemic effects even at low concentrations.

Tetraethyllead – The Poison in Petrol

Celebrated in the 1920s as a "technological innovation," tetraethyllead made engines run more smoothly and the air highly toxic. Production soon claimed its first victims: workers in U.S. factories suffered from hallucinations, convulsions, and severe neurological symptoms. Combustion residues entered the atmosphere through exhaust emissions, where fine lead particles dispersed worldwide. For decades, road traffic was the dominant source of inhalation exposure to lead. The phase-out of leaded gasoline began only in the 1980s and 1990s; it was fully banned in Europe by 2000 and in many developing countries only by 2021.

Since then, average blood lead levels in the population have dropped by more than 90 %. However, urban soils and household dust still contain up to 100 mg of lead per kilogram of soil, concentrations that fall within the precautionary range set for children's play areas under current environmental standards.

Lead – An Ancient Heavy Metal with a Lasting Impact

Lead (*Plumbum*, Pb) is one of the oldest and also one of the most hazardous metals used by humankind. Its malleability, corrosion resistance, and chemical stability made it a versatile material for millennia, used in water pipes, paints, glazes, ammunition, and later in batteries and gasoline.

The routes of exposure are well characterized. In the general population, oral intake predominates, primarily through contaminated household dust, food, or drinking water. Inhalation exposure is most relevant in occupational settings or during renovation activities, such as in metal processing, battery recycling, welding, or the removal of old lead-based paints. Aerosols from lead salts or oxides, which may also arise from exhaust emissions, consist of fine, respirable particles with a high pulmonary deposition rate and systemic bioavailability. After deposition, lead readily passes through the alveolar–capillary barrier into the bloodstream. Organic lead compounds such as tetraethyllead are volatile and lipophilic and can be absorbed both by inhalation and through the skin. This dermal uptake complicates toxicological assessment and is one reason why establishing definitive maximum workplace concentration limits (MAK values) remains challenging. Therefore, the BAT value (biological tolerance value for occupational substances) is preferable to the MAK value (maximum workplace concentration), as it reflects the actual total body burden.

In blood, about 95% of lead is bound to erythrocytes and distributed to the liver, kidneys, brain, and bone, where it accumulates with a biological half-life of up to 30 years.

The toxic mechanisms of lead are multifaceted. It interferes with the function of divalent and trivalent cations, especially calcium, thereby disrupting signal transduction, muscle contraction, and hormone secretion. In the hematopoietic system, lead inhibits key enzymes of heme

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Lead in Art and Restoration

In the 19th century, lead poisoning was a common occupational disease. Painters, plumbers, and glaze workers regularly inhaled lead dust. Typical symptoms included lead colic and, in chronic cases, “painters’ bones,” bone densifications caused by lead deposition.

Lead remains a concern in occupational health, particularly in art conservation and heritage restoration. The metal was long indispensable in stained glass, organ pipes, and ceramic glazes. During soldering or polishing, fine aerosols form that are easily inhaled in poorly ventilated church interiors. The Technical Rule for Hazardous Substances – Lead (TRGS 505), issued by the Federal Institute for Occupational Safety and Health (BAuA), mandates strict protection, from local exhaust systems to regular blood monitoring.
Some historic organs may only be played or restored once indoor air lead levels fall below the permissible limit.

Across Europe, new Workplace Exposure Limits (WELs) are under discussion. The International Lead Association (ILA) proposes a voluntary target of 20 µg Pb/100 mL blood by 2025. The European Commission’s draft directive sets a Biological Limit Value of 15 µg Pb/100 mL blood and a WEL of 0.03 mg/m³ air. Given high body burdens among long-term exposed workers, experts urge realistic transition periods and continued biomonitoring.

synthesis, notably δ-aminolevulinic acid dehydratase and ferrochelatase, leading to anemia and the accumulation of neurotoxic intermediates. In neuronal cells, lead impairs cellular energy metabolism and the transport of Na^+, K^+, and Ca^{2+} ions across membranes. This disrupts neurotransmitter release and synaptic transmission, further aggravated by mitochondrial dysfunction and oxidative stress resulting in DNA damage and lipid peroxidation.

Acute lead poisoning is now rare but can occur after massive inhalation exposure, causing abdominal colic, vomiting, paralysis, and, in extreme cases, coma or cardiovascular failure. Chronic exposure manifests as fatigue, pallor (“lead pallor”), loss of appetite, anemia, and muscle weakness.

Children are particularly vulnerable: they absorb lead up to four times more efficiently than adults, while their blood–brain barrier is still developing. In the central nervous system, lead can irreversibly disrupt dopaminergic and glutamatergic signaling and impair neuronal plasticity. Even blood lead levels below 5 µg Pb per 100 mL of blood have been shown to cause cognitive deficits, attention disorders, and behavioral abnormalities. The World Health Organization therefore emphasizes that there is no safe threshold for lead exposure.

For the general population, exposure is usually low but may rise considerably near recycling facilities or shooting ranges, primarily due to legacy contamination. A major challenge remains the persistence of lead in the environment: once deposited in dust, soil, or paint, it can be re-mobilized decades after use has ceased.

From an ecotoxicological perspective, lead is a multifaceted pollutant. It accumulates in soils, sediments, and aquatic habitats, harming microorganisms, plants, and vertebrates. Birds of prey and scavengers ingest it via game animals whose tissues are contaminated with lead ammunition, leading to fatalities in species such as sea and golden eagles. Consequently, there are ongoing Europe-wide initiatives to ban lead-based hunting ammunition and to further reduce environmental lead emissions overall.

By Ute Haßmann

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