

APPENDIX B

BIOLOGICAL EXPOSURE GUIDELINES (ACGIH BEI AND OSHA EXPANDED STANDARDS ONLY)

TABLE B-1. ADOPTED BIOLOGICAL EXPOSURE INDICES (BEIs) – ACGIH (2012)					
Chemical	CAS No.	Determinant	Sampling Time	BEI®	Notation
<i>B = Background</i>	<i>Ns = Nonspecific</i>	<i>Nq = Nonquantitative</i>		<i>Sq = Semi-quantitative</i>	
Acetone	67-64-1	Acetone in urine	End of shift	50 mg/L	Ns
Acetylcholinesterase inhibiting pesticides	N/A	Cholinesterase activity in red blood cells	Discretionary	70% of individual's baseline	Ns
Aniline	62-53-3	Aniline in urine ¹	End of shift	—	Nq
		Aniline released from hemoglobin in blood	End of shift	—	Nq
		p-Aminophenol in urine ¹	End of shift	50 mg/L	B, Ns, Sq
Arsenic, elemental and soluble inorganic compounds (excludes gallium arsenide and arsine)	7440-38-2	Inorganic arsenic plus methylated metabolites in urine	End of workweek	35 µg As/L	B
Benzene	71-43-2	S-Phenylmercapturic acid in urine	End of shift	25 µg/g creatinine	B
		t,t-Muconic acid in urine	End of shift	500 µg/g creatinine	B
1,3-Butadiene	106-99-0	1,2 Dihydroxy-4-(N-acetylcysteiny)-butane in urine	End of shift	2.5 mg/L	B, Sq
		Mixture of N-1- and N-2-(hydroxybutenyl) valine hemoglobin (Hb) adducts in blood	Not critical	2.5 pmol/g Hb	Sq
2-Butoxyethanol	111-76-2	Butoxyacetic acid (BAA) in urine ¹	End of shift	200 mg/g creatinine	—
Cadmium and inorganic compounds	7440-43-9	Cadmium in urine	Not critical	5 µg/g creatinine	B
		Cadmium in blood	Not critical	5 µg/L	B
Carbon disulfide	75-15-0	2-Thioxothiazolidine-4-carboxylic acid (TTCA) in urine	End of shift	0.5 mg/g creatinine	B, Ns

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Carbon monoxide	630-08-0	Carboxyhemoglobin in blood	End of shift	3.5% of hemoglobin	B, Ns
		Carbon monoxide in end-exhaled air	End of shift	20 ppm	B, Ns
Chlorobenzene	108-90-7	4-Chlorocatechol in urine ¹	End of shift at end of workweek	100 mg/g creatinine	Ns
		p-Chlorophenol in urine ¹	End of shift at end of workweek	20 mg/g creatinine	Ns
Chromium (VI), water soluble fume	N/A	Total chromium in urine	End of shift at end of workweek	25 µg/L	—
		Total chromium in urine	Increase during shift	10 µg/L	—
Cobalt	7440-48-4	Cobalt in urine	End of shift at end of workweek	15 µg/L	B
		Cobalt in blood	End of shift at end of workweek	1 µg/L	B, Sq
Cyclohexanol	108-93-0	1,2-Cyclohexanediol in urine ¹	End of shift at end of workweek	—	Nq, Ns
		Cyclohexanol in urine ¹	End of shift	—	Nq, Ns
Cyclohexanone	108-94-1	1,2-Cyclohexanediol in urine ¹	End of shift at end of workweek	80 mg/L	Ns, Sq
		Cyclohexanol in urine ¹	End of shift	8 mg/L	Ns, Sq
Dichloromethane	75-09-2	Dichloromethane in urine	End of shift	0.3 mg/L	Sq
N,N-Dimethylacetamide	127-19-5	N-Methylacetamide in urine	End of shift at end of workweek	30 mg/g creatinine	—

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N,N-Dimethylformamide (DMF)	68-12-2	N-Methylformamide in urine	End of shift	15 mg/L	—
		N-Acetyl-S-(N-methylcarbamoyl) cysteine in urine	Prior to last shift of workweek	40 mg/L	Sq
2-Ethoxyethanol (EGEE) and 2-Ethoxyethyl acetate (EGEEA)	110-80-5; 111-15-9	2-Ethoxyacetic acid in urine ¹	End of shift at end of workweek	100 mg/g creatinine	—
Ethyl benzene ³	100-41-4	Sum of mandelic acid and phenylglyoxylic acid in urine	End of shift at end of workweek	(0.7 g/g creatinine)	Ns (Sq)
		(Ethyl benzene in end-exhaled air)	(Not critical)	(—)	(Sq)
Fluorides	109-86-4	Fluoride in urine	Prior to shift	2 mg/L	B, Ns
		Fluoride in urine	End of shift	3 mg/L	B, Ns
Furfural	98-01-1	Furoic acid in urine ¹	End of shift	200 mg/L	Ns
n-Hexane	110-54-3	2,5-Hexanedion in urine ²	End of shift at end of workweek	0.4 mg/L	—
Lead ⁴	7439-92-1	Lead in blood	Not critical	30 µg/100 ml	—
Mercury ⁵	N/A	(Total inorganic mercury in urine)	Prior to shift	(35 µg/g creatinine)	(B)
		(Total inorganic mercury in blood)	(End of shift at end of workweek)	(15 µg/L)	(B)
Methanol	67-56-1	Methanol in urine	End of shift	15 mg/L	B, Ns
Methemoglobin inducers	N/A	Methemoglobin in blood	During or end of shift	1.5% of hemoglobin	B, Ns, Sq
2-Methoxyethanol (EGME) and 2-Methoxyethyl acetate (EGMEA)	109-86-4 and 110-49-6	2-Methoxyacetic acid in urine	End of shift at end of workweek	1 mg/g creatinine	—
Methyl n-butyl ketone	591-78-6	2,5-Hexanedione in urine ²	End of shift at end of workweek	0.4 mg/L	—

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Methyl chloroform	71-55-6	Methyl chloroform in end-exhaled air	Prior to last shift of workweek	40 ppm	—
		Trichloroacetic acid in urine	End of workweek	10 mg/L	Ns, Sq
		Total trichloroethanol in urine	End of shift at end of workweek	30 mg/L	Ns, Sq
		Total trichloroethanol in blood	End of shift at end of workweek	1 mg/L	Ns
4,4'-Methylene bis(2-chloroaniline) (MBOCA)	101-14-4	Total MBOCA in urine	End of shift	—	Nq
Methyl ethyl ketone (MEK) ⁶	78-93-3	MEK in urine	End of shift	2 mg/L	(—)
Methyl isobutyl ketone (MIBK)	108-10-1	MIBK in urine	End of shift	1 mg/L	(—)
N-Methyl-2-pyrrolidone	872-50-4	5-Hydroxy-N-methyl-2-pyrrolidone in urine	End of shift	100 mg/L	(—)
Naphthalene ⁷	91-20-3	1-Naphthol ¹ + 2-Naphthol ¹	End of shift	—	Nq, Ns
Nitrobenzene	98-95-3	Total p-nitrophenol in urine	End of shift at end of workweek	5 mg/g creatinine	Ns
		Methemoglobin in blood	End of shift	1.5% of hemoglobin	B, Ns, Sq
Parathion	56-38-2	Total p-nitrophenol in urine	End of shift	0.5 mg/g creatinine	Ns
		Cholinesterase activity in red cells	Discretionary	70% of individual's baseline	B, Ns, Sq
Pentachlorophenol (PCP) ⁸	87-86-5	(Total PCP in urine)	(Prior to last shift of workweek)	(2 mg/g creatinine)	(B)
		(Free PCP in plasma)	(End of shift)	(5 mg/L)	(B)

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Phenol	108-95-2	Phenol in urine ¹	End of shift	250 mg/g creatinine	B, Ns
Polycyclic aromatic hydrocarbons (PAHs)	varies with the compound or mixture	1-Hydroxypyrene (1-HP) in urine ¹	End of shift at end of workweek	—	Nq
2-Propanol	67-63-0	Acetone in urine	End of shift at end of workweek	40 mg/L	B, Ns
Styrene	100-42-5	Mandelic acid plus phenylglyoxylic acid in urine	End of shift	400 mg/g creatinine	Ns
		Styrene in venous blood	End of shift	0.2 mg/L	Sq
Tetrachloroethylene	127-18-4	Tetrachloroethylene in end-exhaled air	Prior to shift	3 ppm	—
		Tetrachloroethylene in blood	Prior to shift	0.5 mg/L	—
Tetrahydrofuran	109-99-9	Tetrahydrofuran in urine	End of shift	2 mg/L	—
Toluene	108-88-3	Toluene in blood	Prior to last shift of workweek	0.02 mg/L	—
		Toluene in urine	End of shift	0.03 mg/L	—
		o-Cresol in urine ¹	End of shift	0.3 mg/g creatinine	B
Toluene diisocyanate ⁹	584-84-9; 91-08-7	Toluene diamine in urine ¹	End of shift	5 µg/g creatinine	Ns
Trichloroethylene	79-01-6	Trichloroacetic acid in urine	End of shift at end of workweek	15 mg/L	Ns
		Trichloroethanol in blood ²	End of shift at end of workweek	0.5 mg/L	Ns
		Trichloroethylene in blood	End of shift at end of workweek	—	Sq
		Trichloroethylene in end-exhaled air	End of shift at end of workweek	—	Sq

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Uranium	7440-61-1	Uranium in urine	End of shift	200 µg/L	—
Xylenes (technical or commercial grade)	95-47-6; 108-38-3; 106-42-3; 1330-20-7	Methylhippuric acids in urine	End of shift	1.5 g/g creatinine	—

¹ Denotes with hydrolysis.

² Denotes without hydrolysis; n-hexane, methyl n-butyl ketone and trichloroethylene.

³ 2012 Notice of Intended Changes (NIC) revises ethyl benzene entry as follows: Sum of mandelic and phenylglyoxylic acids in urine; end of shift at end of workweek; 0.15 g/g creatinine; Ns.

⁴ 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/dl. If the blood Pb 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. (CDC: Preventing Lead Poisoning in Young Children, October 1991; See BEI® and TLV® *Documentation for Lead*).

⁵ 2012 NIC revises mercury entry as follows: Mercury in urine; prior to shift; 20 µg Hg/g creatinine.

⁶ 2012 NIC revises methyl ethyl ketone entry as follows: Methyl ethyl ketone in urine; end of shift; 2 mg/L; Ns.

⁷ 2012 NIC revises naphthalene entry as follows: 1-Naphthol (with hydrolysis) + 2-Naphthol (with hydrolysis); end of shift; no BEI®; Nq, Ns.

⁸ 2012 NIC revises pentachlorophenol entry as follows: Pentachlorophenol (with hydrolysis) in urine; discretionary; no BEI®; Nq.

⁹ 2012 NIC revises toluene diisocyanate entry as follows: Toluene diamine in urine (with hydrolysis) (sum of 2,4- and 2,6- isomers); end of shift; 5 µg/g creatinine; Ns.

**TABLE B-2. OSHA GENERAL INDUSTRY STANDARD-SPECIFIC BIOLOGICAL MONITORING REQUIREMENTS
(29 CFR 1910)**

OSHA Standard	Substance	Analyte(s)	Monitoring Frequency
<i>Note: This table provides a summary of biological monitoring requirements. For detailed information, refer to the listed standard.</i>			
1910.1017	Vinyl chloride	Serum specimen testing for: <ul style="list-style-type: none"> • Total bilirubin • Alkaline phosphatase • Serum glutamic oxalacetic transaminase (SGOT) • Serum glutamic pyruvic transaminase (SGPT) • Gamma glutamyl transpeptidase 	For workers exposed above the action level: <ul style="list-style-type: none"> • Initial medical examination • Every 6 months for each employee who has been employed in vinyl chloride or polyvinyl chloride manufacturing for 10 years or longer. • Annually for all other employees. • After exposure during emergency situations.
1910.1025	Lead	Blood sample testing for: <ul style="list-style-type: none"> • Blood lead • Zinc protoporphyrin (ZPP) Blood sample testing for: <ul style="list-style-type: none"> • Blood lead • Hemoglobin and hematocrit determinations, red cell indices, and examination of smear morphology. • ZPP • Blood urea nitrogen • Serum creatinine • Regular urinalysis with microscopic examination. 	For workers who are or may be exposed at or above the action level for more than 30 days per year: <ul style="list-style-type: none"> • At least every six months • At least every two months for each worker whose last blood sampling and analysis indicated a blood lead level at or above 40 µg/100 g of whole blood (continuing until two consecutive blood samples and analyses indicate a blood lead level below 40 µg/100 g of whole blood). • Within two weeks after receipt of results indicating a blood lead level exceeding the numerical criterion for medical removal (60 µg/100 g of whole blood). • At least monthly during the removal period of each worker removed from exposure to lead due to an elevated blood lead level. For workers who are or may be exposed at or above action level for more than 30 days per year: <ul style="list-style-type: none"> • Initial exam • Annually, if blood lead level is at or above 40 µg/100 g of whole blood at any time in the preceding 12 months.

**TABLE B-2. OSHA GENERAL INDUSTRY STANDARD-SPECIFIC BIOLOGICAL MONITORING REQUIREMENTS
(29 CFR 1910)**

OSHA Standard	Substance	Analyte(s)	Monitoring Frequency
<i>Note: This table provides a summary of biological monitoring requirements. For detailed information, refer to the listed standard.</i>			
		Pregnancy testing or laboratory evaluation of male fertility, if requested by worker.	<ul style="list-style-type: none"> • As soon as possible upon notification by worker of development of signs/symptoms of lead intoxication, worker desires medical advice on effects of current/past exposure on ability to procreate a healthy child, or worker has demonstrated difficulty in breathing during a respirator fitting test or during use. • As medically appropriate for worker removed from exposure due to risk of material impairment of health or otherwise limited pursuant to final medical determination.
1910.1027	Cadmium	<p>Urine testing for:</p> <ul style="list-style-type: none"> • Cadmium in urine (CdU), standardized to grams of creatinine (g/Cr) • Beta-2 microglobulin in urine (B(2)-M), standardized to grams of creatinine (g/Cr), with pH specified <p>Blood sample testing for:</p> <ul style="list-style-type: none"> • Cadmium in blood (CdB), standardized to liters of whole blood (lwb) <p>During required periodic medical examinations workers should be additionally tested for:</p> <ul style="list-style-type: none"> • Blood urea nitrogen • Complete blood count • Serum creatinine • Urinalysis – additional testing for albumin, glucose, and total and low molecular weight proteins. 	<p>For currently and/or previously exposed workers, as specified in the standard:</p> <ul style="list-style-type: none"> • Initial exam • At least annually <ul style="list-style-type: none"> • Within one year after initial exam, and at least biennially thereafter. • At varying follow-up frequencies depending on whether currently or previously exposed and biological monitoring findings, as specified in the standard. • After acute exposure during emergency situations. • Upon termination, as specified in the standard.

**TABLE B-2. OSHA GENERAL INDUSTRY STANDARD-SPECIFIC BIOLOGICAL MONITORING REQUIREMENTS
(29 CFR 1910)**

OSHA Standard	Substance	Analyte(s)	Monitoring Frequency
<i>Note: This table provides a summary of biological monitoring requirements. For detailed information, refer to the listed standard.</i>			
1910.1028	Benzene	Complete blood count testing for: <ul style="list-style-type: none"> • Leukocyte count with differential • Quantitative thrombocyte count • Hematocrit • Hemoglobin • Erythrocyte count and erythrocyte indices After exposure during emergency situations: <ul style="list-style-type: none"> • Urinary phenol test (to be performed on end-of-shift urine sample within 72 hours of the emergency exposure). 	For workers exposed under the exposure scenarios specified in the standard: <ul style="list-style-type: none"> • Initial exam • Annually • Complete blood count repeated within two weeks of initial or periodic examination results indicating abnormal blood conditions specified in the standard. After exposure during emergency situations: <ul style="list-style-type: none"> • Complete blood count tests monthly for three months following exposure if phenol test is ≥ 75 mg phenol/Liter of urine.
1910.1029	Coke oven emissions	Urinalysis testing for: <ul style="list-style-type: none"> • Sugar • Albumin • Hematuria Urinary cytology examination	For workers working in regulated areas at least 30 days per year: <ul style="list-style-type: none"> • Initial exam • Annual urinalysis testing • Annual urinalysis testing plus urinary cytology examination for workers ≥ 45 years old or with \geq five years employment in regulated areas. • Upon termination if worker has not had examination within preceding six months.
1910.1030	Bloodborne pathogens	Blood sample testing for: <ul style="list-style-type: none"> • Hepatitis B virus (HBV) and human immunodeficiency virus (HIV) (source individual) • HBV and HIV (exposed individual) 	Immediately after an exposure incident: <ul style="list-style-type: none"> • Source individual - As soon as feasible, provided consent is obtained as necessary. • Exposed worker - As soon as feasible after consent is obtained. If consent is not obtained for HIV serologic testing at time of baseline blood collection, the sample shall be preserved for at least 90 days, during which time it shall be tested as soon as feasible if consent is obtained.

**TABLE B-2. OSHA GENERAL INDUSTRY STANDARD-SPECIFIC BIOLOGICAL MONITORING REQUIREMENTS
(29 CFR 1910)**

OSHA Standard	Substance	Analyte(s)	Monitoring Frequency
<i>Note: This table provides a summary of biological monitoring requirements. For detailed information, refer to the listed standard.</i>			
1910.1044	1,2-Dibromo-3-chloropropane (DBCP)	Serum specimen testing for: <ul style="list-style-type: none"> • Serum follicle stimulating hormone (FSH) • Serum luteinizing hormone (LH) • Serum total estrogen (females) Sperm count After exposure during emergency situations: <ul style="list-style-type: none"> • Sperm count or above hormone tests if worker has vasectomy or is unable to produce semen. 	For workers in regulated areas: <ul style="list-style-type: none"> • Initial exam • Annually After exposure during emergency situations: <ul style="list-style-type: none"> • As soon as practicable after exposure and repeated three months after exposure.
1910.1045	Acrylonitrile	Test of the intestinal tract, including fecal occult blood screening (for all workers 40 years of age or older, and for any other affected workers for whom, in the opinion of the physician, such testing is appropriate).	For workers who are or will be exposed at or above the action level: <ul style="list-style-type: none"> • Initial exam • Annually • Upon termination if worker has not had examination within preceding six months.

**TABLE B-2. OSHA GENERAL INDUSTRY STANDARD-SPECIFIC BIOLOGICAL MONITORING REQUIREMENTS
(29 CFR 1910)**

OSHA Standard	Substance	Analyte(s)	Monitoring Frequency
<i>Note: This table provides a summary of biological monitoring requirements. For detailed information, refer to the listed standard.</i>			
1010.1047	Ethylene oxide (EtO)	Complete blood count testing for: <ul style="list-style-type: none"> • White cell count (including differential cell count). • Red cell count • Hematocrit • Hemoglobin 	For workers who are or may be exposed at or above the action level for at least 30 days per year: <ul style="list-style-type: none"> • Initial exam • Annually • At termination, or at reassignment to an area without such exposures. After exposure during emergency situations, as medically appropriate. As soon as possible after notification by a worker: <ul style="list-style-type: none"> • Of development of signs or symptoms indicating possible overexposure. • That worker desires medical advice concerning the effects of current or past exposure to EtO on the worker's ability to produce a healthy child.
1910.1050	Methylenedianiline (MDA)	<ul style="list-style-type: none"> • Liver function tests • Urinalysis 	For workers exposed at or above the action level for at least 30 days per year, subject to dermal exposure at least 15 days per year, or whom employers have reason to believe are being dermally exposed: <ul style="list-style-type: none"> • Initial exam • Annually After exposure during emergency situations and when workers develop signs/symptoms of exposure: <ul style="list-style-type: none"> • Initial exam • Repeat liver function tests on physician's advice. If tests are normal, repeat two to three weeks after initial tests. If both are normal, no further testing is required.

**TABLE B-2. OSHA GENERAL INDUSTRY STANDARD-SPECIFIC BIOLOGICAL MONITORING REQUIREMENTS
(29 CFR 1910)**

OSHA Standard	Substance	Analyte(s)	Monitoring Frequency
<i>Note: This table provides a summary of biological monitoring requirements. For detailed information, refer to the listed standard.</i>			
1910.1051	1,3-Butadiene (BD)	Complete blood count with differential and platelet count.	<p>Annually for workers exposed at or above the action level for at least 30 days per year; or at or above the PELs for at least 10 days per year;</p> <p>Annually for workers even after transfer to non-BD exposure jobs (regardless of when transferred) if work history suggests BD exposure:</p> <ul style="list-style-type: none"> ○ At or above the PELs on ≥ 30 days per year for 10 or more years. ○ At or above the action level for ≥ 60 days per year for 10 or more years. ○ Above 10 ppm for ≥ 30 days in any past year. <p>After exposure during emergency situations</p> <ul style="list-style-type: none"> ● As quickly as possible, but no later than 48 hours after an emergency exposure, then monthly for three months.

**TABLE B-2. OSHA GENERAL INDUSTRY STANDARD-SPECIFIC BIOLOGICAL MONITORING REQUIREMENTS
(29 CFR 1910)**

OSHA Standard	Substance	Analyte(s)	Monitoring Frequency
<i>Note: This table provides a summary of biological monitoring requirements. For detailed information, refer to the listed standard.</i>			
1910.1052	Methylene chloride (MC)	<p>The physician or other licensed healthcare professional shall determine the extent of any required laboratory surveillance based on the worker's observed health status and the medical and work history.</p> <p>After exposure during emergency situations (laboratory surveillance as indicated by the worker's health status).</p>	<p>For workers exposed: at or above the action level for at least 30 days per year; at or above the eight-hour TWA PEL or the STEL for at least 10 days per year; or above the eight-hour TWA PEL or STEL for any length of time where a worker has been identified as being at risk from cardiac disease or some other serious MC-related health condition (and requests inclusion in the medical surveillance program):</p> <ul style="list-style-type: none"> • Initial exam • Within 12 months of last surveillance for worker's age 45 years or older, or within 36 months of last surveillance for worker's less than 45 years old. • Upon termination, or reassignment to an area with MC exposure consistently at or below the action level and STEL if the worker has not had surveillance within the preceding six months. • Additional surveillance at frequency (other than above) when recommended in written medical opinion. <p>After exposure during emergency situations.</p>