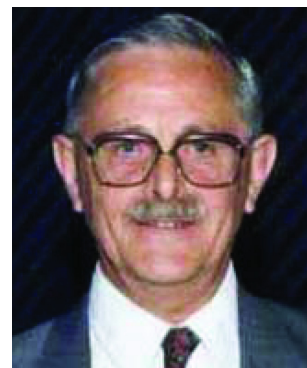


1980년대 초 한국 석탄 탄광의 자료를 이용한 로그-정규분포의 적용

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Assessment of Coal Dust Exposure in Korean Mine in 1980's

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Commentary

Sherwood교수 (1924-2000)는 영국 산업보건 분야의 선구자중 한 분으로 특히 개인시료 채취방법을 처음으로 고안하신 분이다. 1970년대 후반부터 1980년대 초반까지 ILO고문관으로 한국에 오셔서 국립노동과학연구소 (현 한국산업안전보건공단 산업보건연구원) 설립에 중추적인 역할을 하였고 한국의 산업보건분야 발전에 지대한 공헌을 하신 분이다.

이번 자료를 통하여 Sherwood교수의 산업위생 data 처리과정을 볼 수 있음은 매우 기쁜 일이다. 그 분의 data 처리과정은 매우 적절하였고 처음 산업위생분야를 시작하는 대학원 학생들은 물론 기존의 연구자들에게도 좋은 참고자료가 되리라 생각한다. 먼저 log-normal probability 그래프에 data를 입력하여 data의 분포상태를 파악하고, 여기서 대수정규분포를 보였으므로 기하평균값과 기하표준편차 (GSD)를 산출하였다.

위의 data에서 Sherwood교수는 석탄광산의 작업방법에 따른 먼지농도를 비교하였다. 국내 석탄광산에서 작업방법에 따른 공기 중 먼지농도를 비교한 data는 아직까지 발표된 바 없다. 일반적으로 착암기에는 습식장치가 부착되어 있어서 “wet”방법을 적용하고 있으나 Sherwood교수는 습식장치가 부착되지 않은 “dry”방법을 적용하는 탄광을 발견하였고, 이 두 가지 방법에 따른 호흡성 먼지 농도를 비교하였다. 공기 중 먼지농도는 “wet”와 “dry”에서 각각 4.1 mg/m^3 과 26.1 mg/m^3 로서 습식방법을 적용할 때 84.3%의 감소가 있었다. 비록 논문으로 발표하지는 않았으나 습식방법이 먼지발생을 감소하는 데 필수적이라는 사실을 Sherwood교수는 구체적으로 증명하였다. 매우 귀중한 역사적 자료이다. (백남원 서울대 보건대학원 명예교수)

ABSTRACT

1980년대 초 Sherwood교수가 한국에 와 있으면 당시 탄광의 호흡성먼지의 농도를 측정한 자료를 활용하여 로그-정규분포에 대한 분석을 한 자료이다. 탄광의 건조상태에서 농도는 물을 뿌리면서 하는 작업에 비해 매우 높은 수준을 보인다. 건조한 탄광에서 기하평균농도는 26.1 mg/m^3 이었고 물을 뿌린 탄광에서는 4.1 mg/m^3 이었다. 이는 매우 높은 수준이었음을 알 수 있다. 각 탄갱에서의 농도는 로그정규분포를 하였고 석탄을 접하는 탄갱에서의 농도는 1.65 mg/m^3 에서 35 mg/m^3 까지 다양하였다. 호흡성분진의 농도는 석탄을 접하는 탄갱에서 암석을 접하는 탄갱보다 높았는데 이는 분진의 원인이 석탄 때문이었다.

Key words : coal dust, log-normal, rock face, coal face, control

배 경

이 논문의 자료는 Jerry Sherwood 교수가 1980년대 초 한국에 와 있으면서 측정한 일부 자료를 본인이 정리한 것이다. 이 자료는 본인 (이기영 서울대학교 보건대학원 교수)가 1990년 하버드 대학에 있을 때 한국의 역사적인 자료로 Sherwood 교수로부터 직접 전달 받은 것이다. 비록 자료가 제한적이고 오래 된 것이기는 하지만 역사적인 가치가 있다고 생각이 되며 오래 전에 한국의 산업보건을 위해 힘써주신 Sherwood교수를 기리면서 작성하였다.

I. Statistical Treatment of Respirable Coalface Dust Samples from South Korea Mines

1. Initial plots of results from individual mines indicated log-normal distributions, but results are too few to justify detailed analysis of individual mine data.
2. The plots show however that there are two groups of mines showing similar results; those that work dry and those that use wet methods. The only exception is HO with very low GSD so this has been excluded from examination.
3. The attached plot shows the grouped data, based on the following results in rank order:

Dry Working mines (DK, KY) No of samples: 17

Concentration (mg/m ³)	134, 66.1, 54.2, 52.9, 43.8, 41.9, 40.5, 29.4, 23.4, 19.3, 18.4, 16.8, 13.8, 12.9, 11.7, 11.4, 6.4				
No of samples	17	MEAN ± STD	35.11 ± 31.11	GM (GSD)	26.06 (2.20)

Wet Working Mines (CH, HM, WS) No of samples: 31

Concentration (mg/m ³)	133, 26.9, 14.6, 12.6, 11.8, 9.82, 7.7, 7.7, 7.69, 7.43, 6.72, 5.9, 5.5, 5.12, 4.0, 3.7, 3.60, 3.42, 3.17, 3.01, 2.4, 1.9, 1.5, 1.44, 1.3, 1.2, 1.1, 1.0, 1.0, 0.98, 0.98				
No of samples	31	MEAN ± STD	9.62 ± 23.53	GM (GSD)	4.07 (3.10)

4. Calculations:

	Dry work	Wet work
Arithmetic mean =	35.11	9.62
Geometric mean =	3.2601	1.4009
Antilog	26.06	4.07
Geometric standard deviation =	0.7866	1.1299
Antilog	2.20	3.10
(variance =	0.6187	1.2766)

Please compare closely with the values estimated from the plotted results (Figure 1).

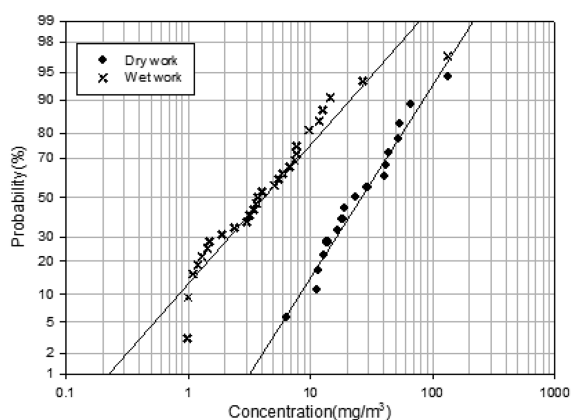


Figure 1. Distribution of respirable dust concentrations in dry and wet works

5. Further Calculations:

The arithmetic means, that are the significant parameters, have been calculated from the observed values. These however are known to deviate randomly from absolute log-normal distributions.

A better estimate of true arithmetic means may be derived from the calculated results using the following formula:

$$\text{Arithmetic mean} = e^{\mu + \sigma^2 / 2}$$

Where, μ and σ are, respectively, the mean and standard deviation of the variable's natural logarithm.

With the following results:

$$\text{Arithmetic mean} = \begin{array}{cc} 35.5 \text{ (dry work)} & 7.71 \text{ (wet work)} \end{array}$$

It can be seen that for dry work this is close to the mean of the observations. For wet work, however, there is considerable divergence; this can be attributed to the fact that the single value taken after blasting (133 mg/m³), markedly affects the observed mean. If this is deleted the arithmetic mean of the observed results is 5.65 mg/m³.

This demonstrates the smoothing effect of using statistically derived values, as no result has to be rejected.

It is possible to estimate the best estimate of the arithmetic mean concentration, which will be the best estimate of hazard and is to be compared with the hygiene standard, from the formula:

$$\text{Best estimate of mean} = e^{mg_n(\sigma^2 / 2)}$$

Where m = best estimate of the mean of the population obtainable from the sample

S^2 = best estimate of the variance (σ^2)

g_n = more complex function tabulated in Aitchison & Brown, The Lognormal Distribution, Cambridge University Press, 1963.

Values for α are not immediately available, so the best estimates are taken to be those above.

Standard error of the best estimate is calculated from the formula:

$$\text{Standard error} = \frac{\alpha}{\sqrt{n}} \sqrt{S^2 + \frac{S^4}{2}}$$

$$\text{Where } \alpha = e^{\mu + \sigma^2 / 2}$$

	Dry work	Wet work
Standard error of best estimate of the mean	= 0.7117	0.4927

Which can, I think, be

transformed into antilog values	= 2.04	1.64
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(but check with statistician who should also have values of σ to enable true best estimates of mean concentrations to be calculated)

6. Summary

Plotting of results grouped according to whether dry or wet work was being undertaken shows that results from the groups of mines follow log-normal distributions.

For dry work mines, the geometric mean value calculated from the distribution is 26.1 mg/m^3 , with geometric standard deviation of 2.20. That is 68% of results lie in the range $12\text{--}57 \text{ mg/m}^3$.

For wet work mines, the geometric mean value is 4.1 mg/m^3 , with GSD of 3.10 - that is 68% of results are in range $1.3\text{--}12.6 \text{ mg/m}^3$.

These appear significantly different and can be tested significantly.

By referring to the plotted results, the probability of any given concentration being exceeded can be estimated. Thus, it can be seen that the probability of the highest value (134 mg/m^3) being exceeded (or equaled) is about 3%, whereas for that in the wet min (133 mg/m^3) it is less than 0.1% - less than 1 in 1000 - confirming that it represents some other population of concentration - those following blasting?

R. J. Sherwood.

15.8.83

II. Application of the Log-Normal distribution to Results of Air Samples in Coal Mines of South Korea

1. Experience has shown that a series of air samples can best be described by a log-normal distribution. Although the numbers of samples are barely adequate this is demonstrated below.

2. Procedure:

List results in rank order 1. For each colliery

2. For each coalfield

3. For all samples

Grade(Area)	Colliery	Rank Order	No of Samples
Coal Face samples			
I	CH	133, 26.9, 9.83, 7.69, 7.43, 6.72, 5.12, 3.60, 3.42, 3.17, 3.01, 1.44, 1.20, 0.98	14
	DK	66.1, 54.2, 52.9, 43.8, 29.4, 19.3, 13.76	7
II	HM	14.6, 12.6, 11.8, 7.7, 5.9, 2.4, 1.9, 1.3, 1.1	9
	KY	13.4, 41.9, 40.5, 23.4, 18.4, 16.8, 12.9, 11.7, 11.4, 6.4	10
III	WS	7.7, 5.5, 4.0, 3.7, 1.5, 1.0, 0.95, 0.95	8
	HO	2.4, 2.2, 2.2, 2.0, 1.9, 1.8, 1.4, 1.2, 0.68	9
Rock Face samples			
I	DK	25.3, 17.8, 2.4, 2.2, 1.6, 1.4	6
II	HM	5.7, 4.3, 3.7, 2.4, 2.2, 1.6	6
	KY	29.7, 4.3, 4.0, 3.1, 2.9, 2.2, 2.0, 1.2, 1.1	9
III	WS	24.6, 8.6, 1.6	8
	HO	3.0, 2.8, 2.2, 2.0, 2.0	

Results from WS & HO are insufficient for analysis, they have therefore been pooled.

3. To plot results log-probability paper is used on which each sample is plotted, concentration against probability, thus for CH there are 14 samples, so that probability is plotted at intervals of 14, that is 7.14%, 14.3%, 21%, 29%.... 93% in response to the question "How many samples are less than ...". This excludes the plotting of the lowest results as 0% less than this.
4. This is undertaken on the attached sheets and curves drawn in by eye. Median and geometric standard deviations can be estimated, and any irregularity spotted. Note for example the two highest results for colliery CH which are away from plotted curve. These were taken after blasting when concentrations of dust present and they represent a different population of concentration which exist when coal is being extracted,
5. If calculation is required, the procedure is as for normal distribution except that logarithm of observed values are used. For interpreting the significance of results, some transformations are necessary and reference should be made to published work.

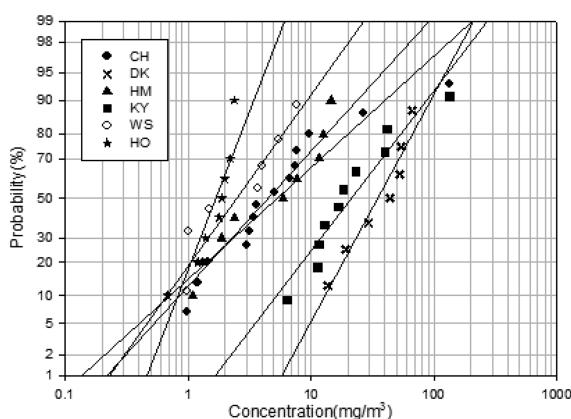


Figure 2. Respiratory dust distribution in different collieries in coal face samples

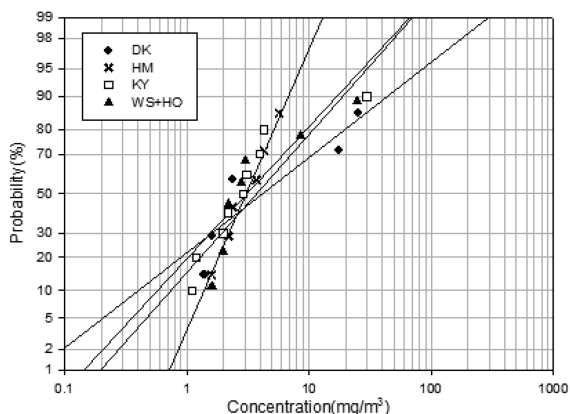


Figure 3. Respiratory dust distribution in different collieries in rock face samples

Appendix

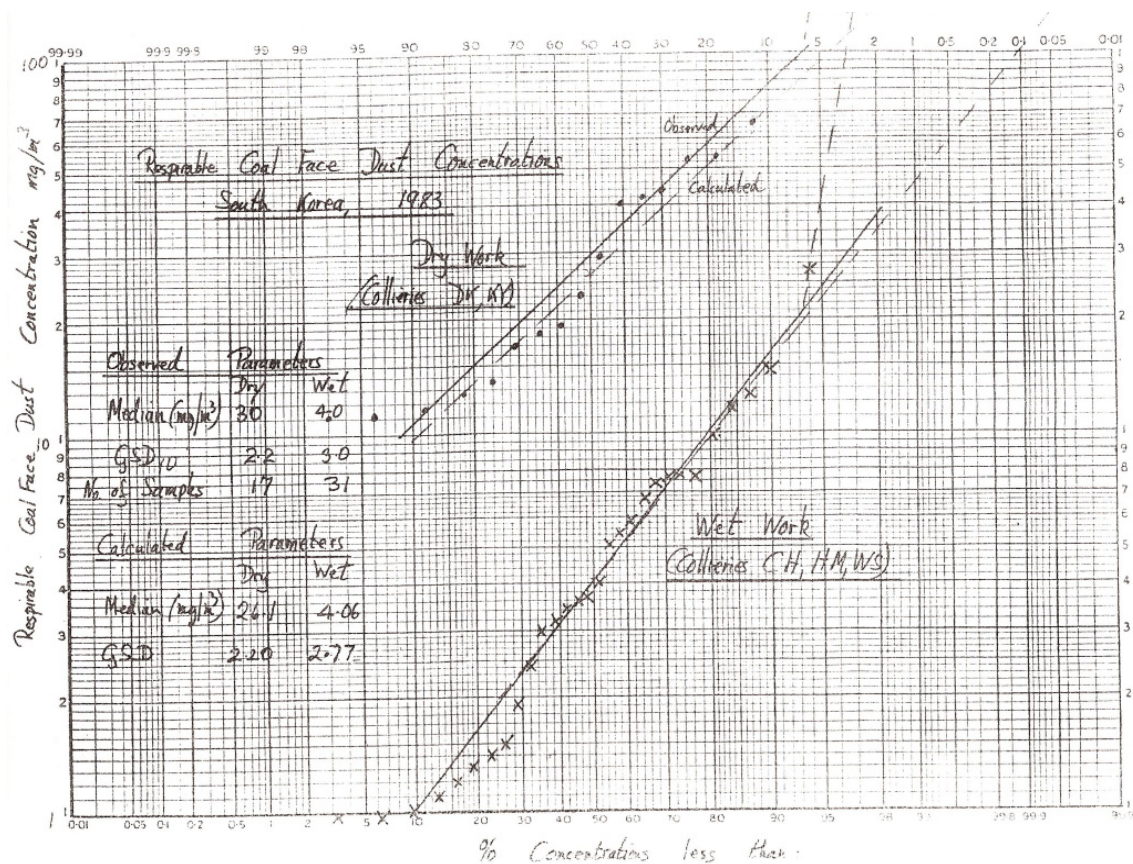


Figure 1. Distribution of respirable dust concentrations in dry and wet works

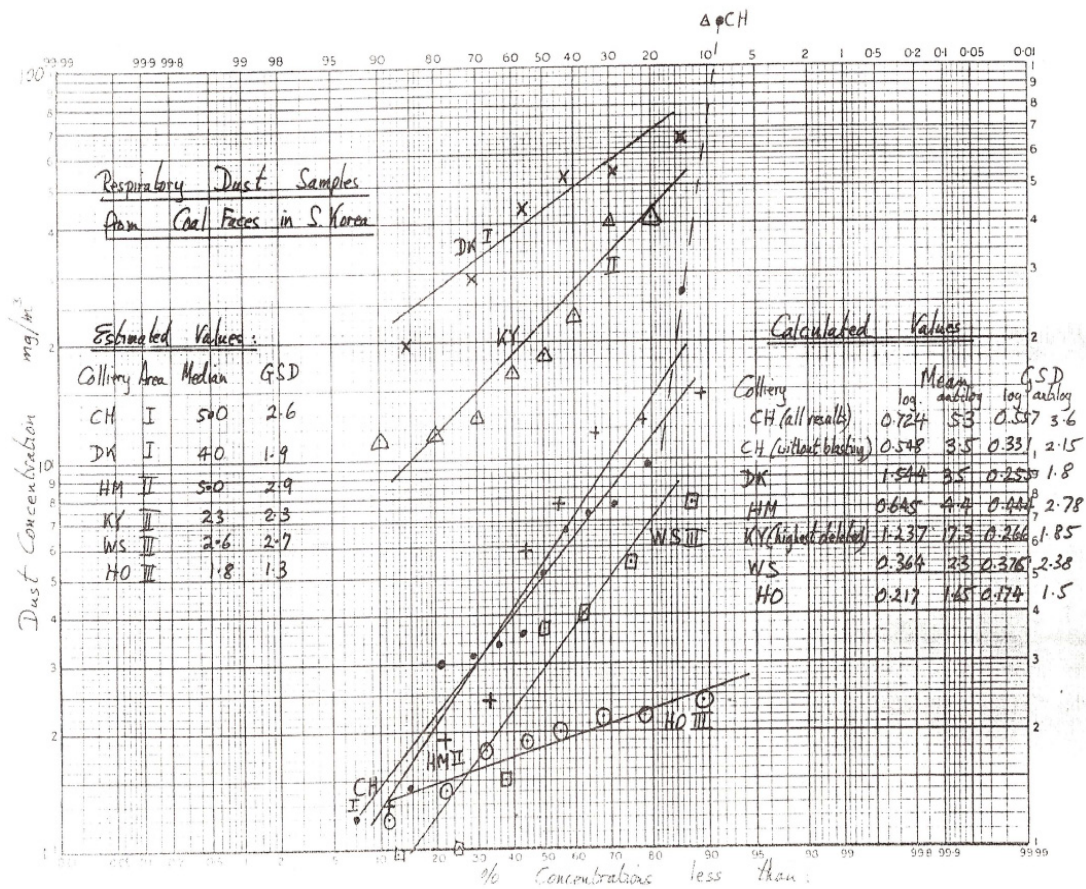


Figure 2. Respiratory dust distribution in different collieries in coal face sample

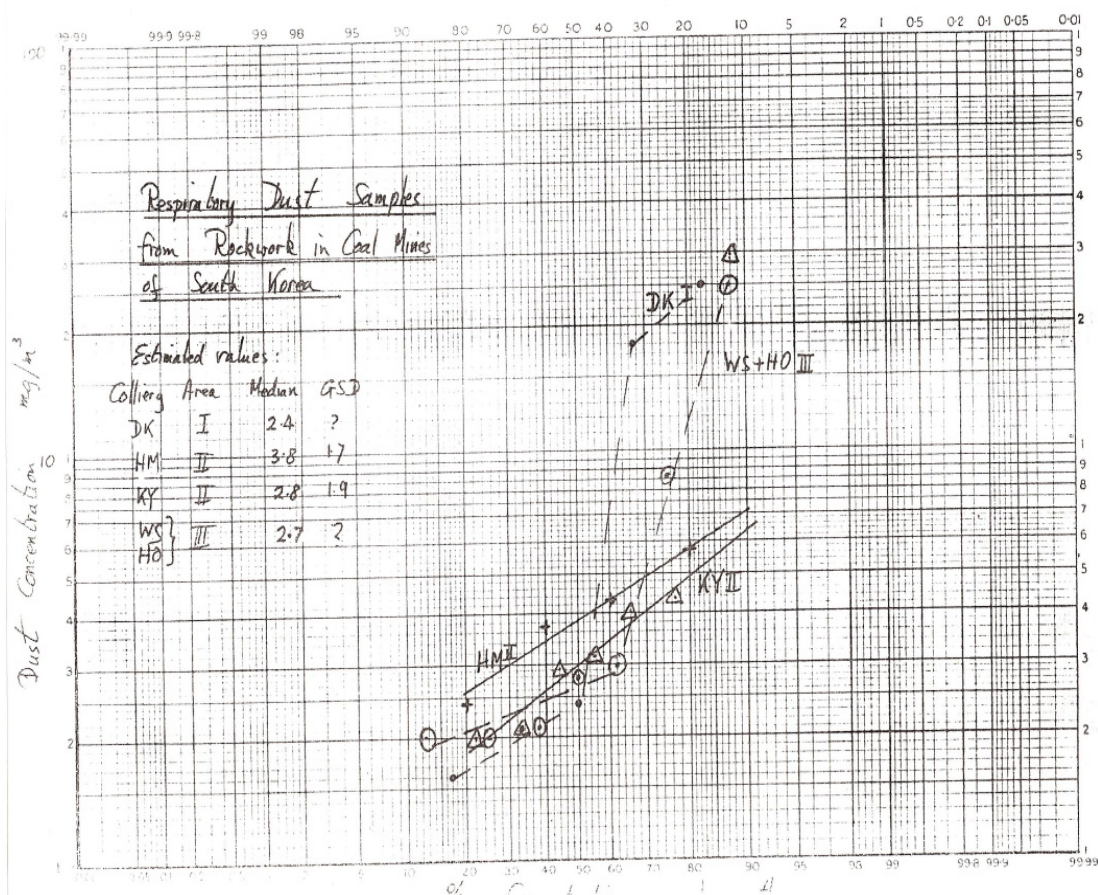


Figure 3. Respiratory dust distribution in different collieries in rock face samples