Biomonitoring of exposure to chemicals

Guideline for specimen collection

The Biomonitoring services of the Finnish Institute of Occupational Health provide services for the biomonitoring of chemical exposure at work and the health risks involved. This guideline presents short summaries of those exposures for which such services are available, as well as of the analyses performed, with emphasis on specimen collection, storage, and shipment. These services are mainly directed to occupational health care in Finland, but are also available to other clients.

The staff of the team may be reached by e-mail, at the address firstname.lastname@ttl.fi

For several analyses, special-washed laboratory ware is required for successful specimen collection. For containers/vials and other required equipment more information is available from the contact person of the analysis.

For accurate interpretation of the results, certain information of the work process and of the exposed person is required. As a checklist of such information, we ask you to fill in the request form, which you can find at the web site of the www.ttl.fi/biomonitoring

The results will be forwarded to the client normally within 3-5 weeks from the receipt of the specimen. For further information contact the responsible person of the analyses. Airmail, fax, or electronic mail can be used, to best suit the client. When a faster result is required, the client is requested to contact the person responsible for the analysis in question. Shortening the time of the analysis usually increases the costs.

Where available, for each analysis, reference limits and biomonitoring action limits are provided.

The (Upper) Reference limit for non-exposed is, unless otherwise specified, the 95th percentile observed for Finns not exposed to the chemical at work. It should be noted that for some analytes, these levels will be different in different geographic locations. Biomonitoring services are prepared to give advice on such matters.

Biomonitoring action limits are concentrations, which the Finnish Institute of Occupational Health recommends not to be exceeded in occupational exposure. In Finland, the biomonitoring action limit of lead in blood is legally binding, those for arsenic in urine, chromium in urine (hexavalent compounds), phenol in urine, lead in blood, mandelic acid in urine in exposure to ethylbenzene, mandelic and phenylglyoxylic acids (MAPGA) in urine in exposure to styrene, mercury in blood and urine, methylenesbis(2-chloroaniline) (MOCA, MbOCA) in urine, methylhippuric acid in urine in exposure to xylene, nickel in urine in exposure to nickel and insoluble nickel compounds and to soluble nickel compounds, and tetrachloroethene in blood, tiothiazolidinecarboxylic acid (TTCA) in urine, toluene in blood and trichloroacetic acid in urine in exposure to trichloroethene are stipulated by the Ministry of Social Affairs and Health (the Decree on Concentrations Known to be Hazardous 1214/2016), the others are guidelines
given by the Institute of Occupational Health, most often derived from good working habits, as defined by occupational exposure limits. For some chemicals the levels are based to derived no-effect level (DNEL) and they are called as **target levels**, i.e. those for chromium and nickel in urine and blood tetrachloroethylene.

The laboratories of the team are accredited by the Finnish Accreditation Service (see [www.finas.fi](http://www.finas.fi)) (Laboratory T013, EN ISO/IEC 17025) and the analytical quality is verified using standard operating procedures and extensive internal and external quality assurance following the quality manual of the laboratory.

This guidance document is kept up-to-date, and the date of updating for each analysis may be found at the bottom of the page.

Laboratory provides also other analyses from biological media. Some examples are collected to the list below.

Indium in serum, chromium, cobalt, manganese, molybdenum, titanium in whole blood, copper and zinc in serum and urine, platinum group metals and uranium in urine. For these analyses biomonitoring action limits are not available and most of them we do not recommend them for biomonitoring of occupational exposure.

For further information contact

**Suzana Abenet**

Finnish Institute of Occupational Health
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
Definitions and general notes on sample collection for biomonitoring

**Morning specimen:** The sample is collected before the workshift toward the end of the working week or period of exposure. Generally, the result reflects exposure over the last few days. Even a minor exposure right before the sample collection will seriously distort the interpretation. For example, if a worker is exposed on Monday and Tuesday, sample collection will take place in Wednesday morning.

**Evening specimen:** The sample is collected at the end of the work shift, in some cases toward the end of the working week or period of exposure. The result mainly reflects exposure during the day of sample collection.

**Whole blood sample:** The sampling vial contains an anticoagulant; the blood collected in the vials must be thoroughly mixed with the anticoagulant in order to prevent clotting.

**Blood sample for the analysis of a volatile chemical.** The vial has to be filled to the rim, and it must be closed well and mixed thoroughly. The specimens tend to be instable and have to be forwarded to the laboratory as fast as possible.

**Specimen is prone to contamination.** Dust from the work place air, or skin or clothing of the worker may contaminate the specimen. The specimen is collected after the worker has showered (or washed hands and, in case of a urine specimen, the urethral orifice) and changed to street clothes. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The laboratories of the Institute of Occupational Health provide special-washed sample containers in Finland.

**Urine sample standardization and dilute urine specimens.** The concentrations observed in the urine are standardized to a relative density of 1.021 kg/l, or to the concentration of creatinine, whichever is considered more appropriate. On an average, the concentration of creatinine in the urine of adult working Finns is 13 mmol/l urine when the urine relative density is 1.021 kg/l. If urine is very dilute (relative density <1.010, or creatinine content < 3 mmol/l), the interpretation is uncertain. When the laboratory receives such a dilute urine specimen, it will request a new specimen to be collected. If a resampling is not possible, the laboratory will carry out the analysis, and notify the uncertainty of the interpretation. It is unlikely that urine is too dilute if excessive fluid consumption is avoided, and if a minimum of three hours has lapsed from the previous urination. The laboratory collecting the specimen may also check the relative density of the specimen before sending it to the laboratory – however not, if the specimen is prone to contamination (see above).

**Storage and transport.** Delays of the specimens in the mail over the week-end should be avoided; specimens collected toward the end of the week are better stored in the refrigerator of the sample collector over the week end and sent on Monday.

Filling in the **analysis request form** carefully helps avoid delays and mistakes. It is especially important to make sure that the name and identification number are accurate. Similarly, the **analysis** needed, **sampling date and time**, as well as the **contact information** should be clearly and accurately indicated.
Alkyl lead

Analysis of lead in urine in a post-shift sample is recommended for the biological monitoring of alkyl lead exposure (tetraethyl and tetramethyl lead). The upper reference limit in a non-exposed population is 0.008 µmol/l and the biomonitoring action limit, 0.1 µmol/l.

Lead in urine, U-Pb

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Alkyl lead compounds, such as tetraethyl and tetramethyl lead.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen</td>
<td>20 ml of urine. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The Institute of Occupational Health provides special-washed sample containers in Finland.</td>
</tr>
<tr>
<td>Sampling time</td>
<td><em>Evening specimen</em>: Post-shift specimen at the end of the working week or exposure period.</td>
</tr>
<tr>
<td>Storage and transport</td>
<td>The specimen is stored in a refrigerator and sent so that reaches the laboratory before the week-end. Specimens collected toward the end of the week are preferably kept in the refrigerator over the week end and sent on Monday.</td>
</tr>
<tr>
<td>Sources of error</td>
<td>Specimen is prone to contamination. Dust from the workplace air, or skin or clothing of the worker may contaminate the specimen. The specimen is collected after the worker has showered (or washed hands and the urethral orifice) and changed to street clothes. Exposure to inorganic lead distorts the interpretation.</td>
</tr>
<tr>
<td>Notes</td>
<td>Exposure to inorganic lead is best assessed by an analysis of lead in blood, see Lead in blood. The concentration of antimony, beryllium, cadmium, chromium, cobalt, manganese, molybdenum, nickel, selenium, thallium, uranium, vanadium and zinc may be determined from the same 20-ml specimen.</td>
</tr>
<tr>
<td>Reference limit for non-exposed</td>
<td>0.008 µmol/l.</td>
</tr>
<tr>
<td>Biomonitoring action limit</td>
<td>0.1 µmol/l. The Finnish Government Decree 1335/2004 stipulates that lead and its compounds may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy, <em>i.e.</em>, the urine lead concentration must not exceed the reference limit for non-exposed (0.008 µmol/l).</td>
</tr>
</tbody>
</table>
| Further information | Suzana Abenet  
Biomonitoring services  
P.Box 40,  
FI-00032 TYÖTERVEYSLAITOS, Finland |
**Aluminium**

Analysis of aluminium in urine in a morning specimen, collected after the weekend, is recommended for the biological monitoring of aluminium exposure. The result reflects exposure to aluminium during the few preceding days, and gives an indication of the body burden of aluminium, and of the health risk involved. The upper reference limit in a non-exposed population is 0.6 µmol/l, and the biomonitoring action limit, 3.0 µmol/l.

### Aluminium in urine, U-Al

<table>
<thead>
<tr>
<th><strong>Exposure</strong></th>
<th>Aluminium and its inorganic compounds.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specimen</strong></td>
<td>20 ml of urine. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The Institute of Occupational Health provides special-washed sample containers in Finland.</td>
</tr>
<tr>
<td><strong>Sampling time</strong></td>
<td>Morning specimen before the work shift on the first day after the weekend.</td>
</tr>
<tr>
<td><strong>Storage and transport</strong></td>
<td>The specimen is stored in a refrigerator and sent so that reaches the laboratory before the week-end. Specimens collected toward the end of the week are preferably kept in the refrigerator over the week end and sent on Monday.</td>
</tr>
<tr>
<td><strong>Sources of error</strong></td>
<td>Specimen is prone to contamination. Dust from the work place air, or skin or clothing of the worker may contaminate the specimen. The specimen is collected after the worker has showered (or washed hands and the urethral orifice) and changed to street clothes. Consumption of aluminium-containing antacid drugs or juices with high aluminium content, elevate the urinary aluminium concentration.</td>
</tr>
<tr>
<td><strong>Reference limit for non-exposed</strong></td>
<td>0.6 µmol/l.</td>
</tr>
<tr>
<td><strong>Biomonitoring action limit</strong></td>
<td>3.0 µmol/l.</td>
</tr>
</tbody>
</table>
| **Further information** | Suzana Abenet  
Biomonitoring services  
P.Box 40,  
FI-00032 TYÖTERVEYSLAITOS, Finland |
**Antimony**

Analysis of antimony in urine in a post-shift specimen collected at the end of the working week is recommended for the biological monitoring of antimony exposure. The upper reference limit in a non-exposed population is 9 nmol/l, and no biomonitoring action limit has been established.

**Antimony in urine, U-Sb**

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Antimony and its inorganic compounds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen</td>
<td>20 ml of urine. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The Institute of Occupational Health provides special-washed sample containers in Finland.</td>
</tr>
<tr>
<td>Sampling time</td>
<td>Post-shift specimen at the end of the working week or exposure period.</td>
</tr>
<tr>
<td>Storage and transport</td>
<td>The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the week-end. Specimens collected toward the end of the week are preferably kept in the refrigerator over the week end and sent on Monday.</td>
</tr>
<tr>
<td>Sources of error</td>
<td><strong>Specimen is prone to contamination.</strong> Dust from the workplace air, or skin or clothing of the worker may contaminate the specimen. The specimen is collected after the worker has showered (or washed hands and the urethral orifice) and changed to street clothes.</td>
</tr>
<tr>
<td>Note</td>
<td>The concentration of beryllium, cadmium, chromium, cobalt, lead, manganese, molybdenum, nickel, selenium, thallium, uranium, vanadium and zinc may be determined from the same 20-ml specimen.</td>
</tr>
<tr>
<td>Reference limit for non-exposed</td>
<td>9 nmol/l.</td>
</tr>
<tr>
<td>Biomonitoring action limit</td>
<td>Not established. The European Union has classified antimony trioxide as possibly carcinogenic (Cat 3; R40, H351). The Finnish Government Decree 1335/2004 stipulates that chemicals in this category may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy, i.e., the urine antimony concentration must not exceed the reference limit for non-exposed (9 nmol/l).</td>
</tr>
</tbody>
</table>
| Further information | Suzana Abenet  
Biomonitoring services  
P.Box 40,  
FI-00032 TYÖTERVEYSLAITOS, Finland |
**Arsenic**

Analysis of inorganic arsenic compounds (As$^{3+}$ and As$^{5+}$) in a post-shift urine specimen is recommended for the biological monitoring of exposure to inorganic arsenic. The upper reference limit for the total sum of inorganic arsenic ((As$^{3+}$ and As$^{5+}$) in a non-exposed population is 30 nmol/l, and the biomonitoring action limit, 70 nmol/l.

### Inorganic arsenic in urine, U-As-i

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Arsenic and inorganic arsenic compounds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen</td>
<td>20 ml of urine. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The Institute of Occupational Health provides special-washed sample containers in Finland.</td>
</tr>
<tr>
<td>Sampling time</td>
<td>Post-shift specimen after the work shift.</td>
</tr>
<tr>
<td>Storage and transport</td>
<td>The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.</td>
</tr>
<tr>
<td>Sources of error</td>
<td><strong>Specimen is prone to contamination.</strong> Dust from the work place air, or skin or clothing of the worker may contaminate the specimen. The specimen is collected after the worker has showered (or washed hands and the urethral orifice) and changed to street clothes. In some geographical locations, well-water contains large amounts of arsenic.</td>
</tr>
<tr>
<td>Note</td>
<td>Arsenic and its metabolites are separated in the analysis; the result includes only the inorganic arsenic compounds (As$^{3+}$ and As$^{5+}$).</td>
</tr>
<tr>
<td>Reference limit for non-exposed</td>
<td>30 nmol/l.</td>
</tr>
<tr>
<td>Biomonitoring action limit</td>
<td>70 nmol/l. This is based on the Ministry of Health and Social Affairs Decree 1214/2016. The European Union has classified arsenic acid and its salts and arsenic trioxide and pentoxide carcinogenic EC No 1272/2008; H350 (Directive 67/548 / EEC; group 1; R45). The Finnish Government Decree 1335/2004 stipulates that chemicals in this category may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy, i.e., the urine inorganic arsenic concentration must not exceed the reference limit for non-exposed (30 nmol/l).</td>
</tr>
</tbody>
</table>
| Further information | Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland |
**Benzene**

Analysis of urinary S-phenylmercapturic acid in a post shift urine specimen is recommended for the biological monitoring of benzene exposure. The upper reference limit for non-exposed non-smokers is 0,5 µg/g creat. and the biomonitoring action limit 4 µg/g creat.

**S-phenylmercapturic acid (U-SPMA)**

- **Exposure**: Benzene.
- **Specimen**: 20 ml of urine.
- **Sampling time**: Post-shift specimen.
- **Storage and transport/sending**: The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.
- **Sources of error**: Cigarette smoke contains benzene and therefore, smoking increases excretion SPMA in urine.
- **Reference limit for non-exposed**: 0,5 µg/g creat (non-smokers).
- **Biomonitoring action limit**: 4 µg/g creat. The European Union has classified benzene as a carcinogen EC No 1272/2008; H340, H350 (Directive 67/548 / EEC; group 1, R45). The Finnish Government Decree 1335/2004 stipulates that chemicals in this category may be hazardous to foetus or pregnant women; thus, exposure to them is not acceptable during pregnancy, i.e., the urine SPMA concentration must not exceed the reference limit for non-exposed (0,5 µg/g creat).

**Further information**

Olli Laine  
Biomonitoring services  
P.Box 40,  
FI-00032 TYÖTERVEYSLAITOS, Finland
Beryllium

Analysis of beryllium in urine is recommended for the biological monitoring of beryllium exposure. The upper reference limit in a non-exposed population is 15 nmol/l. No biomonitoring action limit has been established.

Beryllium in urine, U-Be

**Exposure**
Beryllium and inorganic beryllium compounds.

**Specimen**
20 ml of urine. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The Institute of Occupational Health provides special-washed sample containers in Finland.

**Sampling time**
Post-shift specimen at the end of the working week or exposure period.

**Storage and transport**
The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.

**Sources of error**
*Specimen is prone to contamination.* Dust from the work place air, or skin or clothing of the worker may contaminate the specimen. The specimen is collected after the worker has showered (or washed hands and the urethral orifice) and changed to street clothes.

**Note**
The concentration of antimony, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, thallium, uranium, vanadium and zinc may be determined from the same 20-ml specimen.

**Reference limit for non-exposed**
15 nmol/l.

**Biomonitoring action limit**
Not established.
The European Union has classified beryllium compounds other than aluminium beryllium silicates as carcinogenic EC No 1272/2008; H350i (Directive 67/548 / EEC; group 2; R49).
The Finnish Government Decree 1335/2004 stipulates that chemicals in this category may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy, i.e., the urine beryllium concentration must not exceed the reference limit for non-exposed (15 nmol/l).

**Further information**
Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLLAHTOS, Finland

Biomonitoring services 2019-05-20
Cadmium

Analysis of cadmium in urine is recommended for the biological monitoring of cadmium exposure. Additional information may be obtained from the analysis of cadmium in blood. The upper reference limit in a non-exposed population in urine is 5 nmol/l for non-smokers and 10 nmol/l for smokers, in blood 5 nmol/l for non-smokers and 18 nmol/l for smokers. The biomonitoring action limits are 50 nmol/l in blood and 20 nmol/l in urine. Renal effects of cadmium may be assessed by analyzing the urinary retinol binding protein.

Cadmium in urine, U-Cd

**Exposure**  
Cadmium and inorganic cadmium compounds.

**Specimen**  
20 ml of urine. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The Institute of Occupational Health provides special-washed sample containers in Finland.

**Sampling time**  
Specimen can be collected at any time of the day

**Storage and transport**  
The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.

**Sources of error**  
**Specimen is prone to contamination.** Dust from the work place air, or skin or clothing of the worker may contaminate the specimen. The specimen is collected after the worker has showered (or washed hands and the urethral orifice) and changed to street clothes.

**Note**  
The concentration of antimony, beryllium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, thallium, uranium, vanadium and zinc may be determined from the same 20-ml specimen if the sampling time is after shift.

**Reference limit for non-exposed**  
Non-smokers 5 nmol/l.  
Smokers 10 nmol/l.

**Biomonitoring action limit**  
20 nmol/l.  
This is based on the Ministry of Health and Social Affairs Decree 1214/2016.

The European Union has classified several cadmium compounds as carcinogenic, mutagenic or hazardous to reproductive EC No 1272/2008; H340, H341, H350, H360FD, H361fd (Directive 67/548 / EEC; group 2-3, R45, 63, 68). The Finnish Government Decree 1335/2004 stipulates that exposure to chemicals in these categories is not acceptable during pregnancy, i.e., the urine cadmium concentration must not exceed the reference limit for non-exposed 5 nmol/l (non-smokers) or 10 nmol/l (smokers).

**Further information**  
Suzana Abenet  
Biomonitoring services  
P.Box 40,  
FI-00032 TYÖTERVEYSLAITOS, Finland


Cadmium, continued

Cadmium in blood, B-Cd

**Exposure**
Cadmium and inorganic cadmium compounds.

**Specimen**
5 ml of whole blood.
A heparinised vacuum tube (e.g., Venosafe®, Vacuette® trace element,) is filled with blood and mixed carefully with the anticoagulant.

**Sampling time**
Specimen can be collected at any time of the day.

**Storage and transport**
The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.

**Note**
Both lead and cadmium may be analyzed from the same sample.

**Sources of error**
Specimen is prone to contamination. Dust from the work place air, or skin or clothing of the worker may contaminate the specimen. The specimen is collected after the worker has showered and changed to street clothes.

**Reference limit for non-exposed**
- Non-smokers: 5 nmol/l.
- Smokers: 18 nmol/l.

**Biomonitoring action limit**
50 nmol/l.
The European Union has classified several cadmium compounds as carcinogenic, mutagenic or hazardous to reproductive EC No 1272/2008; H340, H341, H350, H360FD, H361fd (Directive 67/548 / EEC; group 2-3, R45, 63, 68). The Finnish Government Decree 1335/2004 stipulates that exposure to chemicals in these categories is not acceptable during pregnancy, i.e., the blood cadmium concentration must not exceed the reference limit for non-exposed 5 nmol/l (non-smokers) or 18 nmol/l (smokers).

**Further information**
Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
**Carbon disulphide**

Analysis of urinary 2-thiothiazolidine-4-carboxylic acid (TTCA) in a post-shift specimen is recommended for the biological monitoring of carbon disulphide exposure. The upper reference limit in a non-exposed population is 0.3 mmol/mol creatinine, and the biomonitoring action limit, 1.0 mmol/mol creatinine. The biomonitoring action limit corresponds to an 8-h TWA exposure to 5 ppm carbon disulphide.

**2-Thiothiazolidine-4-carboxylic acid in urine, U-TTCA**

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Carbon disulphide.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen</td>
<td>20 ml of urine.</td>
</tr>
<tr>
<td>Sampling time</td>
<td>Post-shift specimen at the end of the working week or exposure period.</td>
</tr>
<tr>
<td>Storage and transport</td>
<td>The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.</td>
</tr>
<tr>
<td>Sources of error</td>
<td>Vegetables of the family <em>Brassica</em> contain TTCA and their consumption may distort the interpretation.</td>
</tr>
<tr>
<td>Reference limit for non-exposed</td>
<td>0.3 mmol/mol creatinine.</td>
</tr>
<tr>
<td>Biomonitoring action limit</td>
<td>1.0 mmol/mol creatinine. The Ministry of Health and Social Affairs Decree 1214/2016 has set an indicative limit value of 1.0 mmol/l for 2-Thiothiazolidine-4-carboxylic acid in urine. The European Union has classified carbon disulphide as possibly hazardous to reproduction (Cat 2; R62-3, H361fd). The Finnish Government Decree 1335/2004 stipulates that exposure to chemicals in this category is not acceptable during pregnancy, i.e., the urine TTCA concentration must not exceed the reference limit for non-exposed (0.3 mmol/mol creatinine).</td>
</tr>
<tr>
<td>Further information</td>
<td>Suzana Abenet Biomonitoring services P.Box 40, FI-00032 TYÖTERVEYSLAITOS, Finland</td>
</tr>
</tbody>
</table>
**Carbon monoxide**

Analysis of carboxyhaemoglobin in a post-shift blood specimen, collected immediately after the cessation of the exposure, is recommended for biological monitoring of carbon monoxide [and dichloromethane, see dichloromethane] exposure. The upper reference limit in a non-exposed population is 0.015 (=1.5%), and the biomonitoring action limit, 0.040 (=4%). The biomonitoring action limit is based on the cardiovascular effects of carbon monoxide.

**Carboxyhaemoglobin in blood**

**Exposure**
Carbon monoxide.

**Specimen**
5 ml whole blood.
A heparinised vacuum tube (e.g., Venosafe®, Vacuette®) is filled with blood and mixed carefully with the anticoagulant.

**Sampling time**
Immediately after the cessation of the exposure.

**Storage and transport**
The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.

**Sources of error**
Smoking elevates the level of carboxyhaemoglobin. Reliable assessment of work exposure to carbon monoxide or dichloromethane requires refraining from smoking for at least 10 h.

**Reference limit for non-exposed**
0.015 (1.5%).

**Biomonitoring action limit**
0.040 (4%).
The Finnish Government Decree 1335/2004 stipulates that carbon monoxide may be hazardous to foetus or pregnant women. During pregnancy, a biomonitoring action limit of 0.02 is applied in exposure to carbon monoxide.

**Further information**
Suzana Abenet  
Biomonitoring services  
P.Box 40,  
FI-00032 TYÖTERVEYSLAITOS, Finland
Chromium

Analysis of urinary chromium in a post-shift specimen at the end of the working week or working period is recommended for the biological monitoring of chromium exposure. The upper reference limit in a non-exposed population is 0.01 µmol/l. The biomonitoring action limit is 0.20 µmol/l in urine for workers exposed to hexavalent chromium. The target level, 0.01 µmol/l, is based on DNEL (derived no-effect level).

Chromium in urine, U-Cr

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Chromium and inorganic chromium compounds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen</td>
<td>20 ml of urine. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The Institute of Occupational Health provides special-washed sample containers in Finland.</td>
</tr>
<tr>
<td>Sampling time</td>
<td>Post-shift specimen at the end of the working week or exposure period.</td>
</tr>
<tr>
<td>Storage and transport</td>
<td>The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.</td>
</tr>
<tr>
<td>Sources of error</td>
<td>Specimen is prone to contamination. Dust from the workplace air, or skin or clothing of the worker may contaminate the specimen. The specimen is collected after the worker has showered (or washed hands and the urethral orifice) and changed to street clothes.</td>
</tr>
<tr>
<td>Note</td>
<td>The concentration of antimony, beryllium, cadmium, cobalt, lead, manganese, molybdenum, nickel, selenium, thallium, uranium, vanadium, and zinc may be determined from the same 20-ml specimen.</td>
</tr>
<tr>
<td>Reference limit for non-exposed</td>
<td>0.01 µmol/l.</td>
</tr>
<tr>
<td>Biomonitoring action limit</td>
<td>0.20 µmol/l for workers exposed to hexavalent chromium. The target level is 0.01 µmol/l. This is based on the Ministry of Health and Social Affairs Decree 1214/2016. The European Union has classified inorganic chromiumVI compounds as carcinogenic (Cat 1, 2 or 3; R45, R49 or R40; H340, H350, H350i, H360FD, H361f). The Finnish Government Decree 1335/2004 stipulates that chemicals in this category may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy, i.e., the urine chromium concentration must not exceed the reference limit for non-exposed (0.01 µmol/l).</td>
</tr>
<tr>
<td>Further information</td>
<td>Suzana Abenet Biomonitoring services P.Box 40, FI-00032 TYÖTERVEYSLAITOS, Finland</td>
</tr>
</tbody>
</table>
**Cobalt**

Analysis of cobalt in urine in a post-shift specimen at the end of the working week or exposure period is recommended for the biological monitoring of cobalt exposure. The upper reference limit in a non-exposed population is 25 nmol/l and the biomonitoring action limit 130 nmol/l, based on the relationship between airborne and urinary cobalt concentrations.

**Cobalt in urine, U-Co**

**Exposure** Cobalt and inorganic cobalt compounds.

**Specimen** 20 ml of urine. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The Institute of Occupational Health provides special-washed sample containers in Finland.

**Sampling time** Post-shift specimen at the end of the working week or exposure period.

**Storage and transport** The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.

**Sources of error** **Specimen is sensitive to contamination:** Dust from the clothing or skin may contaminate the sample. The sample should be collected after washing the hands and the urethral orifice. The sample should be collected in special-washed containers; no additives or preservatives may be added. If the sample is first collected in a disposable container, it should be transferred immediately to the special-washed vial; upon request, the Institute provides these special-washed vials in Finland.

**Note** The concentration of antimony, beryllium, cadmium, chromium, copper, lead, manganese, molybdenum, nickel, selenium, thallium, uranium, vanadium and zinc may be determined from the same 20-ml specimen.

**Reference limit for non-exposed** 25 nmol/l.

**Biomonitoring action limit** 130 nmol/l. The European Union has classified cobalt chloride and sulphate as carcinogenic (Cat 2; R49, H350i). The Finnish Government Decree 1335/2004 stipulates that chemicals in this category may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy, i.e., the urine cobalt concentration must not exceed the reference limit for non-exposed (25 nmol/l).

**Further information** Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
**Dichloromethane (Methylene chloride)**

Analysis of carboxyhaemoglobin in a post-shift blood specimen, collected immediately after the cessation of the exposure, is recommended for biological monitoring of dichloromethane exposure. The upper reference limit in a non-exposed population is 0.015 (=1.5 %), and the biomonitoring action limit, 0.040 (=4 %). The biomonitoring action limit is based on the cardiovascular effects of carbon monoxide.

**Carboxyhaemoglobin in blood, B-Hb-CO**

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Dichloromethane.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen</td>
<td>5 ml whole blood.</td>
</tr>
<tr>
<td></td>
<td>A heparinised vacuum tube (e.g., Venosafe®, Vacuette®,) is filled with blood and mixed carefully with the anticoagulant.</td>
</tr>
<tr>
<td>Sampling time</td>
<td>Immediately after the cessation of the exposure.</td>
</tr>
<tr>
<td>Storage and transport</td>
<td>The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.</td>
</tr>
<tr>
<td>Sources of error</td>
<td>Smoking elevates the level of carboxyhaemoglobin. Reliable assessment of work exposure to dichloromethane requires refraining from smoking for at least 10 h.</td>
</tr>
<tr>
<td>Reference limit for non-exposed</td>
<td>0.015 (1.5 %)</td>
</tr>
<tr>
<td>Biomonitoring action limit</td>
<td>0.040 (4 %).</td>
</tr>
</tbody>
</table>

The European Union has classified dichloromethane as possibly carcinogenic (Cat 3; R40, H351). The Finnish Government Decree 1335/2004 stipulates that chemicals in this category may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy, i.e., the blood carboxyhaemoglobin concentration in exposure to dichloromethane must not exceed the reference limit for non-exposed (0.015).

**Further information**

Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
**Ethylbenzene**

Analysis of urinary mandelic acid in a post-shift specimen, collected at the end of the working week or period, is recommended for the biological monitoring of ethylbenzene exposure. The upper reference limit in a non-exposed population is 0.2 mmol/l, and the biomonitoring action limit corresponding to an 8-TWA exposure to 50 ppm of ethylbenzene is 4.0 mmol/l.

**Mandelic acid in urine, U-Mandel**

<table>
<thead>
<tr>
<th><strong>Exposure</strong></th>
<th>Ethylbenzene.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specimen</strong></td>
<td>20 ml of urine.</td>
</tr>
<tr>
<td><strong>Sampling time</strong></td>
<td>Post-shift specimen at the end of the working week or exposure period.</td>
</tr>
<tr>
<td><strong>Storage and transport</strong></td>
<td>The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.</td>
</tr>
<tr>
<td><strong>Reference limit for non-exposed</strong></td>
<td>0.2 mmol/l.</td>
</tr>
<tr>
<td><strong>Biomonitoring action limit</strong></td>
<td>4.0 mmol/l. The Ministry of Health and Social Affairs Decree <a href="#">1214/2016</a>. has set an indicative limit value of 5.2 mmol/l for mandelic acid in urine. The Finnish Government Decree 1335/2004 stipulates that organic solvents may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy. Therefore, the biomonitoring action limit applied during pregnancy is 0.6 mmol/l, corresponding to an exposure 10% of the Finnish occupational exposure limit.</td>
</tr>
</tbody>
</table>

**Further information**

Suzana Abenet  
Biomonitoring services  
P.Box 40,  
FI-00032 TYÖTERVEYSLAITOS, Finland
**Formic acid and formates**

Analysis of urinary formic acid in a pre-shift specimen is recommended for the biological monitoring of workers exposed to formic acid or formates. The upper reference limit for formate in urine in a non-exposed population is 70 mmol/mol creatinine.

**Formic acid in urine, U-Formia**

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Formic acid and formates.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen</td>
<td>20 ml of urine.</td>
</tr>
<tr>
<td>Sampling time</td>
<td>Morning specimen before the beginning of the work shift at the end of the working week or exposure period.</td>
</tr>
<tr>
<td>Storage and transport</td>
<td>The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.</td>
</tr>
</tbody>
</table>

**Note**

Exposure to methanol is best assessed by an analysis of methanol in urine, see [Methanol in urine](#).

**Reference limit for non-exposed**

70 mmol/mol creatinine.

**Biomonitoring action limit**

Not established (withdrawn 1.11.2013).

**Further information**

Suzana Abenet  
Biomonitoring services  
P.Box 40,  
FI-00032 TYÖTERVEYSLAITOS, Finland
**Indium**

Analysis of urinary indium in a post-shift specimen is recommended for the biological monitoring of indium exposure. The upper reference limit in a non-exposed population is 0.02 µg/l. No biomonitoring action limit has been established.

**Indium in serum, S-In**

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Indium and indium compounds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen</td>
<td>3 ml of serum. One 6 ml vacuum tubes (e.g., Venosafe® or Vacuette® without anticoagulant) are filled with blood and let clot. The serum is separated in a special-washed tube provided by the Institute.</td>
</tr>
<tr>
<td>Sampling time</td>
<td>Post-shift specimen.</td>
</tr>
<tr>
<td>Storage and transport</td>
<td>The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.</td>
</tr>
<tr>
<td>Reference limit for non-exposed</td>
<td>0.02 µg/l.</td>
</tr>
<tr>
<td>Biomonitoring action limit</td>
<td>Not established.</td>
</tr>
</tbody>
</table>
| Further information          | Suzana Abenet
Biomonitoring services       |
|                              | P.Box 40,
|                              | FI-00032 TYÖTERVEYLAITOS, Finland |
**Lead**

Analysis of lead in blood is recommended for the biological monitoring of inorganic lead exposure. The upper reference limit in a non-exposed population is 0.09 µmol/l and the biomonitoring action limit 1.4 µmol/l, based on neuropsychological and physiological effects.

**Lead in blood, B-Pb**

**Exposure**
Lead and inorganic lead compounds.

**Specimen**
5 ml of whole blood.
A heparinised vacuum tube (e.g., Venosafe®, Vacuette® trace element) is filled with blood and mixed carefully with the anticoagulant.

**Sampling time**
Specimen can be collected at any time of the day.

**Storage and transport**
The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.

**Sources of error**
Specimen is prone to contamination. Dust from the work place air, or skin or clothing of the worker may contaminate the specimen. The specimen is collected after the worker has showered and changed to street clothes.

**Reference limit for non-exposed**
0.09 µmol/l.

**Biomonitoring action limit**
1.4 µmol/l.
This is based on the Ministry of Health and Social Affairs Decree 1214/2016. According to the Finnish Government Decree 1154/93, worker, whose blood lead concentration exceeds 2.4 µmol/l, must not work in a job that entails exposure to lead. If the blood lead concentration of one of the workers in a workplace exceeds 1.9 µmol/l, the "employer must specifically monitor the workplace air lead concentration, and the eventual health effects of exposure to lead".

The Finnish Government Decree 1335/2004 stipulates that lead and its compounds may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy, i.e., the blood lead concentration must not exceed the reference limit for non-exposed (0.09 µmol/l).

**Further information**
Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
**Manganese and inorganic manganese compounds**

Analysis of urinary manganese in a post-shift specimen at the end of the working week or work shift can be used for the biological monitoring of manganese exposure. The upper reference limit in a non-exposed population in urine is 10 nmol/l. No biomonitoring action limit has been established.

**Manganese in urine, U-Mn**

<table>
<thead>
<tr>
<th><strong>Exposure</strong></th>
<th>Manganese and inorganic manganese compounds.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specimen</strong></td>
<td>20 ml of urine. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The Institute of Occupational Health provides special-washed sample containers in Finland.</td>
</tr>
<tr>
<td><strong>Sampling time</strong></td>
<td>Post-shift specimen at the end of the working week or exposure period.</td>
</tr>
<tr>
<td><strong>Storage and transport</strong></td>
<td>The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.</td>
</tr>
<tr>
<td><strong>Sources of error</strong></td>
<td>Specimen is prone to contamination. Dust from the work place air, or skin or clothing of the worker may contaminate the specimen. The specimen is collected after the worker has showered (or washed hands and the urethral orifice) and changed to street clothes.</td>
</tr>
<tr>
<td><strong>Note</strong></td>
<td>The concentration of antimony, beryllium, cadmium, chromium, cobalt, lead, molybdenum, nickel, selenium, thallium, uranium, vanadium, and zinc may be determined from the same 20-ml specimen.</td>
</tr>
<tr>
<td><strong>Reference limit for non-exposed</strong></td>
<td>10 nmol/l.</td>
</tr>
<tr>
<td><strong>Biomonitoring action limit</strong></td>
<td>Not established. Average urinary manganese concentrations among welders of manganese-containing steels, and in the manufacture of manganese batteries have usually been below 50 nmol/l.</td>
</tr>
</tbody>
</table>

**Further information**

Suzana Abenet  
Biomonitoring services  
P.Box 40,  
FI-00032 TYÖTERVEYSLAITOS, Finland
Mercury

Analysis of inorganic mercury in blood or of total mercury in urine in a morning specimen is recommended for the biological monitoring of inorganic mercury exposure. The upper reference limit in a non-exposed population is 10 nmol/l for inorganic mercury in blood and 20 nmol/l for mercury in urine. The biomonitoring action limit is 50 nmol/l for inorganic mercury in blood, and 140 nmol/l for mercury in urine. Analysis of mercury in blood may also be used for the assessment of exposure to alkyl mercury compounds, such as methylmercury.

Mercury in blood, B-Hg-I and B-Hg-o

**Exposure**
Mercury and mercury compounds.

**Specimen**
7 ml of whole blood.
One 7-10 ml heparinised vacuum tube (e.g., Venosafe®, Vacuette® trace element) or two 5-6 ml heparinised vacuum tubes (e.g., Venosafe®, Vacuette® trace element) are filled with blood and mixed carefully with the anticoagulant.

**Sampling time**
Specimen can be collected at any time of the day.

**Storage and transport**
The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.

**Sources of error**
**Specimen is sensitive to contamination:** Dust from the clothing or skin may contaminate the sample. The sample should be collected in special-washed vials after changing to street clothes.

**Note**
Inorganic and organic mercury are separated in the analysis. The Finnish mandatory health insurance does not cover the costs of mercury analyses performed for the assessment of mercury exposure from dental amalgam.

**Reference limit for non-exposed**
Inorganic mercury in blood 10 nmol/l.

**Biomonitoring action limit**
Inorganic mercury in blood 50 nmol/l. This is based on the Ministry of Health and Social Affairs Decree 1214/2016.
The Finnish Government Decree 1335/2004 stipulates that mercury and its compounds may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy, i.e., the blood mercury concentration must not exceed the reference limit for non-exposed (10 nmol/l).

**Further information**
Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
**Mercury, continued**

**Mercury in urine, U-Hg**

**Exposure**
Mercury and inorganic mercury compounds.

**Specimen**
20 ml of urine. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The Institute of Occupational Health provides special-washed sample containers in Finland.

**Sampling time**
Morning specimen toward the end of the working week or exposure period.

**Storage**
The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.

**Sources of error**
**Specimen is prone to contamination.** Dust from the work place air, or skin or clothing of the worker may contaminate the specimen. The specimen is collected before the worker has changed to work clothes.

**Note**
There is a strong diurnal variation in the concentration of mercury in urine. Therefore, the sample should be collected at a standardized time of the day, in the morning. The mandatory health insurance does not cover the costs of mercury analyses performed for the assessment of mercury exposure from dental amalgam. See also Mercury in blood, above.

**Reference limit for non-exposed**
20 nmol/l.

**Biomonitoring action limit**
140 nmol/l. This is based on the Ministry of Health and Social Affairs Decree 1214/2016. The Finnish Government Decree 1335/2004 stipulates that mercury and its compounds may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy, i.e., the urine mercury concentration must not exceed the reference limit for non-exposed (20 nmol/l).

**Further information**
Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
**Methanol**

Analysis of urinary methanol in a post-shift specimen collected at the end of the working week is recommended for the biological monitoring of exposure to methanol. The upper reference limit in a non-exposed population is 2 mg/l. No biomonitoring action limit has been established.

**Methanol in urine, U-MeOH**

- **Exposure**: Methanol.
- **Specimen**: 25 ml of urine.
  Urine sample is voided to a disposable vessel. Then, it is transferred immediately to a class container and closed with a Teflon stopper. The sample is let cool down in refrigerator. The Institute of Occupational Health provides sample containers in Finland.
- **Sampling time**: Post-shift specimen at the end of the working week or exposure period.
- **Storage and transport**: The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.
- **Reference limit for non-exposed**: 2 mg/l.
- **Biomonitoring action limit**: 15 mg/l. From 1.4.2014. The Finnish Government Decree 1335/2004 stipulates that organic solvents may be hazardous to foetus or pregnant women; thus exposure to methanol is not acceptable during pregnancy, i.e., the concentration of methanol must not exceed the reference limit for non-exposed (2 mg/l).

**Further information**

Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
**Methylene iodide (Diiodomethane)**

Analysis of carboxyhaemoglobin in a post-shift blood specimen, collected immediately after the cessation of the exposure, is recommended for biological monitoring of methylene iodide exposure. The upper reference limit in a non-exposed population is 0.015 (=1.5 %), and the biomonitoring action limit, 0.040 (=4 %). The biomonitoring action limit is based on the cardiovascular effects of carbon monoxide.

**Carboxyhaemoglobin in blood, B-Hb-CO**

**Exposure**
Diodomethane (methylene iodide).

**Specimen**
5 ml whole blood.
A heparinised vacuum tube (e.g., Venosafe®, Vacuette®) is filled with blood and mixed carefully with the anticoagulant.

**Sampling time**
Immediately after the cessation of the exposure.

**Storage and transport**
The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.

**Sources of error**
Smoking elevates the level of carboxyhaemoglobin. Reliable assessment of work exposure to diiodomethane requires refraining from smoking for at least 10 h.

**Reference limit for non-exposed**
0.015 (1.5 %).

**Biomonitoring action limit**
0.040 (4 %).
The Finnish Government Decree 1335/2004 stipulates that carbon monoxide may be hazardous to foetus or pregnant women. Therefore, a biomonitoring action limit of 0.02 (2%) is applied during pregnancy.

**Further information**
Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
**Molybdenum**

Analysis of molybdenum in urine in a post-shift specimen collected after the working week is recommended for the biological monitoring of antimony exposure. The upper reference limit in a non-exposed population is 1340 nmol/l, and no biomonitoring action limit has been established.

**Molybdenum in urine**

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Molybdenum and its inorganic compounds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen</td>
<td>20 ml of urine. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The laboratories of the Institute of Occupational Health provide special-washed sample containers.</td>
</tr>
<tr>
<td>Sampling time</td>
<td>Post-shift specimen at the end of the working week or exposure period</td>
</tr>
<tr>
<td>Storage and transport</td>
<td>The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the week-end. Specimens collected toward the end of the week are preferably kept in the refrigerator over the week end and sent on Monday.</td>
</tr>
<tr>
<td>Sources of error</td>
<td>Specimen is sensitive to contamination: Dust from the clothing or skin may contaminate the sample. The specimen is collected after the worker has showered (or washed hands and the urethral orifice) and changed to street clothes.</td>
</tr>
<tr>
<td>Note</td>
<td>The concentration of antimony, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, nickel, selenium, thallium, uranium, vanadium, and zinc may be determined from the same 20-ml specimen.</td>
</tr>
<tr>
<td>Reference limit for non-exposed</td>
<td>1340 nmol/l.</td>
</tr>
<tr>
<td>Biomonitoring action limit</td>
<td>Not established.</td>
</tr>
</tbody>
</table>

**Further information**

Suzana Abenet  
Biomonitoring services  
P.Box 40,  
FI-00032 TYÖTERVEYSLAITOS, Finland
**Naphthalene and mixtures of polycyclic aromatic hydrocarbons (PAH)**

Analysis of urinary 2-naphthol in a post-shift specimen at the end of the working week or exposure period, is recommended for the biological monitoring of naphthalene or mixtures of polycyclic aromatic hydrocarbons (PAH) containing naphthalene (e.g. wood creosote). The upper reference limit for a non-exposed population is 7 µg/l for non-smokers and 30 µg/l for smokers. No biomonitoring action limit has been established.

**2-Naphthol in urine, U-2-Naftol**

**Exposure**
Naphthalene and mixtures containing naphthalene (e.g. wood creosote).

**Specimen**
20 ml of urine.

**Sampling time**
Post-shift specimen at the end of the working week or exposure period.

**Storage and transport**
The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the week-end. Specimens collected toward the end of the week are preferably kept in the refrigerator over the week end and sent on Monday.

**Sources of error**
Consumption of broiled or grilled food may elevate urinary naphthol concentrations.

**Note**
Exposure to less volatile PAH mixtures is best assessed using the analysis of 1-pyrenol in urine.

**Reference limit for non-exposed**
Non-smokers 7 µg/l.
Smokers 30 µg/l.

**Biomonitoring action limit**
Not established.

The Finnish Ministry of Labour Decree 838/1993 stipulates that PAH compounds may be carcinogenic. European Union has classified naphthalene as possible carcinogen (Cat 3; R40, H351). According to the Finnish Government Decree 1335/2004 chemicals in these categories may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy, i.e., the urine naphthol concentration must not exceed the reference limit for non-exposed (7 µg/l, non-smokers; 30 µg/l, smokers).

**Further information**
Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
Nickel

Analysis of urinary nickel in a post-shift specimen collected at the end of the working week or exposure period is recommended for the biological monitoring of nickel exposure. The upper reference limit in a non-exposed population is 0.05 µmol/l. The biomonitoring action limit is 0.20 µmol/l in exposure to readily soluble and 0.10 µmol/l in exposure to slightly soluble nickel salts. Target level, 0.05 µmol/l, is based on DNEL (derived no–effect level).

Nickel in urine, U-Ni

**Exposure**
Nickel and inorganic nickel compounds.

**Specimen**
20 ml of urine. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The laboratories of the Institute of Occupational Health provide special-washed sample containers.

**Sampling time**
Post-shift specimen at the end of the working week or exposure period.

**Storage**
The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the week-end. Specimens collected toward the end of the week are preferably kept in the refrigerator over the week end and sent on Monday.

**Sources of error**
Specimen is prone to contamination. Dust from the work place air, or skin or clothing of the worker may contaminate the specimen. The specimen is collected after the worker has showered (or washed hands and the urethral orifice) and changed to street clothes.

**Note**
The concentration of antimony, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, selenium, thallium, uranium, vanadium and zinc may be determined from the same 20-ml specimen.

**Reference limit for non-exposed**
0.05 µmol/l.

**Biomonitoring action limit**
0.20 µmol/l in exposure to soluble nickel salts
0.10 µmol/l in exposure to nickel and slightly soluble nickel salts.
The target level is 0.05 µmol/l.
This is based on the Ministry of Health and Social Affairs Decree 1214/2016.
The European Union has classified nickel compounds as carcinogenic (Cat 1 or 3; R49 or R40, H350i, H351, H360D). The Finnish Government Decree 1335/2004 stipulates that chemicals in these categories may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy, i.e., the urine nickel concentration must not exceed the reference limit for non-exposed (0.05 µmol/l).

**Further information**
Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
Organophosphate insecticides

Acetylcholinesterase enzyme activity measurement in paired blood samples are recommended as indicators of exposure to organophosphate pesticides. The biomonitoring action limit is a 30% decrease in the acetylcholinesterase activity compared to the value observed before the exposure.

Acetylcholinesterase in blood, B-AChEs

**Exposure**
Organophosphate insecticides (e.g., azamethiphos, dimethoate).

**Specimen**
Whole blood (heparin as anticoagulant) as 12 separate spots on four filter papers:
5 ml of blood is collected in a heparinised vacuum tube (e.g. Venosafe®, Vacuette®,) and mixed carefully with the anticoagulant. Sample is let cool down for half an hour at room temperature. Then, 50 µl blood is transferred with a pipette onto filter paper. Altogether 12 spots on four separate discs of filter paper are needed; they are air-dried for one hour at room temperature and protected from direct sunlight. The filter paper discs are individually enclosed in small plastic bags (Minigrip®).

**Sampling time**
Paired samples, baseline specimen before starting the work (at least four weeks’ period without exposure to any organophosphate pesticide is needed), and the second specimen as a post-shift specimen at the end of the working week or exposure period.

**Storage**
The specimens closed in the plastic bags are stored dry at room temperature and protected from sunlight until sending.

**Interpretation**
Over a 30% decrease in the acetylcholinesterase activity indicates considerable exposure. Exposure should be stopped and work should not be continued until the activity reaches 70% of the baseline level.

**Further information**
Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
**Phenol**

Analysis of urinary phenol in a post-shift specimen is recommended for the biological monitoring of exposure to phenol. The upper reference limit in a non-exposed population is 0.2 mmol/l, and the biomonitoring action limit, corresponding to an 8-h TWA exposure to 2 ppm phenol is 1.3 mmol/l.

**Phenol in urine, U-Fenol**

**Exposure**
Phenol.

**Specimen**
20 ml of urine.

**Sampling time**
Post-shift specimen at the end of the working week or exposure period.

**Storage and transport**
The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.

**Sources of error**
Certain drugs (e.g., antiseptic mouth rinses) contain phenol/phenyl compounds and may increase the urinary phenol concentration.

**Note**
Urinary phenol concentration does not reliably indicate exposure to benzene. See benzene, t,t-muconic acid in urine.

**Reference limit for non-exposed**
0.2 mmol/l.

**Biomonitoring action limit**
1.3 mmol/l.
This is based on the Ministry of Health and Social Affairs Decree 1214/2016.
The European Union has classified phenol as possibly mutagenic (Cat. 3; R68, H341).
The Finnish Government Decree 1335/2004 stipulates that chemicals in this category may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy, i.e., the urine phenol concentration must not exceed the reference limit for non-exposed (0.2 mmol/l).

**Further information**
Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYS-LaITOS, Finland
**Polychlorinated biphenyls (PCB)**

Analysis of serum PCB in a fasting morning specimen is recommended for the biological monitoring of exposure to PCBs. The upper reference limit (sum of 3 most common chlorobiphenyls, PCB 138, PCB 153, PCB 180) in a non-exposed population age 50 years or younger is 1.0 µg/l and for people over 50 years the respective value is 1.8 µg/l. No biomonitoring action limit has been established.

**Polychlorinated biphenyls in fasting serum, fS-PCB**

**Exposure**
Polychlorinated biphenyls and products containing PCB.

**Specimen**
8 ml *fasting serum.*
Two 10 ml vacuum tubes (e.g., Venosafe® or Vacuette® without anticoagulant) are filled with blood and let clot. The serum is separated in a special-washed tube provided by the Institute.

**Sampling time**
Morning specimen before the beginning of the work shift at the end of the working week or exposure period. In sudden short term exposure, the first possible fasting specimen is collected.

**Storage and transport**
The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.

**Reference limit for non-exposed**
Sum of 3 chlorobiphenyl isomers
1.0 µg/l for people 50 years or younger, 1.8 µg/l for people over 50 years. Introduced in 1.1.2014.

**Biomonitoring action limit**
Not established.
The Finnish Ministry of Labour Decree 838/1993 stipulates that PCB compounds may be carcinogenic and may therefore be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy (Government Decree 1335/2004), i.e., blood serum PCB concentration must not exceed the reference limit for non-exposed (1.0 µg/l).

**Further information**
Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
Polycyclic aromatic hydrocarbons (PAH)

Analysis of urinary 1-pyrenol (1-hydroxypyrene) in a post-shift specimen collected at the end of the working week or exposure period is recommended for the biological monitoring of pyrene or PAH-mixtures containing pyrene. The upper reference limit for a non-exposed population is 0.8 µg/l and the biomonitoring action limit is 2.6 µg/l.

1-Pyrenol in urine, U-Pyr

**Exposure**

Pyrene, pyrene-containing mixtures of polycyclic aromatic hydrocarbons (PAH) such as creosote.

**Specimen**

20 ml of urine.

**Sampling time**

Post-shift specimen at the end of the working week or exposure period.

**Storage and transport**

The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.

**Sources of error**

Smoking increases urinary pyrenol concentrations 1-3 nmol/l. Likewise, consumption of broiled or grilled food may elevate urinary pyrenol concentrations.

**Note**

Exposure to more volatile PAH-mixtures may be assessed by the analysis of naphthol in urine.

**Reference limit for non-exposed**

0.8 µg/l.

**Biomonitoring action limit**

2.6 µg/l.

The Finnish Ministry of Labour Decree 838/1993 stipulates that PAH compounds may be carcinogenic. The European Union has classified pyrene fraction as possibly carcinogenic (H350). According to the Finnish Government Decree 1335/2004 chemicals in this category may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy, i.e., the urine pyrenol concentration must not exceed the reference limit for non-exposed (0.8 µg/l).

**Further information**

Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
Selenium

Analysis of selenium in a post-shift urine sample, collected at the end of the working week or exposure period, may be used for the biological monitoring of workers exposed to selenium. The upper reference limit is 0.07 mg/g creatinine. No biomonitoring action limit has been established.

Selenium in urine, U-Se

**Exposure**
Selenium and selenium compounds.

**Specimen**
20 ml of urine. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The Institute of Occupational Health provides special-washed sample containers in Finland.

**Sampling time**
Post-shift specimen at the end of the working week or exposure period.

**Storage and transport**
The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.

**Sources of error**
Specimen is prone to contamination. Dust from the work place air, or skin or clothing of the worker may contaminate the specimen. The specimen is collected after the worker has showered (or washed hands and the urethral orifice) and changed to street clothes.

**Notes**
Consumption of trace element preparations containing selenium (e.g., yeast-selenium preparations) elevates urinary selenium concentrations.

The concentration of antimony, beryllium, cadmium, chromium, cobalt, lead, manganese, molybdenum, nickel, thallium, uranium, vanadium, and zinc may be determined from the same 20-ml specimen.

**Reference limit for non-exposed**
0.07 mg/g creatinine.

**Bimonitoring action limit**
Not established.

**Further information**
Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
**Styrene**

Analysis of urinary mandelic and phenylglyoxylic acids in a morning specimen, collected at the end of the working week or exposure period, is recommended for the biological monitoring of styrene exposure. The upper reference limit in a non-exposed population is 0.2 mmol/l (sum of mandelic and phenylglyoxylic acids), and the biomonitoring action limit, corresponding to the occupational exposure limit of 20 ppm, is 1.2 mmol/l.

### Mandelic and phenylglyoxylic acids in urine, U-MaPGa

<table>
<thead>
<tr>
<th><strong>Exposure</strong></th>
<th>Styrene.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specimen</strong></td>
<td>20 ml of urine.</td>
</tr>
<tr>
<td><strong>Sampling time</strong></td>
<td>Morning specimen before the work shift at the end of the working week or exposure period.</td>
</tr>
<tr>
<td><strong>Storage and transport</strong></td>
<td>The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.</td>
</tr>
<tr>
<td><strong>Reference limit for non-exposed</strong></td>
<td>Sum of mandelic and phenylglyoxylic acids 0.2 mmol/l.</td>
</tr>
<tr>
<td><strong>Biomonitoring action limit</strong></td>
<td>Sum of mandelic and phenylglyoxylic acids 1.2 mmol/l. This is based on the Ministry of Health and Social Affairs Decree 1214/2016. The Finnish Government Decree 1335/2004 stipulates that organic solvents may be hazardous to foetus or pregnant women; thus exposure to styrene is not acceptable during pregnancy, i.e. the sum concentration of mandelic and phenylglyoxylic acids must not exceed the reference limit for non-exposed (0.2 mmol/l).</td>
</tr>
<tr>
<td><strong>Further information</strong></td>
<td>Suzana Abenet Biomonitoring services P.Box 40, FI-00032 TYÖTERVEYSLAITOS, Finland</td>
</tr>
</tbody>
</table>
**Tetrachloroethene (perchloroethylene)**

Analysis of tetrachloroethene in blood in a pre-shift morning specimen, collected at the end of the working week or exposure period, is recommended for the biological monitoring of continuous tetrachloroethene exposure. In occasional exposure, the specimen is collected next morning after the exposure. The upper reference limit in non-exposed persons is 0.1 µmol/l, and the biomonitoring action limit 1.2 µmol/l.

**Tetrachloroethene (perchloroethylene) in blood, B-PerklEt**

**Exposure**

Tetrachloroethene (Perchloroethylene).

**Specimen**

8 ml of whole blood.
A 10 ml heparinised vacuum tube (e.g., Venosafe®, Vacuette®) is filled with blood and mixed carefully with the anticoagulant.

**Sampling time**

Morning specimen before the work shift at the end of the working week or exposure period. In occasional exposure the specimen should be collected in the morning after the day of exposure.

**Storage and transport**

The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.

**Sources of error**

All exposure between the end of the workday and the sample collection in the following morning elevates blood tetrachloroethene concentration considerably and thus distorts the interpretation.

**Reference limit for non-exposed**

0.1 µmol/l.

**Biomonitoring action limit**

1.2 µmol/l.
This is based on the Ministry of Health and Social Affairs Decree 1214/2016.
The target level is 0.1 µmol/l.
The European Union has classified tetrachloroethene as possibly carcinogenic (Cat 3; R40, H351).
The Finnish Government Decree 1335/2004 stipulates that chemicals in this category may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy, i.e., the blood tetrachloroethene concentration must not exceed the reference limit for non-exposed (0.1 µmol/l).

**Further information**

Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
Thallium

Analysis of urinary thallium in a post-shift specimen is recommended for the biological monitoring of thallium exposure. The upper reference limit in a non-exposed population is 5 nmol/l. No biomonitoring action limit has been established.

Thallium in urine, U-Tl

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Thallium and inorganic thallium compounds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen</td>
<td>20 ml of urine. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The laboratories of the Institute of Occupational Health provide special-washed sample containers.</td>
</tr>
<tr>
<td>Sampling time</td>
<td>Post-shift specimen at the end of the working week or exposure period.</td>
</tr>
<tr>
<td>Storage and transport</td>
<td>The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.</td>
</tr>
<tr>
<td>Sources of error</td>
<td>Specimen is prone to contamination. Dust from the workplace air, or skin or clothing of the worker may contaminate the specimen. The specimen is collected after the worker has showered (or washed hands and the urethral orifice) and changed to street clothes.</td>
</tr>
<tr>
<td>Note</td>
<td>The concentration of antimony, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, uranium, vanadium, and zinc may be determined from the same 20-ml specimen.</td>
</tr>
<tr>
<td>Reference limit for non-exposed</td>
<td>5 nmol/l.</td>
</tr>
<tr>
<td>Biomonitoring action limit</td>
<td>Not established.</td>
</tr>
</tbody>
</table>
| Further information | Suzana Abenet  
Biomonitoring services  
P.Box 40,  
FI-00032 TYÖTERVEYSLAITOS, Finland |
**Toluene**

Analysis of toluene in blood in a pre-shift morning specimen, collected at the end of the working week or exposure period, is recommended for the biological monitoring of continuous toluene exposure. In occasional exposure, the specimen is collected in the morning after the exposure. The upper reference limit in a non-exposed population is 50 nmol/l and the biomonitoring action limit corresponding to an 8-h TWA exposure to 50 cm³/m³ of toluene is 500 nmol/l.

**Toluene in blood, B-Tolu**

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Toluene.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen</td>
<td>8 ml whole blood. A 10-ml heparinised vacuum tube (e.g., Vacuette®, Venosafe®) is filled with blood and mixed carefully with the anticoagulant.</td>
</tr>
<tr>
<td>Sampling time</td>
<td>Morning specimen before the work shift at the end of the working week or exposure period in continuous exposure. In occasional exposure the specimen should be collected in the morning after the day of exposure.</td>
</tr>
<tr>
<td>Storage and transport</td>
<td>The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.</td>
</tr>
<tr>
<td>Sources of error</td>
<td>All exposure between the end of the workday and the sample collection in the following morning elevates blood toluene concentration and thus distorts the interpretation.</td>
</tr>
<tr>
<td>Reference limit for non-exposed</td>
<td>50 nmol/l.</td>
</tr>
<tr>
<td>Biomonitoring action limit</td>
<td>500 nmol/l. This is based on the Ministry of Health and Social Affairs Decree 1214/2016. The European Union has classified toluene as possibly hazardous to reproduction (Cat 3; R63, H361d). Thus exposure is not acceptable during pregnancy, i.e., the blood toluene concentration must not exceed the reference limit for non-exposed (50 nmol/l).</td>
</tr>
</tbody>
</table>
| Further information | Suzana Abenet  
Biomonitoring services  
P.Box 40,  
FI-00032 TYÖTERVEYSLAITOS, Finland |
**Uranium**

Analysis of urinary uranium in a post-shift specimen collected at the end of the working week is recommended for the biological monitoring of exposure to uranium and uranium compounds. The upper reference limit in a non-exposed population is 0.03 µg/g creatinine. No biomonitoring action limit has been established.

**Uranium in urine, U-U**

<table>
<thead>
<tr>
<th>Exposure</th>
<th>Uranium and uranium compounds.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specimen</td>
<td>20 ml of urine. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The Institute of Occupational Health provides special-washed sample containers in Finland.</td>
</tr>
<tr>
<td>Sampling time</td>
<td>Post-shift specimen at the end of the working week or exposure period.</td>
</tr>
<tr>
<td>Storage and transport</td>
<td>The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.</td>
</tr>
<tr>
<td>Sources of error</td>
<td>Specimen is sensitive to contamination: Dust from the clothing or skin may contaminate the sample. The sample should be collected after washing the hands and the urethral orifice.</td>
</tr>
<tr>
<td>Note</td>
<td>The concentration of antimony, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, thallium, vanadium and zinc may be determined from the same 20-ml specimen.</td>
</tr>
<tr>
<td>Reference limit for non-exposed</td>
<td>0.03 µg/g creatinine.</td>
</tr>
<tr>
<td>Biomonitoring action limit</td>
<td>Not established.</td>
</tr>
<tr>
<td>Further information</td>
<td>Suzana Abenet Biomonitoring services P.Box 40, FI-00032 TYÖTERVEYSLAITOS, Finland</td>
</tr>
</tbody>
</table>
**Vanadium**

Analysis of urinary vanadium in a post-shift specimen collected at the end of the working week is recommended for the biological monitoring of exposure to vanadium and vanadium compounds. The upper reference limit in a non-exposed population is 7 nmol/l and the biomonitoring action limit 600 nmol/l.

**Vanadium in urine, U-V**

**Exposure**
Vanadium and vanadium compounds.

**Specimen**
20 ml of urine. Special-washed containers have to be used, and no preservatives may be added. If the urine sample is voided to a disposable vessel, it has to be transferred immediately to the special-washed sample container. The Institute of Occupational Health provides special-washed sample containers in Finland.

**Sampling time**
Post-shift specimen at the end of the working week or exposure period.

**Storage and transport**
The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.

**Sources of error**
Specimen is sensitive to contamination: Dust from the clothing or skin may contaminate the sample. The sample should be collected after washing the hands and the urethral orifice.

**Note**
The concentration of antimony, beryllium, cadmium, chromium, cobalt, copper, lead, manganese, molybdenum, nickel, selenium, thallium, uranium and zinc may be determined from the same 20-ml specimen.

**Reference limit for non-exposed**
7 nmol/l.

**Biomonitoring action limit**
600 nmol/l. The European Union has classified vanadium pentoxide as genotoxic (Cat 3; R68, H341) and hazardous to reproduction (Cat 3; R63, H361d). The Finnish Government Decree 1335/2004 stipulates that chemicals in these categories may be hazardous to foetus or pregnant women; thus exposure to them is not acceptable during pregnancy, i.e., the urine vanadium concentration must not exceed the reference limit for non-exposed (7 nmol/l).

**Further information**
Suzana Abenet
Biomonitoring services
P.Box 40,
FI-00032 TYÖTERVEYSLAITOS, Finland
## Xylenes

Analysis of urinary methylhippuric acids in a post-shift specimen is recommended for the biological monitoring exposure to xylenes. The upper reference limit (sum of the three isomers) in a non-exposed population is 0.2 mmol/l and the biomonitoring action limit, corresponding to an 8-h TWA exposure to 50 ppm xylene, is 5.0 mmol/l.

### Methylhippuric acids in urine, U-Methipp

<table>
<thead>
<tr>
<th><strong>Exposure</strong></th>
<th>Xylene.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Specimen</strong></td>
<td>20 ml of urine.</td>
</tr>
<tr>
<td><strong>Sampling time</strong></td>
<td>Post-shift specimen at the end of the working week or exposure period.</td>
</tr>
<tr>
<td><strong>Storage and transport</strong></td>
<td>The specimen is stored in a refrigerator and sent so that it reaches the laboratory before the weekend. Specimens collected toward the end of the week are preferably kept in the refrigerator over the weekend and sent on Monday.</td>
</tr>
</tbody>
</table>

**Reference limit for non-exposed**

| **Sum of isomers, 0.2 mmol/l.** |

**Biomonitoring action limit**

| **Sum of isomers, 5 mmol/l.** |

This is based on the Ministry of Health and Social Affairs Decree 1214/2016. The Finnish Government Decree 1335/2004 stipulates that organic solvents may be hazardous to foetus or pregnant women; thus the biomonitoring action limit applied during pregnancy is 0.7 µmol/l, corresponding to an exposure 10% of the Finnish occupational exposure limit.

**Further information**

Suzana Abenet  
Biomonitoring services  
P.Box 40,  
FI-00032 TYÖTERVEYSLAITOS, Finland
### Table 1. Limit values

<table>
<thead>
<tr>
<th>Analyses</th>
<th>Reference limit for non-exposed</th>
<th>Biomonitoring action limit / target level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkyl lead (urine)</td>
<td>0.008 µmol/l</td>
<td>0.1 µmol/l</td>
</tr>
<tr>
<td>Aluminium (urine)</td>
<td>0.6 µmol/l</td>
<td>3.0 µmol/l</td>
</tr>
<tr>
<td>Antimony</td>
<td>9 nmol/l</td>
<td>Not established.</td>
</tr>
<tr>
<td>Arsenic, inorganic</td>
<td>30 nmol/l</td>
<td>70 nmol/l</td>
</tr>
<tr>
<td>Asetylcholinesterase</td>
<td></td>
<td>30% decrease from the baseline level.</td>
</tr>
<tr>
<td>Beryllium</td>
<td>15 nmol/l</td>
<td>Not established.</td>
</tr>
<tr>
<td>Butoxyacetic acid</td>
<td>0.5 mmol/mol creat.</td>
<td>60 mmol/mol creat.</td>
</tr>
<tr>
<td>tert-Butylalcohol (TBA)</td>
<td>1 µmol/l</td>
<td>30 µmol/l</td>
</tr>
<tr>
<td>Cadmium (blood)</td>
<td>5 nmol/l (non-smokers)</td>
<td>50 nmol/l</td>
</tr>
<tr>
<td></td>
<td>18 nmol/l (smokers)</td>
<td></td>
</tr>
<tr>
<td>Cadmium (urine)</td>
<td>5 nmol/l (non-smokers)</td>
<td>20 nmol/l</td>
</tr>
<tr>
<td></td>
<td>10 nmol/l (smokers)</td>
<td></td>
</tr>
<tr>
<td>Carboxyhaemoglobin (blood)</td>
<td>0.015 ( = 1.5%)</td>
<td>0.040 ( = 4.0%)</td>
</tr>
<tr>
<td>Chromium (urine)</td>
<td>0.01 µmol/l</td>
<td>0.20 µmol/l</td>
</tr>
<tr>
<td></td>
<td>0.8 µg/l</td>
<td>7 µg/l</td>
</tr>
<tr>
<td>Cobalt (urine)</td>
<td>25 nmol/l</td>
<td>130 nmol/l</td>
</tr>
<tr>
<td></td>
<td>0.8 µg/l</td>
<td>7 µg/l</td>
</tr>
<tr>
<td>Copper (serum)</td>
<td>13 - 21 µmol/ men</td>
<td>Not established for occupational exposure.</td>
</tr>
<tr>
<td></td>
<td>12 - 28 µmol/l women</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0.14 - 1.0</td>
<td>Not established for occupational exposure.</td>
</tr>
<tr>
<td>(24-hour urine)</td>
<td>0.2 - 1.4 µmol/d</td>
<td>Not established for occupational exposure.</td>
</tr>
<tr>
<td>2-Ethoxyacetic acid</td>
<td>0.5 mmol/mol creat.</td>
<td>20 mmol/mol creat.</td>
</tr>
<tr>
<td>Formic acid</td>
<td>70 mmol/mol creat.</td>
<td>Not established.</td>
</tr>
<tr>
<td>2,5-Hexanedione</td>
<td>0.5 mmol/mol creat.</td>
<td>2 mmol/mol creat.</td>
</tr>
<tr>
<td>Hydroxy-N-methyl-2-pyrrolidone</td>
<td>1 µmol/l</td>
<td>900 µmol/l</td>
</tr>
<tr>
<td>Indium</td>
<td>0.02 µg/l</td>
<td>Not established.</td>
</tr>
<tr>
<td>Isocyanate metabolites</td>
<td>0.2 µmol/mol creat.</td>
<td>Not established.</td>
</tr>
<tr>
<td>Lead (blood)</td>
<td>0.09 µmol/l</td>
<td>1.4 µmol/l</td>
</tr>
<tr>
<td>Mandelic acid</td>
<td>0.2 mmol/l</td>
<td>4.0 mmol/l exposure to ethylbenzene</td>
</tr>
<tr>
<td>Mandelic and phenylglyoxylic acids</td>
<td>0.2 mmol/l</td>
<td>1.2 mmol/l</td>
</tr>
<tr>
<td>Manganese (urine)</td>
<td>10 nmol/l</td>
<td>Not established.</td>
</tr>
<tr>
<td></td>
<td>295 nmol/l</td>
<td>Not established for occupational exposure.</td>
</tr>
<tr>
<td>Mercury, inorganic (blood)</td>
<td>10 nmol/l</td>
<td>50 nmol/l</td>
</tr>
<tr>
<td>Mercury (urine)</td>
<td>20 nmol/l</td>
<td>140 nmol/l</td>
</tr>
<tr>
<td>Methanol</td>
<td>2 mg/l</td>
<td>15 mg/l</td>
</tr>
<tr>
<td>2-(2-Methoxyethoxy)acetic acid</td>
<td>0.5 mol/mol creat.</td>
<td>50 mmol/mol creat.</td>
</tr>
<tr>
<td>1-Methoxy-2-propanol</td>
<td>5 µmol/l</td>
<td>100 µmol/l</td>
</tr>
<tr>
<td>Analyses</td>
<td>Reference limit for non-exposed</td>
<td>Biomonitoring action limit / target level</td>
</tr>
<tr>
<td>----------------------------------------------</td>
<td>---------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Methylenebis(2-chloroaline)</td>
<td>0.5 µmol/mol creat.</td>
<td>5 µmol/mol creat.</td>
</tr>
<tr>
<td>Methyleneedianiline</td>
<td>0.5 µmol/mol creat.</td>
<td>3 µmol/mol creat.</td>
</tr>
<tr>
<td>Methylenedianiline</td>
<td></td>
<td>0.5 µmol/mol creat. target level</td>
</tr>
<tr>
<td>Methyl ethyl ketone (2-Butanone)</td>
<td>1.5 µmol/l</td>
<td>20 µmol/l</td>
</tr>
<tr>
<td>Methylhippuric acids</td>
<td>0.2 mmol/l</td>
<td>5 mmol/l</td>
</tr>
<tr>
<td>Methyl isobutyl ketone</td>
<td>0.1 mmol/mol creat.</td>
<td>0.5 mmol/mol creat.</td>
</tr>
<tr>
<td>Molybdenum (urine)</td>
<td>1340 nmol/l</td>
<td>Not established.</td>
</tr>
<tr>
<td>(blood)</td>
<td>1,4 µg/l</td>
<td>Not established.</td>
</tr>
<tr>
<td>trans,trans-Muconic acid</td>
<td>2 µmol/l</td>
<td>14 µmol/l</td>
</tr>
<tr>
<td>2-Naphthol</td>
<td>7 µg/l (non-smokers)</td>
<td>Not established.</td>
</tr>
<tr>
<td>Nickel (soluble salts)</td>
<td>0.05 µmol/l</td>
<td>0.20 µmol/l</td>
</tr>
<tr>
<td>(slightly soluble salts)</td>
<td>0.05 µmol/l</td>
<td>0.10 µmol/l</td>
</tr>
<tr>
<td>Phenol</td>
<td>0.2 mmol/l</td>
<td>1.3 mmol/l</td>
</tr>
<tr>
<td>Phenoxycbenzoic acid</td>
<td>1 µmol/mol creat.</td>
<td>Not established.</td>
</tr>
<tr>
<td>Polychlorinated biphenyls (PCB)</td>
<td>1.0 µg/l individuals age 50 years or younger</td>
<td>Not established.</td>
</tr>
<tr>
<td>1-Pyrenol</td>
<td>0.8 µg/l</td>
<td>2.6 µg/l</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.07 mg/g creat.</td>
<td>Not established.</td>
</tr>
<tr>
<td>Retinol binding protein</td>
<td>300 µg/g creat.</td>
<td>Possible irreversible affects &gt; 1000 µg/g creat.</td>
</tr>
<tr>
<td>Tetrachloroethene (perchloroethylene)</td>
<td>0.1 µmol/l</td>
<td>1.2 µmol/l</td>
</tr>
<tr>
<td>Thallium</td>
<td>5 nmol/l</td>
<td>0.1 µmol/l target level.</td>
</tr>
<tr>
<td>2-Thiothiazolidine-4-carboxylic acid</td>
<td>0.3 mmol/mol creat.</td>
<td>Not established.</td>
</tr>
<tr>
<td>Titanium (blood)</td>
<td>1 µg/l</td>
<td>Not established for occupational exposure.</td>
</tr>
<tr>
<td>(urine)</td>
<td>680 nmol/l</td>
<td>Not established for occupational exposure.</td>
</tr>
<tr>
<td>Toluene</td>
<td>50 nmol/l</td>
<td>500 nmol/l</td>
</tr>
<tr>
<td>Trichloroacetic acid</td>
<td>30 µmol/l</td>
<td>120 µmol/l</td>
</tr>
<tr>
<td>Uranium</td>
<td>0.03 µg/g creat.</td>
<td>Not established.</td>
</tr>
<tr>
<td>Vanadium</td>
<td>7 nmol/l</td>
<td>600 nmol/l</td>
</tr>
<tr>
<td>Zinc (fasting plasma)</td>
<td>7 - 14 µmol/l</td>
<td>Not established for occupational exposure.</td>
</tr>
<tr>
<td>(urine)</td>
<td>1 – 12 µmol/l</td>
<td>Not established for occupational exposure.</td>
</tr>
</tbody>
</table>