

NOTES

Investigation of Dust Levels in Different Areas of Underground Coal Mines

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Dust concentration levels in underground coal mines are of primary importance and have to be controlled to prevent pulmonary disease in miners. Different mining areas are exposed to different dust levels and to minimize the probability of occupational respiratory disease of coal miners, it is necessary to evaluate dust concentration in the different working areas. This study aimed to evaluate dust concentration levels in different areas of underground coal mines. Data obtained from the measurements in 1978–2006 were evaluated with the analysis of variance (ANOVA) and the Tukey-Kramer procedure. It was concluded that production areas had higher dust concentration levels; thus, production workers may have respiratory disorders related to exposure to coal dust in their work environment.

dust underground mining

1. INTRODUCTION

Working conditions in underground mining are associated with a considerable number of health risk factors, such as high physical workload, noise, vibration, radiation exposure, diesel exhaust, high temperature and humidity, and exposure to dust and gas phase hazardous substances [1, 2, 3]. Dust is generated and dispersed into mine air through rock breakage, rock loading, transportation and unloading, and through the flow of ventilation air. Dust is produced in all rock-breaking processes. The quantity of potential airborne dust is related to the quantity of broken rock [4]. Coal miners are typically exposed to mixed coal dust in the workplace. Significant exposure to coal dust may occur especially during underground coal mining [5]. Inhalation of coal mine dust is associated with the development of pulmonary disease in miners [6]; an occupational respiratory disease of coal

miners occurs due to exposure to respirable dust generated during various mining operations [7]. In this study, data obtained from the dust measurement studies done in various underground coal mines in 1978–2006 were evaluated with the analysis of variance (ANOVA) and the Tukey-Kramer procedure. Dust measurements were divided into five categories: heading faces, longwall faces, gate roads, stone drifts and haulage roads. In the statistical analyses, the comparisons of dustiness between years and mining areas were made with average dust concentration values. It was concluded that heading and longwall faces were the most dusty areas of longwall mining working methods.

2. SAMPLING PROCEDURES

Data came from dust measurements made by the mines' personnel in different underground coal

mines in 1978–2006 investigated to evaluate dust concentration. The personnel working in the mines made three kinds of dust measurements to fight against dust. Those were periodic, precaution and investigation measurements. Periodic measurements were the regular measurements carried out once a month in production areas such as longwall and heading faces, every 4 months in gate roads and stone drifts and every 6 months in underground haulage roads. The sampling locations were classified as heading faces, longwall faces, gate roads, stone drifts and haulage roads and the enterprises numbered them. The dust samplers were placed in the direction of the air flow, at the level of the workers' breathing. The dust conditions of the working environment of the mines were determined with gravimetric dust equipment Casella 113 A type (Casella London Ltd., UK). In Turkish coal mines, the permissible limit of dust concentration is 5 mg/m^3 .

Precaution measurements were the measurements carried out in various districts where dust concentration was greater than 5 mg/m^3 . They were not regular. Investigation measurements were the measurements carried out, in addition to the periodic and precaution measurements, in newly constructed mining areas when there was a claim regarding the issue. When dust concentration was greater than 5 mg/m^3 , firstly the measurement was repeated with different dust measurement equipment. Following the detection of the basis of the problem, production had to be stopped in accordance with the regulations, and only studies related to fighting dust were allowed.

3. STATISTICAL METHOD

ANOVA was applied to the dust measurement values obtained from different underground coal mines. ANOVA is an approach that uses sample data to test whether the values of two or more unknown population means were likely to be equal [8]. The main idea of ANOVA is to compare variation within each group to variation between the groups; if the groups vary considerably from one group to another in comparison to the within-group variation, the null

hypothesis that all the groups have similar levels of the response variable can be rejected [9]. Two-way ANOVA is a procedure that examines the effects of two independent variables concurrently [10]. In two-way ANOVA, if factor *A* has *h* levels and factor *B* has *g* levels, in a balanced design without replication, there will be *hg* treatment combinations. Assuming that for both factors the levels used are the only ones of interest, then a parametric model is appropriate. The model can be given as follows [11, 12]:

$$y_{ij} = \mu + \alpha_i + \beta_j + \varepsilon_{ij}, \quad (1)$$

where $i = 1, \dots, h$; $j = 1, \dots, g$; y_{ij} —the response obtained when factor *A* is at level *i* and factor *B* is at level *j*; μ —overall mean; α_i —the effect of level *i* of factor *A*; β_j —the effect of level *j* of factor *B*; ε_{ij} —random error term.

4. DATA ANALYSIS

Dust measurement data obtained from the gravimetric samplers at the five sampling locations were gathered for seven underground coal mines. They were divided into the five categories listed in section 1. The values are shown in Figure 1. It was investigated if those results indicated a significant variation either between the years or between the mining areas. Two-way ANOVA was used to make simultaneous comparisons between the mean values and also to determine whether there was a significant relation between variables. An ANOVA table is the general format of output for this type of analysis; it contains basic information about the analysis (Table 1).

TABLE 1. Two-Way ANOVA Table for Data in Figure 1

Source of Variation	SS	df	MS	F Values
Years	12.23812	28	0.437076	4.247492
Mining areas	45.23249	4	11.30812	109.892
Error	11.52503	112	0.102902	
Total	68.99564	144		

Since the purpose of this analysis was to determine if there was a significant difference in

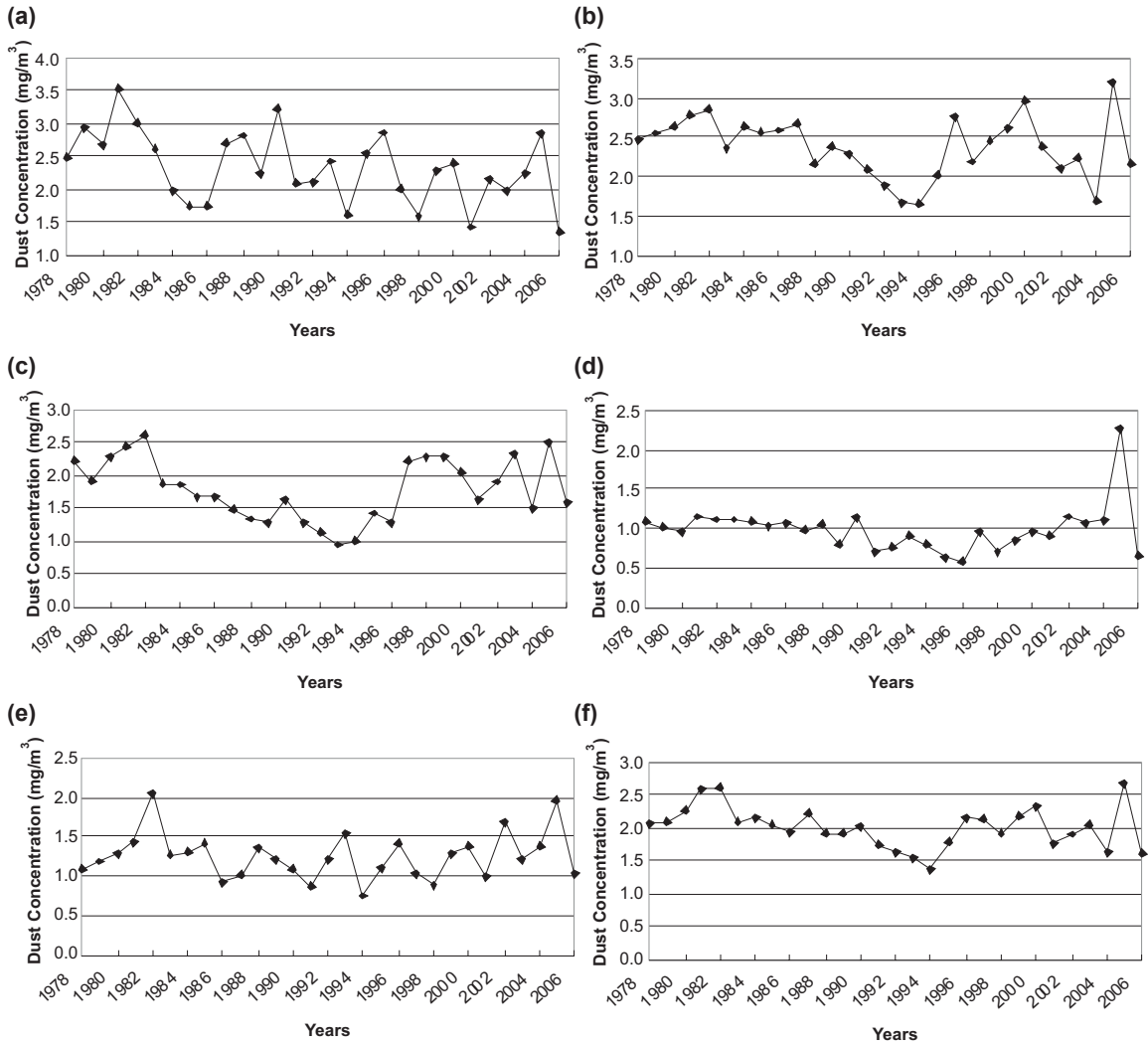


Figure 1. Dust levels in different areas of underground coal mines: (a) heading faces, (b) longwall faces, (c) gate roads, (d) stone drifts, (e) haulage roads and (f) mean values.

the effect of years or mining areas, the following hypotheses were written for years:

$$H_0: \alpha_1 = \dots = \alpha_{29} = 0,$$

$$H_1: \alpha_1 \neq \dots \neq \alpha_{29} \neq 0.$$

As usual the null hypothesis is one of no difference between the levels, whereas the alternative hypothesis is that at least some of them differ [11]. From the *F* distribution table the critical value $F_{0.95}(28, 112)$ was 1.58. Since the calculated *F* value given in Table 1 exceeded the critical value, the null hypothesis was rejected and it was concluded that the dust levels at the mines changed at the .05 significance level in 1978–2006.

Similarly the following hypothesis were written for mining area factors:

$$H_0: \beta_1 = \dots = \beta_5 = 0,$$

$$H_1: \beta_1 \neq \dots \neq \beta_5 \neq 0.$$

From the *F* distribution table the critical value $F_{0.95}(4, 112)$ was 2.45. Since the calculated *F* value was greater than the critical value, the null hypothesis of no difference between the levels of mining area factors was rejected and the alternative hypothesis was accepted. Therefore, it can be said that there was a difference in the mining area level treatments at a significance level of $\alpha = .05$. At this stage, the object of the investigation was to determine which of the mining areas had the highest dust concentration level. If the null hypothesis was rejected, the Tukey-Kramer procedure could be used to determine which population means differed statistically significantly from the others and to compare all means of groups simultaneously. The critical range in the Tukey-Kramer procedure was calculated from Equation 2 [13]:

$$\text{critical range} = q_u \sqrt{\frac{MSE}{r}}, \quad (2)$$

where q_u —value obtained from Studentized Range Distribution Table, MSE —mean square error from the ANOVA output table and r —the number of levels [13, 14].

It was found the q_u value from the table for $\alpha = .05$ and the critical range were calculated as 0.234. To make multiple comparisons in the Tukey-Kramer procedure, it is necessary to

calculate the absolute difference between the means of two groups. If the absolute difference between the sample means exceeds the critical range, a pair is considered significantly different [14]. Figure 2 shows dust concentration levels by mining area. Table 2 shows the absolute differences of dust concentration levels by mining area. Figure 3 shows the absolute differences of dust levels in different areas of underground coal mines.

TABLE 2. Multiple Comparisons of the Tukey-Kramer Procedure (Critical Range: 0.234)

Comparison	Absolute Difference	Results
Heading faces to longwall faces	0.05	heading faces not significantly different than longwall faces
Heading faces to gate roads	0.55	heading faces significantly different than gate roads
Heading faces to stone drifts	1.34	heading faces significantly different than stone drift
Heading faces to haulage roads	1.07	heading faces significantly different than haulage roads
Longwall faces to gate roads	0.60	longwall faces significantly different than gate roads
Longwall faces to stone drifts	1.39	longwall faces significantly different than stone drifts
Longwall faces to haulage roads	1.12	longwall faces significantly different than haulage roads
Gate roads to stone drifts	0.79	gate roads significantly different than stone drifts
Gate roads to haulage roads	0.52	gate roads significantly different than haulage roads
Stone drifts to haulage roads	0.27	stone drifts significantly different than haulage roads

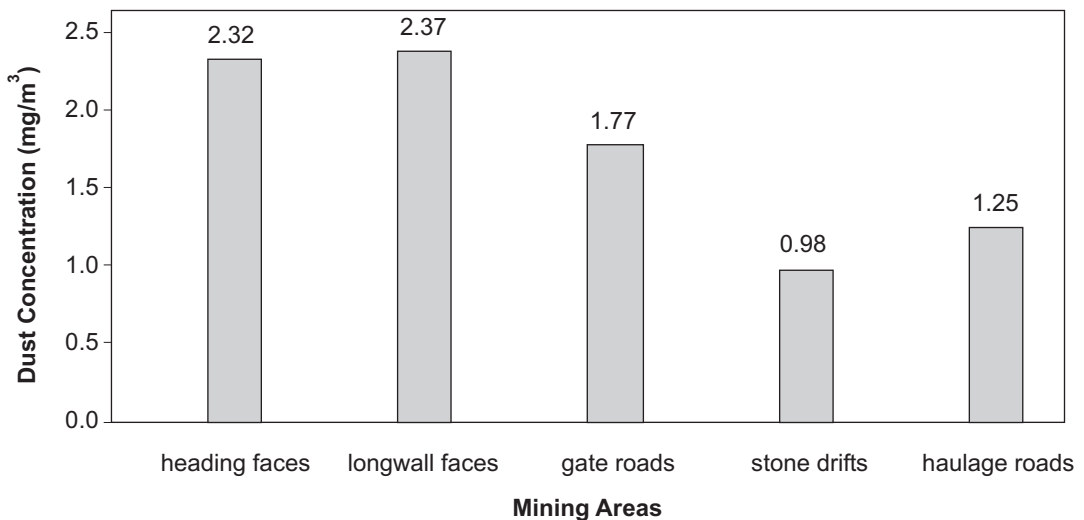


Figure 2. Mean dust concentration levels in different mining areas.

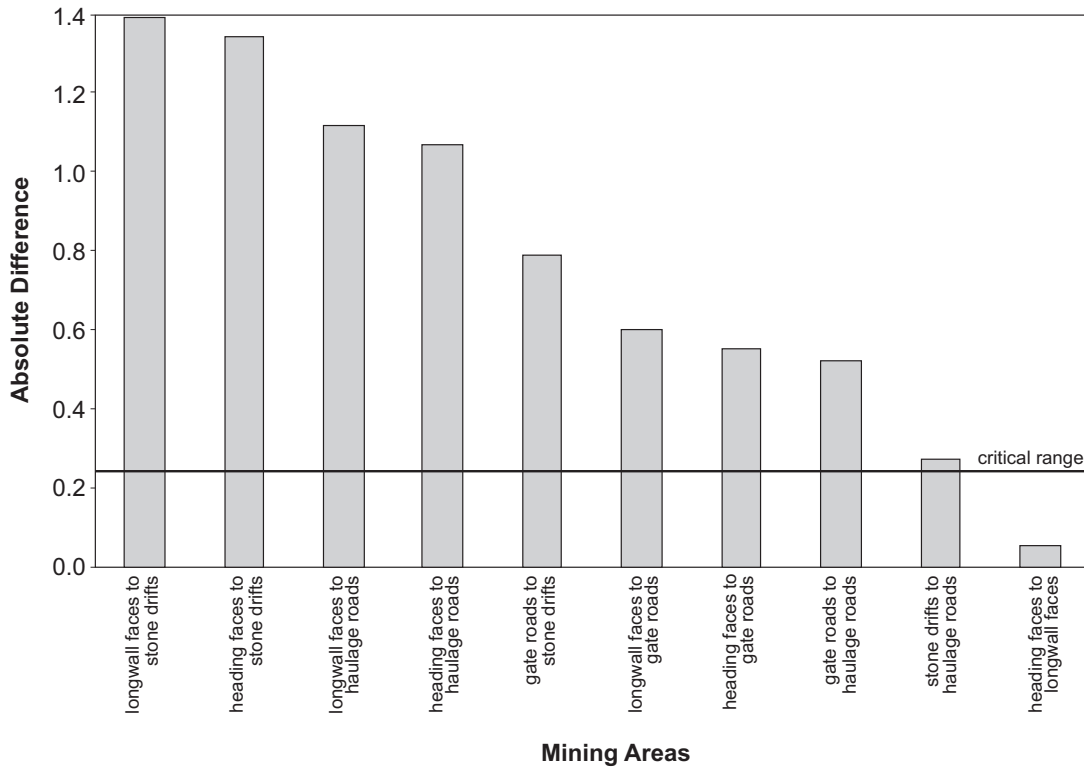


Figure 3. Absolute differences of dust levels for different categories of mining areas.

The Tukey-Kramer procedure showed that there was a significant mean difference between heading/longwall faces and gate roads, stone drifts and haulage roads because the absolute mean differences were greater than the critical range. No significant mean differences were revealed between heading and longwall faces. Therefore, it can be said that there was a significant difference between production areas and gate roads, stone drifts and haulage roads at the .05 level of significance. Most dust particles in mines are composed of mineral fragments. Mineral dusts are formed whenever any rock is broken by impact, abrasion, crushing, cutting, grinding or explosives. The main production methods of the mines are quarried by hand, the pneumatic-pick winning method, drilling-blasting and loading. Therefore, production areas such as heading and longwall faces have higher dust concentration levels than the other units and it can be expected that coal workers’ pneumoconiosis mostly occurs in production areas. The other units—in the order of dustiness—are gate roads, haulage roads and stone drifts.

5. CONCLUSIONS

The aim of the study was to evaluate dust concentration levels in different working areas. The statistical analyses presented in this paper indicated that production areas were exposed to higher dust concentration levels than other mining areas. It was found that the dustiest areas in underground coal mines were the coal faces. Therefore, production workers may have respiratory disorders related to exposure to coal dust in their work environment. The levels of dust concentration should be essentially controlled in the production areas. To reduce dust exposure at coal faces, adequate air velocity should be supplied. The dust levels in the surveyed mines showed lower values than permissible. If the permissible dust levels in Turkey’s coal mines are reduced, the probability of developing occupational respiratory diseases of coal miners will decrease.

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