Successful Experiences with a Handy Equipment to Measure Dust Concentrations in Various Workplaces

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Abstract: Performance of a direct-reading handy equipment for dust counting in workroom air, PDR (MIE, USA), was field-tested in comparison with the results of low-volume air sampling-gravimetry. Application in 64 workplaces of various type dust work with dust concentrations of up to 1.6 mg/m³ showed that the agreement was generally good with a correlation coefficient (r) >0.64. The calculated regression line had a slope close to one, and the intercept on the axis was next to nil, suggesting that the measurement with PDR is essentially the same with that by low-volume air sampling. Further analysis by types of dust work disclosed that the correlation was best when examined in 12 foundries with r as large as 0.95. In contrast, r was small (0.52) in 11 welding workplaces, possibly due to smaller particle size of dust generated during welding.

Key words: Dust counting, Foundry, Handy equipment, PDR, Welding

Pneumoconiosis, especially silicosis, is among the most important occupational diseases in many countries, although the total number of cases as well as the proportion of severe cases among them have been gradually decreasing in recent years in Japan¹⁾, owing primarily to improvements in industrial hygiene. Accordingly, it is a common understanding that the measurement of dust concentration is essential for improvement of work conditions. Standard equipments such as high- or low-volume air samplers are however bulky in size and usually need electric power supply through a cord for operation. In addition, gravimetry is vulnerable to technical errors.

Trials have been made in recent years, accordingly, to develop handy and portable equipments for this purpose^{2–6)} with due validation either by laboratory testing⁴⁾ or through field application⁶⁾. Recently, we had successful experiences in field application of a compact equipment in measuring respirable dust concentrations in several types of dust

workplaces. The experiences will be described in this report together with its limitations.

The equipment tested was a 'Personal Data RAM' Model pDR-1000 Airborne Particles Monitor (PDR in brief), a product of MIE Inc, Bedford MA, U.S.A. The equipment is 15 cm × 9 cm × 6 cm in size and about 500 g in weight, and takes advantage of natural (*i.e.*, non-forced) air movement through a slit for air sampling. Thus, the instrument has no suction pump, and therefore apparently is not suitable (although no quantitative data are available) for measurement when the airflow is very limited (*e.g.*, in a small office or storage room). Dust measurement is based on light scattering effects with power supply from installed batteries. The reading is given in terms of mg/m³, by automatic conversion of light scattering to the gravimetric unit, with use of an equipment-installed conversion factor. Although the instrument is originally designed for personal sampling (thus the movement of a worker is taken into account in air sampling), it was applied for stationary sampling in the present study because it might be too large and heavy for Japanese workers of a small body size. Although the instrument can record average counts for every second, the

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Table 1. Correlation in measurement results between low-volume air sampling and PDR

Type of work	No.	Dust concentration ^a (mg/m ³)				Regression parameter ^b			
		GM	GSD	Min.	Max.	α	β	r	p
Welding	11	0.18	2.42	0.03	0.51	0.11	0.40	0.52	0.05
Powder handling	17	0.06	2.12	0.02	0.23	0.03	0.90	0.68	<0.01
Foundry	12	0.49	2.20	0.14	1.55	-0.06	1.11	0.95	<0.01
Grinding	24	0.07	2.22	0.02	0.25	0.02	1.08	0.83	<0.01
Total	64	0.11	3.08	0.02	1.55	0.01	0.99	0.64	<0.01

^a GM, geometric mean; GSD, geometric standard deviation (dimensionless); Min., the minimum value observed; Max., the maximum value observed (all by PDR). ^b α and β are the vertical axis intercept and the slope of a calculated regression line of $Y = \alpha + \beta X$, where X and Y are dust concentrations (mg/m³) as measured by low-volume air sampling and PDR, respectively.

average of every one minute was employed in the present study to save energy in the batteries, from which the mean dust concentration for a given time period (i.e., 70 to 90 min. as to be described below) was calculated.

For comparison, concentrations of respirable particles (<7.07 μm in aerodynamic diameter⁷⁾) were measured by means of a low-volume air sampler (LVAS; Model 9023-1; Kanomax International, Suita, Osaka, Japan), coupled with pre- and post-sampling measurement of the weight of the filter [T60 A20 (55 mm in diameter), PALL Corp., East Hills NY, U.S.A.]. The flow rate was set at 30 L/min and the collection was for 70~90 min/sampling. An elutriation device was attached for fractionated collection of particles. The two measurements were made side-by-side, and at one site per workplace in 64 dust workplaces of various types, utilizing both equipments for stationary sampling.

The results of measurements by PDR at a total of 64 workplaces are presented in Table 1 in comparison with the results by LVAS. The 64 pairs are depicted also as a scatter diagram (Fig. 1A) together with a calculated regression line to show correlation. It is clear that the over-all correlation is satisfactory ($r=0.642$, $p<0.01$, $n=64$), that the slope was close to 1 ($\beta=0.992$), and that the intercept on the vertical axis was next to zero ($\alpha=0.014$), the observation as a whole indicating that the results by the two types of measurement agree well with each other.

Further perusal of Fig. 1A suggested that, in the dust level range of 0~0.5 mg/m³ (by LVAS), there is a group of data that deviate from the regression line. Analysis by types of workplace disclosed that a majority of the data was from 11 welding workplaces. When these data from the welding workplaces were analyzed separately (Fig. 1B), the regression line (with $\alpha=0.108$ and $\beta=0.395$) had a significantly ($p<0.01$ by F test) shallower slope than that for all cases combined. In contrast, the survey in 12 foundries (Fig. 1C) gave a much

Fig. 1. Scatter diagrams to show correlation in measurement results between low-volume air sampling and PDR.

Each dot shows results by two types of measurements in one dust workplace. The line shows a calculated regression line. For regression line parameters, the correlation coefficient and its statistical significance, and the minimum and the maximum concentrations observed, see Table 1. [A] All workplaces in combination ($n=64$), [B] Welding workplaces ($n=11$), [C] Foundries ($n=12$).

steeper slope ($\beta=1.11$; $p<0.01$) as compared with that for welding workplaces ($\beta=0.40$; $p=0.05$) and an essentially nil intercept ($\alpha=-0.056$) (Table 1). The dust concentration range in the foundries was also widest of all (*i.e.*, from 0.14 to 1.55 mg/m³; Table 1). Thus, it appears that the 12 pairs of data in foundries strongly and favorably affect the over-all correlation among the 64 sets of data.

At least two points deserve discussion. The first point is the reason for the shallow slope (*i.e.*, PDR data being smaller than LVAS results) in welding workplaces. A previous report from this study group⁸⁾ shows that the ratio (by weight) of the respirable particles over the total particles [*i.e.*, the particles measured with (respirable) and without (total) fractionation] was highest in welding workplace and lowest in foundries among four types of the dust workplaces studied. Such high proportion of respirable (and therefore smaller) particles in welding work may be associated with the shallow slope. It should also be taken into account that the shape of the dust from welding is not spherical but quite irregular. From practical viewpoint however, the disagreement of PDR readings with LVAS results can be readily corrected by multiplying the PDR readings with a factor of 2.5 [=1/0.40, or an inverse number of the slope (see Table 1)].

The other point to be considered is the limitation in the types of dust work studied. Only four types of dust work (*i.e.*, grinding, powder handling, foundry and welding workplaces) were surveyed in the present study (Table 1), and there remains an apparent need of testing in other types of dust workplaces, *e.g.*, mining, tunnel work, quarry, or metal powder production. It might be further possible to apply the PDR equipment for measurement of dust levels in non-industrial settings such as agricultural fields^{9, 10)} as well as commutation circumstances¹¹⁾.

In over-all conclusion, dust concentration measurement with a handy PDR appears to be promising as it gave the results similar to that by LVAS in powder handling and grinding workplaces, and particularly in foundries. The results may differ, however, in welding workplaces, and further studies are apparently necessary for the evaluation of the applicability of PDR in other types of dust workplaces.

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