Comments for Mine Safety and Health Administration Public Meeting on Request for Information on Exposure of Underground Miners to Diesel Exhaust
(Docket No. MSHA-2014-0031)
Mine Safety and Health Administration Headquarters
201 12th St, South, Rooms 7W204 and 7W206
Arlington, VA
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By

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Thank you for allowing me the opportunity to speak today. I am Dr. Roger O. McClellan, an Advisor on Toxicology and Human Health Risk Analysis matters with emphasis on issues concerning airborne materials and their potential health effects in workers and the general population. I have had a special interest in and have conducted research on the health hazards of diesel exhaust emissions since the 1970s. I have included a more extended biography with these comments as Attachment A.

I offer this statement on behalf of the Diesel Emissions Task Force of the Industrial Minerals Association – North America (IMA-NA). I advise the Task Force on scientific developments regarding the potential health effects of exposure of workers to diesel exhaust emissions. I have also offered advice on these matters to Tronox Alkali. Tronox and the other non-metal mines in the Task Force all use diesel equipment to some degree and are interested in learning more about the potential health effects of diesel exhaust to ensure the safety and health of their employees.

The Task Force and I have read with interest MSHA's Request for Information on Exposure of Underground Miners to Diesel Exhaust (Docket No. MSHA-2014-0031) published in the Federal Register on Wednesday, June 8, 2016.[1] It is my understanding that MSHA issued the Request for Information (RFI) and is holding this and other public meetings to gather information to enable the agency to review its "existing standards and policy guidance on controlling miner's exposure to diesel exhaust to evaluate the effectiveness of the provisions now in place to preserve miner's health."[2] We appreciate the opportunity to submit information and statements to assist MSHA in gathering the relevant facts and evidence. I am here to urge

[1] 82 Fed. Reg. 36,826 (June 8, 2016).

[2] *Id.* at 36,826.

MSHA to ground its inquiry in science and to consider *all* of the currently available science on the potential health effects of exposure to diesel exhaust.

It is critically important in this initial phase of MSHA's review that the currently available scientific information on the health hazards and risks of exposure to diesel exhaust, including uncertainties, be accurately and completely depicted. In short, it is important that MSHA gets the science right! This is the case because that science will ultimately be used to *inform* policy decisions on exposure levels and durations for standards that demonstrate "on the basis of the best available evidence that no miner will suffer material impairment of health or functional capacity even if such miner has regular exposure to the hazards" involved.[3] Let me emphasize the importance of all parties to these proceedings recognizing that the science *informs* the policy decisions inherent in setting the standards, the science does not in and of itself dictate a particular policy outcome. Science alone is insufficient to set the standard because science alone cannot provide a bright line between levels and durations of exposure with or without impairment of health.

MSHA's review of its diesel regulations was inspired by certain developments in the ever-evolving scientific inquiry into diesel exhaust exposure and whether such exposure could lead to lung cancer and other health outcomes. MSHA summarized some – but not all – of that research in Section I.B of the RFI, entitled "Recent Research." As I will explain, it is clear that MSHA is focused on the results of the Diesel Exhaust in Miners Study or "DEMS," to the exclusion of other work that has been done with the DEMS data. The DEMS study was conducted by the National Cancer Institute (NCI) and National Institute for Occupational Safety and Health (NIOSH).

[3] 30 U.S.C. § 811(a)(6)(A).

Beginning in 1997, NIOSH and NCI investigators reviewed historical data for eight non-metal mines that were volunteered by their management to be part of the study. The DEMS analyses are therefore based on estimates of exposure for 1997 and earlier, with the most influential exposure occurring in 1982 and earlier because a 15 year lag yielded the most significant results regarding increased risk of death from lung cancer. The investigators published the final DEMS results in 2012. (Attfield et al, 2012, and Silverman et al, 2012).

To fully understand and interpret the DEMS data, it is important to go beyond the two papers cited in the RFI (Attfield et al, 2012, and Silverman et al, 2012). MSHA must also critically evaluate the five papers describing the original estimates of Respirable Elemental Carbon (REC) exposure for the DEMS workers developed by the original NIOSH and NCI investigators (Stewart et al, 2010; Coble et al, 2010; Vermeulen et al, 2010a; Vermeulen et al 2010b; and Stewart et al, 2012). And, as I will discuss today, independent researchers working with the DEMS data have identified important limitations of DEMS that must be considered in any future assessment. I am one of those researchers, and my colleagues and I have published several papers with the results of our work in the peer-reviewed journal "Risk Analysis." With cooperation from NIOSH, NCI and the National Center for Health Statistics (NCHS), we were given access to the confidential DEMS data under carefully defined conditions.

The DEMS results and the results of a second epidemiological study of diesel exhaust exposure in United States truck drivers[4] were used by the International Agency for Research on Cancer (IARC) in 2012 to change its classification of the carcinogenicity of diesel exhaust. IARC used the results from DEMS and the Truckers Study to conclude there was "sufficient" epidemiological evidence that diesel exhaust was carcinogenic and to change its categorization

[4] (Garshick et al., 2012) (Truckers Study).

of diesel exhaust exposure from "probably carcinogenic to humans" (a conclusion IARC reached in 1988) to "carcinogenic to humans."

Thereafter, EPA and the industry sponsors of the Health Effects Institute (HEI) asked the HEI to assemble a Panel to evaluate DEMS and the Truckers Study to determine whether those studies could be utilized in a future quantitative risk assessment.

To understand why a quantitative risk assessment is significant, it is necessary for me to explain the difference between hazard and risk. The term "hazard" is used to characterize the likelihood that an agent or work place circumstance, such as exposure to diesel exhaust, may under some exposure conditions cause cancer. Carcinogenic hazards are typically described in *qualitative* terms, like those used by IARC in its Monograph evaluation process, which classifies agents in five categories: (1) carcinogenic to humans, (2a) probably carcinogenic to humans, (2b) possibly carcinogenic to humans, (3) not classifiable as to carcinogenicity in humans, and (4) probably not carcinogenic to humans. Those kinds of hazard identifications are qualitative in nature – IARC does not make quantitative estimates of the potency of the agents for causing cancer.

Risk, on the other hand, is a *quantitative* concept and is defined as the probability that a consequence, occurrence of cancer, will occur as a result of a specific exposure (duration and concentration at a particular time in life) to an agent identified as being capable of causing cancer, i.e. has a carcinogenic hazard. The calculation of the probability of occurrence of a particular disease occurring as a result of a specific exposure requires knowledge of both the exposure *and* the potency of the hazardous agent for causing cancer at a particular exposure level and duration. The U.S. Environmental Protection Agency (USEPA) and NIOSH have developed quantitative estimates of cancer-causing potency for only a very modest number of agents.

Neither EPA nor NIOSH have formally developed quantitative estimates of the cancer causing potential of diesel exhaust exposure. I note, however, that development of a quantitative estimate of cancer causing potency for an agent is not necessarily required for regulatory action to limit exposure to the agent. For example, EPA's extensive regulations for diesel engines are not based on a quantitative estimate of cancer risk.

The HEI Epidemiological Panel concluded that both DEMS and the Truckers Study were sufficiently robust to be used in a future quantitative risk assessment, concluding they "were well designed and carefully conducted embodying the attributes of epidemiological studies that are considered important for risk assessment."[5] However, there is more to the HEI Panel's conclusion than the RFI acknowledges. The HEI Panel concluded that the DEMS and Trucker Study provided a useful basis for quantitative risk assessment of exposure *to older diesel engine exhaust*. The DEMS investigators found that the most influential exposure resulting in an increase in lung cancer risk were for 1982 and earlier. The investigators did not measure exposures to newer diesel engine emissions and thus did not take into account the dramatic changes in technology in diesel engines and diesel fuel. The HEI Panel also acknowledged that both studies had significant uncertainties and cautioned that those uncertainties must be factored into any attempt to derive an exposure response relationship for diesel exhaust particulate matter in a quantitative risk assessment. The RFI does not acknowledge those important qualifications, but MSHA's prospective work should do so.

I do extend my compliments to the investigators who conducted DEMS, to NIOSH and NCI for sponsoring it and to the operators and employees of the eight mines that participated in DEMS. The database available from DEMS is remarkable and is still being analyzed and

[5] 81 Fed. Reg. at 36,829 (quoting HEI Press Release, "New Report Examines Latest Studies of Lung Cancer Risk in Workers Exposed to Exhaust from Older Diesel Engines," Nov. 24, 2015).

interpreted. In my opinion, what has occurred with the DEMS data and the multiple analyses will ultimately be recognized as a landmark set of epidemiological analyses. It is extraordinarily rare that a large and complex data set such as that from DEMS is shared and used by multiple investigators beyond the team that collected the data and conducted the initial analyses. It was possible in this case because the DEMS data set was acquired by U.S. government scientists and, thus, the data are the property of the U.S. government. Moreover, the independent scientific analysts were able to obtain funding from a coalition of sources led by the Engine Manufacturers Association that were willing to financially support conduct of the analyses without controlling the analytic process or being allowed to review the results of the analyses before they were published in the peer-reviewed literature. This is a great example of the way science should work, especially when the science is going to be used to inform important public policy decisions.

As those analysts learned, there are substantial uncertainties in the DEMS' estimates of Respirable Elemental Carbon (REC) exposure, used as a surrogate measure for diesel exhaust, and the association between diesel exhaust exposure and lung cancer made by the original NIOSH/NCI investigators and those of the independent analysts using alternative estimates of REC exposure, central for radon exposure, and alternative REC-response models. In the DEMS project, Respirable Elemental Carbon (REC) was used as the metric for diesel exhaust exposure. However, it is important to recognize that *REC was not directly measured for any of the DEMS workers* in the eight mines from the beginning of dieselization (as early as 1947) through December 31, 1997 (the end of follow-up for all enrollees). In the absence of measured REC concentrations *all of the REC exposures used in the analysis of the DEMS data are estimates*. This includes the exposure estimates developed by the original investigators (Attfield et al, 20123 and Silverman et al, 2012) and reported in five papers by NIOSH/NCI investigators that were not cited in the RFI (Stewart et al, 2010; Coble et al., 2010; Vermeulen et al, 2010a,2010b; Stewart et al, 2012). The exposure estimates developed by later analysts (Crump and Van Landingham, 2012; Moolgavkar et al, 2015; Crump et al, 2015; and Crump, Van Landingham and McClellan, 2016) were also estimates of REC. Going forward, MSHA must recognize this serious limitation in any analyses of the DEMS data.

MSHA also must give due consideration to the papers reporting the results of analyses conducted by independent analysts (Moolgavkar et al, 2015; Crump et al, 2012; and Crump, Van Landingham and McClellan, 2016). These papers are not cited in the RFI. Using the DEMS data, the independent analysts' first replicated the analyses of the original investigators verifying that they were using the same DEMS data. Most importantly, in another step, the analysts extended the analyses using alternative models, alternative exposure estimates and controlling for radon exposure.

At the request of the IMA-NA, I have prepared a "Critique of the Health Effects Institute Special Report 19, "Diesel Emissions and Lung Cancer: An Evaluation of Recent Epidemiological Evidence for Quantitative Risk Assessment" (November 2015) (McClellan, 2015) [Attachment B]. In reviewing the HEI report, I drew on my four decades of experience following the literature and conducting research on the health hazards of diesel exhaust exposure, my participation as a member of the IARC Panel that reviewed the carcinogenic hazard of diesel exhaust in 1988, my personal attendance as an observer to the 2012 IARC review and personal participation in conducting extended analyses using the DEMS data.

I have attached a copy of my critique for the record. Let me briefly summarize my critique with emphasis on the multiple analyses of the DEMS data.

(1) The DEMS data set has been analyzed by multiple analysts with widely varying results that emphasize serious uncertainties in the underlying data that should be acknowledged when the results are used to inform policy decisions.

(2) It is important to recognize there are substantial differences among the eight mines studied in DEMS as can be seen by reviewing Table 1. There are meaningful differences in the (a) mode of operation from conventional mining with truck haulage to continuous long wall mining operations with conveyer belt movement of ore, (b) ventilation varying from natural ventilation with limited air movement to very substantial ventilation (1,630 thousand $ft^3$/min), and (c) wide differences in diesel equipment usage from 638 to 6,892 Adjusted Horse Power. Moreover, the mines are located in four different states (Ohio, Missouri, Wyoming and New Mexico) with very different cultural, economic and work environments. It is important to recognize that these differences are such that it is challenging to control for all potential variables in the epidemiological analyses and treat all the workers as being drawn from a single population.

(3) The worker population in the eight facilities were engaged in very different work activities and, hence, differences in exposure to diesel exhaust. Approximately one-third of the workers always worked on the surface (4008 workers and < 81 lung cancers), another one-third always worked underground (4080 workers and 82 lung cancers) and the other one-third spent some time working on the surface and sometime underground (4227 workers and < 44 lung cancers). Note the crude incidence for the latter group is only half of the other two groups, i.e. < 44 lung cancers in 4,227 ever-underground workers versus < 81 lung cancers in 4,008 surface workers and 82 lung cancers in 4,008 always-underground workers..

(4) The HEI Epidemiology Panel, individually and collectively, had limited professional knowledge of underground mining operations and use of diesel equipment in such operations. One member of the Panel is internationally recognized as an expert on diesel engine emissions. However, the other panel members had limited professional knowledge of diesel technology. The HEI Panel was invited to visit at least one of the mines included in DEMS, but declined the invitation.

(5) The most serious uncertainty in the DEMS data set and any epidemiological analyses based on it is the total lack of any measurements of Respirable Elemental Carbon (REC). As I have mentioned, all analyses are based on *estimated REC*. The estimates of REC developed by the original NCI/NIOSH investigators (using an extrapolation from CO measurements) are for some mines markedly different than the more straightforward REC estimates developed by the independent analysts using aggregate diesel equipment horse power (HP) and total mine ventilation (see Figure 2). The differences in the REC estimates are most substantial for the limestone and salt facilities which used substantial diesel HP and had less ventilation compared to the other mines (Table 1). The limestone and salt mines also had the highest portion of radon measurements above the limit of detection.

(6) It is important to recognize differences in the several metrics used for diesel exhaust exposure. As noted, the DEMS uses REC. This is different than Diesel Particulate Matter (DPM) metric used by MSHA for the Permissible Exposure Level. The DPM metric is based on Total Carbon, including both elemental carbon and organic carbon.

(7) A major strength of the DEMS data set is the availability of smoking history data in the case-control study for 198 lung cancer cases and 562 incidence density-sampled control subjects. Smoking information was not, however, available for the larger cohort.

(8) Both the original NCI/NIOSH investigators and the independent analysts observed that smoking status (never, former, or current smoker) and smoking intensity (former smoker of $\geq 2$ packs per day to never smoker: Odds Ratio (OR) = 5.40 (95% CI = 2.23 to 13.06; current smoker of $\geq 2$ packs per day versus never smoker: OR = 12.41, 95% CI of 5.57 to 2.66) was strongly associated with increased lung cancer. The original investigators found that among never smokers, ever-underground workers and surface workers had a similar OR suggesting that the lung cancer risk by surface only workers was mainly due to smoking.

(9) The original investigators found the lung cancer risk was substantially higher for surface-only workers than those who ever worked underground for both current and former smokers. For current smokers of 1 to less than 2 packs/day compared to never smoker the surface only workers had an OR = 13.34, 95% CI of 4.50 to 39.53 compared with an OR = 4.51, 95% CI of 1.5 to 13.58 for the ever underground workers. This unusual and unexpected finding was not adequately explained and suggests that a strong degree of caution should be exercised in using a group that combines individuals who spent some time working on the surface and some time working underground *and* always underground workers as done in the analyses conducted by the original investigators in creating an ever-underground group.

(10) The analyses of the original investigators and the analyses of the independent analysts both identify strong differences in lung cancer hazard associated with REC exposure among the different mine populations. The greatest lung cancer risk was in the limestone workers, with lower lung cancer risk associated with REC exposure in the potash and trona workers. Indeed, the OR for the potash workers was statistically significant at only the highest quartile of cumulative REC. Moreover, for trona workers the ORs for neither average REC intensity nor for cumulative REC were statistically significant.

(11) The HEI Report, building on work of independent analysts developing alternative REC exposure estimates, in detailed Appendix F, encouraged the development of an alternative REC exposure estimate based on mine diesel equipment HP and ventilation (CFM) (see Figure 1). In my opinion, this REC exposure estimate is the most defensible REC exposure estimate among those developed by the original investigators and the independent analysts.

(12) Using the HP-CFM based REC exposure estimates, none of the trend slopes for the OR were statistically significant ($p > 0.05$). Moreover, these trend slopes were smaller by roughly factors of five without control for radon exposure and factors of 12 with control for radon exposure, a well-recognized carcinogenic hazard, compared to those estimated in the original DEMS analysis. Also, the 95% confidence intervals for these trend slopes had only minimal overlap with those for the slopes in the original DEMS analyses (Table 2).

(13) In my opinion, the results of the original analyses of the DEMS data and those of the independent analysts in aggregate are probably adequate for evaluating the carcinogenic hazard of exposure to traditional diesel exhaust characteristic of diesel engines and high sulfur content fuels used in the 1980s and earlier. As the HEI Panel recognized, DEMS did not investigate exposure to newer diesel engines or fuel.

(14) In my opinion, the uncertainties in the results from analyses of the DEMS data are so substantial that extraordinary caution should be exercised in moving beyond their use in hazard characterization to using any single analytical result based on the DEMS population for quantitative risk assessment. Indeed, our quantitative understanding of the lung cancer risks of diesel exhaust exposure may be no better today than existed when MSHA made policy judgments to publish a final rule on May 18, 2006 phasing in a final Diesel Particulate Matter Permissible Exposure Limit of 160 micrograms of TC per cubic meter of air ($160_{TC}$ $\mu g/m^3$).

(15) NIOSH has already initiated preparation of a Diesel Exhaust Risk Assessment (DERA) which will be available to MSHA and OSHA for use in regulatory decision making. I am eager to share my critique with the NIOSH scientists developing the DERA so they can be fully informed about the serious limitations in the original analyses conducted by the NIOSH/NCI investigators and the need to consider the later results published by independent analysts. Recognizing that any DERA developed by NIOSH will have potential for use by MSHA in regulatory rule making, it is important that MSHA encourage NIOSH to make public that agency's risk assessment protocol and related activities for public review and comment at an early date.

I will be pleased to engage in scientific dialogue with MSHA as you move forward with this important review of the science on the health hazards of exposure to diesel exhaust and evaluation of the adequacy of current MSHA regulations. To truly provide an adequate scientific basis for a review of "the effectiveness of the existing standards in controlling miners' exposure to diesel exhaust"[6] and "to preserve miners' health,"[7] MSHA must give due consideration to *all* of the currently available science in this area. If MSHA's review does not account for all of the relevant science, it is possible that estimates of the potential cancer hazards of miner's exposure to diesel exhaust may not be accurately characterized. This, in turn, could lead to inappropriate revision of the present regulations and misdirected actions to limit exposure of miners to diesel exhaust.

Thank you again for the opportunity to speak today.

[6] 81 Fed. Reg. at 36,829.

[7] *Id.*

Attachment A: Roger O. McClellan Biography

Attachment B: Critique of Health Effects Institute Special Report 19, "Diesel Emissions and Lung Cancer: An Evaluation of Recent Epidemiological Evidence for Quantitative Risk Assessment"

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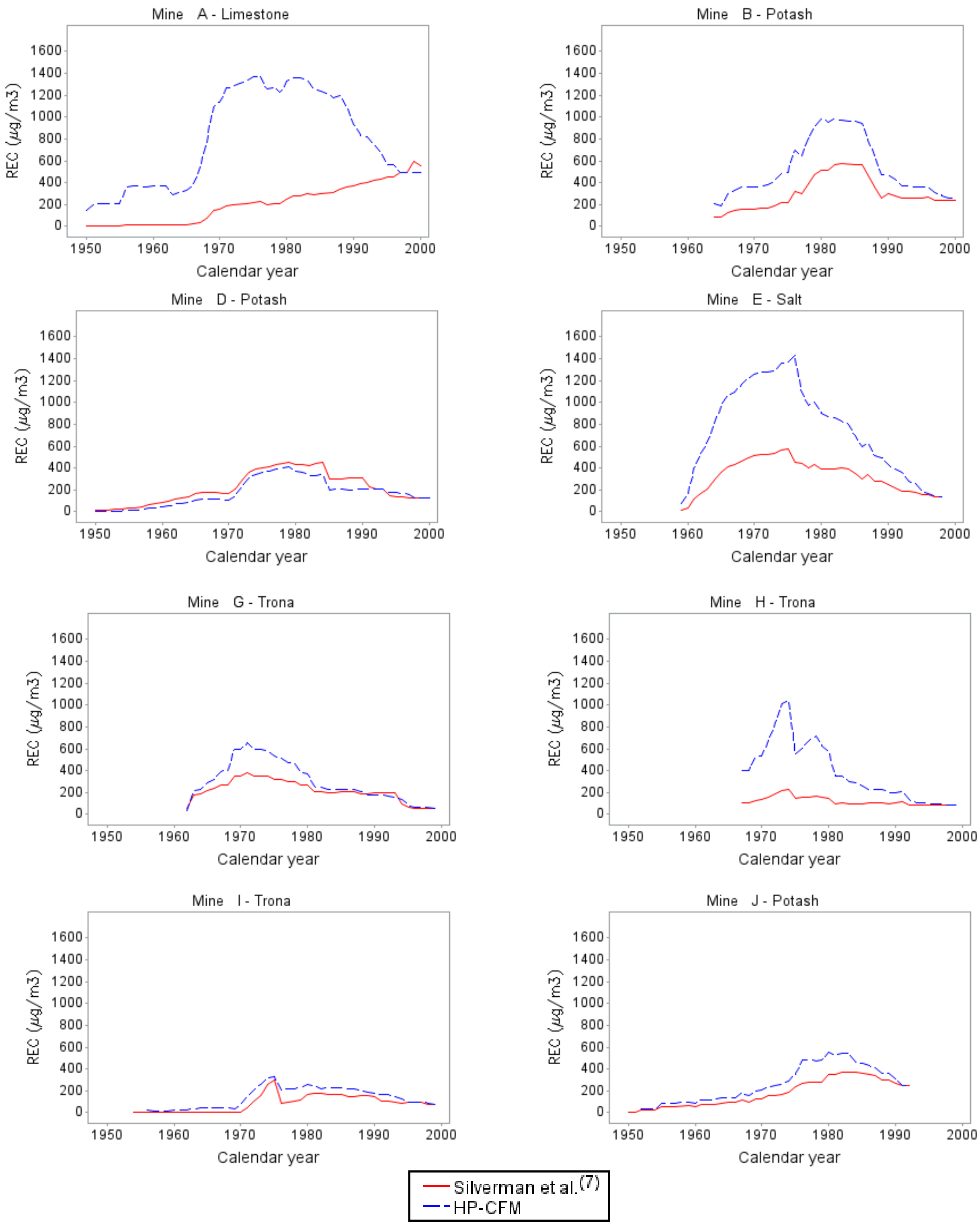


Figure 1: Alternative Respirable Elemental Carbon Metrics Using CO (red), developed by the original investigators versus HP-CFM (blue) Developed by Crump et al (2016).

Table 1: Characteristics of the Mines in the Diesel Exhaust in Miners Study (DEMS) (From Crump et al, 2016)

| Mine | State | Ore | Ventilation | Year of First Diesel Use | Primary Mode of Operation | All Years: CO # samples | CO % > LOD | Radon # samples | Radon % > LOD | 1982 Activity: CFM $f^3$/min (in thousands) | Diesel (Adj HP) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| A | Missouri | Limestone | Natural | 1947 | Cv/H | 248 | 70 | 37 | 84 | -- | 6,862 |
| B | New Mexico | Potash | Mechanical | 1964 | Cv/Con, Ct | 447 | 62 | 18 | 44 | 250 | 892 |
| D | New Mexico | Potash | Mechanical | 1950 | Cv/H, Cv/Con, Ct | 323 | 54 | 61 | 39 | 360 | 2,326 |
| J | New Mexico | Potash | Mechanical | 1952 | Cv/H, Cv/Con, Ct | 178 | 52 | 13 | 38 | 240 | 1,421 |
| E | Ohio | Salt | Mechanical | 1959 | Cv/H | 207 | 66 | 39 | 70 | 233 | 2,804 |
| G | Wyoming | Trona | Mechanical | 1962 | Cv/Con, Ct | 276 | 50 | 17 | 24 | 450 | 638 |
| H | Wyoming | Trona | Mechanical | 1967 | Cv/Con, LW, Ct | 2361 | 39 | 40 | 15 | 950 | 1,110 |
| I | Wyoming | Trona | Mechanical | 1956 | Cv/Con, Ct, LW | 2000 | 54 | 54 | 20 | 1,630 | 1,493 |
| Total | | | | | | 6040 | 50 | 279 | 42 | | |

The above data were compiled from the Stewart et al.[1] and the substantial DEMS data files. Primary Mode of Operation: Cv/H – conventional with truck haulage, Cv/Con – conventional with conveyor belts, Ct – Continuous with conveyor belts, and LW – long wall with conveyor belts. Specific data for ventilation rates and HP are shown for 1982 for illustrative purposes, as 1982 was the last year of effective exposure for workers, assuming a 15 year-lag, as follow-up ended in 1997.

Table 2: Comparison of Conditional Original Logistic Regression Resulted (Silverman et al, 2012) with Results of Similar Analyses except based on New REC Estimates Defined Using HP and CFM (From Crump et al, 2016)

| Analysis | Quartiles of cumulative REC, lagged 15 years ($\mu g/m^3$-y) | Cases | Controls | OR (95% CI) | $p_{trend}$ | Slope $(\mu g/m^3\text{-}y)^{-1}$ 95% CI |
|---|---|---|---|---|---|---|
| **All Subjects** | | | | | | |
| Silverman et al.[7] | 0 to < 3 | 49 | 158 | 1.0 (referent) | 0.001 | 0.00073* |
| | 3 to < 72 | 50 | 228 | 0.74 (0.40 to 1.38) | | (0.00028,0.0012)* |
| | 72 to < 536 | 49 | 157 | 1.54 (0.74 to 3.20) | | |
| | ≥ 536 | 50 | 123 | 2.83 (1.28 to 6.26) | | |
| REC estimates from | 0 to < 3 | 49 | 158 | 1.0 (referent) | 0.0006 | 0.00082 |
| Silverman et al.[7] | 3 to < 72 | 50 | 228 | 0.79 (0.41 to 1.52) | | (0.00035,0.0013) |
| and "without | 72 to < 536 | 49 | 157 | 1.62 (0.75 to 3.49) | | |
| radon" controls[12] | ≥ 536 | 50 | 123 | 3.24 (1.40 to 7.55) | | |
| HP-CFM REC | 0 to < 6.6 | 49 | 172 | 1.0 (referent) | 0.06 | 0.00016 |
| estimates and | 6.6 to < 129 | 50 | 191 | 1.05 (0.58 to 1.93) | | (-0.000012,0.0003) |
| "without radon" | 129 to < 891 | 49 | 168 | 1.60 (0.79 to 3.24) | | |
| controls | ≥ 891 | 50 | 135 | 2.37 (1.02 to 5.50) | | |
| HP-CFM REC | 0 to < 6.6 | 49 | 172 | 1.0 (referent) | 0.63 | 0.00005 |
| estimates and | 6.6 to < 129 | 50 | 191 | 1.02 (0.55 to 1.90) | | (-0.00016,0.00026) |
| "with radon" | 129 to < 891 | 49 | 168 | 1.20 (0.56 to 2.56) | | |
| controls | ≥ 891 | 50 | 135 | 1.37 (0.5 to 3.77) | | |
| **All Subjects Who Ever Worked Underground** | | | | | | |
| Silverman et al.[7] | 0 to < 81 | 29 | 92 | 1.0 (referent) | 0.004 | 0.00065* |
| | 81 to < 325 | 29 | 52 | 2.46 (1.01 to 6.01) | | (0.00020,0.0011)* |
| | 325 to < 878 | 29 | 69 | 2.41 (1.00 to 5.82) | | |
| | ≥ 878 | 29 | 51 | 5.10 (1.88 to 13.87) | | |
| REC estimates from | 0 to < 97 | 31 | 158 | 1.0 (referent) | 0.01 | 0.00073 |
| Silverman et al.[7] | 97 to < 384 | 31 | 90 | 1.90 (0.78 to 4.63) | | (0.00022,0.0012) |
| and "without | 384 to < 903 | 31 | 80 | 2.73 (1.08 to 6.88) | | |
| radon" controls[12] | ≥ 903 | 31 | 84 | 5.04 (1.77 to 14.30) | | |
| HP-CFM REC | 0 to < 130 | 31 | 144 | 1.0 (referent) | 0.16 | 0.00014 |
| estimates and | 130 to < 531 | 31 | 99 | 2.03 (0.83 to 4.96) | | (-0.000062,0.0003) |
| "without radon" | 531 to < 2149 | 31 | 99 | 3.45 (1.27 to 9.41) | | |
| controls | ≥ 2149 | 31 | 70 | 3.84 (1.07 to 13.74) | | |
| HP-CFM REC | 0 to < 130 | 31 | 144 | 1.0 (referent) | 0.69 | 0.00005 |
| estimates and | 130 to < 531 | 31 | 99 | 1.83 (0.73 to 4.61) | | (-0.00020,0.00030) |
| "with radon" | 531 to < 2149 | 31 | 99 | 2.47 (0.79 to 7.73) | | |
| controls | ≥ 2149 | 31 | 70 | 2.5 (0.49 to 12.79) | | |
| **All Subjects Who Only Worked Underground** | | | | | | |
| HP-CFM REC | 0 to < 106 | 14 | 26 | 1.0 (referent) | 0.27 | 0.00024 |
| estimates and | 106 to < 410 | 15 | 28 | 1.89 (0.4 to 9.07) | | (-0.000179,0.0007) |
| "without radon" | 410 to < 1486 | 14 | 17 | 3.15 (0.47 to 21.05) | | |
| controls | ≥ 1486 | 15 | 26 | 4.73 (0.58 to 38.84) | | |
| HP-CFM REC | 0 to < 106 | 14 | 26 | 1.0 (referent) | 0.36 | 0.00027 |
| estimates and | 106 to < 410 | 15 | 28 | 1.91 (0.38 to 9.75) | | (-0.000316,0.0009) |
| "with radon" | 410 to < 1486 | 14 | 17 | 5.61 (0.61 to 51.33) | | |
| controls | ≥ 1486 | 15 | 26 | 9.39 (0.47 to 187.84) | | |

*Calculated by us after reproducing Silverman et al results