Size-Selective Sampling of Oil Mist in Air and Subjective Symptoms among Machine Workers

Shohei KIRA*, Yusaku NOGAMI2, Kazuhisa TAKETA1 and Masana OGATA1

1 Department of Public Health, Okayama University Medical School, 2–5–1, Shikata-cho, Okayama 700, Japan
2 Department of Science, Okayama University of Science, 1–1, Ridai-cho, Okayama 700, Japan

Received February 21, 1997 and accepted May 9, 1997

Abstract: Oil mists at an automobile factory were measured size-selectively. Furthermore, subjective symptoms were surveyed through the distribution of a questionnaire. The measured levels of respirable-size, 2–10 micrometer oil mists at 3 selected workshops ranged 0.04–0.09 mg/m³ for the lower exposed group (17 men), 0.10–0.18 mg/m³ for the higher exposed group (16 men) to water-insoluble oil, and 0.08–0.29 mg/m³ for the higher exposed group (19 men) to water-soluble oil. The higher the level of exposure to respirable-size particulates, the more workers complained of dissatisfaction with air quality. As to the subjective symptoms, the “yes” rate for “irritated nose” and “sneezing” showed significant differences among the unexposed, lower exposed, and higher exposed groups. Workers using water-soluble oil complained of “uncomfortable smell” more than those who used water-insoluble oil. The results of this study suggested that it is necessary to measure the levels of oil mists size-selectively.

Key words: Oil mist, Respirable-size, Subjective symptoms

Introduction

Machine oils are widely used at metal processing factories for lubricating, cutting, grinding, and cooling agents. Some investigators have indicated that certain health hazards, e.g., respiratory disorders1–2) and the possibility of cancer3–5) may result from a prolonged exposure to machine oil mists. A recent study by Karube et al.6) reviewed the toxicities of various mists. The threshold limit value for mineral oil mists, mainly based on the hazardous effects on the respiratory system, has been documented at 3 mg/m³ by the Japan Society for Occupational Health (JSOH)7). To date, only a few reports have assessed the effects on workers exposed to subthreshold limit values, either of the respirable (2–10 µm) type or the nonrespirable type. In our previous survey8), we reported a relationship between oil mist exposure levels and the rate of development of subjective symptoms in workers at a machine factory. This survey also revealed an increase in the rate of dissatisfaction with air quality, and nasopharyngeal symptoms even at subthreshold limit value. In the present study, we measured oil mists in the air of an automobile factory size-selectively, that is, we measured oil mists of respirable-size (2–10 µm) and those measuring more than 10 µm in diameter. At the same time, we carried out questionnaire surveys to determine subjective symptoms among workers. Then we analyzed the relationship between the levels of oil mists of respirable-size and subjective symptoms as a complement to our previous study8).

Materials and Methods

Prior to the present study, we examined the size distribution of oil mists in the air of the machine workshops of an automobile factory. An Andersen’s cascade impactor (AN-200 type, Shibata Sci. Inst., Japan) was operated at 28.3 l/min for 45 min. The effective cut sizes of this sampler are
RESPIRABLE-SIZE OIL MIST AND SUBJECTIVE SYMPTOMS OF WORKERS

11, 7, 4.7, 3.3, 2.1, 1.1, 0.65, and 0.43 µm. Then we analyzed the size-distribution of oil mists according to Fujimura's method. We measured the levels of oil mists at each workshop by using portable samplers in accordance with our previous report. Briefly, a sampler head of a cascade impactor (PN-46N type: Shibata Sci. Inst., Japan) was used with 2 stages of stainless-steel plates to collect oil mists. The upper stage collected particulates larger than 10 µm, while the lower stage collected particulates measuring 2–10 µm. The air was sampled at 2.5 l/min by portable pumps (MP-30C type, Shibata Sci. Inst., Japan) for 2 hr, during morning and afternoon work-shifts. The above procedures are a modification of the method used by Ando and Tamura.

Mineral oils collected on the membrane filters of the Andersen sampler or the stainless-steel plates of the portable samplers were extracted with 20 ml of carbon tetrachloride (CCl₄). The amount recovered was measured by using an oil meter with an infrared spectrometer (OIL-102 type, Yanagimoto Co., Japan) at 2,900–3,000 cm⁻¹. A standard solution of heavy oil type B was used for calibration. Thus, the levels of oil mists were equivalent to their CCl₄-extractable portions.

Three of the 14 workshops that used cutting fluids and one unexposed control group were selected at an automobile factory. The first workshop was using both water-soluble and water-insoluble cutting fluids (17 workers). The second workshop was using a water-soluble cutting fluid only (16 workers). The third workshop was using a water-insoluble cutting fluid only (19 workers). These three exposed groups were working in the same building, which was ventilated generally but not locally. Oil mist levels were measured at four to six points at each workshop within those areas where workers were expected to be exposed. Seventy-seven workers who were engaged in transporting or assembling metal parts and were not being exposed to oil mists were chosen as the unexposed control group for the present analysis. Questionnaires were distributed through safety and health personnel, then collected within one week. Both exposed and unexposed workers were male, and were working in 12-hr shifts, including a night shift once or twice a week. All rates were calculated from valid respondents and statistical analysis was carried out. To compare the rates, the statistical analysis used was the Chi-square (χ²) test. The characteristics of all the analyzed workers are shown in Table 1.

<table>
<thead>
<tr>
<th>Group or Workshop</th>
<th>Age distribution (yr) Mean value (S.D.)</th>
<th>Work duration (yr) Mean value (S.D.)</th>
<th>Smoker (%)</th>
<th>Number of worker</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unexposed</td>
<td>43.8 (8.4)</td>
<td>9.8 (7.9)</td>
<td>67.4</td>
<td>77</td>
</tr>
<tr>
<td>Workshop 1</td>
<td>40.1 (8.2)</td>
<td>15.3 (9.2)</td>
<td>64.7</td>
<td>17</td>
</tr>
<tr>
<td>Workshop 2</td>
<td>44.6 (5.8)</td>
<td>16.9 (4.8)</td>
<td>56.3</td>
<td>16</td>
</tr>
<tr>
<td>Workshop 3</td>
<td>44.4 (8.3)</td>
<td>16.9 (9.6)</td>
<td>47.4</td>
<td>19</td>
</tr>
</tbody>
</table>

All values were calculated using valid data obtained from respondents.

Results and Discussion

Figure 1 shows the patterns of the size distribution curves of oil mists in the air of machine workshops. Oil mists consisted of both water-soluble (filled circle) and water-
insoluble (open circle) machine oils, and formed peaks ranging from 2 to 10 μm in size. Chan et al.\textsuperscript{12} reported the existence of respirable-size particles in oil mists consisting of machine fluids or oil. Our present results corroborate their observations. Therefore, our results indicate the need for size-selective measurement of oil mists, in addition to the measurement of total exposure levels.

Table 2 shows the results measured by the size-selective sampling of the \textit{CCl$_4$}-extractable portion. The lowest levels of both respirable-size particles and total amount were observed at workshop 1. Levels at workshops 2 and 3 were similar, except that the origin of the machine oils differed. Based on the present measurements, we compared the rate of subjective symptoms among the three exposed groups and the single non-exposed group.

Table 3 shows the results of self-assessments of workshop air quality by the exposed groups and the non-exposed group. When there was increased exposure to respirable-size particles, as in the case of the combined group of workers from workshops 2 and 3, workers tended to complain more about air quality. Some of the reasons for dissatisfaction were “hazy air,” “wish to use fans,” and “uncomfortable smell,” with a statistical difference of \( p<0.01 \) by the \( \chi^2 \) test (2 × 3 table). With respect to “uncomfortable smell,” workers using water-soluble oils showed a higher “yes” rate than those who used water-insoluble oils even when the exposure levels were similar. Table 4 shows the rates of subjective symptoms related to respiratory, nasopharyngeal, and skin trouble, and other common manifestations among workers subject to different exposure levels. The “yes” rates for “irritated nose” and “sneezing” increased in accordance with the level of exposure, showing a statistical difference (\( p<0.05 \)) among the three groups after summarizing number of group at workshops 2 and 3. In our previous study\textsuperscript{8}, we reported that nasopharyngeal symptoms were correlated to the exposure levels of oil mists by total amounts, ranging 0.09–0.81 mg/m$^3$. The present results suggest that workers exposed to oil mists complained of dissatisfaction with their work.

\begin{table}
\centering
\caption{Oil mists in the air of workshops in machine factories}
\begin{tabular}{|c|c|c|c|c|}
\hline
Workshop & \multicolumn{2}{c|}{Geometric mean value} & \multicolumn{2}{c|}{Type of oil*} \\
 & \multicolumn{2}{c|}{2–10 μm (range)} & \multicolumn{2}{c|}{Total (range)} & \\
\hline
Workshop 1 & 0.06 (0.04–0.09) & 0.16 (0.09–0.36) & 4 & soluble + insoluble \\
Workshop 2 & 0.14 (0.10–0.18) & 0.31 (0.22–0.43) & 6 & insoluble \\
Workshop 3 & 0.13 (0.08–0.29) & 0.36 (0.20–0.81) & 5 & soluble \\
\hline
\end{tabular}
\end{table}

\begin{table}
\centering
\caption{Self-assessment of ambient air quality by workers}
\begin{tabular}{|c|c|c|c|c|}
\hline
Question & Style of answer & Unexposed & Workshop 1 & Workshop 2 & Workshop 3 \\
\hline
Hazy air* & Always & 0 (65) & 6.3 (16) & 13.3 (15) & 26.3 (19) & 14.7 (34) \\
Wish to use fans** & Aways & 20.3 (59) & 58.8 (17) & 86.7 (16) & 84.2 (19) & 85.7 (35) \\
Wish to breathe open air & Always & 11.5 (61) & 6.3 (16) & 13.3 (15) & 21.1 (19) & 17.6 (34) \\
Uncomfortable smell** & Always & 10.0 (60) & 18.8 (16) & 30.8 (13) & 52.6 (19) & 43.8 (32) \\
Overall quality of air & Bad & 29.9 (67) & 17.6 (17) & 43.8 (16) & 36.8 (19) & 40.0 (35) \\
\hline
\end{tabular}
\end{table}

workshops; see text and Table 2. *,, **: statistical differences of \( p<0.01 \) and \( p<0.001 \) were observed by the \( \chi^2 \) test (2 × 3 table).
environment even when the values of the CCl₄-extractable portions were under 1 mg/m³. Furthermore, the levels of respirable-size particulates were closely related to nasopharyngeal symptoms: uncomfortable smell, irritated nose, and sneezing.

We conclude that a combined assessment, involving the measurement of oil mist levels by size-selective sampling and a questionnaire survey of subjective symptoms among workers, is a useful strategy for preventing health hazards and improving safety and comfort in the work environment.

### Table 4. Subjective symptoms of workers exposed to oil mists

| Subjective symptoms       | Unexposed | Workshop | | | |
|---------------------------|-----------|----------|---|---|
|                           | 1         | 2         | 3 | |
| Irritated nose**          | 19.5 (77) | 25.0 (16) | 37.5 (16) | 52.6 (19) |
| Sneezing**                | 14.7 (75) | 31.3 (16) | 37.5 (16) | 36.8 (19) |
| Irritated throat*         | 14.7 (75) | 18.8 (16) | 37.5 (16) | 31.6 (19) |
| Coughing                  | 6.6 (76)  | 25.0 (16) | 18.8 (16) | 15.8 (19) |
| Feeling of odd taste      | 0 (76)    | 0 (16)    | 0 (16)    | 10.5 (19) |
| Nausea                    | 9.2 (76)  | 12.5 (16) | 12.5 (16) | 26.3 (19) |
| Irritated eyes            | 14.7 (75) | 12.5 (16) | 12.5 (16) | 21.1 (19) |
| Eye mucus                 | 12.0 (75) | 6.3 (16)  | 25.0 (16) | 15.8 (19) |
| Itchy hands               | 16.0 (75) | 6.3 (16)  | 12.5 (16) | 26.3 (19) |
| Itchy face                | 9.3 (75)  | 0 (16)    | 0 (16)    | 15.8 (19) |
| Generalized itching       | 2.7 (75)  | 12.5 (16) | 6.3 (16)  | 10.5 (19) |
| Heartburn                 | 11.8 (76) | 18.8 (16) | 12.5 (16) | 15.8 (19) |
| Epigastric pain           | 17.1 (76) | 18.8 (16) | 12.5 (16) | 15.8 (19) |
| Constipation              | 20.0 (75) | 25.0 (16) | 37.5 (16) | 31.6 (19) |
| Diarrhea                  | 13.3 (75) | 0 (16)    | 6.3 (16)  | 15.8 (19) |
| Headache                  | 10.7 (75) | 12.5 (16) | 0 (16)    | 10.5 (19) |
| Lower-back pain           | 38.7 (75) | 31.3 (16) | 37.5 (16) | 57.9 (19) |
| Auditory disturbance      | 25.0 (75) | 6.3 (16)  | 18.8 (16) | 47.4 (19) |
| Persistent cold, if caught| 29.7 (74) | 6.3 (16)  | 37.5 (16) | 26.3 (19) |

workshops: see text and Table 2. *, **: statistical differences of p<0.10 and p<0.05 were observed by the χ² test (2 × 3 table).
Acknowledgments

The authors wish to thank Ms. June Young and Dr. Tammy Holliday of Texas A & M University at Galveston for correcting this manuscript, and Dr. Takehiko Ito of Okayama University for preparing this manuscript.

References


