

AN INDUSTRIAL HYGIENE CHARACTERIZATION
OF EXPOSURES TO DIESEL EMISSIONS
IN AN UNDERGROUND COAL MINE

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ABSTRACT

Problems exist in the United States' effort to achieve energy self sufficiency. Increasing coal production to meet President Carter's energy self sufficiency is a prime problem for the rest of the century and beyond. The use of diesels in underground coal mines has been suggested as a mining method to aid in this needed, increased production. Many questions exist about the effects on humans in such environments. NIOSH Division of Respiratory Disease Studies has undertaken a research effort to characterize the environments of existing diesel coal mines. The results of one of the studies will be presented. Preliminary assessments of carbon monoxide, nitrogen dioxide, C₁-C₅ aldehydes and organic acids, aliphatic hydrocarbons, sulfates, total and respirable dust, and polycyclic aromatic hydrocarbons (PAH) are presented. Nitrogen dioxide and total aldehydes are suggested as possible species to quantify diesel exposure.

INTRODUCTION

Diesel powered mining equipment is extensively used today in underground metal and non-metal mines. The U.S. Bureau of Mines estimates there are more than 4,400 diesel units being used in metal and non-metal mines as of 1978 (1). The first diesel vehicle was introduced in a Western coal mine in 1946. Since that time, 33 coal mines have decided to use diesel powered equipment in their mines (2).

During 1976, NIOSH began a five-year effort to study the health implications of diesel use in coal mines. This effort includes inhalation toxicology studies, morbidity and mortality cohort studies, research industrial hygiene characterizations, and control technology assessments.

The objective of the industrial hygiene portion of this study was to characterize occupational exposures in dieselized coal mines. The benefits of the characterization are two-fold. First, meaningful toxicity testing requires knowledge of realistic exposure levels from the occupational setting. As a minimum, such levels must be known to allow valid extrapolations for dose-response relationships. Second, documenting existing levels in diesel coal mines establishes a data base for future epidemiological studies, and evaluation of control efforts.

METHOD

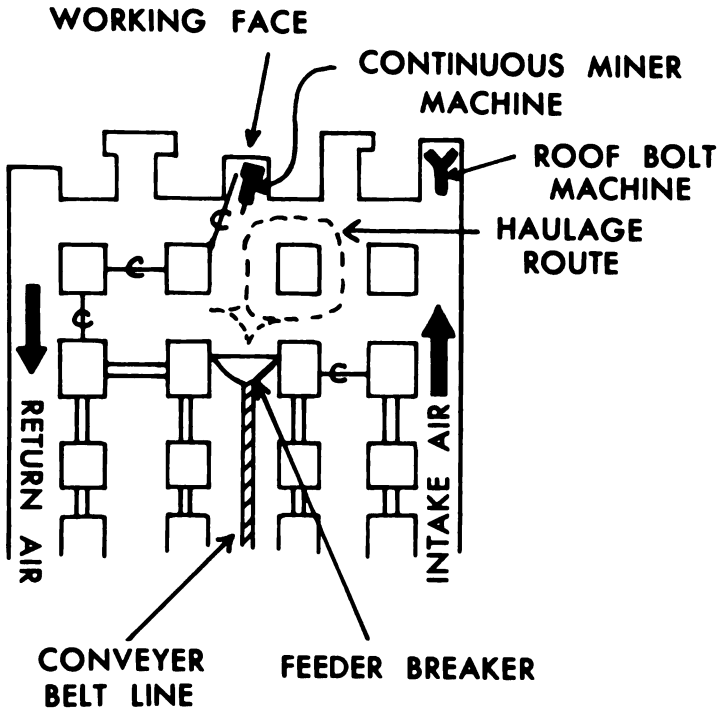
Certain chemical species known to be present in diesel exhaust were selected for study (3,4). These were particulates, nitrogen dioxide, carbon monoxide, carbon dioxide, cyclohexane extractable hydrocarbons, aldehydes, aliphatic hydrocarbons, organic acids, and sulfates. The collection and analytical methods are summarized in Table 1. The sampling plan was to place a sampler on each major piece of equipment within the breathing zone of the operator. Area samples were also taken in the intake air, the return air, at the haulage station, and at the feeder-breaker as located on the map in Figure 1. Samples were positioned so as not to interfere with mining operations. The samplers were put in place before mining began and collected after mining was finished to obtain full shift samples. Gas detector tubes for CO, CO₂, SO₂, and NO₂ were collected on a time-available basis.



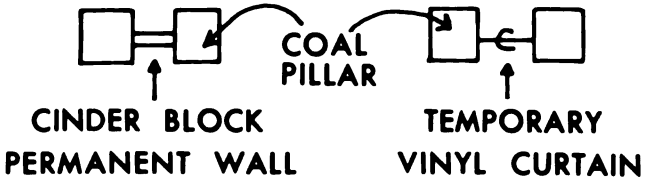
Table 1. SAMPLING AND ANALYTICAL METHODS

Exposure	Method	Analysis
CO	Detector Tubes Ecolyzer	---
NO ₂	Passive Dosimeters Ecolyzer	Colorometric (5)
CO ₂ , SO ₂	Detector Tubes	---
C ₁ -C ₅ Aldehydes	Impinger	Gas Chromatograph (6)
Aliphatic Hydrocarbons	Charcoal Tubes Low Flow Pumps	Gas Chromatograph (7)
Total and Respirable Dust	DM 800 Filters WO/W Cyclone MSA Model G Pump 2.0 LPM	Gravimetric
Cyclohexane Soluble Fractions	Silver Membrane Filter B Filter WO/W Cyclone MSA Model G Pump	Sonication (8) Gravimetric
Organic Acids Combined Carboxylic Acids	15 ml Impinger NaOH 2 hrs. MSA Model G pump 1 Liter/Min.	Ion Chromatograph (9)

Figure 1. Typical mine section.



KEY:



BACKGROUND

A coal mine is a dynamic system in which workers move from place to place throughout the grid of tunnels. Machinery is mounted on wheels or treads and is also mobile during a shift. Since the objective of mining is the removal of coal, the actual shape of the workplace also changes as the mine advances into uncut coal. Ventilating air is directed through the mine tunnels using cinder block walls, vinyl curtains, and auxiliary forced air systems, Figure 2. Using these techniques, the air flow pattern is changed to provide clean air to the advancing work area. The ventilation pattern is illustrated by the block diagram shown as Figure 3. Most of the mined-out tunnels in the studied mine were 20 ft. wide and 6-14 ft. high.

Coal was removed from the working face using a Jeffery electric powered continuous miner machine. Two Wagner Teletrams, model MTT-F20-18(S), were used to haul coal from the continuous miner to the feederbreaker. These teletrams were powered by Cat D330 diesel engines equipped with water exhaust gas conditioners. These vehicles are approved under Schedule 31, for use in gassy mines. At the feederbreaker, the teletrams dump the coal where it is partially crushed, loaded onto a conveyor belt, and transported to the surface. Once the continuous miner has advanced to the last roof support, it is withdrawn from that area and moved to the next working face, where the mining process continues. An electric powered roof bolter machine is then brought to the freshly mined face. Roof supports are installed to prepare for additional cuts in that area.

RESULTS

As seen in Table 2, production from the mine varied widely. Day-to-day variability in the sampler, therefore, is to be expected. Mining operations frequently encounter equipment problems requiring maintenance and causing delays. This problem is reflected in the various down times; when no coal was being mined. Ventilation rates also varied throughout the tunnel network and from shift to shift. This too is responsible for some of the sample variability. Table 2 shows the ventilation rate for the section return to illustrate this point.

Table 3 presents the results of total and respirable dust measurements. The total dust measurements are divided into area and breathing zone samples. Both kinds of samples show

Figure 2. Ventilation pattern across the working face.

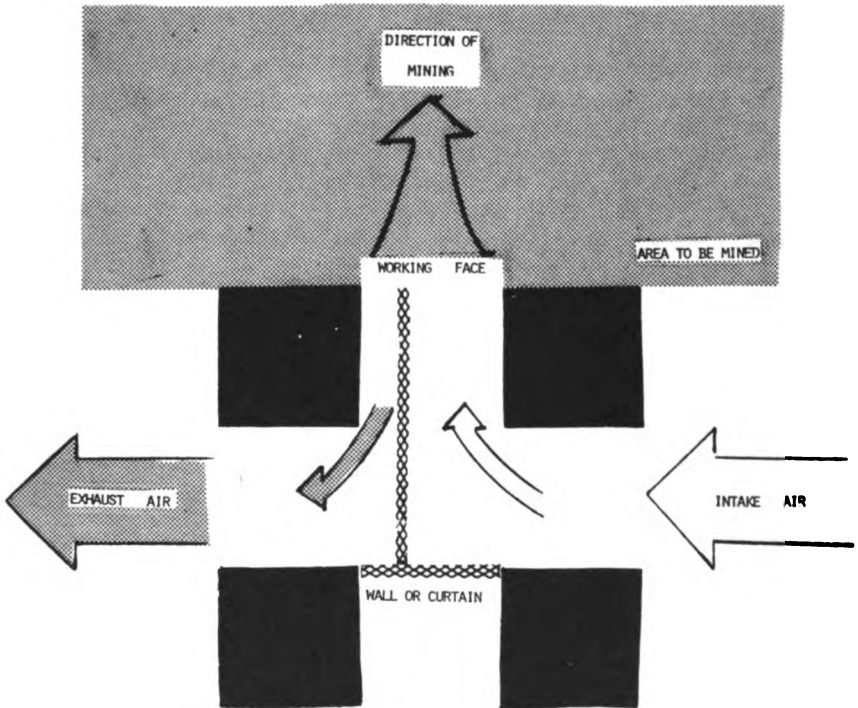


Figure 3. Ventilation network.

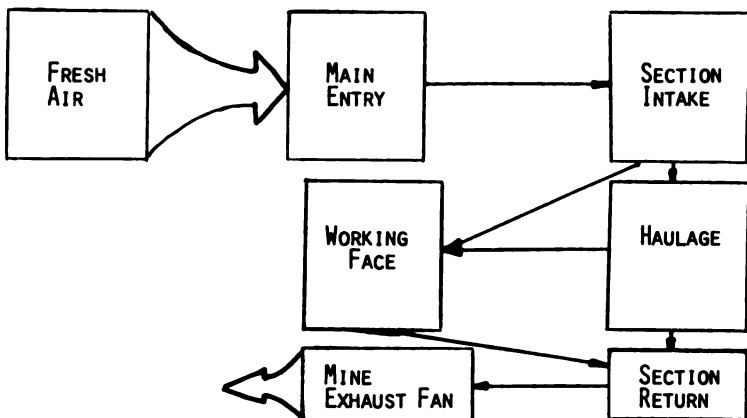


Table 2. PRODUCTION AND VENTILATION

Date	Shift	Tons Mined	Down Time Minutes	Section Return Ventilation x 1000 CFM
5/15/78	1	840	200	112.0
5/15/78	2	340	125	
5/16/78	1	600	250	81.3
5/16/78	2	840	95	
5/17/78	1	924	95	87.7
5/17/78	2	984	60	
5/18/78	1	456	335	86.7
5/18/78	2	1284	20	
5/19/78	1	864	80	74.9

Table 3. TOTAL DUST
mg/m³

Location	No. of Samples	Geometric Mean	Geometric Standard Deviation
Intake Air	6	0.49	3.08
Haulage Area	5	1.33	2.17
Feeder Area	6	0.96	1.54
Return Air	6	1.64	4.24
Breathing Zone Samples:			
Continuous Miner Op.	7	2.15	3.63
Roof Bolt Operator	3	1.13	2.36
Teletram Operator	6	0.91	3.54

the wide variability, reflected in the geometric standard deviation, that would be predicted from the production ventilation variability. The highest area level was obtained from the return air, which is basically the exhaust ventilation for that portion of the mine. The highest breathing zone sample was obtained for the continuous miner operator, which is considered a category that normally experiences higher dust levels, whether the mine is diesel or not. Respirable dust data are shown in Table 4. The conclusions concerning total dust are the same for respirable dust, though on the average, levels are slightly lower except for return air.

Nitrogen dioxide data in Table 5 are 8-hour time-weighted averages (TWA). The NIOSH recommended standard for nitrogen dioxide exposure contains a fifteen minute ceiling value of 1 ppm. While the observed eight-hour averages were well below this value, there is no way to determine from these measurements if the limit was exceeded during any fifteen minute period. However, these results are important in evaluating the diesel contribution to mine contamination since combustion is the only nitrogen dioxide source in this mine.

Data on cyclohexane extractable material shown in Table 6 were collected on the total and respirable dust samples. Although the means are low, there are excursions above the 1979 TLV of 0.2 mg/m³ shown in the range.

The aldehyde data in Table 7 show relatively low levels on the average; however, these may serve as an indicator of the diesel exposure.

The data in Table 8 relating other measurements show the relatively low levels of other species. The measurement of total hydrocarbons, however, was affected by the high moisture content of the mine atmosphere. Future studies should therefore avoid this methodology.

DISCUSSION

Due to the variability of mining operations, a single day's sample may not adequately reflect average concentrations for research purposes. Intercomparison of samples, however, from different work stations such as the feeder area or haulage area should be done for same day samples, to eliminate the large day-to-day variation.

Particulate levels are probably dependant on coal dust more than diesel emissions because:

Table 4. RESPIRABLE DUST
mg/m³

Location	No. of Samples	Geometric Mean	Geometric Standard Deviation
Intake Air	5	0.42	2.85
Haulage Area	6	0.78	1.99
Feeder Area	5	0.34	2.02
Return Air	6	1.76	2.07
Breathing Zone Samples:			
Continuous Miner Op.	6	1.68	2.47
Roof Bolt Operator	3	0.91	1.97
Teletram Operator	7	0.58	1.68

Table 5. NITROGEN DIOXIDE
ppm

Location	No. of Samples	Geometric Mean	Geometric Standard Deviation	Range
Intake Air	41	0.08	3.66	.01-.30
Haulage Area	17	0.25	1.68	.09-.62
Feeder Area	14	0.34	1.52	.17-.68
Return Air	25	0.26	1.56	.14-.67
Breathing Zone Samples:				
Continuous Miner Op.	16	0.24	1.66	.11-.46
Roof Bolt Operator	10	0.03	2.80	.01-.17
Teletram Operator	15	0.21	1.52	.08-.45

Table 6. CYCLOHEXANE EXTRACTABLE FRACTION
mg/m³

Location	No. of Samples	Geometric Mean	Geometric Standard Deviation	Coefficient of Variation
Intake Air	12	0.03	1.97	82%
Haulage Area	9	0.08	1.98	76%
Feeder Area	19	0.08	2.13	74%
Return Air	18	0.09	2.63	67%
Breathing Zone Samples:				
Continuous Miner Op.	6	0.07	2.59	70%
Roof Bolt Operator	2	0.07	1.10	96%
Teletram Operator	7	0.04	2.93	72%

Table 7. TOTAL ALDEHYDES
ppm

Location	No. of Samples	Geometric Mean	Geometric Standard Deviation	Range
Intake Air	8	2	4.45	0-68
Haulage Area	7	31	1.65	16-55
Feeder Area	15	32	3.23	0-144
Return Air	16	20	1.71	8-46
Breathing Zone Samples:				
Continuous Miner Op.	5	13	1.24	0-18
Roof Bolt Operator	2	0	1.00	0
Teletram Operator	3	11	1.56	7-17

Table 8. OTHER RESULTS AND MEASUREMENTS

Carbon Dioxide	.04-.08%
Carbon Monoxide	0-2 PPM
Carboxylic Acids	2-6 ppb
Sulfates	< 50 ug/m ³
Hydrocarbons	Charcoal tubes affected by high relative humidity
Relative Humidity	87-95%
Temperature	54° F
Pressure	28.97-29.36 in Hg.

- o The cyclohexane soluble fraction is relatively constant regardless of the dust levels as seen by the coefficient of variation which does not change greatly; and
- o The observed dust levels are highest near the sources of coal dust generation.

More indicative of the diesel emissions than particulate levels are NO₂ levels, which in this mine are due to combustion. However in other mines these levels may be due to blasting, thus interfering with diesel exposure monitoring. A better candidate, therefore, is total aldehydes which show the expected pattern for exposure. High levels are found around the tram and along the haulage areas and low levels are observed for the roof bolter who normally works in the fresh intake air.

SUMMARY

Using available equipment, we have begun to characterize the diesel coal mine environment. We have established ranges of contaminants that may be expected. We have identified compounds which may be used to quantify worker's diesel exposure. Finally, we intend to pursue an analysis of the correlation between production, ventilation, and observed concentrations in the dieselized coal mines.

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