Lead exposure: to reappraise action levels or not?

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INTRODUCTION

Inorganic lead is a cumulative toxic metal found ubiquitously in the environment and was one of the first metals to be used in industry. Hence, occupational diseases associated with lead exposure were the first to be described.[1] Workers are exposed to lead during production, use, maintenance, recycling and disposal of lead material and products. Exposure is encountered in various industrial sectors such as construction, manufacturing, wholesale trade, transportation and remediation, and even through hobbies.[1-3]

MEDICAL SURVEILLANCE

A medical surveillance programme for lead must include taking a detailed medical and occupational/environmental history. The following is important to establish: (a) exposure to lead in current and previous jobs, (b) personal protection equipment and engineering controls used, (c) biological and air monitoring data, (d) hygiene practices,[1] and (e) exposure through hobbies and other non-occupational sources. Smoking in the workplace has been established to result in higher lead exposure due to contamination by unwashed hands and settling of airborne lead dust or fumes on cigarettes.[4,5]

Medical and reproductive histories are essential in identifying individuals at increased risk of adverse health effects from lead exposure. Susceptibility to symptoms from adverse effects of lead exposure demonstrates significant inter-individual variability. There are several factors that influence the risk of lead toxicity in adults, including pre-existing diseases affecting relevant target organs (e.g. hypertension, renal disease), nutritional deficiencies that modify the absorption or distribution of lead (e.g. low dietary calcium or iron deficiency and zinc deficiency), advanced age, and genetic susceptibility (the presence of polymorphism on the Vitamin D receptor B allele result in higher blood lead [this is additionally seen with the ALAD2 allele] and tibia lead levels).[1,5,6]

Physical examination should establish the presence of target organ damage or dysfunction, as well as gingival lead lines, and wrist or foot drop. Long-term lead exposure can cause encephalopathy, peripheral neuropathy, cognitive delays, anaemia, and digestive and renal problems.[3,4]

ABSORPTION OF LEAD

In the workplace, inorganic lead is absorbed predominantly via inhalation and/or ingestion of lead-contaminated water and food. The absorbed fraction is dependent on particle size (there is an inverse relationship, i.e. the smaller the particle size the better the absorption) and solubility.[3,6] Dermal absorption is generally < 1%.[7] Absorbed lead not excreted through the kidneys, bile or faeces is distributed among three compartments, namely, blood, soft tissue (liver, kidneys, lungs, brain, spleen, muscles and heart), and mineralising tissues such as the bone and teeth (95% of the total body lead). Ninety-nine percent of blood lead is associated with red blood cells and the remaining 1% is in the plasma; the latter is the fraction that can distribute to the different compartments. The half-life of lead in blood is approximately 28 days.[7,8]

Interestingly, bone lead is distributed between cortical (inert with a half-life of 10-30 years)[6] and trabecular bone (labile component with a half-life of 90 days), and concentrates primarily at sites of the most calcification when exposure occurs.[8] Absorbed lead is capable of mobilising quickly in and out of soft tissue. The half- life in soft tissue is approximately 40 days[6]. Bone-to-blood lead mobilisation increases with advanced age, fractures, chronic disease, hyperthyroidism, periods of immobilisation (being bedridden, etc.), renal disease, lactation and pregnancy, menopause, physiologic stress, and calcium deficiency.[8]

Once a significant amount of lead is accumulated in the body, the hazardous health effects are likely to be irreversible. Lead body burden increases continuously with additional exposure after blood lead levels plateau.

BIOMARKERS OF LEAD EXPOSURE

Internal dose indicators such as blood and urinary lead values can be used to quantify the amount of lead in the body. These are routinely used to estimate occupational exposure because they are closely correlated with lead toxicity.[9] The relationship between blood lead levels and plasma is curvilinear i.e. as blood lead levels increase, the plasma levels increase proportionally.[8] A limitation, however, is that blood lead levels reflect only recent or current exposure to lead and not the true accumulated body burden of lead.

Blood lead levels are a better reflection of internal dose than urinary lead levels.[9] Urinary lead estimation is considered to reflect lead that has diffused from the plasma compartment and excreted through the kidneys. Although favoured as a non-invasive collection, spot urine samples are unreliable and require correction for creatinine excretion due to the large biological variations.[6] It is further suggested that a single blood lead estimate cannot differentiate between low-level chronic lead exposure and high-level short lead exposure; thus, serial blood lead measurements are recommended.[6]

Because internal lead mobilises between bone, blood, and soft tissue, the interpretation of blood lead levels cannot accurately assess lead exposure.[6] The amount of lead excreted, and the timing of excretion, are dependent on a number of factors (as stated above) and, hence, significant changes in individual blood lead levels may take several months, or sometimes years, even after complete removal from the exposure source(s). The normally inert pool poses a special risk because it is a potential endogenous source of lead that can maintain blood lead levels long after exposure has ended.[7] Toxic blood lead levels can reflect a combination of both current lead exposure and an endogenous source of accumulated lead exposures.[8]

MEDICAL MANAGEMENT

In 2007, Kosnet et al. published *Recommendations for Medical Management of Adult Lead Exposure*, which included a summary of the adverse health risks associated with different blood lead concentrations, and corresponding medical management (Table 1).[10] The article notes that recent research has increased concern about the toxicity of lead at

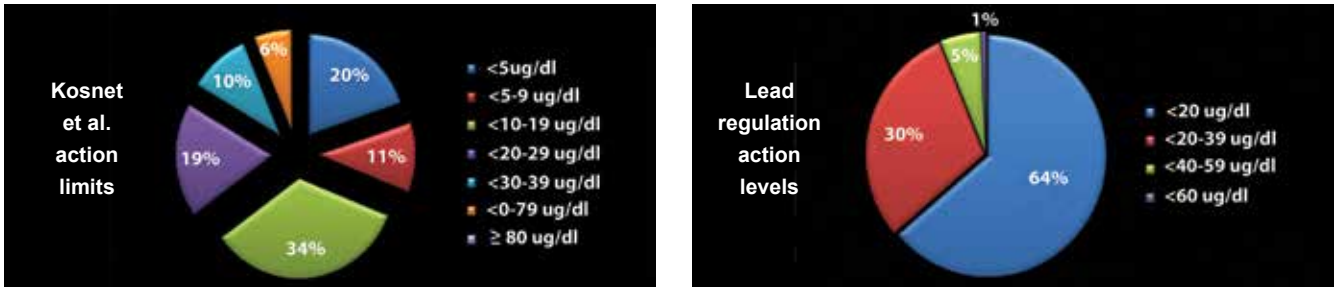

Figure 1. Blood lead levels for male workers at different action levels (2013-2017)

low blood levels and supports a reappraisal of the levels of lead exposure that may be safely tolerated. The recommendation to remove individuals from exposure if a single blood lead result exceeds 30 ug/dl is consistent with the American Conference of Governmental Industrial Hygienists (ACGIH). However, the South African Lead Regulations, GNR.236 of 28 February 2002,[11] recommend removal at 60 ug/dl for men and women not capable of procreation, and 40 ug/dl for women of reproductive age.

To illustrate the impact of the different cut-off levels for medical management, we analysed the Ampath data from 2013-2017 for male blood lead results. We grouped the results based on the action levels recommended from Kosnet et al.[10] and the Lead Regulations[12] (Figure 1).

If the recommendations from Kosnet et al. are adhered to, medical management is required for 80% of male workers with results above 5 ug/dl, and 16% should be removed from the workplace (results >30 ug/dl). However, using the South African Lead Regulations as reference, medical management is required for only 36% of workers (those with results above 20 ug/dl) and only 1% need to be removed from the workplace (>60 ug/dl).

CONCLUSION

Lead concentration in whole blood is the primary biomarker used to monitor exposure to inorganic lead. Recent research has increased concern about lead toxicity at low doses, with an increase in the number of studies showing confirmed hypertension and kidney dysfunction in adults at blood lead concentrations <20 ug/dl.[10] With new research at hand, the reappraisal of the levels of lead exposure that may be safely tolerated should be considered.

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Table 1. Adverse health risks associated with different blood lead levels (BLLs), and corresponding medical management

Blood lead level (ug/dl)	Short-term risks (exposure <1 year)	Long-term risks (exposure ≥1 year)	Recommended medical management
<5	None documented	None documented	None indicated
5-9	• Possible spontaneous abortion • Possible postnatal development delay	• Possible spontaneous abortion • Possible postnatal development delay • Possible hypertension and kidney dysfunction	• Discuss health risks • **Reduce exposure** for women of reproductive age
10-19	• Possible spontaneous abortion • Possible postnatal development delay	• Possible spontaneous abortion • Possible postnatal development delay • **Hypertension and kidney dysfunction** • **Reduced birth weight** • Possible subclinical neurocognitive deficits	As above for BLL 5-9 ug/dl plus: • **Decrease exposure** • **Increase biological monitoring** • **Consider removal** from exposure to avoid long-term risks if exposure control over an extended period does not decrease Pb levels <10 ug/dl, or if medical conditions present that increase risk with continued exposure
20-29	As above for BLL 10-19 ug/dl		• **Remove** from lead exposure if repeat BLL measured in 4 weeks remains ≥20 ug/dl
30-39	• **Spontaneous abortion** • **Reduced birth weight** • Possible postnatal development delay	• **Spontaneous abortion** • **Reduced birth weight** • Possible postnatal development delay • **Hypertension and kidney dysfunction** • Possible subclinical neurocognitive deficits	• **Remove** from exposure

BLL: blood lead level; Pb: blood lead

Reproduced from: Recommendations for Medical Management of Adult Lead Exposure.[10]