Recommendation of Occupational Exposure Limits
(2016–2017)

The Japan Society for Occupational Health

The Japan Society for Occupational Health (JSOH) recommends the Occupational Exposure Limits (OELs) as reference values for preventing adverse health effects on workers caused by occupational exposure to chemical substances, continuous or intermittent noise, impulsive or impact noise, heat stress, cold stress, whole-body vibration, hand-arm vibration and time-varying electric, magnetic and electromagnetic fields and ultraviolet and ionizing radiation.

Characteristics of OELs and Instructions for Users

1. OELs should be applied by individuals well-trained and experienced in occupational health.
2. OELs cannot be applied in cases where exposure duration or work intensity exceeds the prerequisite conditions for setting an OEL.
3. OELs are set based on various information obtained from experiences in industries and experiments on humans and animals. However, the quantity and quality of information used in setting OELs is not always the same.
4. Types of health effects considered in setting OELs depend on the substances involved; an explicit health impairment provides the basis for OELs in certain substances, while health effects such as discomfort, irritation or CNS suppressive effects afford the basis in others. Thus, OELs cannot be used simply as a relative scale of toxicity.
5. Due to the variance in individual susceptibilities, discomfort, deterioration of pre-existing ill health or occupational disease may be induced at levels of exposure below the OELs, even though the chances of this should be remote.
6. Because OELs do not represent a definitive borderline between safe and hazardous conditions, it is not correct to conclude that working environments above OEL are the direct and sole cause of health impairment in workers, or vice versa.
7. OELs cannot be applied as reference values in non-occupational environments.
8. OELs will be revised when JSOH considers it necessary.
9. JSOH welcomes the submission, by concerned parties or individuals, of opinions based on scientific aspects of OELs.
10. In the reproduction of any Tables and/or Figures of OELs, JSOH requires that the full text of OELs be quoted to prevent misunderstanding and misuse.

I. Occupational Exposure Limits for Chemical Substances

1. Definitions

Exposure concentration is defined as the concentration of a chemical substance in air which will be inhaled by a worker during a job without the use of protective respiratory equipment.

Occupational Exposure Limit-Mean (OEL-M) for mean concentration of a chemical substance is defined as the reference value to the mean exposure concentration at or below which adverse health effects caused by the substance do not appear in most workers working for 8 hours a day, 40 hours a week under a moderate work-load. Exposure above OEL-M should be avoided even where duration is short or work intensity is light. If mean levels and duration of exposure corresponding to segments of various jobs can be measured or estimated, then an overall exposure concentration can be determined as the time-weighted average concentration.

Occupational Exposure Limit-Ceiling (OEL-C) of occupational exposure to a chemical substance is defined as the reference value to the maximal exposure concentration of the substance during a working day at or below which adverse health effects do not appear in most workers. The main reason why OEL-C is recommended for some substances is that the toxicity in question can induce immediate adverse effects such as irritation or CNS suppressive effects. However, it is quite difficult in practice to measure the momentary maximal exposure concentration. Short-term measurement lasting for 5 minutes or less at the time when the highest exposure concentration is expected may be used as a substitute for the measurement of maximal exposure concentration.
2. Variability of exposure concentration

Exposure concentration fluctuates around the mean value. OEL-M should be referred to only when the fluctuation is not large. Allowable range of fluctuation depends on the substance. In practical terms, the mean exposure concentration for a period of 15 minutes during which maximum exposure concentration is expected should not exceed 1.5 times OEL-M, unless otherwise notified.

3. Skin absorption

“S” marks in Tables I-1 and I-2 show that a significant dose from the view of systemic health effects or absorption of the substance concerned may be absorbed through the skin when the substance is in contact with the skin. OELs are set at conditions under which no skin absorption will take place.

4. Interaction with other working conditions

Other working conditions, such as work intensity, heat stress and abnormal atmospheric pressure, must be considered, since their co-existence could cause an increase in the inhaled dose of a chemical substance, thereby intensifying its effects on workers’ health.

5. OEL for exposure to mixture of chemical substances

OEL-M values listed in Table I-1 and I-2 are applicable in cases where the substance exists alone. When workers are exposed to a mixture of chemical substances and there is no reliable evidence to the contrary that the effects of the chemicals are assumed to be additive, the effects should be assumed as additive.

The users should refer not to each OEL-M value, but rather to the following equation:

\[ I = \frac{C_1}{T_1} + \frac{C_2}{T_2} + \ldots + \frac{C_i}{T_i} \]

\[ C_i = \text{mean exposure concentration for each component } i \]

\[ T_i = \text{OEL-M for each component } i \]

Any value of \( I \) exceeding 1 indicates an exposure that is above OEL.

| Substance [CAS No.] | OEL | Skin absorption | Class of carcino-genicity | Class of sensitizing potential | Reproductive Toxicants | Year of proposal |
|---------------------|-----|----------------|--------------------------|-------------------------------|------------------------|-----------------|
| Acetaldehyde [75-07-0] | 50* | 90* | 2B | | | '90 |
| Acetic acid [64-19-7] | 10 | 25 | | | | '78 |
| Acetic anhydride [108-24-7] | 5* | 21* | | | | '90 |
| Acetone [67-64-1] | 200 | 470 | | | | '72 |
| Acrylaldehyde [107-02-8] | 0.1 | 0.23 | | | | '73 |
| Acrylamide [79-06-1] | — | 0.1 | S | 2A | 2 | '04 |
| Acrylonitrile [107-13-1] | 2 | 4.3 | S | 2A* | | '88 |
| Allyl alcohol [107-18-6] | 1 | 2.4 | S | | | '78 |
| 2-Aminoethanol [141-43-5] | 3 | 7.5 | | | | '65 |
| Ammonia [7664-41-7] | 25 | 17 | | | | '79 |
| Aniline [62-53-3] | 1 | 3.8 | S | | 1 | '88 |
| o-Anisidine [90-04-0] | 0.1 | 0.5 | S | 2B | | '96 |
| p-Anisidine [104-94-9] | 0.1 | 0.5 | S | | | '96 |
| Antimony and compounds (as Sb except Sb) | — | 0.1 | | | | ('13) |
| Arsenic and compounds (as As) [7440-38-2] | (Table III-2) | 1 | | 1 | | '00 |
| Arsenic [7784-42-1] | 0.01 | 0.032 | | | | '92 |
| 0.1* | 0.32* | | | | | |
| Atrazine [1912-24-9] | 2 | | | 3 | | '15 |
| Benzene [71-43-2] | (Table III-2) | S | 1 | | | '97 |
| Beryllium and compounds (as Be) [7440-41-7] | — | 0.002 | | 1ψ | 1 | '63 |
| Boron trifluoride [7637-07-2] | 0.3 | 0.83 | | | | '79 |
| Bromine [7726-95-6] | 0.1 | 0.65 | | | | '64 |
| Bromoform [75-25-2] | 1 | 10.3 | | | | '97 |
| Substance [CAS No.]                                  | OEL          | Skin absorption | Class of carcinogenicity | Class of sensitizing potential | Reproductive Toxicants | Year of proposal |
|-----------------------------------------------------|--------------|-----------------|--------------------------|-------------------------------|------------------------|------------------|
| 1-Bromopropane [106-94-5]                           | 0.5 ppm 2.5 mg/m³ | S               |                           |                               | 2                      | '12              |
| 2-Bromopropane [75-26-3]                            | 1 ppm 5 mg/m³  | S               |                           |                               | 1                      | '99              |
| Buprofezin [69327-76-0]                             | — ppm 2 mg/m³  |                 |                           |                               |                        | '90              |
| Butanone (all isomers) [106-97-8]                   | 500 ppm 1,200 mg/m³ | S               |                           |                               |                        | '88              |
| 1-Butanol [71-36-3]                                 | 50* ppm 150* mg/m³ | S               |                           |                               |                        | '87              |
| 2-Butanol [78-92-2]                                 | 100 ppm 300 mg/m³ |                 |                           |                               |                        | '87              |
| Butyrate [123-86-4]                                 | 100 ppm 475 mg/m³ |                 |                           |                               |                        | '94              |
| 2-Butoxy alcohol [75-65-0]                          | 50 ppm 150 mg/m³ | S               |                           |                               |                        | '87              |
| Butylyamine [109-73-9]                              | 5* ppm 15* mg/m³  |                 |                           |                               |                        |                 |
| n-Butyl-2,3-epoxy-propyl ether [2426-08-6]          | (Table I-2)    |                 |                           |                               |                        |                 |
| Cadmium and compounds (as Cd) [7440-43-9]           | — ppm 0.05 mg/m³ |                 |                           | 1                             | 1                      | '76              |
| Calcium cyanide (as CN) [592-01-8]                  | — ppm 5* mg/m³  | S               |                           |                               |                        | '01              |
| Carbaryl [63-25-2]                                  | — ppm 5 mg/m³  |                 |                           |                               |                        | '89              |
| Carbon dioxide [124-38-9]                           | 5,000 ppm 9,000 mg/m³ | S               |                           |                               | 1*                     | '15              |
| Carbon disulfide [75-15-0]                          | 1 ppm 3.13 mg/m³ | S               |                           |                               |                        | '71              |
| Carbon monoxide [630-08-0]                          | 50 ppm 57 mg/m³ |                 |                           |                               |                        | '91              |
| Carbon tetrachloride [56-23-5]                      | 5 ppm 31 mg/m³  | S               | 2B                        |                               |                        |                 |
| Chlorine [7782-50-5]                                | 0.5* ppm 1.5* mg/m³ |                 |                           |                               |                        |                 |
| Chlorobenzene [108-90-7]                            | 10 ppm 46 mg/m³ |                 |                           |                               |                        | '93              |
| Chlorodifluoromethane [75-45-6]                     | 1.000 ppm 3.500 mg/m³ |                 |                           |                               | 2                      | '87              |
| Chloroethane [75-00-3]                              | 100 ppm 260 mg/m³ |                 |                           |                               |                        | '93              |
| Chloroform [67-66-3]                                | 3 ppm 14.7 mg/m³ | S               | 2B                        |                               |                        | '05              |
| Chloromethane [74-87-3]                             | 50 ppm 100 mg/m³ |                 |                           |                               | 2                      | '84              |
| Chloromethyl methyl ether (technical grade) [107-30-2] | — ppm — mg/m³  |                 |                           |                               |                        |                 |
| Chloropicrin [76-06-2]                              | 0.1 ppm 0.67 mg/m³ |                 |                           |                               |                        | '68              |
| Chromium and compounds (as Cr) [7440-47-3]          | — ppm 0.05 mg/m³ |                 |                           |                               | 2                      | '89              |
| Chromium Metal                                      | — ppm 0.5 mg/m³ |                 |                           |                               | 1                      |                 |
| Chromium (III) compounds                            | — ppm 0.5 mg/m³ |                 |                           |                               | 1                      |                 |
| Chromium (VI) compounds                             | — ppm 0.05 mg/m³ |                 |                           |                               | 1                      |                 |
| Certain Chromium (VI) compounds                     | — ppm 0.01 mg/m³ |                 |                           |                               | 1                      |                 |
| Cobalt and compounds (as Co) [7440-48-4]           | — ppm 0.05 mg/m³ |                 |                           |                               | 1                      | '92              |
| Cobalt metal with tungsten carbide                  | — ppm 2A mg/m³ |                 |                           |                               |                        |                 |
| Cobalt and compounds (without tungsten carbide)     | — ppm 2B mg/m³ |                 |                           |                               |                        |                 |
| Cresol (all isomers)                                | 5 ppm 22 mg/m³ | S               |                           |                               | '86              |
| Cyclohexane [110-82-7]                              | 150 ppm 520 mg/m³ |                 |                           |                               | '70              |
| Cyclohexanol [108-93-0]                             | 25 ppm 102 mg/m³ |                 |                           |                               | '70              |
| Cyclohexanone [108-94-1]                            | 25 ppm 100 mg/m³ |                 |                           |                               | '70              |
| Diazinon [333-41-5]                                 | — ppm 0.1 mg/m³ | S               |                           |                               | '89              |
| Diborane [19287-45-7]                               | 0.01 ppm 0.012 mg/m³ |                 |                           |                               | '96              |
| Dibutyl phthalate [84-74-2]                         | — ppm 5 mg/m³  |                 |                           |                               | 2                      | '96              |
| n-Dichlorobenzenene [95-50-1]                       | 25 ppm 150 mg/m³ |                 |                           |                               | '94              |
| p-Dichlorobenzenene [106-46-7]                      | 10 ppm 60 mg/m³ | 2B              |                           |                               | 3                      | '98              |
| 1,4-Dichloro-2-butene [764-41-0]                    | 0.002 ppm 0.02 mg/m³ |                 |                           |                               | 2B                      | '15              |
| 3,3’-Dichloro-4,4’-diaminodiphenylmethane (MBOCA) [101-14-4] | — ppm 0.005 mg/m³ | S               | 2A*                       |                               | '12              |
| Dichlorodifluoromethane [75-71-8]                   | 500 ppm 2,500 mg/m³ |                 |                           |                               | '87              |
| 1,1-Dichloroethane [75-34-3]                        | 100 ppm 400 mg/m³ |                 |                           |                               | '93              |
| 1,2-Dichloroethane [107-06-2]                       | 10 ppm 40 mg/m³  | 2B              |                           |                               | '84              |
| 2,2’-Dichloroethyl ether [111-44-4]                 | 15 ppm 88 mg/m³ | S               |                           |                               | '67              |
| 1,2-Dichloroethylene [540-59-0]                     | 150 ppm 590 mg/m³ |                 |                           |                               | '70              |
| Substance [CAS No.] | Substance [CAS No.] | OEL | Skin absorption | Class of carcinogenicity | Class of sensitizing potential | Reproductive Toxicants | Year of proposal |
|---------------------|---------------------|-----|-----------------|--------------------------|-------------------------------|------------------------|------------------|
| Dichloromethane [75-09-2] | 50 ppm | 170 mg/m³ | S | 2A | Airway | Skin | '99 |
| 1,2-Dichloropropane [78-87-5] | 100 ppm* | 340 ppm* | 4.6 | 1<sup>1</sup> | 2 | 2 | '13 |
| 2,2-Dichloro-1,1,1-trifluoroethane [306-83-2] | 10 ppm | 62 ppm | 5 | '00 |
| Diethylamine [109-89-7] | 10 ppm | 30 ppm | 30 | 2B | 1<sup>a</sup> | '89 |
| Di(2-ethylhexyl) phthalate [117-81-7] | — | 5 | 5 | '95 |
| Diethyl phthalate [84-66-2] | — | 5 | 5 | '95 |
| N,N-Dimethyl acetamide [127-19-5] | 10 ppm | 36 ppm | 2 | '90 |
| Dimethylamine [124-40-3] | (Table I-2) | (Table I-2) | (Table I-2) | (Table I-2) | (Table I-2) | (Table I-2) | (Table I-2) |
| N,N-Dimethylamine [121-69-7] | 5 ppm | 25 ppm | S | '93 |
| N,N-Dimethylformamide (DMF) [68-12-2] | 10 ppm | 30 ppm | S | 2B | 2 | 2 | '74 |
| Dimethyl sulfate [77-78-1] | 0.1 ppm | 0.52 ppm | 0.52 | 2A<sup>v</sup> | '80 |
| 1,2-Dinitrobenzene [528-29-0] | 0.15 ppm | 1 ppm | 1 | '94 |
| 1,3-Dinitrobenzene [99-65-0] | 0.15 ppm | 1 ppm | 1 | '94 |
| 1,4-Dinitrobenzene [100-25-4] | 0.15 ppm | 1 ppm | 1 | '94 |
| 1,4-Dioxane [123-91-1] | 1 ppm | 3.6 ppm | S | 2B | '15 |
| Diphenylmethane-4,4'-diisocyanate (MDI) [101-68-8] | — | 0.05 ppm | 0.05 | 1 | '93 |
| Dusts (Table I-3) | (Table I-3) | (Table I-3) | (Table I-3) | (Table I-3) | (Table I-3) | (Table I-3) | (Table I-3) |
| Ethyl acetate [141-78-6] | 200 ppm | 720 ppm | 2 | '95 |
| Ethylamine [75-04-7] | 10 ppm | 18 ppm | 1 | '79 |
| Ethyl benzene [100-41-4] | 50 ppm | 217 ppm | 2B | 2 | '01 |
| Ethylenediamine [107-15-3] | 10 ppm | 25 ppm | S | 2 | 2 | '91 |
| Ethylene glycol monoethyl ether [110-80-5] | 5 ppm | 18 ppm | S | 2 | '85 |
| Ethylene glycol monooctyl ether acetate [111-15-9] | 5 ppm | 27 ppm | S | 2 | '85 |
| Ethylene glycol monomethyl ether [109-86-4] | 0.1 ppm | 0.31 ppm | S | 1 | '09 |
| Ethylene glycol monomethyl ether acetate [110-49-6] | 0.1 ppm | 0.48 ppm | S | 1 | '09 |
| Ethylene oxide [75-21-8] | 1 ppm | 1.8 ppm | 1<sup>v</sup> | 2 | 1 | '90 |
| Ethylenimine [151-56-4] | 0.5 ppm | 0.88 ppm | S | 2B | 3 | '90 |
| Ethyl ether [60-29-7] | 400 ppm | 1,200 ppm | 1,200 | 2A | 2 | 1 | '97 |
| 2-Ethyl-1-hexanol [104-76-7] | (Table I-2) | (Table I-2) | (Table I-2) | (Table I-2) | (Table I-2) | (Table I-2) | (Table I-2) |
| Etofenprox [80844-07-1] | — | 3 | 3 | '95 |
| Fenitrothion [122-14-5] | — | 1 ppm | S | '81 |
| Fenobucarb [3766-81-2] | — | 5 ppm | S | '89 |
| Fenthion [55-38-9] | — | 0.2 ppm | S | '89 |
| Flutolanil [66332-96-5] | — | 10 ppm | 10 | '90 |
| Formaldehyde [50-00-0] | 0.1 ppm | 0.12 ppm | 0.12 | 2A | 2 | 1 | '07 |
| Formic acid [64-18-6] | 0.2 ppm | 0.24 ppm | 0.24 | '07 |
| Fimalide [27355-22-2] | 5 ppm | 9.4 ppm | 9.4 | '78 |
| Furfural [98-01-1] | — | 10 ppm | 10 | '90 |
| Furfuryl alcohol [98-00-0] | 2.5 ppm | 9.8 ppm | 9.8 | ('89) |
| Gasoline [8006-61-9] | 5 ppm | 20 ppm | 20 | '78 |
| Glutaraldehyde [111-30-8] | 100 ppm | 300 ppm | 300 | 2B | '85 |
| Heptane [142-82-5] | 0.03 ppm | 1 ppm | 1 | 1 | '06 |
| Hexachlorobutadiene [87-68-3] | 0.01 ppm | 0.12 ppm | 0.12 | '13 |
| Hexane [110-54-3] | 40 ppm | 140 ppm | 140 | '85 |
| Hexane-1,6-diisocyanate (HDI) [822-06-0] | 0.005 ppm | 0.034 ppm | 0.034 | 1 | '95 |
| Substance [CAS No.]                        | OEL | Skin absorption | Class of carcinogenicity | Class of sensitizing potential | Reproductive Toxicants | Year of proposal |
|------------------------------------------|-----|----------------|--------------------------|--------------------------------|------------------------|-------------------|
|                                          | ppm | mg/m³ | Airway | Skin |                        |                   |                  |
| Hydrazine (anhydrous) and Hydrazine hydrate [302-01-2/7803-57-8] | 0.1 | 0.13 | S | 2B | 1 | '98 |
| Hydrogen chloride [7647-01-0]            | 2*  | 3.0*       | S | 90 | 14                       |                  |                  |
| Hydrogen cyanide [74-90-8]               | 5   | 5.5        | S | 90 | 14                       |                  |                  |
| Hydrogen fluoride [7664-39-3]            | 3*  | 2.5*       | S | 00 | 00                       |                  |                  |
| Hydrogen selenide [7783-07-5]           | 0.05| 0.17       | S | 63 | 63                       |                  |                  |
| Hydrogen sulfide [7783-06-4]            | 5   | 7          | S | 91 | 91                       |                  |                  |
| Indium and compounds [7440-74-6]        |     |            |       |   |                          | 2A                | '07              |
| Iodine [7553-56-2]                      | 0.1 | 1          | 2    | 68 | 68                       |                  |                  |
| Isobutyl alcohol [78-83-1]              | 50  | 150        | S   | 87 | 87                       |                  |                  |
| Isopentyl alcohol [123-51-3]            | 100 | 360        | S   | 66 | 66                       |                  |                  |
| Isopropyl alcohol [67-63-0]             | 400*| 980*       | S   | 87 | 87                       |                  |                  |
| Isoprothiolane [50512-35-1]             |     | 5          | S   | 93 | 93                       |                  |                  |
| Lead and compounds (as Pb except alkyl lead compounds) [7439-92-1] |     |            |     | 16 | 16                       |                  |                  |
| Lithium hydroxide [1310-65-2]           |     | 1          | 2    | 95 | 95                       |                  |                  |
| Malathion [121-75-5]                    |     | 10         | 10   | 89 | 89                       |                  |                  |
| Maleic anhydride [108-31-6]             | 0.1 | 0.4        | S   | (15) | (15)                     |                  |                  |
| Manganese and compounds (as Mn except organic compounds) [7439-96-5] |     |            |     | 08 | 08                       |                  |                  |
| Man-made mineral fibers**                |     |            |     |    |                          |                  |                  |
| Ceramíc fibers, Micro glass fibers       |     |            |     |    |                          |                  |                  |
| Continuous filament glass fibers,       |     |            |     |    |                          |                  |                  |
| Glass wool fibers, Rock wool fibers,     |     |            |     |    |                          |                  |                  |
| Slag wool fibers                         |     |            |     |    |                          |                  |                  |
| Mepronil [55814-41-0]                   |     | 5          | 5   | 90 | 90                       |                  |                  |
| Mercury vapor [7439-97-6]               |     | 0.025      | 2   | 98 | 98                       |                  |                  |
| Methacrylic acid [79-41-4]              | 2   | 7.0        | 2   | 12 | 12                       |                  |                  |
| Methanol [67-56-1]                      | 200 | 260        | S   | 63 | 63                       |                  |                  |
| Methyl acetate [79-20-9]                | 200 | 610        | S   | 63 | 63                       |                  |                  |
| Methyl acrylate [96-33-3]               | 2   | 7          | S   | 04 | 04                       |                  |                  |
| Methylamine [74-89-5]                   | 10  | 13         | 1   | 79 | 79                       |                  |                  |
| Methyl bromide [74-83-9]                | 1   | 3.89       | S   | 03 | 03                       |                  |                  |
| Methyl n-butyl ketone [591-78-6]        | 5   | 20         | S   | 84 | 84                       |                  |                  |
| Methylcyclohexane [108-87-2]            | 400 | 1,600      | S   | 86 | 86                       |                  |                  |
| Methylcyclohexanol [25639-42-3]         | 50  | 230        |     | 80 | 80                       |                  |                  |
| Methylcyclohexanone [1331-22-2]         | 50  | 230        | S   | 87 | 87                       |                  |                  |
| Methyl methacrylate [80-62-6]           | 8.3 | 2          | 2   | 12 | 12                       |                  |                  |
| 4,4'-Methyleneedianiline [101-77-9]     |     | 0.4        | S   | 95 | 95                       |                  |                  |
| Methyl ethyl ketone [78-93-3]           | 200 | 590        | S   | 64 | 64                       |                  |                  |
| Methyl isobutyl ketone [108-10-1]       | 50  | 200        | S   | 84 | 84                       |                  |                  |
| N-Methyl-2-pyrrolidone [872-50-4]       | 1   | 4          | S   | 02 | 02                       |                  |                  |
| Methylnitrosohydrophthalic anhydride [11070-44-3] | 0.007 | 0.05    | 1   | 02 | 02                       |                  |                  |
| Nickel [7440-02-0]                      |     | 1          | 2   | 11 | 11                       |                  |                  |
| Nickel carbonyl [13463-39-3]            | 0.001| 0.007     | 3   | 66 | 66                       |                  |                  |
| Nickel compounds (Total dusts) (as Ni)  |     |            |     | 11 | 11                       |                  |                  |
| [7440-02-0], Nickel compounds, soluble  |     | 0.01       | 1   | 11 | 11                       |                  |                  |
| Nickel compounds, not soluble           |     | 0.1        | 1   | 11 | 11                       |                  |                  |
| Nickel smelting dusts [7440-02-0]       |     | 1          | 1   | 11 | 11                       |                  |                  |
| Nitric acid [7697-37-2]                 | 2   | 5.2        | S   | 82 | 82                       |                  |                  |
| Substance [CAS No.] | OEL | Skin absorption | Class of carcinogenicity | Class of sensitizing potential | Reproductive Toxicants | Year of proposal |
|---------------------|-----|-----------------|--------------------------|-------------------------------|------------------------|----------------|
| p-Nitroaniline [100-01-6] | — | 3 ppm | S |  |  | '95 |
| Nitrobenzene [98-95-3] | 1 ppm | 5 mg/m³ | S | 2B |  | ('88) |
| p-Nitrochlorobenzene [100-00-5] | 0.1 ppm | 0.64 mg/m³ | S |  |  | '89 |
| Nitrogen dioxide [10102-44-0] (pending) | — | — | — | — |  | — |
| Nitroglycerin [55-63-0] | 0.05 ppm | 0.46 mg/m³ | S |  |  | '86 |
| Nitroglycol [628-96-6] | 0.05 ppm | 0.31 mg/m³ | S |  |  | '86 |
| Nonane [111-84-2] | 200 ppm | 1,050 mg/m³ |  |  |  | '89 |
| Octane [110-65-9] | 300 ppm | 1,400 mg/m³ |  |  |  | '89 |
| Oil mist, mineral | — | 3 ppm | 1 |  |  | '77 |
| Ozone [10028-15-6] | 0.1 ppm | 0.2 mg/m³ | S |  |  | '63 |
| Parathion [56-38-2] | — | 0.1 ppm | S |  |  | ('80) |
| Pentachlorophenol [87-86-5] | — | 0.5 ppm | S | 2 |  | ('89) |
| Pentane [109-66-0] | 300 ppm | 880 mg/m³ |  |  |  | '87 |
| Pentyl acetate, All isomers | 50 ppm | 266.3 mg/m³ |  |  |  | '08 |
|  | [628-63-7; 123-92-2; 626-38-0; 620-11-1; 625-16-1; 624-41-9; 926-41-0] | 100 ppm | 532.5 mg/m³ |  |  |  |
| Perfluorooctanoic acid [335-67-1] | — | 0.005 ppm | 1 |  |  | '08 |
| Phenol [108-95-2] | 5 ppm | 19 mg/m³ | S | 3 |  | '78 |
| m-Phenylenediamine [108-45-2] | — | 0.1 ppm | 3 |  |  | '99 |
| o-Phenylenediamine [95-54-5] | — | 0.1 ppm | 3 |  |  | '99 |
| p-Phenylenediamine [106-50-3] | — | 0.1 ppm | 1 |  |  | '97 |
| Phosgene [75-44-5] | 0.1 ppm | 0.4 mg/m³ |  |  |  | '96 |
| Phosphine [7803-51-2] | 0.3 ppm | 0.42 mg/m³ |  |  |  | '98 |
| Phosphoric acid [7664-38-2] | — | 1 ppm |  |  |  | ('90) |
| Phosphorus (yellow) [7723-14-0] | — | 0.1 ppm |  |  |  | ('89) |
| Phosphorus pentachloride [10026-13-8] | 0.1 ppm | 0.85 mg/m³ |  |  |  | '89 |
| Phosphorus trichloride [7719-12-2] | 0.2 ppm | 1.1 mg/m³ |  |  |  | '89 |
| Phthalic anhydride [85-44-9] | 0.33 ppm | 2 mg/m³ | 1 |  |  | '98 |
| o-Phthalodinitrile [91-15-6] | 0.01 ppm | S |  |  |  | '09 |
| Picric acid | — | — | 2 |  |  | '14 |
| Platinum, soluble salts (as Pt) [7440-06-4] | — | 0.001 ppm | 1 | 1 |  | '00 |
|  | [7440-16-6] | — | 0.001 ppm | 2 |  |  | '07 |
| Potassium cyanide (as CN) [151-50-8] | — | 5 ppm | S | 1ψ 1ψ 1ψ |  | '06 |
| Potassium hydroxide [1310-58-3] | — | 2 ppm | S |  |  |  | '78 |
| Potassium hydroxide [1310-58-3] | — | 2 ppm | S |  |  |  | '78 |
| Propylene imine [75-55-8] | 2 ppm | 4.7 mg/m³ |  |  |  | '67 |
| Pyridaphenthion [119-12-0] | — | 0.2 ppm | S |  |  | '89 |
| Rhodium (Soluble compounds, as Rh) [7440-16-6] | — | 0.001 ppm | 2 |  |  | '07 |
| Selenium and compounds (as Se, except SeH₂ and SeF₆) [7782-49-2] | — | 0.1 ppm |  |  |  | '00 |
| Silver and compounds (as Ag) [7440-22-4] | — | 0.01 ppm |  |  |  | '91 |
| Sodium cyanide (as CN) [143-33-9] | — | 5 ppm | S |  |  | '01 |
| Sodium hydroxide [1310-73-2] | — | 2 ppm | S |  |  | '78 |
| Styrene [100-42-5] | 20 ppm | 85 mg/m³ | S | 2B |  | '99 |
| Sulfur dioxide [7446-09-5] (pending) | — | — | — | — |  | '61 |
| Sulfuric acid [7664-93-9] | — | 1 ppm |  |  |  | '00 |
| Sulfur monochloride [10025-67-9] | 1 ppm | 5.5 ppm |  |  |  | '76 |
| Tetrachloroethylene [127-18-4] (pending) | 1 ppm | 6.9 ppm | S | 2B |  | '84 |
| Tetraethoxyethane [78-10-4] | 10 ppm | 85 mg/m³ | S | 2B |  | '72 |
| Tetraethoxyilane [78-10-4] | 10 ppm | 85 mg/m³ | S | 2B |  | '91 |
| Substance [CAS No.] | OEL | Skin absorption | Class of carcinogenicity | Class of sensitizing potential | Reproductive Toxicants | Year of proposal |
|---------------------|-----|-----------------|--------------------------|-------------------------------|------------------------|-----------------|
| Tetraethyl lead (as Pb) [78-00-2] | — | 0.075 ppm | S | Airway | Skin | '65 |
| Tetrahydrofuran [109-99-9] | 50 ppm | 148 mg/m³ | S | Skin | — | '15 |
| Tetramethoxysilane [681-84-5] | 1 | 6 ppm | S | Airway | Skin | '91 |
| Thiuram [137-26-8] | 0.1 ppm | 1 mg/m³ | 1 | Skin | — | '08 |
| Titanium dioxide (nanoparticle, as Ti) [13463-67-7] | — | 0.3 ppm | 2B | Skin | — | '13 |
| Toluene [108-88-3] | 50 | 188 ppm | S | Skin | — | ('13) |
| Toluene diisocyanates [26471-62-5] | 0.005 ppm | 0.035 mg/m³ | 2B | Airway | Skin | '92 |
| Trichloron [52-68-6] | 0.2 ppm | 0.14 mg/m³ | S | Skin | — | '10 |
| α-Toluidine [95-53-4] | 1 | 4.4 ppm | S | 1ψ | — | '91 |
| 1,1,1-Trichloroethane [71-55-6] | 200 ppm | 1,100 mg/m³ | S | Skin | — | '74 |
| 1,1,2-Trichloroethane [79-00-5] | 10 | 55 ppm | S | Skin | — | ('78) |
| Trichloroethylene [79-01-6] | 25 | 135 ppm | 1ψ | Skin | — | '15 |
| Trichlorofluoromethane [75-69-4] | 1,000* ppm | 5,600* mg/m³ | S | Skin | — | '87 |
| Trichloro-1,2,2-trifluoroethane [76-13-1] | 500 ppm | 3,800 mg/m³ | S | Skin | — | '87 |
| Tricyclazole [41814-78-2] | — | 3 ppm | 1 | Skin | — | '90 |
| Trimellitic anhydride [552-30-7] | 0.0005 ppm | 0.004* mg/m³ | S | Skin | — | '15 |
| 1,2,3-Trimethylbenzene [526-73-8] | 25 | 120 ppm | S | Skin | — | '84 |
| 1,2,4-Trimethylbenzene [95-63-6] | 25 | 120 ppm | S | Skin | — | '84 |
| 1,3,5-Trimethylbenzene [108-67-8] | 25 | 120 ppm | S | Skin | — | '84 |
| Trinitrotoluene (all isomers) | — | 0.1 ppm | S | Skin | — | '93 |
| Turpentine | 50 | 280 ppm | 1 | Skin | — | '91 |
| Vanadium compounds | — | 1 ppm | 2B | Skin | — | '68 |
| Ferrovanadium dust [12604-58-9] | — | 1 ppm | 2B | Skin | — | '03 |
| Vanadium pentoxide [1314-62-1] | — | 0.05 ppm | 2B | Skin | — | '75 |
| Vinyl chloride [75-01-4] | (pending) | 1ψ | — | Skin | — | — |
| Xylene (all isomers and their mixture) | 50 | 217 ppm | 2 | Skin | — | '01 |
| Xylene for industrial use | — | 2 ppm | 3 | Skin | — | — |
| Xylene (ortho-, meta-, para-xylene and their mixture) | — | 2 ppm | 3 | Skin | — | — |
| Zinc oxide fume [1314-13-2] | (pending) | — | — | Skin | — | '69 |

1. ppm: parts of vapors and gases per million of substance in air by volume at 25°C and atmospheric pressure (760 torr, 1,013 hPa); OELs in ppm are converted to those in mg/m³, in which the values are rounded off with 2 significant digits.
2. ( ) in the year of proposal column indicates that revision was done in the year without change of the OEL value.
3. *: Occupational Exposure Limit-Ceiling; exposure concentration must be kept below this level.
4. **: Fibers longer than 5 μm and with an aspect ratio equal to or greater than 3:1 as determined by the membrane filter method at 400 × magnification phase contrast illumination.
5. ψ: Substance whose OEL is set based on non-carcinogenic health effects; see III.
6. a: Exposure concentration should be kept below a detectable limit though OEL is set at 2.5 ppm provisionally.
7. b: OEL for gasoline is 300 mg/m³, and an average molecular weight is assumed to be 72.5 for conversion to ppm unit.
8. c: Not applicable to women of child bearing potential.
9. #: Precaution should be given for lower exposure than OEL-M or OEL-B. As for reproductive toxicity, it is generally known that there is a sensitive period, during pregnancy for example, and such effects of this substance have been identified.
10. †: Provisional.
II. Occupational Exposure Limits Based on Biological Monitoring

1. Definition

Biological monitoring in the occupational setting consists of (1) measuring the concentration of a chemical substance or its metabolite(s) in biological specimens, and/or (2) determining early health effects by using biological specimens which are predictors or warning signs of the occurrence of adverse health effects.

Occupational Exposure Limit Based on Biological Monitoring (OEL-B) are defined as the reference values to the data obtained by biological monitoring at or below (depending on agents, above) which the adverse health effects do not appear in most workers who are exposed to the chemical substances.

2. Characteristics of OEL-B

(1) In setting OEL-B, consideration is given to the exposure-effect and/or exposure-response relationships between biological monitoring values and health effects, or to the relationship between biological monitoring values and OEL-Ms.

(2) There is a possibility that exposure concentration of chemical substances in the workplace will not closely associate with biological monitoring values due to various factors.

See JSOH’S web site for brief summary of OEL documentation at http://sanei.or.jp

### Table I-2. Occupational exposure limits for chemical substances (Provisional)

| Substance [CAS No.] | OEL Skin absorption | Class of carcinogenicity | Class of sensitizing potential | Reproductive Toxicants | Year of proposal |
|---------------------|---------------------|--------------------------|--------------------------------|------------------------|-----------------|
| n-butyl-2,3-epoxy-propyl ether [2426-08-6] | 0.25 ppm | 1.33 mg/m³ | 2B | 2 | 3 | ’16 |
| Dimethylamine [124-40-3] | 2 ppm | 3.7 mg/m³ | 3 | 3 | pending | ’16 |
| 2-Ethyl-1-hexanol [104-76-7] | 1 ppm | 5.3 mg/m³ | 2B | 2 | '16 |
| Lead and compounds (as Pb except alkyl lead compounds) [7439-92-1] | 0.03 ppm | 0.03 mg/m³ | | | |

See JSOH’S web site for brief summary of OEL documentation at http://sanei.or.jp

### Table I-3. Occupational exposure limits for dusts

| Class of Dusts | Dusts other than I |
|----------------|--------------------|
| Class 1       | Activated charcoal, Alumina, Aluminum, Bentonite, Diatomite, Graphite, Kaolinite, Pagodite, Pyrites, Pyrite cinder, Talc |
| Class 2       | Dusts containing less than 3% crystalline silica, Bakelite, Carbon black, Coal, Cork dust, Cotton dust, Iron oxide, Grain dust, Joss stick material dust, Marble, Portland cement, Titanium oxide, Zinc oxide |
| Class 3       | Limestone‡, Inorganic and organic dusts other than Classes 1 and 2 |
| Asbestos***   | (Table III-2) |

1. *: Respirable crystalline silica and respirable dust consist of particles captured by the following collection efficiency, $R(d_{ae})$.

$$R(d_{ae})=0.5[1+\exp(-0.06d_{ae})]/[1-F(x)]$$

$d_{ae}$: aerodynamic diameter of particle ($\mu$m), $F(x)$: cumulative distribution function of the standardized normal variable $x=\ln(d_{ae}/\Gamma)/\ln(\Sigma)$, In natural logarithm, $\Gamma=4.25$ $\mu$m, $\Sigma=1.5$

2. **: Total dust comprises particles with a flow speed of 50 to 80 cm/sec at the entry of a particle sampler.

3. ***: Fibers longer than 5 $\mu$m and with an aspect ratio equal to or greater than 3:1 as determined by the membrane filter method at 400 x magnification (4 mm objective) phase contrast illumination.

4. ‡: Do not include asbestos nor ≥1% crystalline silica.

5. ™: Substance whose OEL is set based on non-carcinogenic health effects; see III.

II. Occupational Exposure Limits Based on Biological Monitoring

1. Definition

Biological monitoring in the occupational setting consists of (1) measuring the concentration of a chemical substance or its metabolite(s) in biological specimens, and/or (2) determining early health effects by using biological specimens which are predictors or warning signs of the occurrence of adverse health effects.

Occupational Exposure Limit Based on Biological Monitoring (OEL-B) are defined as the reference values to the data obtained by biological monitoring at or below (depending on agents, above) which the adverse health effects do not appear in most workers who are exposed to the chemical substances.

2. Characteristics of OEL-B

(1) In setting OEL-B, consideration is given to the exposure-effect and/or exposure-response relationships between biological monitoring values and health effects, or to the relationship between biological monitoring values and OEL-Ms.

(2) There is a possibility that exposure concentration of chemical substances in the workplace will not closely associate with biological monitoring values due to various
Table II-1.  Occupational exposure limits based on biological monitoring

| Substance                                           | Assay material | Parameter                        | OEL-B    | Sampling time                                      | Year of proposal |
|-----------------------------------------------------|----------------|----------------------------------|----------|---------------------------------------------------|------------------|
| Acetone                                             | urine          | Acetone                          | 40 mg/l  | Within 2 h prior to end of shift                  | '01              |
| 2-Butoxyethanol and 2-Butoxyethyl acetate           | urine          | Butoxyacetic acid                | 200 mg/g·Cr | End of shift                                      | '08              |
| Carbon disulfide                                     | urine          | 2-thiothiazolidine-4-carboxylic acid† | 0.5 mg/g·Cr | End of shift (Avoid sizable intake of brassica vegetables) | '15              |
| Cobalt and inorganic compounds (except cobalt oxides) | blood          | Cobalt                           | 3 μg/l   | Within 2 h prior to end of shift at end of work week | '05              |
|                                                     | urine          | Cobalt                           | 35 μg/l  | Within 2 h prior to end of shift at end of work week | '05              |
| Chlorobenzene                                        | urine          | 4-Chlorocatechol (hydrolysis)    | 120 mg/g·Cr | End of shift                                      | '08              |
| 3,3’-Dichloro-4,4’-diaminodiphenyl-methane (MBOCA)  | urine          | total MBOCA                      | 50 μg/g·Cr | End of shift at end of work-week                  | '94              |
| Dichloromethane                                      | urine          | Dichloromethane                  | 0.2 mg/l | End of shift                                      | '05              |
| Hexane                                              | urine          | 2.5-Hexanidine (after acid hydrolysis) | 3 mg/g·Cr | End of shift at end of work-week                  | '94              |
|                                                     | urine          | 2.5-Hexanidine (without acid hydrolysis) | 0.3 mg/g·Cr | End of shift at end of work-week                  |                   |
| Indium and compounds                                 | serum          | Indium                           | 3 μg/l   | Not critical                                      | '94              |
| Lead and compounds (except alkyl lead compounds)     | blood          | Lead                             | 15 μg/100 ml | Not critical                                      | '07              |
|                                                     | blood          | Protoporphyrin                   | 80 μg/100 ml/RBC | Not critical                                    | '13              |
|                                                     | urine          | δ-Aminolevulinic acid            | 5 mg/l   | Not critical (After one month or more since consecutive exposure) | '94              |
| Mercury and compounds (except alkyl mercury compounds)| urine         | total inorganic mercury          | 35 μg/g·Cr | Not critical                                      | '93              |
| Methanol                                            | urine          | Methanol                         | 20 mg/l  | End of shift                                      | '10              |
| Methyl ethyl ketone                                  | urine          | Methyl ethyl ketone              | 5 mg/l   | End of shift at or A few hours after high exposure | '06              |
| Methyl isobutyl ketone                               | urine          | Methyl isobutyl ketone           | 1.7 mg/l | End of shift                                      | '07              |
| Phenol                                              | urine          | Phenol                           | 250 mg/g·Cr | End of shift                                      | '08              |
| Polychlorobiphenyls (PCBs)                          | blood          | total PCB                        | 25 μg/l  | Not critical                                      | '06              |
| Styrene                                             | urine          | Mandelic acid + Phenylglyoxylic acid | 430 mg/l | End of shift at end of work-week                  | '07              |
|                                                     | blood          | Styrene                          | 0.2 mg/l | End of shift at end of work-week                  | '07              |
| Tetrahydrofuran                                      | urine          | Tetrahydrofuran                  | 2 mg/l   | End of shift                                      | '15              |
| Toluene                                             | blood          | Toluene                          | 0.6 mg/l | Within 2 h prior to end of shift at end of work week | '99              |
|                                                     | urine          | Toluene                          | 0.06 mg/l | End of shift at end of work-week                  | '99              |
| Trichloroethylene                                    | urine          | total trichloro-compounds        | 150 mg/l | End of shift at end of work-week                  | '99              |
|                                                     | urine          | Trichloroethanol                 | 100 mg/l | End of shift at end of work-week                  | '99              |
|                                                     | urine          | Trichloroacetic acid             | 50 mg/l  | End of shift at end of work-week                  | '99              |
| Xylene                                              | urine          | total (o-, m-, p-) methylhippuric acid | 800 mg/l | End of shift at end of work-week                  | '05              |

†: Provisional

See JSOH website for brief summary of OEL documentation at http://sanei.or.jp/oel-eng
factors, e.g., intra- and inter-individual variation in metabolism, social habits such as smoking and alcohol consumption, working conditions, working time, skin absorption, use of personal protective equipment, and possible exposure to the substances outside the workplace. Biological monitoring values could exceed OEL-B even though exposure to the chemical substances is below OEL-M, and vice versa. Both OEL-M and OEL-B must be satisfied at the workplace.

(3) Biological specimens should be collected at the time that is most likely to represent the particular exposure to the substances concerned, or at the time most likely to predict occurrence of the particular adverse health effects. Only biological monitoring values measured under this condition can be referred to OEL-B.

(4) OEL-B is applied to cases of single-substance absorption. For exposure to a mixture of substances, interactions in terms of absorption, metabolism, accumulation, excretion and health effects must also be considered.
III. Occupational Carcinogens

JSOH classifies the occupational carcinogens based primarily on the epidemiological evidences*, but the results of the animal experiments and their extrapolation to human are also considered. The classification is made by strength of the evidence, but does not reflect the carcinogenic potency.

JSOH considers that the classification of occupational carcinogens proposed by the International Agency for Research on Cancer (IARC) is appropriate in principle. JSOH also discussed the classification of several agents based on other information sources and finalized the list of occupational carcinogens in Table III-1a, b, c. Group 1 includes the agents which are carcinogenic to humans. Group 2 indicates the agents which are probably or possibly carcinogenic to humans, classifying them into two sub-groups on the basis of degree of evidence: Group 2A is assigned to the agents with more sufficient evidence (probably carcinogenic to humans), Group 2B to those with less

| Table III-1a. Group 1 carcinogens |
|----------------------------------|
| Substance                        | CAS No. | Year of proposal |
| 4-Aminobiphenyl                  | 92-67-1 | '81, '86         |
| Arsenic and inorganic arsenic compounds* | 7440-38-2 | '81, '86, ('00) |
| Asbestos                         | 1332-21-4 | '81, '86, ('00) |
| Benzene                          | 71-43-2 | '81, '86, ('97)  |
| Benzidine                        | 92-87-5 | '81, '86         |
| Benzotrichloride                 | 98-07-7 | '81, '86, ('01)  |
| Beryllium and compounds*†        | 7440-41-7 | '86, '16         |
| Bis (chloromethyl) ether         | 542-88-1 | '81, '86         |
| 1,3-Butadiene                    | 106-99-0 | '91, '95, '01    |
| Cadmium and compounds*           | 7440-43-9 | '86, '91, '96    |
| Chromium (VI) compounds          | 18540-29-9 | '81, '86         |
| Coal-tar pitch volatiles         | —       | '81, '86, ('04)  |
| Coal-tars                        | 8007-45-2 | '81, '86, ('04)  |
| 1,2-Dichloropropane              | 78-87-5 | '13, '14         |
| Erionite                         | 12510-42-8 | '91              |
| Ethylene oxide                   | 75-21-8 | '86, '90, '96    |
| Ionizing radiation               | —       | '12              |
| Mineral oils (untreated and mildly treated) | — | '81, '86, '91 |
| 2-Naphthylamine                  | 91-59-8 | '81, '86         |
| Nickel smelting dusts*           | 7440-02-0 | '81, '86, '91, ('09) |
| Polychlorinated biphenyls (PCB)* | 53469-21-9, 11097-69-1 | '86, '91, '16 |
| Shale oils                       | 68308-34-9 | '95              |
| Silica (crystalline)             | 14808-60-7 | '91, '01        |
| Soots                            | —       | '81, '86         |
| Sulphur dichlordiethyl           | 505-60-2 | '86              |
| Talc containing asbestiform fibers | 14807-96-6 | '91          |
| 2,3,7,8-Tetrachlorodibeno-p-dioxin | 1746-01-6 | '86, '00 |
| Tobacco smoke                    | —       | '10              |
| o-Toluidine†                     | 95-53-4 | '86, '95, '01, '16 |
| Trichloroethylene                | 79-01-6 | '96, '15         |
| Vinyl chloride                   | 75-01-4 | '81, '86         |
| Wood dust                        | —       | '98              |

*Evaluation does not necessarily apply to all individual chemicals within the group.
†Provisional.
( ) in the year of proposal indicates year of reconsideration resulting in no classification change.
(possibly carcinogenic to humans).

Only when scientifically reasonable information is available, JSOH will estimate a reference value corresponding to an individual excess lifetime risk of cancer due to exposure to a Group I carcinogen, and show it in Table III-2. JSOH does not recommend either the reference value as a safety exposure level or the individual excess lifetime risk as an acceptable risk level. The reference value should be applied only by experts well-trained and well-experienced in occupational health to avoid or minimize the risk of occupational cancer.

The occupational carcinogens may have OEL in Table I-1. These values must be used with caution. Some substances had epidemiological or experimental evidences that carcinogenicity was observed only at significantly higher concentrations than those for non-carcinogenic health effects, but the others did not. For the latter case, the substance is indicated as ψ in Table I-1**.

Epidemiological evidences include serum epidemiology and molecular epidemiology.

### Table III-1b. Group 2A carcinogens

| Substance                                      | CAS No. | Year of proposal |
|------------------------------------------------|---------|------------------|
| Acrylamide                                     | 79-06-1 | '91, '95, ('04)  |
| Acrylonitrile                                  | 107-13-1| '86              |
| Benzal chloride                                | 98-87-3 | '91, '01         |
| Benzo [a] pyrene                               | 50-32-8 | '86              |
| Benzyl chloride                                | 100-44-7| '91, '01         |
| Chloromethyl methyl ether (technical grade)    | 107-30-2| '92, ('01)       |
| 4-Chloro-o-toluidine                           | 95-69-2 | '91, '01         |
| CI Direct Black 38**                           | 1937-37-7| '86, '91, '95, '01 |
| CI Direct Blue 6**                             | 2602-46-2| '86, '91, '95, '01 |
| CI Direct Brown 95**                           | 1607-86-6| '86, '91, '95, '01 |
| Cobalt metal with tungsten carbide†            | 7440-48-4, | '16          |
|                                                | 12070-12-1|            |
| Creosotes                                      | 8001-58-9| '91          |
| 1,2-Dibromoethane                              | 106-93-4| '86, '95, '01  |
| 3,3’-Dichloro-4,4’-diaminodiphenylmethane (MBOCA) | 101-14-4| '93, ('12)    |
| Dichloromethane                                | 75-09-2 | '91, '14, '15  |
| Diethyl sulphate                               | 64-67-5 | '86           |
| Dimethyl sulphate                              | 77-78-1 | '86           |
| Dimethylcarbamoyl chloride                     | 79-44-7 | '86, '91      |
| Epichlorohydrin                                | 106-89-8| '86, '91      |
| Formaldehyde                                   | 50-00-0 | '86, '91      |
| Glycidol                                       | 556-52-5| '01          |
| Indium and compounds (inorganic, hardly soluble) | 7440-74-6| '13       |
| PAHs (Cyclopenta [c,d] pyrene,                   | 27208-37-3| '16       |
| Dibenz [a,h] anthracene, Dibenz [a,j] acridine, | 53-70-3 |               |
| Dibenzo [a,l] pyrene,                          | 224-42-0|              |
| 1-Nitropyrene, 6-Nitrochrysene†                 | 191-30-0|               |
|                                                | 5522-43-0|             |
|                                                | 7496-02-8|            |
| Styrene oxide                                  | 96-09-3 | '92          |
| 1,2,3-Trichloropropane                         | 96-18-4 | '01          |
| Tris (2,3-dibromopropyl) phosphate             | 126-72-7| '91          |
| Vinyl bromide                                  | 593-60-2| '91          |
| Vinyl fluoride                                 | 75-02-5 | '98          |

**Dyes metabolized to benzidine.
†Provisional.
( ) in the year of proposal indicates year of reconsideration resulting in no classification change.
Table III-1c. Group 2B carcinogens

| Substance | CAS No. | Year of proposal |
|-----------|---------|------------------|
| Acetamide | 60-35-5 | '91              |
| Acetoaldehyde | 75-07-0 | '91              |
| o-Aminoazotoluene | 97-56-3 | '91              |
| p-Aminoazobenzene | 60-09-3 | '91              |
| Amitrole | 61-82-5 | '86              |
| Antimony trioxide | 1309-64-4 | '91, ('13) |
| o-Anisidine | 90-04-0 | '91, ('96)       |
| Anthraquinone | 84-65-1 | '15             |
| Auramine (technical grade) | 492-80-8 | '86            |
| Benzofuran | 271-89-6 | '15             |
| Benzophenone | 119-61-9 | '15             |
| Benzoyl chloride | 98-88-4 | '16             |
| Benzyl violet 4B | 1694-09-3 | '91             |
| 2,2-Bis (bromomethyl) propane-1,3-diol | 3296-90-0 | '01             |
| Bitumens | 8052-42-4 | '91             |
| Bromodichloromethane | 75-27-4 | '95             |
| n-Butyl-2,3-epoxypropyl ether | 2426-08-6 | '16             |
| β-Butyro lactone | 3068-88-0 | '95           |
| Carbon black | 1333-86-4 | '91             |
| Carbon tetrachloride | 56-23-5 | '86             |
| Catechol | 120-80-9 | '01             |
| Chlordane | 57-74-9 | '01             |
| Chlordecone (Kepone) | 143-50-0 | '01             |
| Chloroendic acid | 115-28-6 | '91             |
| Chlorinated paraffins | — | '91             |
| p-Chloroaniline | 106-47-8 | '95             |
| Chloroform | 67-66-3 | '86, ('05)      |
| 1-Chloro-2-methylpropene | 513-37-1 | '01             |
| 3-Chloro-2-methylpropene | 563-47-3 | '01             |
| Chlorophenoxy acetic acid herbicides | — | '86             |
| p-Chloro-o-phenylenediamine | 95-83-0 | '91             |
| Chloroprene | 126-99-8 | '01             |
| Chlorothalonil | 1897-45-6 | '01          |
| CI acid red 114 | 6459-94-5 | '95             |
| CI basic red 9 | 569-61-9 | '95             |
| CI direct blue 15 | 2429-74-5 | '95           |
| Citrus red No.2 | 6358-53-8 | '91             |
| Cobalt and compounds (without tungsten carbide) | 7440-48-4 | '95             |
| p-Cresidine | 120-71-8 | '91             |
| Cumene | 98-82-8 | '15             |
| Dantron | 117-10-2 | '15             |
| N,N’-Diacetyl benzidine | 613-35-4 | '91             |
| 2,4-Diaminoanisole | 615-05-4 | '91             |
| 4,4’-Diaminodiphenyl ether | 101-80-4 | '91            |
| 2,4-Diaminotoluene | 95-80-7 | '91             |
| 1,2-Dibromo-3-chloropropane | 96-12-8 | '91             |
| 2,3-Dibromopropan-1-ol | 96-13-9 | '01             |
| p-Dichlorobenzene | 106-46-7 | '91, ('98)     |
| Substance                                      | CAS No.  | Year of proposal |
|-----------------------------------------------|----------|-----------------|
| 3,3’-Dichlorobenzidine                        | 91-94-1  | '86             |
| 1,4-Dichloro-2-butene                         | 764-41-0 | '15             |
| 3,3’-Dichloro-4,4’-diaminodiphenyl ether      | 28434-86-8 | '91       |
| 1,2-Dichloroethane                            | 107-06-2 | '91             |
| 1,3-Dichloropropene (technical grade)         | 542-75-6 | '91             |
| 1,3-Dichloro-2-propanol                       | 96-23-1  | '15             |
| Dichlorvos                                    | 62-73-7  | '01             |
| Diepoxybutane                                 | 1464-53-5 | '91       |
| Diethanolamine                                | 111-42-2 | '15             |
| Di (2-ethylhexyl) phthalate                   | 117-81-7 | '91             |
| 1,2-Diethylhydrazine                          | 1615-80-1 | '91       |
| Diglycidyl resorcinol ether                   | 101-90-6 | '91             |
| Diisopropyl sulfate                           | 2973-10-6 | '95       |
| p-Dimethylaminioazobenzene                    | 60-11-7  | '91             |
| 2,6-Dimethylaniline                           | 87-62-7  | '95             |
| 3,3’-Dimethylbenzidine (o-Tolidine)            | 119-93-7 | '91             |
| N,N-Dimethylformamide                         | 68-12-2  | '91             |
| 1,1-Dimethylhydrazine                         | 57-14-7  | '91             |
| 3,3’-Dimethoxybenzidine (o-Dianisidine)       | 119-90-4 | '86             |
| 2,4-(or 2,6-) Dinitrotoluene                  | 121-14-2 | '98             |
| 1,4-Dioxane                                   | 123-91-1 | '86, ('15)     |
| Disperseblue 1                                | 2475-45-8 | '91       |
| DDT                                           | 50-29-3  | '86             |
| 1,2-Epoxybutane                               | 106-88-7 | '01             |
| Ethyl acrylate                                | 140-88-5 | '91             |
| Ethylbenzene                                  | 100-41-4 | '01             |
| Ethyl methanesulphonate                       | 62-50-0  | '91             |
| Ethylene thiourea                             | 96-45-7  | '86             |
| Ethylenimine                                  | 151-56-4 | '01             |
| (2-Formylhydrazino)-4-(5-nitro-2-furyl) thiazole | 3570-75-0 | '91       |
| Furan                                          | 110-00-9 | '01             |
| Gasoline                                      | 8006-61-9 | '01       |
| Glycidaldehyde                                | 765-34-4 | '91             |
| Hexachlorocyclohexanes                        | 319-84-6 | '91             |
| HC blue No. 1                                 | 2784-94-3 | '95       |
| Heptachlor                                    | 76-44-8  | '01             |
| Hexamethylphosphoramide                       | 680-31-9 | '01             |
| Hydrazine (anhydrous) and Hydrazine hydrate   | 302-01-2, 7803-57-8 | '86, ('98) |
| Isoprene                                      | 78-79-5  | '95             |
| Lead and compounds (except alkyl lead)*       | 7439-92-1 | '91, ('16) |
| Magenta (containing CI basic red 9)            | 632-99-5 | '95             |
| Magnetic fields, extremely low-frequency      | —        | '15             |
| Man-made mineral fibers                       | —        | '91, '03       |
| (Ceramic fibers, Micro glass fibers)          |          |                 |
| 2-Methylaziridine (Propylene imine)           | 75-55-8  | '91             |
| 4,4’-Methylene bis (2-methylaniline)          | 838-88-0 | '91             |
| 4,4’-Methyleneedianiline                     | 101-77-9 | '91, ('95)     |
| Methyl isobutyl ketone                       | 108-10-1 | '15             |
| Methyl mercuries                              | 7439-97-6 | '95       |
| Substance                                                                 | CAS No.   | Year of proposal |
|--------------------------------------------------------------------------|-----------|------------------|
| 2-Methyl-1-nitroanthraquinone                                            | 129-15-7  | '91              |
| N-Methyl-N-nitrosourethane                                               | 615-53-2  | '91              |
| α-Methylstyrene                                                          | 98-83-9   | '15              |
| Mirex                                                                    | 2385-85-5 | '01              |
| Naphthalene                                                              | 91-20-3   | '15              |
| Nickel compounds (except nickel carbonyl and nickel smelting dusts)*    | 7440-02-0 | '81, '86, '91, ('09) |
| 2-Nitroanisole                                                           | 91-23-6   | '98              |
| Nitrobenzene                                                             | 98-95-3   | '98              |
| Nitrilotriacetic acid and its salts                                      | 139-13-9  | '91              |
| Nitrogen mustard-N-oxide                                                 | 126-85-2  | '91              |
| 5-Nitroacenaphthene                                                      | 602-87-9  | '91              |
| Nitromethane                                                             | 75-52-5   | '01              |
| 2-Nitropropane                                                           | 79-46-9   | '91              |
| N-Nitrosodiethanolamine                                                  | 1116-54-7 | '01              |
| N-Nitrosomorpholine                                                      | 59-89-2   | '91              |
| Oil orange SS                                                            | 2646-17-5 | '91              |
| PAHs (Benz[a]anthracene, Benz[j]aceanthrylene, Benzo[b]fluoranthene, Benzo[c]phenanthrene, Benzo[j]fluoranthene, Benzo[k]fluoranthene, Chrysene, Dibenz[a, h]acridine, Dibenz[c, h]acridine, Dibenzo[a, h]pyrene, Dibenzo[a, l]pyrene, 7H-Dibenzo[c, g]carbazole, 1,3-Dinitropyrene, 1, 6-Dinitropyrene, 1,8-Dinitropyrene, 5-Methylchrysene, 3-Nitrobenzantrhene, 4-Nitropyrene)* | 56-55-3, 202-33-5, 205-99-2, 195-19-7, 205-82-3, 207-08-9, 218-01-9, 226-36-8, 224-53-3, 189-64-0, 189-55-9, 194-59-2, 75321-20-9, 42397-64-8, 42397-65-9, 3697-24-3, 17117-34-9, 57835-92-4 |
| Phenyl glycidyl ether                                                    | 122-60-1  | '91              |
| Polybrominated biphenyls                                                 | 59536-65-1| '91              |
| Polychlorophenols (technical grades)                                     | —         | '86              |
| Ponceau 3R                                                               | 3564-9-8  | '91              |
| Ponceau MX                                                               | 3761-53-3 | '91              |
| 1,3-Propane sultone                                                      | 1120-71-4 | '91              |
| β-Propiolactone                                                          | 57-57-8   | '91              |
| Propylene oxide                                                          | 75-56-9   | '91, '95         |
| Radiofrequency electromagnetic fields                                     | —         | '15              |
| Styrene                                                                  | 100-42-5  | '91              |
| 1,1,2,2-Tetrachloroethane                                                | 79-34-5   | '15              |
| Tetrachloroethylene                                                      | 127-18-4  | '91, ('01)       |
| Tetrafluoroethylene                                                      | 116-14-3  | '01              |
| Tetranitromethane                                                        | 509-14-8  | '98              |
| 4,4’-Thiodianiline                                                       | 139-65-1  | '91              |
| Thiourea                                                                 | 62-56-6   | '95              |
| Titanium dioxide                                                         | 13463-67-7| '15              |
Table III-2. Reference values corresponding to an individual excess lifetime risk of cancer

| Substance                              | Individual excess lifetime risk of cancer | Reference value | Method of estimation          | Year of estimation |
|----------------------------------------|------------------------------------------|-----------------|------------------------------|--------------------|
| Arsene and inorganic arsenic compounds | $10^{-3}$                                 | 3 $\mu$g/m$^3$  | Average relative risk model   | '00                |
|                                        | $10^{-4}$                                 | 0.3 $\mu$g/m$^3$|                              |                    |
| Asbestos                               | $10^{-3}$                                 | 0.15 fibers/ml  | Average relative risk model   | '00                |
|                                        | $10^{-4}$                                 | 0.015 fibers/ml |                              |                    |
| containing asbestos fibers             | $10^{-3}$                                 | 0.03 fibers/ml  |                              |                    |
|                                        | $10^{-4}$                                 | 0.003 fibers/ml |                              |                    |
| other than chrysotile                  | $10^{-3}$                                 | 0.03 fibers/ml  |                              |                    |
|                                        | $10^{-4}$                                 | 0.003 fibers/ml |                              |                    |
| Benzene                                | $10^{-3}$                                 | 1 ppm           | Average relative risk model   | '97                |
|                                        | $10^{-4}$                                 | 0.1 ppm         |                              |                    |
| Ionizing radiation                     | (Table III-3)                             |                 |                              | '12                |
| Nickel smelting dusts (as Ni)          | $10^{-3}$                                 | 10 $\mu$g/m$^3$| Average relative risk model   | '09                |
|                                        | $10^{-4}$                                 | 1 $\mu$g/m$^3$  |                              |                    |

*, See Table I-1 for Group 1 and Group 2A carcinogens.

** Evaluation does not necessarily apply to all individual chemicals within the group.

† Provisional.

( ) in the year of proposal indicates year of reconsideration resulting in no classification change.

Table III-3 indicates reference values corresponding to an individual excess lifetime risk of cancer for ionizing radiation. A series of the reference values, i.e. unit risk doses of ionizing radiation, are shown as Radiation Exposure Induced Death (REID) levels of 100, 50, 10, 1 for 1,000 population with stratified by sex, age and exposure situation (single, repeated). Dose and dose-rate effectiveness factor (DDREF) of 1 is being adopted primarily, and REID levels with DDREF of 2 are also calculated for comparison. The reference values here are being calculated based on exposure-response relationship of low LET radiation, indicating that the values should not be applied in the case that internal exposure is considered.
### Table III-3. Unit risk doses of ionizing radiation: Risk of Exposure-Induced Death (REID) levels of 100, 50, 10, 1, for 1,000 population

| REID  | 18 | 28 | 38 | 48 | 58  |
|-------|----|----|----|----|-----|
| Male  |    |    |    |    |     |
| $10^{-1}$ | 892.2 | 1,075.5 | 1,342.1 | 1,760.8 | 2,441.8 |
| $5 \times 10^{-2}$ | 440.8 | 535.2 | 676.9 | 911.2 | 1,325.0 |
| $10^{-2}$ | 87.4 | 106.8 | 136.7 | 189.0 | 291.6 |
| $10^{-3}$ | 8.7 | 10.7 | 13.7 | 19.1 | 30.0 |
| $10^{-4}$ | 0.9 | 1.1 | 1.4 | 1.9 | 3.0 |
| Female |    |    |    |    |     |
| $10^{-1}$ | 762.9 | 939.2 | 1,204.2 | 1,628.9 | 2,320.5 |
| $5 \times 10^{-2}$ | 374.1 | 462.3 | 597.7 | 821.7 | 1,207.9 |
| $10^{-2}$ | 73.7 | 91.4 | 119.0 | 166.0 | 251.9 |
| $10^{-3}$ | 7.3 | 9.1 | 11.9 | 16.6 | 25.5 |
| $10^{-4}$ | 0.7 | 0.9 | 1.2 | 1.7 | 2.6 |

Revised exposure until age 68 (from first exposure age to the end of age 67) (mSv/year) DDREF=1

| REID  | 18 | 28 | 38 | 48 | 58  |
|-------|----|----|----|----|-----|
| Male  |    |    |    |    |     |
| $10^{-1}$ | 34.1 | 50.8 | 83.5 | 160.2 | 412.8 |
| $5 \times 10^{-2}$ | 16.4 | 24.5 | 40.3 | 77.5 | 203.9 |
| $10^{-2}$ | 3.2 | 4.8 | 7.8 | 15.1 | 40.4 |
| $10^{-3}$ | 0.3 | 0.5 | 0.8 | 1.5 | 4.0 |
| $10^{-4}$ | 0.03 | 0.05 | 0.08 | 0.15 | 0.40 |
| Female |    |    |    |    |     |
| $10^{-1}$ | 28.6 | 42.7 | 70.1 | 133.0 | 342.4 |
| $5 \times 10^{-2}$ | 13.8 | 20.7 | 33.9 | 64.5 | 167.5 |
| $10^{-2}$ | 2.7 | 4.0 | 6.6 | 12.6 | 33.0 |
| $10^{-3}$ | 0.3 | 0.4 | 0.7 | 1.3 | 3.3 |
| $10^{-4}$ | 0.03 | 0.04 | 0.07 | 0.13 | 0.33 |

Revised 10 year exposure, (10 years from first exposure age) (mSv/year) DDREF=1

| REID  | 18 | 28 | 38 | 48 | 58  |
|-------|----|----|----|----|-----|
| Male  |    |    |    |    |     |
| $10^{-1}$ | 101.7 | 126.8 | 168.1 | 245.8 | 412.8 |
| $5 \times 10^{-2}$ | 49.2 | 61.4 | 81.4 | 119.6 | 203.9 |
| $10^{-2}$ | 9.6 | 12.0 | 15.9 | 23.4 | 40.4 |
| $10^{-3}$ | 1.0 | 1.2 | 1.6 | 2.3 | 4.0 |
| $10^{-4}$ | 0.10 | 0.12 | 0.16 | 0.23 | 0.40 |
| Female |    |    |    |    |     |
| $10^{-1}$ | 85.5 | 108.2 | 145.3 | 211.0 | 342.4 |
| $5 \times 10^{-2}$ | 41.5 | 52.5 | 70.5 | 102.6 | 167.5 |
| $10^{-2}$ | 8.1 | 10.3 | 13.8 | 20.1 | 33.0 |
| $10^{-3}$ | 0.8 | 1.0 | 1.4 | 2.0 | 3.3 |
| $10^{-4}$ | 0.08 | 0.10 | 0.14 | 0.20 | 0.33 |
Repeated 5 year exposure, (5 years from first exposure age) (mSv/year) DDREF=1

(a) Male

| REID | age at first exposure |
|------|----------------------|
| 10^{-1} | 192.5 236.8 306.4 430.4 673.3 |
| 5x10^{-2} | 93.3 115.0 149.3 211.4 337.9 |
| 10^{-2} | 18.2 22.5 29.3 41.7 68.0 |
| 10^{-3} | 1.8 2.2 2.9 4.2 6.8 |
| 10^{-4} | 0.18 0.22 0.29 0.42 0.68 |

(b) Female

| REID | age at first exposure |
|------|----------------------|
| 10^{-1} | 161.8 202.3 266.4 376.7 581.4 |
| 5x10^{-2} | 78.6 98.3 129.7 184.1 287.1 |
| 10^{-2} | 15.4 19.2 25.4 36.2 56.9 |
| 10^{-3} | 1.5 1.9 2.5 3.6 5.7 |
| 10^{-4} | 0.15 0.19 0.25 0.36 0.57 |

Single exposure (mSv) DDREF=2

(a) Male

| REID | Age |
|------|-----|
| 10^{-1} | 1.541 1.801 2.139 2.599 3.245 |
| 5x10^{-2} | 0.797 0.946 1.153 1.455 1.911 |
| 10^{-2} | 0.165 0.199 0.251 0.336 0.486 |
| 10^{-3} | 0.017 0.020 0.026 0.042 0.053 |
| 10^{-4} | 0.0017 0.0020 0.0026 0.0042 0.0053 |

(b) Female

| REID | Age |
|------|-----|
| 10^{-1} | 1.403 1.692 2.084 2.646 3.436 |
| 5x10^{-2} | 0.707 0.863 1.085 1.425 1.940 |
| 10^{-2} | 0.142 0.176 0.227 0.309 0.453 |
| 10^{-3} | 0.014 0.019 0.025 0.036 0.047 |
| 10^{-4} | 0.0014 0.0019 0.0025 0.0036 0.0047 |

Repeated exposure until age 68 (from first exposure age to the end of age 67) (mSv/year) DDREF=2

(a) Male

| REID | age at first exposure |
|------|----------------------|
| 10^{-1} | 63.5 93.4 150.2 276.5 650.5 |
| 5x10^{-2} | 30.7 45.3 73.2 136.8 337.3 |
| 10^{-2} | 6.0 8.8 14.4 27.2 70.2 |
| 10^{-3} | 0.6 0.9 1.4 2.7 7.1 |
| 10^{-4} | 0.06 0.09 0.14 0.27 0.71 |

(b) Female

| REID | age at first exposure |
|------|----------------------|
| 10^{-1} | 54.9 81.4 131.9 244.7 596.9 |
| 5x10^{-2} | 26.6 39.5 64.2 120.1 301.3 |
| 10^{-2} | 5.2 7.7 12.6 23.7 60.9 |
| 10^{-3} | 0.5 0.8 1.3 2.4 6.1 |
| 10^{-4} | 0.05 0.08 0.13 0.24 0.61 |

Repeated 10 year exposure, (10 years from first exposure age) (mSv/year) DDREF=2

(a) Male

| REID | age at first exposure |
|------|----------------------|
| 10^{-1} | 191.2 235.3 304.2 424.7 650.5 |
| 5x10^{-2} | 93.2 115.1 149.9 212.5 337.3 |
| 10^{-2} | 18.3 22.6 29.7 42.6 70.2 |
| 10^{-3} | 1.8 2.3 3.0 4.3 7.1 |
| 10^{-4} | 0.18 0.23 0.30 0.43 0.71 |

(b) Female

| REID | age at first exposure |
|------|----------------------|
| 10^{-1} | 165.2 207.5 274.3 387.7 596.9 |
| 5x10^{-2} | 80.5 101.2 134.4 191.7 301.3 |
| 10^{-2} | 15.8 19.9 26.5 38.0 60.9 |
| 10^{-3} | 1.6 2.0 2.6 3.8 6.1 |
| 10^{-4} | 0.16 0.20 0.26 0.38 0.61 |

Repeated 5 year exposure, (5 years from first exposure age) (mSv/year) DDREF=2

(a) Male

| REID | age at first exposure |
|------|----------------------|
| 10^{-1} | 358.0 433.6 545.5 726.9 1,032.7 |
| 5x10^{-2} | 176.0 214.5 272.8 371.6 550.8 |
| 10^{-2} | 34.8 42.6 54.7 76.1 118.5 |
| 10^{-3} | 3.5 4.3 5.5 7.7 12.1 |
| 10^{-4} | 0.35 0.42 0.55 0.77 1.21 |

(b) Female

| REID | age at first exposure |
|------|----------------------|
| 10^{-1} | 310.9 385.1 497.8 681.2 989.7 |
| 5x10^{-2} | 152.1 189.1 246.1 341.5 510.3 |
| 10^{-2} | 29.9 37.3 48.8 68.6 105.3 |
| 10^{-3} | 3.0 3.7 4.9 6.9 10.6 |
| 10^{-4} | 0.30 0.37 0.49 0.69 1.06 |
IV. Occupational Sensitizers

This table is the list of occupational sensitizers to the airway and skin (Table IV). The sensitizers are classified into Group 1 substances which induce allergic reactions in humans, Group 2 substances which probably induce allergic reactions in humans, and Group 3 substances which are considered possibly to induce allergic reactions in humans based on animal experiments.

Recommendation of occupational exposure limits for the occupational sensitizers does not necessarily consider either prevention of sensitization or allergic reaction. Any substance which is not included in the list does not indicate that the substance is not a sensitizer.

Table IV. Occupational sensitizers

| Airway                                              |
|-----------------------------------------------------|
| **Group 1**                                         |
| Beryllium*, Cobalt*, Colophony (Rosin)*, Diphenylmethane-4,4’-diisocyanate (MDI), Glutaraldehyde, Hexane-1,6-diisocyanate, Methyltetrahydropthalic anhydride, Phthalic anhydride, Platinum*, Toluene diisocyanates*, Trimellitic anhydride† |
| **Group 2**                                         |
| Chlorothalonil, Chromium*, Ethylenediamine, Formaldehyde, Maleic anhydride†, Methyl methacrylate, Nickel*, Piperazine |

| Skin                                                |
|-----------------------------------------------------|
| **Group 1**                                         |
| Aniline, Benzoyl peroxide, N-butyl-2,3-epoxy-propyl ether†, Chlorothalonil, Chromium*, Cobalt*, Colophony (Rosin)*, 4,4’-Diaminodiphenylmethane, 2,4-Dinitrochlorobenzene (DNCB), Epichlorohydrin, Formaldehyde, Glutaraldehyde, Hydrazine*, Mercury*, 4,4’-Methylenedianiline, Nickel†, 4-Phenylbenzenesulfonamide, Platinum*, Resorcinol, Sodium ethylmercury 2-sulfidobenzoate (Thimerosal), Thiuram, Trichloroethylene†, Tri (propylene glycol) diacrylate, N,N’,N’’-Tris (β-hydroxyethyl)-hexahydro-1,3,5-triazine, Turpentine*, m-Xylylendiamine |
| **Group 2**                                         |
| Acrylamide, Benomyl, Beryllium*, Butyl acrylate, Copper*, Dibutyl phthalate, Dichloropropane, Dicyclohexylcarbodiimide, Ethylene oxide, Ethylenediamine, Hydroquinone, Iodine*, Maleic anhydride, Methyl acrylate, Methyl methacrylate, Picric acid, Polyvinyl chloride plasticizers*, Rodium*, Toluene diamine*, Toluene diisocyanates*, Usnic acid |
| **Group 3**                                         |
| *-Chloroaniline, Dimethylamine†, o-Phenylenediamine, m-Phenylenediamine |

*Evaluation does not necessarily apply to all individual chemicals within the group. †Provisional.

The revised definition of “Occupational sensitizer” has been applied to the substances proposed in 1998 or later, and the substances listed before 1998 are not fully re-examined at this time; please note that OEL values are not necessarily recommended to all the substances listed here. See JSOH web site for brief summary of OEL documentation at http://sanei.or.jp/oel-eng

V. Reproductive Toxicants

The Japan Society for Occupational Health (JSOH) classifies reproductive toxicants on the basis of evidence of reproductive toxicity obtained from epidemiological studies and other studies in humans, as well as that from experimental studies in animals. The classification is made based on the strength of the evidence for adverse effects on reproduction in humans, but does not reflect the potency of such adverse effects. Namely, the classification does not necessarily indicate that exposures to the classified substances at the present Occupational Exposure Limit (OEL-M) levels induce adverse effects on reproduction. The definition of reproductive toxicity and the classification criteria for judgment are as follows.

1. Definition of reproductive toxicity

Reproductive toxicity includes adverse effects on reproductive functions in males and females, as well as on the offspring. Effects on functions such as fertility, pregnancy, delivery, and lactation in women, and fertility/insemination in men are within the scope of the definition. Substances that have adverse effects on reproductive organs are also included within the classification criteria if it is suspected that the reproductive functions referred to above are affected. In the case of offspring, reproductive toxicity is defined as the effects on the development of the embryo/fetus including teratogenic insults by prenatal exposure to the substance and/or the effects on the infant by postnatal exposure via lactation due to transfer in breast milk. If effects on post-weaning growth, behavior, function, sexual
maturation, carcinogenesis, accelerated aging, and other processes are clearly demonstrated in the offspring as a result of parental exposure, then such effects are considered as reproductive toxicity.

2. Classification and judgment criteria
1) Classification of reproductive toxicants:
  Reproductive toxicants shall be classified in Group 1, Group 2, or Group 3, defined as follows.
  Group 1: Substances known to cause reproductive toxicity in humans.
  Group 2: Substances presumed to cause reproductive toxicity in humans.
  Group 3: Substances suspected to cause reproductive toxicity in humans.

2) Judgment criteria for the classification of reproductive toxicity:
  Group 1: Substances for which sufficient evidence in humans has been obtained from epidemiological studies and other human studies shall be classified.
  Sufficient evidence that demonstrates reproductive toxicity in humans is required, where sufficient means two or more reports of epidemiological studies conducted in an appropriate manner. A single epidemiological study can be used as the evidence for classification to this group if any of the following conditions are satisfied: a) the study takes into consideration both dose-response relationships and co-exposure to other substances or potential confounding factors, in an appropriate manner; b) the study is supported by many non-epidemiological study reports on, for example, clinical cases or accidental exposures, indicating reproductive toxicity and it can therefore be decided overall that there is sufficient evidence of toxicity in humans.
  Animal experimental data are considered as supportive information.
  Group 2: Substances for which sufficient evidence demonstrating reproductive toxicity has been obtained in appropriate animal experiments, and thus presumed to cause reproductive toxicity in humans, shall be classified.
  Judgment shall be made on the basis of animal experiments, namely, evidence showing obvious adverse effects on reproduction in animals, identified by appropriately conducted animal experimental studies, and thus reasonably indicating that the substance causes reproductive toxicity in humans. When judgment is made from the results of animal experiments, it is required that the observed effects should not be the consequences of secondary non-specific effects of other general toxicities, and that the identified mechanism of action be non-species-specific and therefore relevant for extrapolation to humans. In addition, if the observed changes are small and exert only non-significant effects on the life or function of the subject, then such changes are considered as not satisfying the requirement.
  Group 3: Substances for which limited evidence has been demonstrated shall be classified.
  Substances are allocated into this group when reproductive toxicities are suspected from reports in humans or from animal experiments. If information for reproductive toxicity is obtained from epidemiological studies, other human studies, and/or animal experiments, but such evidence is not considered to be sufficient for allocating the substance to Group 1 or Group 2, then classification in Group 3 should be considered.

3. Classified reproductive toxicants
  Table V. lists the substances classified in each reproductive toxicant group according to the judgment criteria.

Table V. Reproductive toxicants

| Group 1 | Arsenic and compounds, 2-Bromopropane, Cadmium and compounds, Carbon disulfide, Carbon monoxide, Di (2-ethylhexyl) phthalate, Ethylene glycol monomethyl ether, Ethylene glycol monomethyl ether acetate, Ethylene oxide, Lead and compounds, Perfluorooctanoic acid (PFOA), Polychlorodibenzofurans (PCB), Toluene |
| Group 2 | Acrylamide, 1-Bromopropane, Chlorodifluoromethane, Chloromethane, N,N-Dimethylacetamide, N,N-Dimethylformamide (DMF), Ethyl benzene, Ethylene glycol monoethoxy ether, Ethylene glycol monooxyethyl ether acetate, Inorganic mercury (including mercury vapor), Manganese and compounds, Methanol, Pentachlorophenol (PCP), Styrene, Vanadium and compounds, Xylene for industrial use |
| Group 3 | Atrazine, n-Butyl-2,3-epoxypropylether, Chromium and compounds, p-Dichlorobenzene, Ethyleneimine, Nickel and compounds, Phenol, Tetrachloroethylene, Trichloroethylene, Xylene (ortho-, meta-, para-xylene and their mixture) |

Not all substances that may exert reproductive toxicity are identified.

‡ Precaution should be given for lower exposure than OEL-M or OEL-B. As for reproductive toxicity, it is generally known that there is a sensitive period, during pregnancy for example, and such effects of this substance have been identified.

†† provisional

See JSOH web site for brief summary of OEL documentation at http://sanei.or.jp/oel-eng
referred to above. The judgment is made for substances for which OEL is recommended by JSOH based on information described in the documentation for Recommendation of Occupational Exposure Limits by JSOH and other relevant information; this does not mean that substances not included in the table do not meet the classification criteria of reproductive toxicity. There may be some substances for which reproductive toxicity might be observed below the level of OEL-M or OEL-B; in such cases, precautionary notice is given by adding a symbol (＃) next to the substances in Table V.

VI. Occupational Exposure Limits for Continuous or Intermittent Noise

Occupational exposure limits (OELs) for continuous or intermittent noise exposure are recommended as follows to protect against noise-induced hearing loss.

1. **OELs for continuous or intermittent noise**
   
   Values in Fig. VI or Table VI-1 show OELs, at or below which noise-induced permanent threshold shift (NIPTS) is expected to be below 10 dB at or below a frequency of 1 kHz, below 15 dB at 2 kHz, and below 20 dB at or more than 3 kHz after more than 10 years of continuous or intermittent noise exposure for 8 hours a day in most workers.

2. **Applicable noise**
   
   OELs can be applied to wide and narrow-band noise with band width below 1/3 octave. OELs are temporarily applicable to pure tones regarded as narrow-band noise. Impulsive or impact noise is excluded from the application (see Section VII).

3. **Application method**
   
   (1) In the case of continuous noise exposure throughout the work-time, OELs corresponding to the exposure duration should be taken from Fig. VI or Table VI-1.
   
   (2) In the case of intermittent noise exposure, an equivalent exposure duration is considered to be the sum of exposure duration throughout the work-time minus an effective resting duration, and OELs corresponding to the equivalent exposure duration should be taken from Fig. VI or Table VI-1. The effective resting duration is the duration when the noise levels are below 80 dB.
   
   (3) In the case that noise is analyzed by an octave band filter, OELs corresponding to exposure duration are the values at the left ordinate of Fig. VI or in Table VI-1. In the case that noise is analyzed by a narrower band filter with a band width of 1/3 octave or less, OELs are the values at the right ordinate of Fig. VI or the values subtracted 5 from the figures in Table VI-1.

4. **OELs by A-weighted sound pressure level**
   
   Basically, frequency analysis of noise is recommended. In the case of evaluating with an A-weighted sound pressure level, OELs in Table VI-2 should be used.

5. **Noise measurement**
   
   For measurement methods, refer to ‘Japan Industrial
VII-i. Occupational Exposure Limits for Impulsive or Impact Noise

Occupational Exposure Limits (OELs) for impulsive or impact noise exposure in the workplace are recommended as follows to protect against noise-induced hearing loss.

1. OELs for impulsive or impact noise

In the case that total frequency of exposure to impulsive or impact noise is at or below 100 times a day, the peak sound pressure level shown in Fig. VII-1 is recommended as the OEL corresponding to the duration of impulsive or impact noise explained in “3. Measurement method”.

In the case that total number of exposures to impulsive or impact noise is above 100 times a day, the sum of the peak sound pressure level in Fig. VII-1 with the adjustment value in Fig. VII-2 to correct the difference of exposure frequency is recommended as OEL. At or below these limits, NIPTS is expected to be below 10 dB at or below a frequency of 1 kHz, below 15 dB at 2 kHz, and below 20 dB at or more than 3 kHz after more than 10 years of impulsive or impact noise exposure in most workers.

2. Applicable noise

These OELs are applicable to impulsive or impact noise only. In the case of mixed exposure to both impulsive or impact noise and continuous or intermittent noise, both OELs should be satisfied.
3. Measurement method

Impulsive or impact noises are classified by their oscilloscope-measured wave forms into two groups, as shown in Fig. VII-3 (A) and (B). In Fig. VII-3 (A), A duration is defined as the duration between $T_0$ and $T_D$. In Fig. VII-3 (B), B duration is defined as the duration between $T_0'$ and $T_D'$ if no reflection sound exists, or the sum of durations between $T_0$ and $T_0'$ and between $T_0''$ and $T_D''$ if reflection sound dose exist. In the case of (B), $T_0'$ or $T_0''$ is determined by the intersection of a wave envelope indicating sound pressure change with a line indicating a sound pressure 20 dB below peak sound pressure. This method is also applicable in the case of multiple reflection sounds.

VII-ii. Occupational Exposure Limit for Impulsive or Impact Noise by A-Weighted Sound Pressure Level

1. Occupational exposure limit (OEL)

In the case that total frequency of exposure to impulsive or impact noise is at or below 100 times a day, OEL is 120 dB at A-weighted sound pressure level. In the case that total frequency of exposure to impulsive or impact noise is above 100 times a day, the adjustment value in Fig. VII-2 corresponding to frequency of exposure should be added for OEL determination.

2. Application

OEL is applicable to type B wave in Fig. VII-3 only.

3. Measurement method

Maximum values should be measured by the Sound Level Meter (JIS C 1509-1-2005) with use of an A-weighted frequency response and fast dynamic characteristic.

VIII. Occupational Exposure Limits for Heat Stress

1. Occupational Exposure Limits

Permissible heat exposure limits were proposed as table VIII-1 on the presumption that any unfavorable physiological response should not be caused by the heat stress.

2. Application

These exposure limits show the condition for which the workers work without health impairment nor decrease in work efficiency for one hour of continuous work or two hours of intermittent work. The workers mentioned here are healthy adult male workers, adapted themselves to hot environment, well used to the work, wearing usual summer clothes, and taking enough water and salt.

Hot environment means the condition which the regulation of body temperature is mainly performed by the evaporation responding to the complex of ambient temperature, humidity, and heat radiation.

Adaptation is the effect of the vicarious physiological change of the worker working under hot environment.

The thermal adaptation is obtained by usually working for one week under hot environment. If hot environment exposure is ceased, the adaptation effect is lost immediately and usually disappears in two weeks. Therefore, it is necessary to pay attention to the workers’ condition when their adaptation is not enough or when they return to work after two or more days off.

The unfavorable physiological response is the state that physiological burdens such as increase of the heart rate, a rise in temperature, the increase of the quantity of water loss continue increasing.

Therefore, if the physiological burden on worker continues increasing under hot environment, some engineering measures should be taken or other measures like wearing cool clothes and reducing work load should be performed to decrease heat strain. The heat stress consists of factors such as environmental thermal condition, heat production through metabolism and heat exposure time.

The work load means metabolic energy used at the work. We expressed the degree in RMR (Relative Metabolic Rate) and classified in five categories as shown in
table VIII-2. RMR is calculated by the following expression.

\[
RMR = \frac{(\text{energy consumption on exertion}) - (\text{energy consumption at rest})}{(\text{basal metabolic rate})}
\]

RMR values according to common movements are displayed in Table VIII-3. This table should be referred to estimate the work load.

In an ordinal industrial setting, many of the works are manually performed continuously with the work load of around RMR 1.0. And most of the work loads are not more than RMR 2. However, it is considered possible to work continuously for one hour by the work load of RMR 4, we set one hour continuous work as the basic work unit for the work load up to RMR 4. Furthermore, although the work exceeding RMR 4 may exist, we assumed those work must be performed intermittently, as it is difficult to continue for one hour.

Therefore, regarding the working hour mentioned here, we classify the work into continuous work or intermittent work. We assumed one-hour work as the evaluation unit for continuous work and proposed the method of evaluating the environment in one-hour continuous work for normal eight hours. Likewise, we assumed two-hour work as the evaluation unit for intermittent work and proposed the method of evaluating the environment in two-hour intermittent work similarly. We adopted these methods in order to make it applicable to the real industrial workshop and to make it possible to evaluate in a short time.

3. Thermal index and method for measuring workload

We decided to use the environmental index corresponding to the physiological response by the heat stress for an evaluation of the hot environment. As the best method now, we adopted WBGT (Wet Bulb Globe Temperature, heat index) as the simple and practical index for the thermal condition.

Calculation of thermal index

Methods for the measurement of thermal index are described elsewhere. WBGT is calculated as follows.

Calculation of WBGT

(1) Inside the room or outdoors without sunlight radiation

\[
\text{WBGT} = 0.7\text{NWB} + 0.3\text{GT}
\]

(2) Outdoors with sunlight radiation

\[
\text{WBGT} = 0.7\text{NWB} + 0.2\text{GT} + 0.1\text{DB}
\]

NWB (natural wet bulb temperature): Wet bulb tempera-

At measurement, it is important to comprehensively evaluate the thermal load affected by the ambient thermal condition and artificial heat production in the workplace. The actual situation including the workers’ condition should be fully understood such as the work position, the work intensity, the time and frequency of the heat exposure. We estimate the actual work condition as follows.

In the case of continuous work, the thermal condition of the workplace should be defined as the highest one-hour value of WBGT in a daily working hour.

In the case of two-hour intermittent work, the thermal condition of the workplace should be defined by two-hour time-weighted value of WBGT.

\[
\text{Two-hour time-weighted value of WBGT} = \frac{(\text{WBGT}_1 \times t_1 + \text{WBGT}_2 \times t_2 + \ldots + \text{WBGT}_n \times t_n)}{120 \text{ minutes}}
\]

\[t_1, t_2, \ldots, t_n: \text{Each time at work or at break (minute)}\]

The method to calculate work load of two-hour intermittent work is as follows.

If the workers are engaged to heavy/moderate work load for more than one hour, we define it as moderate workload.

If the workers are engaged to light work load for more than one hour, and the rest to moderate workload, we define it as light work load.

When each of the work load is of concern, we calculate the two-hour load average of the work load as follows.

\[
\text{Two-hour load average of the work load} = \frac{(\text{WL}_1 \times t_1 + \text{WL}_2 \times t_2 + \ldots + \text{WL}_n \times t_n)}{120 \text{ minutes}}
\]

\[t_1, t_2, \ldots, t_n: \text{Each time at work or at break (minute)}\]
### 4. Year of proposal: 1982

**Table VIII-1.** Occupational Exposure Limits for heat stress

| Work load | OELs (WBGT (°C)) |
|-----------|------------------|
| RMR ~1 (Very Light, ~130 kcal/h) | 32.5 |
| RMR ~2 (Light, ~190 kcal/h) | 30.5 |
| RMR ~3 (Moderate, ~250 kcal/h) | 29.0 |
| RMR ~4 (Moderate, ~310 kcal/h) | 27.5 |
| RMR ~5 (Heavy, ~370 kcal/h) | 26.5 |

**Table VIII-2.** Work load and metabolic energy (kcal/h)

| Work load | Metabolic energy (kcal/h) |
|-----------|--------------------------|
| RMR ~1 (Very Light, ~130 kcal/h) | ~130 |
| RMR ~2 (Light, ~190 kcal/h) | ~190 |
| RMR ~3 (Moderate, ~250 kcal/h) | ~250 |
| RMR ~4 (Moderate, ~310 kcal/h) | ~310 |
| RMR ~5 (Heavy, ~370 kcal/h) | ~370 |

**Table VIII-3.** Classification of RMR by work

| RMR | Principal motion sites | Motion | Examples of works |
|-----|------------------------|--------|-------------------|
| 0–0.5 | hand | moving mechanically | call handling (seated) 0.4, data entry 0.5, gage monitoring (seated) 0.5, straightening (hammer tapping, 98 times/min) 0.9, vehicle driving 1.0 |
| 0.5–1.0 | moving consciously | |
| 1.0–2.0 | hand movement with some upper limb movement | hand movement with some forearm movement | lathe work (pairing, 0.83 minutes/unit) 1.1, surveillance work (standing) 1.2, walking slowly on level ground (45 m/min) 1.5 |
| 2.0–3.0 | | hand movement with some upper arm movement | walking (ordinal, 71 m/min) 1.1, concrete polishing (lightly) 2.0, circular saw work 2.5, stair walking (down, 50 m/min) 2.6 |
| 3.0–4.0 | upper limb | normal movement | chinning grinder (grinding 150 kg parts, 6 min. / unit) 3.0, riding bicycle (level ground, 170 m/min) 3.4, walking (fast, 95 m/min) 3.5, riveting (1.3/min) 4.2, filing (36 cm file, 150 times / min.) 4.2, rough saw 5.0 |
| 4.0–5.5 | | relatively big movement with power | |
| 5.5–6.5 | whole body | normal movement | tapping (poking 7 kg, 16-20 times/min) 5.7, shoveling (6 kg, 18 times/min) 6.5, stair walking (up, 45 m/min) 6.5 |
| 6.5–8.0 | lifting, turning, pulling, pushing, throwing | relatively big movement with equal power | hammering (6.8 kg, 26 times/min.) 7.8, pile up (15 kg, 10 times/min) 9.0 |
| 8.0–9.5 | moving up-and-down, scraping | especially momentary | |
| 10.0–12.0 | whole body (same as above) | physically strenuous work with a bit of leeway; may continue for sometime | pushing at full power 10.0, pickaxe (concrete bursts) 10.5, shovel (72 times/min.) 11.0 |
| 12.0 | physically strenuous work such as construction work | concentrate on whole body movement and can tolerate only for less than one minute | hammering (4.5 kg, 29 times/min) 19.3 |
IX. Occupational Exposure Limits for Cold Stress

Workers should wear appropriate clothing to protect themselves from cold stress in cold environments. The values of thermal insulation of the combination of clothing are shown in Table IX-1.

Recommendations about clothing: Wear several layers of loose clothing. Layering provides better insulation. Make sure to protect the ears, face, hands and feet in extremely cold weather. Boots should be waterproof and insulated. Avoid touching cold metal surfaces with bare skin.

The gloves are necessary to prevent frostbite of the hands. The appropriate gloves should be chosen, depending on work, and waterproof gloves in some cases. If the degree of the chilliness is severer, mittens are more effective.

The relationship between equivalent temperature and thermal insulation of clothing, during both light and moderate workloads is presented in Table IX-2.

### Table IX-1. Thermal performance of clothing

| Combination of clothing                                                                 | clo value |
|----------------------------------------------------------------------------------------|-----------|
| Underwear (top /bottom), shirt, trousers, coat, vest, socks, shoes                      | 1.11      |
| Underwear (top /bottom), thermal jumper, thermal trousers, socks, shoes                 | 1.40      |
| Underwear (top /bottom), shirt, trousers, coat, over jacket, cap, gloves, socks, shoes | 1.60      |
| Underwear (top /bottom), shirt, trousers, coat, over jacket, over trousers, socks, shoes| 1.86      |
| Underwear (top /bottom), shirt, trousers, coat, over jacket, over trousers, cap, gloves, socks, shoes | 2.02 |
| Underwear (top /bottom), over jacket, over trousers, thermal jumper, thermal trousers, socks, shoes | 2.22 |
| Underwear (top /bottom), over jacket, over trousers, thermal jumper, thermal trousers, cap, gloves, socks, shoes | 2.55 |
| Cold protective clothing                                                                | 3–4.5     |
| Sleeping bag                                                                            | 3–8       |

### Table IX-2. Occupational exposure limits for cold stress (Maximal work duration in a 4-hour shift)

| Temperature | Work load   | Maximal work duration (min) |
|-------------|-------------|-----------------------------|
| −10−25°C    | Light work  | (RMR~2) ~ 50                |
|             | Moderate work | (RMR~3) ~ 60               |
| −26−40°C    | Light work  | (RMR~2) ~ 30                |
|             | Moderate work | (RMR~3) ~ 45               |
| −41−55°C    | Light work  | (RMR~2) ~ 20                |
|             | Moderate work | (RMR~3) ~ 30               |

### Table IX-3. Cooling power of wind on exposed body areas air expressed as equivalent chill temperature

| wind velocity (m/sec) | 0 | −5 | −10 | −15 | −20 | −25 | −30 | −35 | −40 | −45 | −50 |
|-----------------------|---|----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| calm                  | 0 | −5 | −10 | −15 | −20 | −25 | −30 | −35 | −40 | −45 | −50 |
| 2                     | −1| −6 | −11 | −16 | −21 | −27 | −32 | −37 | −42 | −47 | −52 |
| 3                     | −4| −10| −15 | −21 | −27 | −32 | −38 | −44 | −49 | −55 | −60 |
| 5                     | −9| −15| −21 | −28 | −34 | −40 | −47 | −53 | −59 | −66 | −72 |
| 8                     | −13| −20| −27 | −34 | −41 | −48 | −55 | −62 | −69 | −76 | −83 |
| 11                    | −16| −23| −31 | −38 | −46 | −53 | −60 | −68 | −75 | −83 | −90 |
| 15                    | −18| −26| −34 | −42 | −49 | −57 | −63 | −73 | −80 | −88 | −96 |
| 20                    | −20| −28| −36 | −44 | −52 | −60 | −68 | −76 | −84 | −92 | −100|
When air temperature is lower, the worker should wear clothing with higher thermal insulation power. And also, when a workload is low, the worker should wear higher thermal insulation clothing, because the internal heat produced by the body is lower than in the case of a higher workload.

In the cold environment, the wind velocity becomes a critical factor as well as air temperature.

An equivalent chill temperature chart relating the air temperature and the wind velocity is presented in Table IX-3.

Maximum work period recommended for properly clothed workers, working 4-hour shifts, at air temperatures and workloads are shown in Table IX-4. The workload is expressed in RMR (Relative Metabolic Rate) with the identical case of occupational exposure limits for heat stress. Light workload is less than RMR 2, (less than 190 kcal/h, metabolic energy), and moderate workload is RMR 2-3 (about 250 kcal/h, metabolic energy).

| Air temperature | Work load | RMR | Maximum work period (min) |
|-----------------|-----------|-----|--------------------------|
| −10~−25°C       | light work | (RMR-2) | ~50                      |
|                 | moderate work | (RMR-3) | ~60                      |
| −26~−40°C       | light work | (RMR-2) | ~30                      |
|                 | moderate work | (RMR-3) | ~45                      |
| −41~−55°C       | light work | (RMR-2) | ~20                      |
|                 | moderate work | (RMR-3) | ~30                      |

wind velocity is below 0.5 m/sec, in an almost windless environment.

The standard work conditions are for four hours by shift work taking a rest in a recovery room for at least 30 minutes after one work sequel to.

Table IX-5. Physical effects by cold chill index and equivalent temperature

| Cold chill index | Equivalent air temperature (°C) | Physical effects |
|-----------------|---------------------------------|------------------|
| 1,000           | −14                             | Very cold        |
| 1,200           | −22                             | Extremely cold   |
| 1,400~1,550     | −30~−38                         | Frostbite of exposed skin in one hour |
| 1,700~1,900     | −45~−53                         | Dangerous outside activity such as walking, frostbite occurs on exposed part of the face in one minute |
| 2,000~2,300     | −61~−69                         | Frostbite occurs on exposed part of the face in 30 seconds |

When air temperature is lower, the worker should wear clothing with higher thermal insulation power. And also, when a workload is low, the worker should wear higher thermal insulation clothing, because the internal heat produced by the body is lower than in the case of a higher workload.

In the cold environment, the wind velocity becomes a critical factor as well as air temperature.

An equivalent chill temperature chart relating the air temperature and the wind velocity is presented in Table IX-3.

Maximum work period recommended for properly clothed workers, working 4-hour shifts, at air temperatures and workloads are shown in Table IX-4. The workload is expressed in RMR (Relative Metabolic Rate) with the identical case of occupational exposure limits for heat stress. Light workload is less than RMR 2, (less than 190 kcal/h, metabolic energy), and moderate workload is RMR 2-3 (about 250 kcal/h, metabolic energy).

There is much continuous light work (RMR 1-2), and moderate work of RMR 3 in some cases. In the workload of these levels, physical loads to thermoregulation system by the cold stress, is bigger than the load to breathing and the circulatory system in the body function by the work.

The standard work conditions are for four hours shift work, taking a rest for at least 30 minutes after each shift work, wearing adequate cold-protective clothing to work in an almost windless environment.

Physical effects by cold chill index and equivalent temperature are shown in Table IX-5.

In cold environments, skin temperatures decrease particularly in the tip of the hands and feet. Body temperatures decrease, when heat production in the body is less than the heat radiation on the equilibrium of the internal heat balance.

Tremors and unconsciousness appear by hypothermia. Core temperature such as rectal temperature should keep above 36°C. Outbreak of more intense tremors is the danger signal that temperature is decreasing more, and one should promptly stop exposure to the cold.

Work efficiency decreases and is unsafe due to pain, tightening and the chilliness of the peripheral parts such as hands and feet. Furthermore, the skin temperature of the toes is approximately 13°C, and 10°C at the fingers. Pain and numbness by cold is a danger signal leading to frostbite.

X. Occupational Exposure Limits for Whole Body Vibration

0.35 m/s²Aeq (8)
XI. Occupational Exposure Limits for Hand-Arm Vibration

![Graph showing occupational exposure limits for hand-arm vibration using vibration total value of frequency-weighted r.m.s. acceleration.](image)

Fig. XI. Occupational exposure limits for hand-arm vibration using vibration total value of frequency-weighted r.m.s. acceleration.

### Table XI. Occupational exposure limits for hand-arm vibration using vibration total value of frequency-weighted r.m.s. acceleration

| Exposure time (min) | Vibration total value of frequency-weighted r.m.s. acceleration (m/s² rms) |
|--------------------|---------------------------------------------------------------|
| ≤6                 | 25.0                                                          |
| 10                 | 19.4                                                          |
| 15                 | 15.8                                                          |
| 30                 | 11.2                                                          |
| 60                 | 7.92                                                          |
| 90                 | 6.47                                                          |
| 120                | 5.60                                                          |
| 150                | 5.01                                                          |
| 180                | 4.57                                                          |
| 210                | 4.23                                                          |
| 240                | 3.96                                                          |
| 270                | 3.73                                                          |
| 300                | 3.54                                                          |
| 330                | 3.38                                                          |
| 360                | 3.23                                                          |
| 390                | 3.11                                                          |
| 420                | 2.99                                                          |
| 450                | 2.89                                                          |
| 480                | 2.80                                                          |

XII. Occupational Exposure Limits for Time-Varying Electric, Magnetic and Electromagnetic Fields (up to 300 GHz)

### Table XII-1. Static magnetic fields (Frequency: 0–0.25 Hz)

|                  | OEL-M        | OEL-C |
|------------------|--------------|-------|
| Head, trunk      | 200 mT (1.63×10⁴ Am⁻¹) | 2T    |
| Extremities      | 500 mT (4.08×10⁴ Am⁻¹) | 5T    |

### Table XII-2. Low frequency time-varying electric and magnetic fields (Frequency: 0.25 Hz–100 kHz)

| Frequency (f)    | EF*           | Magnetic flux density | MF†          |
|------------------|---------------|-----------------------|--------------|
| 0.25–1.0 Hz      | 50/f mT       | 4.08 × 10⁴/f Am⁻¹     |              |
| 1.0–25 Hz        | 20 kVm⁻¹      | 4.08 × 10⁴/f Am⁻¹     |              |
| 25–500 Hz        | 500/f kVm⁻¹   | 50/f mT               | 81.4 Am⁻¹    |
| 500–814 Hz       | 500/f kVm⁻¹   | 0.1 mT                | 81.4 Am⁻¹    |
| 814–60 kHz       | 614 Vm⁻¹      | 0.1 mT                | 81.4 Am⁻¹    |
| 60–100 kHz       | 614 Vm⁻¹      | 6/f mT                | 4.880/f Am⁻¹ |

*EF: electric field. †MF: magnetic field.
XIII. Occupational Exposure Limit for Ultraviolet Radiation

Occupational Exposure Limit for ultraviolet radiation with wavelengths between 180 nm and 400 nm is recommended to be 30 J/m² as effective irradiance integrated over 8 hours a day, to avoid acute effects on eye (cornea or conjunctiva) or the skin. This value is not applicable to laser radiation.

Effective irradiance is defined as follows:

\[ E_{\text{eff}} = \sum_{\lambda=180 \text{ nm}}^{400 \text{ nm}} E_{\lambda} S(\lambda) \Delta \lambda \]

where:
- \( E_{\text{eff}} \) = effective irradiance
- \( E_{\lambda} \) = spectral irradiance at exposure
- \( S(\lambda) \) = relative spectral effectiveness (Table XIII)
- \( \Delta \lambda \) = band width

Table XII-3. Radio-frequency electromagnetic fields
(Frequency: 0.1 MHz~300 GHz)

| Frequency (f) | EF* | Magnetic flux density | MF† | Power density |
|--------------|-----|----------------------|-----|--------------|
| 0.1~3.0 MHz  | 614Vm⁻¹ | 6/f µT                | 4.88/f Am⁻¹ |
| 3.0~30 MHz   | 1,842/f Vm⁻¹ | 6/f µT             | 4.88/f Am⁻¹ |
| 30~400 MHz   | 61.4Vm⁻¹   | 0.2 µT              | 0.163Am⁻¹  | 10Wm⁻²       |
| 400~2000 MHz | 3.07f⁰⁵Vm⁻¹ | 0.01f⁰⁵µT        | 8.14f⁰⁵mAm⁻¹ | f/40 Wm⁻²   |
| 2~300 GHz    | 137Vm⁻¹    | 0.447 µT           | 0.364Am⁻¹  | 50Wm⁻²       |

*EF: electric field. †MF: magnetic field.

Fig. XII-1. OEL-Ms of time-varying electric fields.

Fig. XII-2. OEL-Ms of static and time-varying magnetic fields.
**Table XIII. Ultraviolet radiation and relative spectral effectiveness**

| Wavelength (nm) | Relative spectral effectiveness | Wavelength (nm) | Relative spectral effectiveness | Wavelength (nm) | Relative spectral effectiveness |
|-----------------|---------------------------------|-----------------|---------------------------------|-----------------|---------------------------------|
| 180             | 0.012                           | 280             | 0.880                           | 325             | 0.00050                         |
| 190             | 0.019                           | 285             | 0.770                           | 328             | 0.00044                         |
| 200             | 0.030                           | 290             | 0.640                           | 330             | 0.00041                         |
| 205             | 0.051                           | 295             | 0.540                           | 333             | 0.00037                         |
| 210             | 0.075                           | 297             | 0.460                           | 335             | 0.00034                         |
| 215             | 0.094                           | 300             | 0.300                           | 340             | 0.00027                         |
| 220             | 0.120                           | 303             | 0.120                           | 345             | 0.00023                         |
| 225             | 0.150                           | 305             | 0.060                           | 350             | 0.00020                         |
| 230             | 0.190                           | 308             | 0.025                           | 355             | 0.00016                         |
| 235             | 0.230                           | 310             | 0.015                           | 360             | 0.00013                         |
| 240             | 0.300                           | 313             | 0.006                           | 365             | 0.00011                         |
| 245             | 0.360                           | 315             | 0.003                           | 370             | 0.000094                        |
| 250             | 0.430                           | 316             | 0.0023                          | 375             | 0.000077                        |
| 254             | 0.500                           | 317             | 0.0020                          | 380             | 0.000064                        |
| 255             | 0.520                           | 318             | 0.0016                          | 385             | 0.000053                        |
| 260             | 0.650                           | 319             | 0.0012                          | 390             | 0.000044                        |
| 265             | 0.810                           | 320             | 0.0010                          | 395             | 0.000036                        |
| 270             | 1.000                           | 322             | 0.00067                         | 400             | 0.000030                        |
| 275             | 0.970                           | 323             | 0.00054                         |                 |                                 |

**Members of the Committee for Recommendation of Occupational Exposure Limits (2015–2016)**

**Chairperson**
Toru TAKEBAYASHI (Tokyo)

**Members**
Ginji ENDO (Osaka), Tetsuhito FUKUSHIMA (Fukushima), Kunio HARA (Tokyo), Hajime HORI (Kita-Kyusyu), Gaku ICHIHARA (Chiba), Kanae KARITA (Tokyo), Takahiko KATOH (Kumamoto), Toshihiro KAWAMOTO (Kita-Kyusyu), Shinji KUMAGAI (Kita-Kyusyu), Yukinori KUSAKA (Fukui), Muneyuki MIYAGAWA (Tokyo), Tetsuo NOMIYAMA (Matsumoto), Kazuyuki OMAE (Tokyo), Tatsuya TAKESHITA (Wakayama), Yuko YAMANO (Tokyo), Kazuhiro YOKOYAMA (Tokyo)

**Drafting members**
Kouji HARADA (Kyoto), Seichi HORIE (Kita-Kyusyu), Hyogo HORIGUCHI (Sagamihara), Masayoshi ICHIBA (Saga), Akiyoshi ITO (Kita-Kyusyu), Satoko IWASAWA (Tokyo), Michihiro KAMUJIMA (Nagoya), Yasuo MORIMOTO (Kita-Kyusyu), Katsuyuki MURATA (Arita), Hirokazu OKUDA (Kanagawa), Kazuhiro SATO (Fukui), Tomotaka SOBUE (Osaka), Yasushi SUWAZONO (Chiba), Shigeru TANAKA (Saitama), Masashi TSUNODA (Sagamihara), Susumu UENO (Kita-Kyusyu), Kenichi AZUMA (Osaka), Akiti TAKEUCHI (Osaka), Teruomi TSUKAHARA (Matsumoto), Takenori YAMAUCHI (Tokyo)

**Specialized members**
Tatsuya ISHITAKE (Kurume), Tsutomu OKUNO (Kawasaki)

**Advisory members**
Yoko ENDO (Hyogo), Masayuki IKEDA (Kyoto), Toshio KAWAI (Osaka), Reiko KISHI (Sapporo), Akio KOIZUMI (Kyoto), Kasuke NAGANO (Kanagawa), Tamie NASU (Nagoya), Haruhiko SAKURAI (Tokyo), Hiroshi SATOH (Tokyo), Hidesuke SHIMIZU (Tokyo), Masatoshi TANAKA (Fukushima), Yasuhiro TKHEUCHI (Nagoya), Eiji YANO (Tokyo)