Biomonitoring in Occupational Settings

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Occupational Biomonitoring
International Union of Pure & Applied Chemistry

“A systematic continuous or repeated measurement and assessment of workplace agents or their metabolites either in tissues, secreta, excreta or any combination of these to evaluate exposure and health risk compared to an appropriate reference”
Occupational Biomonitoring

History & Purpose

- Conducted in U.S. & Germany since 1980
- One way to assess exposure & health risk—
  not a measure of adverse health effects
- Allows assessment of integrated exposure by different routes including—
  - inhalation
  - dermal
  - oral
- Information about body burden, protective equipment, work habits, non-work exposure, previous exposure (e.g., 9/11 incident)
Occupational Biomonitoring
Underlying Issues

- IH tool used to prevent harmful exposures
- Guidance values based on occupational exposure limits—protection against chronic hazards limited
- Sampling based on toxicokinetics of substance
- Variability due to individual factors (age, disease, etc.) requires protection of workers’ rights
- Employers responsible for preventing harmful exposures; must make monitoring results available to workers or their representatives
Occupational Biomonitoring
Guidance Values—Used to Assess Results

- Developed by non-government and government agencies; used in several countries
- US and UK guidance values are mandatory for a limited number of substances (e.g., lead & cadmium)
- German biological tolerance values (BATs) are maximum permissible quantities of a substance
Occupational Biomonitoring Guidance Values
Biological Exposure Exposure Indices (BEIs)

- Developed by the American Conference of Governmental Industrial Hygienists (ACGIH)—a private US organization

- ACGIH BEIs for 43 substances; 31 have notations
  - Nonspecific = 21
  - Semi-quantitative = 9
  - Background = 16

- Generally represent levels in healthy workers exposed at ACGIH Threshold Limit Values (TLVs)

- Generally indicate concentrations below which there will be no adverse health effects
Ns=nonspecific. The determinant is observed after exposure to other chemicals.

B=background. May be present in specimens of non-occupationally workers at concentrations which could confound results. Such background concentrations are incorporated into the BEI.

Sq=Semi-quantitative. The determinant indicates exposure to the chemical, but the quantitative interpretation of the result is ambiguous. Should be used as screening test if a quantitative test is not practical.

**NITROBENZENE**

*Synonyms*: Nitrobenzol; Oil of Nitrobenzene; Nitrobenzol Oil; Oil of Nitrobenzole

**CAS number**: 98-95-3

**Molecular formula**: C₆H₅NO₂

### RECOMMENDED BEI®

<table>
<thead>
<tr>
<th>Determinant</th>
<th>Sampling Time</th>
<th>BEI</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total p-nitrophenol in urine</td>
<td>End of shift at end of workweek</td>
<td>5 mg/g creatinine</td>
<td>Ns</td>
</tr>
<tr>
<td>Methemoglobin in blood</td>
<td>End of shift</td>
<td>1.5% of hemoglobin</td>
<td>B, Ns, Sq</td>
</tr>
</tbody>
</table>

### Properties

Nitrobenzene is a colorless to pale yellow, oily liquid with a strong odor detectable at 5 ppb. It has a boiling point of 211°C and a saturated vapor pressure of less than 1 torr at 25°C. It is slightly soluble in water and is miscible with most organic solvents. The oil–water distribution coefficient is about 80.

Hydroxylation to aminophenols and 2) direct hydroxylation with formation of nitrophenols. The main metabolic pathways are shown in bold arrows in Figure 1. All metabolites except phenylhydroxylamine were found in the urine of exposed humans and animals, the phenyl moiety being conjugated with glucuronic, sulfuric, or mercapturic acid.
**LEAD, Elemental and Inorganic**

**CAS number:** 7439-92-1 (elemental lead)

**Empirical formula:** Pb

**RECOMMENDED BEI®**

<table>
<thead>
<tr>
<th>Determinant</th>
<th>Sampling Time</th>
<th>BEI</th>
<th>Notation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead in blood</td>
<td>Not critical</td>
<td>30 µg/100 ml</td>
<td></td>
</tr>
</tbody>
</table>

**Note:** Women of childbearing potential, whose blood Pb exceeds 10 µg/dl, are at risk of delivering a child with a blood Pb over the current Centers for Disease Control guideline of 10 µg/d. If the blood lead of such children remains elevated, they may be at increased risk of cognitive deficits. The blood Pb of these children should be closely monitored and appropriate steps should be taken to minimize the child’s exposure to environmental lead. (1)

**Properties**

Elemental lead is a soft, malleable, blue-gray heavy metal with a cubic crystal structure. (2) The physical and chemical properties of elemental lead include: (2) molecular weight, 207.2; density, 11.34 g/cm² at 20°C; melting point, 327.4°C; boiling point, 1740°C; and vapor pressure, 1.777 torr at 1000°C.

lead are distinct from that of inorganic lead. This BEI only applies to elemental lead and inorganic lead salts.

**Possible Nonoccupational Exposure**

Lead is ubiquitous in the environment. A cumulative total of about 300 million metric tons of
Occupational Biomonitoring
How It Is Used

- **Cal/OSHA Lead and Cadmium Standards**
  - component of medical surveillance programs
  - potential for overexposure triggers requirement

- **NIOSH Health Hazard Evaluations (HHEs)**
  - can clarify exposure/health effects relationship
  - investigations can ID new biomonitoring methods

- **Occupational Research Studies**
  - ID exposed workers
  - compare to NHANES
Interpretation of Biomonitoring Results
Cal/OSHA Cadmium Standard Title 8 §5207

- Cd levels in urine and blood & $\beta_2$ microglobulin in urine are assessed with medical exams & history

- Results determine frequency of medical exams, medical removal, and kidney/other health effects

- Certain medications can confound interpretation of results

- $\beta_2$ microglobulin levels can indicate health problems unrelated to Cd exposure
Communication of Biomonitoring Results
Cal/OSHA Cadmium Standard Title 8 §5207

- Worker gets copy of biomonitoring results (with sheet explaining results) & physician’s written medical opinion from employer within two weeks

- Physician’s written medical opinion includes—
  - worker’s diagnosis
  - medical conditions that Cd may impact
  - results of other tests which assess Cd absorption
  - recommendations regarding work removal or limitations
  - statement that all info (med exam, test results, etc.) has been clearly and carefully explained to the worker
  - employer info limited to findings related to CD exposure
Biomonitoring—Workers’ Rights
UK Health & Safety Executive (HSE)

How Your Rights Are Protected

- Understand test results & actions to be taken
- Decide who has access to results (union; anon., pooled)
- Sample analysis limited to chemical exposures at work
- Test results will not affect employment conditions
Investigated ETS exposure among workers in 3 casinos

Conducted medical exams, environ. & biol. monitoring, interviews, symptom surveys

Made recommendations to employers & workers
NIOSH ETS Casino Workers HHE
Interpretation & Communication of Results

- Increased urinary levels of NNAL during work shift is evidence of workplace exposure to a tobacco-specific carcinogen (non-poker dealers)

- Exposure to ETS components (nicotine, formaldehyde, naphthalene, etc.) in workplace air

- Employer recommendations included:
  - ban smoking in casinos
  - form H&S committees

- Employee recommendations included:
  - stop smoking
  - see doctor for health concerns
What NIOSH Did

- We talked to nonpoker (NP) casino dealers about symptoms that may have been related to ETS exposure.
- We took personal breathing zone and area air samples to measure ETS.
- We took urine samples to see if components of ETS were absorbed into NP casino dealers’ bodies.
- We surveyed NP casino dealers and casino office staff about their work, medical problems, and symptoms.

What NIOSH Found

- NP casino dealers reported having respiratory symptoms. They thought these symptoms were related to ETS.
- We found ETS components in the air. These components include nicotine, 4-vinyl pyridine, respirable dust, solanesol, benzene, toluene, p-dichloromethane, naphthalene, formaldehyde, and acetaldehyde.
- We found increased urinary levels of one ETS component during the work shift. This finding shows that these components were absorbed in NP casino dealers’ bodies.
- More NP casino reported respiratory symptoms than administrative and engineering employees, but the differences between the groups were not statistically significant.
Occupational Biomonitoring Research Study

- Phthalate study of 156 workers from 8 industries
  - Phthalate, PVC, & film mfg.
    - rubber boot, gasket, & hose mfg.
    - vehicle filter mfg.
    - nail-only salons
- Evaluate use of metabolites (mid- & end-shift) to identify worker phthalate exposure
- Data on occupational exposure to DEP, DBP, & DEHP

- No well-designed epi study of phthalate-exposed workers
- NIOSH sought to identify industries with likely exposure as first step
- DBP & DEHP selected based on their toxicity in animals
- DEP had highest level in Third NHANES
- Study considered pilot
Occupational Biomonitoring Phthalate Study
Hines et al. 2009—Study Results

- DEHP exposure evidence strongest in **PVC film mfg.**, **PVC compounding**, and **rubber boot mfg.** Metabolites exceeded NHANES levels by 8-, 6-, & 3-fold, respectively

- DBP exposure most evident in **rubber gasket**, **phthalate**, and **rubber hose mfg.** Metabolites exceeded NHANES levels by 26-, 25-, & 10-fold, respectively

- DBP exposure in **nail-only salons** was 2-fold higher than NHANES levels

- DEP and DMP metabolites in **phthalate mfg.** were 4- & >1000-fold higher than NHANES levels, respectively
Within shift increases in urinary metabolites indicate workplace exposure to phthalates.

No exposure limits or normal levels established for phthalate metabolites in urine; health significance, if any, of results not known.

Workers sent letters containing background info on phthalates, group and individual results and how compare to NHANES, & phthalate use at workplace.

Lack of knowledge about health significance of results highlighted in letter.
### Table 1: Your Results: Phthalate Metabolites in Urine

<table>
<thead>
<tr>
<th>Phthalate Used in Your Workplace?</th>
<th>Phthalate Metabolite</th>
<th>Your Results (µg/g)</th>
<th>Group Results (Range) (µg/g)</th>
<th>Adult U.S. General Population Average* (µg/g)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>DMP</td>
<td></td>
<td>ND-7650</td>
<td>1.0</td>
</tr>
<tr>
<td></td>
<td>DEP</td>
<td></td>
<td>8.59-15300</td>
<td>159</td>
</tr>
<tr>
<td></td>
<td>DBP</td>
<td></td>
<td>ND-1810</td>
<td>16.1</td>
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<tr>
<td></td>
<td>BzBP</td>
<td></td>
<td>ND-438</td>
<td>12.0</td>
</tr>
<tr>
<td></td>
<td>DEHP</td>
<td>MEHP</td>
<td>ND-1480</td>
<td>3.96</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MEHHP</td>
<td>ND-8690</td>
<td>17.2</td>
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<tr>
<td></td>
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<td>MEOHP</td>
<td>ND-5440</td>
<td>11.4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>MECPP</td>
<td>ND-2030</td>
<td>NM</td>
</tr>
<tr>
<td></td>
<td>DiBP</td>
<td>MIBP</td>
<td>ND-915</td>
<td>2.31</td>
</tr>
<tr>
<td></td>
<td>DnOP</td>
<td>MCPP</td>
<td>ND-69.3</td>
<td>2.37</td>
</tr>
<tr>
<td></td>
<td>DnNP</td>
<td>MCOP</td>
<td>ND-80.0</td>
<td>NM</td>
</tr>
<tr>
<td></td>
<td>DnDP</td>
<td>MCNP</td>
<td>ND-14.8</td>
<td>NM</td>
</tr>
</tbody>
</table>

* A total of 156 workers was in the study group.

** MCOP and MCNP were measured on 37 workers.

### Table 2: Your Results: Creatinine in Urine

<table>
<thead>
<tr>
<th>Creatinine</th>
<th>Your Results (g/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mid Shift</td>
</tr>
</tbody>
</table>

### Abbreviations:

DMP = dimethyl phthalate  
MMP = mono-methyl phthalate
Biomonitoring in Occupational Settings
Summary of Key Issues

- Goal of occupational biomonitoring is to reduce hazardous exposures in workplace & health risks

- Biomonitoring guidance values often are based on OELs that do not protect against chronic toxicity

- Biomonitoring is required as a component of medical surveillance programs in a limited number of Cal/OSHA standards

- Communication of occupational biomonitoring results varies depending on setting (HHEs, research study, compliance with standard)