Guidelines for personal exposure monitoring of chemicals: Part III

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Abstract: This Document, “Guidelines for personal exposure monitoring of chemicals” (“this Guideline”), has been prepared by “The Committee for Personal Exposure Monitoring” (“the Committee”) of the Expert Division of Occupational Hygiene & Ergonomics, Japan Society for Occupational Health. Considering the background of the growing importance of personal exposure monitoring in risk assessment and the need to prepare for the introduction of monitoring using personal samplers from an administrative perspective in recent years, the Committee was organized in November 2012. The Committee has prepared this Guideline as a “practical guideline” for personal exposure monitoring, so as to offer proposals and recommendations to the members of the Japan Society for Occupational Health and to society in general. The scope of this Guideline covers all chemical substances and all related workplaces regarded as targets for general assessment and the management of risk. It thus is not to be considered to comment on legal regulations and methodology. The main text provides the basic methods and concepts of personal exposure monitoring, while 31 “Appendices” are provided in this Guideline throughout the series; technical descriptions, statistical bases, and actual workplace examples are provided in these appendices, to assist better understanding. The personal exposure monitoring described as per this Guideline is equivalent to an “expert-centered basic method to reasonably proceed with the assessment and management of risk at workplaces.” It is considered that practicing and expanding on this method will significantly contribute in reforming the overall framework of occupational hygiene management in Japan.
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Chapter 2: Method for Personal Exposure Monitoring

3. Planning of Monitoring
3-1 Setting of similar exposure group

In this Guideline, targets of exposure assessment and measurement are defined as a “Similar Exposure Group (SEG).” This term refers to a group of workers who are assumed to have a similar degree of exposure. Workers within a workplace are grouped as one SEG, and then the overall situation of the exposure (the average and distribution of exposure) is assessed. On the basis of this assessment, necessary control measures for each SEG are then to be taken.

In accordance with the organization of a workplace, workers involved in similar work (i.e., personnel who are assumed to have a similar degree of exposure) are categorized to make an SEG. The concept of this categorization may be a little unfamiliar at first. The basic idea of the
categorization is that because assessment of each individual requires too much effort, workers with similar exposure can be grouped for more efficient assessment.

In some instances, workers sharing the same job title in the same workplace are actually engaged in different types of work. Should this be the case, it will be necessary to confirm with the supervisor about the actual details of the work situation. Generally, the size of an SEG (the number of workers constituting an SEG) will be considered in many cases to be three or more. There are some cases of an SEG having only one or two workers; conversely some large SEG’s consist of several tens of workers. Workers rarely subjected to exposure (such as workplace supervisors and office staff) may be collected as one SEG as per the workplace organization (for example: division). (In this case, exposure of the SEG is regarded as a “minimum” and so further measurement may be omitted). As a result of this, when the exposure assessment in a workplace is progressed through to its conclusion, all workers without exception will have eventually been targets of exposure assessment.

After an SEG is set, it may be set again by subdivision and reconstruction as required. On some occasions, a Geometric Standard Deviation (GSD) obtained on the basis of exposure monitoring can be too large. This is because of an inappropriate setting of the SEG, due to the fact of several SEGs having essentially different exposures having been grouped together in one SEG. In such a case, the judgment criterion is set at “3.0” as GSD value. If GSD exceeds this value, it does not necessarily mean that the SEG needs to be set again. Rather it is recommended that the appropriateness of the make-up of that particular SEG be verified.

Appendix 6 shows examples of SEGs in actual workplace settings and also the number of workers in one SEG. In these examples, the number of workers constituting one SEG is predominantly from one to five (please refer to Appendix 6).

In this Guideline, exposure assessment is conducted for each SEG unit. However, in addition to this technique, personal exposure monitoring methods include a means of monitoring the workers with maximum exposure selected from the workplace. For this method, explanations are given for reference purposes in the appendix (please refer to Appendix 7).

3-2 Judgment of necessity for monitoring and order of priority

The necessity for monitoring and the order of priority are judged on the basis of the results of basic characterization. If a risk assessment supervisor has less experience in measurement or is not confident in his/her judgment, then it is recommended that measurement be performed. Table 2.5 shows the concept of determining the necessity for monitoring and the order of priority with respect to the estimated control class of exposure.

There are two major cases where “no monitoring” is selected by judgment in actual workplaces, i.e., the estimated “high exposure case” or the estimated “low exposure case.”

“High exposure case” corresponds to the exposure level of the control class 3 or 2B (Table 2.3 and 2.5). Table 2.6 shows the cases in which the estimated exposure is high, but “no monitoring” is selected by judgment. If control measures are available that can relatively easily control the exposure, even if the exposure is high, a risk assessment supervisor is not required to perform an immediate measurement, rather they are first to recommend the control measures to the manager to perform the modifications. The above is one important alternative. Examples of such a case can include: the installation of a partition wall, the placing of an enclosure over the source of hazards, or moving the workplace to a side away from the wind (the windward side). If such measurement proves to be expensive or if the (true) exposure is close to the occupational exposure limit, a large number of samples will be required to statistically prove their values. In these situations, it is good to remember a saying that is common in Europe and the USA. It says “it is more reasonable to use money for exposure reduction than to spend a large amount of money for measurements to prove that the occupational exposure limit is not exceeded”15. In other words, it is the rational choice to introduce easy control

| Control class | Necessity for monitoring and order of priority |
|---------------|---------------------------------------------|
| 1A            | Lower on the order of priority; monitoring may be omitted |
| 1B            | Low on the order of priority; monitoring may be omitted (only when the basis is highly reliable) |
| 1C            | Measurement (order of priority: intermediate) |
| 2A            | Measurement (order of priority: high) |
| 2B            | Measurement (order of priority: high), or control measures to be taken |
| 3             | Immediate control measures to be taken, or verification after measurement to be made (order of priority: high) (such as a case where personal protective equipment is used for the time being) |
measures without delay, and thereafter, measurement is conducted to confirm the effectiveness.

Moreover, there may be cases in which exposure is so significant that immediate control measures are required (Table 2.6). Such a case could occur when a large amount of particles is generated, an event that can very often be visibly observed. If such a case, which exposure is apparently severe, exists, it is unethical to carry out measurement before securing the situation. The purpose of personal exposure monitoring is to suppress risk, and it is not for the purpose of monitoring the actual situation (for example a serious situation caused by exposure).

After implementing the above control measures, the exposure shall be assessed again. In the case where an exposure is assumed to be high and measurement cannot be conducted under such conditions since immediate risk reduction measures are not able to be undertaken, then respiratory protective equipment may be used as interim measures.

“Low exposure case” corresponds to the exposure levels of the control classes 1C, 1B, 1A (Table 2.3 and 2.5). In case the exposure is assumed to be at these levels, the order of priority decreases in the following order: 1C, 1B, 1A.

“Exposure neither high nor low” corresponds to the control class 2A which is the “gray zone.” In this case, the order of priority for measurement is high because it may indeed be the case that the actual exposure is in fact 2B or higher (and hence requiring risk reduction measures) but yet to be confirmed.

Examples of judgment results on the necessity of monitoring exposure assessment at actual workplaces are given in Appendix 8. In these examples, more than 90% of all the assessments (classification of control class) are estimated, which reveals that measurement has not necessarily been performed in many instances, and that estimation of exposure is an important means (please refer to Appendix 8).

3-3 Number of samples

For a certain SEG, there are various theories as to the appropriate number of samples required for eight-hour (one-shift) monitoring in order that a relatively large enough number of samples may be obtained for statistical accuracy. This Guideline recommends five or more samples, whereas the personal exposure monitoring method in Europe and the USA often recommend a minimum number of samples of five to six<sup>11</sup>.

On the other hand, the actual number of samples collected in workplaces is relatively small. In the example of a certain workplace presented in the appendix, slightly more than 40% of all measurements have samples sizes of four or less. What this means is that there are many cases in which judgment can be used even for a small number of samples (please refer to Appendix 9).

For example, there is a situation in which measurement is conducted for confirmation with a small number of samples (smaller than five) when the exposure is estimated to be low in the pre-screening. In this case, a small number of samples is not an issue, even though the accuracy of measurement results will be low. On the contrary, in the case of prudent judgment of exposure, such as in the case in which an estimated exposure falls in the control class 2A (the “gray zone”), or a large amount of facility investment is required as a result of assessment, the minimum number of samples of five shall be fulfilled, or, depending on the situation, more samples should be obtained for more accurate assessment. As such, a risk assessment supervisor does not necessarily stick to the minimum sample number of five, but rather should make flexible judgments depending on the situation in order to ensure effective use of both human and financial resources.

The exposure monitoring method proposed by NIOSH (USA), sometimes cites requirement for a large number of samples. However, this is often not practical (please refer to Appendix 10). Concerning the number of samples required for short-term monitoring, basically the same idea for eight-hour monitoring should apply. In this case this Guideline recommends that the number of samples be five or more. However, the number of samples actually collected seems to be much less than that in eight-hour monitoring. In ac-

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**Table 2.6.** Cases where “no monitoring” is selected in judgment for high exposure and examples (*)

| Situation and case | Examples |
|--------------------|----------|
| Exposure may be reduced by easy control measures | Countermeasures for management of workplace environment |
| | Placing an enclosure on the open source of hazards |
| | Installation of simple partition wall or a curtain |
| | Moving the vessels of organic solvents (source of hazards) to a fume hood |
| | Countermeasures for management of work |
| | Moving the workplace to the windward side |
| | Removing the contaminated tools, chemical cleaning cloth and wastes |
| Extremely high exposure requiring immediate control measures | Concentration of particles is apparent and visibly high |
| | Odor is very strong |
| | A large amount of steam is emitted in an enclosed space |

* Generally speaking, exposure reassessment is conducted after taking control measures, followed by measurement, if needed.
tual examples given in the appendix, approximately 90% reported the number of samples of four or less (please refer to Appendix 9).

Should the number of samples be less than five, the same exposure assessment (judgment of control class) should be applied as though the number of samples was greater than five. This is described in Section 5-2.

3-4 Setting monitoring duration (eight-hour monitoring)

In planning eight-hour (one-shift) monitoring, as a general rule, all work hours during which workers are subjected to exposure shall be monitored. This is because basic characterization may fail to fully grasp all the changes in work over a single day. During initial monitoring of the same SEG, it is advisable to perform eight-hour (or as close to eight hours as possible) monitoring. This principle also applies when it is obvious that the contents of work involve temporal changes during the course of a day.

On the other hand there will exist cases in which the monitoring duration may be shorter than eight hours. The appropriate monitoring duration can vary depending on the following three situations:

1) The Case in which basic characterization has (fully) confirmed that the work (exposure) hours are limited, and that no other exposure exists (or, the exposure is very low, if any). In this case only the work time period shall be monitored, while exposure during other time periods may be considered negligible.

2) The “Case in which basic characterization has confirmed” that the work (exposure) hours are long; however, the process or the contents of work during such hours are “identical,” and temporal changes are small. Monitoring may be conducted for a duration shorter than the work hours (for example: eight hours), while exposure during the time period during which no monitoring has been conducted may be regarded as equal to that during the monitored time period. In this case, the longer the monitoring duration the better, and it is recommended that, if possible, it be four hours or more, and at least two hours in principle.

3) The Case in which the work (exposure) hours are long and the contents of work during the hours are “almost identical,” but it cannot be determined, or “it is not fully confirmed,” that temporal changes are small. In this case, the longer the monitoring duration the better, and it is recommended that, if possible, and as in the preceding case, the minimum monitoring duration be four hours or more, and at least two hours.

In Case 3) (above), it should be noted that the shorter the monitoring duration the lower the reliability of the result. Care should be taken when the resultant evaluation falls within the “gray zone” (at or near control class 2A). To be specific, suppose that the result of a short-term monitoring (for example: two hours) indicates the control class 2A (efforts needed to take exposure reduction measures), but was close to control class 2B (required to take exposure reduction measures). In this case, the reliability of the result is not high, and the possibility exists that the true control class is actually 2B. As a consequence of this, the following measures may be adopted:

(i) Extension of the monitoring duration in order to allow for additional monitoring.

(ii) Changing the control class to 2B to be on the safe side.

(iii) Multiplication of the measured value (original value) by a certain factor in order to assess it to be on the safe side. There is an approach of taking a factor of “2.0” for a monitoring duration of two to four hours. Detailed explanations are given in the appendix (please refer to Appendix 11).

Meanwhile, if the resultant exposure is sufficiently small (control classes 1A and 1B) or sufficiently large (control class 3), in the case of short-term monitoring, these results may be adopted as they are. This is because the risk associated with uncertainty in such a determination may be considered negligible. In this case though, the reliability of the result will be lowered to some extent.

In Cases 2) and 3) (above), the minimum monitoring duration is set at two hours in principle. In order to apply such monitoring duration, it should be emphasized that basic characterization shall be conducted in advance to prove that the work situations throughout the work hours remain “identical” or “almost identical.” The supervisor can determine the sample duration in a flexible manner. It is not advisable to automatically follow the method (iii) (multiplication by a factor, above).

Planning of monitoring duration also relates to the estimated degree of exposure (control class). For instance, if the exposure is estimated to be sufficiently low in the basic characterization (control classes 1A, 1B), even short-term monitoring is more likely to achieve the objective. If, on the other hand, the estimated exposure is higher than the above (control classes 1C, 2A, 2B, etc.), then a longer monitoring duration should be considered in order to enhance monitoring accuracy.

If the work hours exceed eight hours, monitoring should basically be performed throughout those longer hours (for example: 10 hours). In this case, the calculated eight-hour occupational exposure limit is used as a reference value for assessment. This is later described in Section 5-4. Furthermore, the same concept would apply as in the case of eight-hour monitoring (as mentioned in this Section) when reducing the monitoring duration (for example shorter than 10 hours).

Workplaces often face practical considerations. An example includes whether or not to continue sampling (removing some samplers) for the time periods without exposure, but within the eight-hour work, such as noon recess or clerical work during the work. There is no need to remove samplers in this case. However, if the samplers
become a hindrance during the rest or they may become damaged or contaminated, then they may be removed as needed. In general, active samplers are often removed. The interpretation of the time periods they are removed is explained in Section 5-1.

3-5 Setting monitoring duration (short-term monitoring)

Short-term monitoring (exposure assessment) is mainly conducted to prevent acute health effects, and it is as important as eight-hour monitoring. The following are the major three cases in which short-term monitoring should be planned:

1) The Case in which basic characterization before monitoring has revealed a short duration task that is expected to have high exposure. Sometimes short-term monitoring is performed in parallel with eight-hour monitoring; at other times only short-term monitoring is performed.

2) The Case in which eight-hour monitoring has resulted in high exposure, the cause of which is suspected to be a specific short duration task.

3) The Case in which eight-hour monitoring has resulted in small exposure, but monitoring conducted thereafter suggests suspiciously high exposure in a short duration task.

As stated in Case 1) (above), eight-hour monitoring is not necessarily required. For example, if major work (exposure) during eight hours is a specific short duration task or repetition of an identical short duration task, monitoring of only such short term is performed and eight-hour monitoring may be omitted. When considering personal exposure monitoring in general workplaces, the major monitoring target at the time of initiating assessment is a typical short duration task found in eight-hour monitoring and in an initial survey (Case 1) (above). However, as assessment, monitoring, and control measures progress with the passage of time, the frequency of eight-hour monitoring would decrease, while monitoring of short duration tasks, as presented in Case 3) (above) tends to increase. Since there are many short duration tasks having different frequencies, initial surveys often fail to identify such tasks. They may thereafter be identified after a series of site surveys.

The duration of short-term monitoring is set in consideration of the fact that the results are to be compared to the short-term exposure limit (TLV-STEL). TLV-STEL is defined as the “15-minute time weighted average of exposure concentration that shall not be exceeded.” Thus monitoring is performed with a view to grasping the maximum “15 minutes of exposure concentration” for the (short duration) task in question. Consequently, if the work hours are 15 minutes or less, the total work duration shall be monitored. However, if they are in excess of 15 minutes, monitoring shall be conducted for the 15-minute task that is assumed to have the maximum exposure.

In cases the work hours are in excess of 15 minutes, the maximum exposure duration cannot be assumed, or when the exposure may be considered fairly constant during the task, then monitoring of the total work (for example, 30 minutes for 30-minute work) may be an option. In these cases, the time weighted average (for example 30-minute average concentration) is regarded as the maximum value of the 15-minute time weighted average during the work hours and is assessed using the STEL as a reference value. This is due to the fact that the resultant measured data provides no clue about the variations of exposure during the monitoring.

When performing a short-term monitoring for substances having a ceiling value (TLV-C, or the maximum permissible concentration defined by the Japan Society for Occupational Health), monitoring is performed for several minutes or more within the time period during which exposure is assumed to be at its peak. Measurement using a real-time monitor equipped with a data logger, for instance, would provide a maximum instantaneous value (the instantaneous maximum exposure). However, in general, this instantaneous value shall not be compared to the ceiling value. This is because the ceiling values were set before real-time monitors were available. Short-term monitoring is not generally performed for a period of one minute or so. As for TLV-C, monitoring for 15 minutes is acceptable. However, substances with a very short life and strong irritating property can be an exception. The maximum permissible concentration defined by the Japan Society for Occupational Health assumes monitoring “for a short period of time up to about five minutes during which the maximum exposure is considered to occur.”

3-6 Selection of workers to be monitored

Workers to be monitored shall be selected from those who are on duty during a given working day and belong to a SEG. In conjunction with this, the work schedule for the day shall be verified with supervisors and/or the workers to be monitored themselves. This should be done so that the workers are not engaged in non-routine tasks. There should be no special restriction on the number of days (from one day or several days) for monitoring. There should also be no restriction on how workers are selected (e.g., the minimum number of workers to be monitored). However five workers or more are recommended; this corresponds to the fact that the recommended total number of samples is at least five.

Some possible judgments are as follows. For the control classes 2A or 2B, the number of workers should in principle be at least five for an SEG of five or more, while for an SEG of five or less, all workers should be monitored. For the control classes 1 or 3 on the other hand, a proper conclusion can be reached even with monitoring of a small number of workers. Should there be any differences in exposure among the SEG, workers with higher exposure should be selected to avoid an un-
Considering the day-to-day variance in a workplace environment, in principle, the statutory Working Environment Measurement requires a two-day measurement. However, due to operational reasons, often only a one-day measurement is performed. In such a case a GSD ($\sigma_D = 1.95$, but 0.084 is used for calculation) corresponding to the day-to-day variance is applied to the obtained GSD to estimate the GSD for a two-day measurement. Consequently, both the primary reference value (the 95th percentile) and the secondary reference value (the estimated value of the arithmetic average) to be used for assessment would be higher compared to the corresponding values obtained from the one-day measurement data. This Guideline does not recommend any such numerical adjustment.

Measured values obtained from personal exposure monitoring include the variance concerning workers as well as the day-to-day variance. Variances of eight-hour average exposure concentration of workers within an SEG can be organized as follows:

1) Worker-to-worker variance: variance among workers of the average long-term exposure.

2) Day-to-day variance I: variance due to daily variance of workplace environments (corresponding to day-to-day variance in the Working Environment Measurement).

3) Day-to-day variance II: variance due to daily variance of the work movement of workers themselves and their transfer route.

In personal exposure monitoring, since factors to be reflected differ depending on how workers to be monitored and monitoring days are selected, it is difficult to plan monitoring that would enable adequate reflection of them on the measured values. In addition, when the number of workers to be monitored is limited, or in the case of one-day monitoring, it is a difficult task to include numerical adjustments for Working Environment Measurement. Therefore, this Guideline recommends that no special restriction be imposed on workers and monitoring days when selecting the workers to be monitored. As well, no numerical adjustments shall be made when monitoring is conducted only for one day or when one worker is monitored several times. The appendix provides a detailed description of the above variance elements (please refer to Appendix 12).

However, it remains the case that variances exist in workers and monitoring days. And therefore monitoring on different days or workers is recommended as far as it is practicable.

It should be noted too that the reliability of the results would be lower if all the variance factors 1) to 3) are not captured. This is especially the case in which the resultant evaluation falls within the “gray zone” (at or near control class 2A). In this case, care should be taken. This is similar to the case in which the actual monitoring duration is shorter for eight-hour monitoring as mentioned above (Section 3-4). In this case, the control class may have to be changed if the variance factors are fully considered. Thus, as mentioned in Section 3-4, in such a case, careful judgment should be exercised and/or additional measures should be undertaken as needed; further monitoring may be a possible option. For outdoor work, the day-to-day variance I tends to be particularly significant. This too requires great care.

If the resultant exposure is sufficiently low (control classes 1A, 1B), or evidently high (control class 3), and if the variance factors are not fully captured, these results may be used as they are. However, if basic characterization allows these intermediate exposure (control classes 1C, 2A, 2B) to be estimated, an approach may be taken to plan the monitoring to consider these variance factors as much as possible. This is outlined in Section 3-4.

It is also the case that international methods of personal exposure monitoring do not allow any numerical adjustments after monitoring for day-to-day variance or worker-to-worker variance. This is also the case with this Guideline. 3-7 Sampling method and condition setting

Each sampling method, type of collecting substances, and sampling rate shall be planned on the basis of the estimated airborne concentration of the substances and also sampling duration. This is to secure the amount of samples necessary for analysis and also not to cause breakthrough or re-diffusion of the substances. Depending on the occupational exposure limit of target substances, it is recommended, if possible, that a sampling rate and duration be set to allow monitoring of airborne concentrations up to approximately 1/10 of the occupational exposure limit. If the occupational exposure limit is low in the case of short-term monitoring, active samplers (with sampling rate of 200 ml/min or higher, etc.) should be used, and not passive ones (typical sampling rate for organic solvents approximately 30–40 ml/min). As passive samplers take some time for airborne substances to diffuse into adsorbent layers, they are not generally considered appropriate for short-term monitoring of several minutes or less. Please refer to the instruction manual of each sampler since the minimum sample time differs depending on the shape of samplers.

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