Health Effects of DPM Exposure (Toxicology)

a) One commenter submitted two abstracts for toxicology studies:
   - A study suggesting that a diesel/biodiesel blend may cause more male reproductive system abnormalities than neat diesel fuel [Kisin 2014].
   - A literature review linking toxicology literature to epidemiological literature for ambient particulate matter [Schlesinger 2006].

b) Another commenter submitted a press release with information stating that new technology diesel engine (NTDE) exhaust did not cause cancer in rats. This press release contained figures showing the reductions in particle mass and number emissions since 2004. [ACES Press release with figures].

c) A third commenter submitted a review article that included information summarizing toxicology studies. [McClellan 2012a].

Risks of DPM Exposure (Epidemiology)

a) Two commenters from academia and public health organizations described and submitted two studies, analyzing data from the Canadian National Enhanced Cancer Surveillance System, that found a twofold higher risk for bladder cancer and rectal cancer among men with more than 10 years of high exposures to diesel emissions. [Latifovic 2015], [Kachuri 2016]. One of these commenters also described and submitted a study of lung cancer in the Australian mining sector, with an estimated 38 excess lung cancer deaths per 1,000 male workers for those with average environmental carbon exposures of 44 $\mu g/m^3$ [Peters 2016].

b) Another member of academia submitted a quantitative risk assessment study. [Vermeulen 2016].

c) A commenter from a non-U.S. government institute described and submitted a lengthy institute report (~130 pages) on lung cancer risk and diesel emissions. [Mohner 2016b].

d) A commenter from a non-U.S. mining company submitted an Institute of Medicine report (18 pages) on exposure-response relationships for diesel exhaust and lung cancer. [MacCalman 2015].

e) Representatives of two trade associations submitted written copies of testimony by Dr. Roger O. McClellan on two different days of MSHA hearings, plus figures and tables presented by Dr. McClellan during oral testimony. [McClellan testimony July 2016, 19 pages], [McClellan testimony November 2016, 42 pages], [McClellan figures and tables]. One of these commenters also submitted an "invited commentary" on fine particulate matter ($PM_{2.5}$) from a scientific journal [McClellan 2016].

f) One of these trade association representatives offered comments on health effects of DPM exposure, which the second endorsed [Comment], [Comment]:
   - The Diesel Exhaust in Miners Study (DEMS), while impressive, has some flaws. The study assesses exposures from diesel-powered fleets ending in the early 1990s. "These fleets have been largely replaced or overhauled such that in 2016, …the fleets…are much newer with cleaner emissions." The commenter submitted seven DEMS studies, some of which were also submitted to the docket by MSHA or others: [Silverman 2012], [Attfield 2012], [Stewart 2010], [Coble 2010], [Vermeulen 2010a], [Vermeulen 2010b], [Stewart 2012].

- In contrast, the Health Effects Institute (HEI) Advanced Collaborative Emissions Study (ACES) showed that emissions from modern diesel engines demonstrated dramatic improvements and "the absence of any significant health effects." The commenter submitted two ACES documents: [HEI ACES executive summary], [ACES press release with Figures].
- The HEI Special Report 19 is also flawed. A critique by Dr. McClellan noted that most HEI Diesel Epidemiology Panel members had limited professional knowledge of diesel technology and use of diesel equipment in mining operations. None had ever visited an underground mine using diesel-powered equipment, despite an invitation to tour a mine in Wyoming—this commenter stated that "until you've actually been in different mining operations, you're clueless about how they actually use diesel equipment." [HEI Special Report 19] [Critique of HEI 19]. This commenter summarized Dr. McClellan's critique as follows:
  - There are substantial uncertainties about respirable elemental carbon (REC) exposure and confounding effects of cigarette smoking and radon exposure. Newer analyses (e.g., [Crump 2016]) of DEMS, using equipment horsepower and ventilation as an improved exposure surrogate (HP-CFM), show a lower risk of lung cancer, with radon measurements demonstrating a clear influence of radon exposure.
  - New analyses of the DEMS dataset illustrate the importance of making epidemiologic data available for review by other scientific teams, and of considering all results to inform public policy decisions.
  - The DEMS results are most relevant to traditional pre-1990 diesel technology, with limited relevance to new technology diesel engines (engine technology, exhaust after-treatment and ultra-low-sulfur fuel), that have "extraordinarily low emissions of particulate matter and nitrogen oxides." [Khalek 2011], [Khalek 2015]. The DEMS results underscore the benefits of shifting to new technology diesel engines.
- This commenter mentioned NIOSH preparation of a diesel exhaust risk assessment (DERA), urged the DERA team to visit some members' mines to see diesel fleets operating underground, and asked what role MSHA will have in work on the NIOSH DERA.
- This commenter also submitted a discussion of operations at a trona mine in Wyoming to illustrate the kind of information available for rigorous evaluation of exposure at each mine, as it relates to uncertainty in exposure estimates that need to be addressed by the HEI panel. [Trona mine discussion]. The discussion included:
  - A description of key variables that affect DPM exposures at different nonmetal mines, particularly the nature and extent of ventilation, the volumes of ore moved, and the amount and kind of diesel equipment used, including horsepower, and types of surface processing and purification operations. This trona mine is a gassy mine with high ventilation rates; much of its equipment is electrically powered.
  - Charts showing DPM concentrations over time as well as data tables showing equipment used in DEMS study mines, and a statement that this type of data is needed to construct accurate DPM exposure estimates for each mine in the DEMS studies. A detailed equipment listing is provided for 1982, since several analyses of DEMS data find

the strongest DPM-lung cancer correlation when a 15-year lag is used. [Commenter figures and tables, pp. 7–13].
    - A discussion of radon measurements and confounding of risk estimates for DPM.
    - Discussion of exposure differences and lung cancer rates in always-underground versus never-underground workers, with Moolgavkar (2015) finding lower lung cancer hazard ratios and lower statistical significance for always-underground workers than Attfield (2012) did for ever-underground workers using the same statistical methods. [Moolgavkar 2015], [Attfield 2012].
    - The importance of addressing uncertainty in DPM uncertainty estimates jointly with uncertainty estimates for the epidemiologic findings (i.e., uncertainty estimates for each step in a complex process).
    - The importance of touring a mine to understand exposures, with a discussion of visiting the trona mine. [Mine visit discussion].
- This commenter also submitted a four-page critique of exposure estimates used in the DEMS studies. [Exposure estimate comments]. These comments discussed the following points:
    - A 2012 report prepared by five trade associations and submitted to IARC, titled *A Global and Historical Perspective on the Exposure Characteristics of Traditional and New Technology Diesel Exhaust.* The DEMS and other epidemiology studies of diesel exhaust were conducted before particulate emissions from diesel engines were regulated. Prior to 1988 in the United States and 1992 in Europe, no controls were required for diesel particulate emissions in on-highway engines, only controls for nitrogen oxides, carbon monoxide (CO), hydrocarbons, and visible smoke. The first non-road particulate emissions standards appeared in 1996 in the Unites States and 1999 in Europe. Because of the significant impact that different diesel technologies have on the character of diesel emissions, the emission technologies incorporated in the diesel engines under consideration in any epidemiological or toxicological study must be identified carefully and specifically. [EMA et al. 2012; report begins on page 6].
    - Issues with using CO as a surrogate for DPM exposure, including incorrect assumptions that CO and DPM emissions from different engines correlate well, that historical CO exposures correlate with engine horsepower, or that the correlation of CO and PM emissions from different diesel engines is sufficiently proportional and linear to allow for 1:1 scaling over the years of the study. This critique cites studies (Clark 1999, Xu 2005, and McKain 2012; not submitted to the docket) that find no reliable relationship between CO and DPM. Several of the DEMS studies relied on CO as an exposure surrogate: [Stewart 2010], [Coble 2010], [Vermeulen 2010a], [Vermeulen 2010b], [Stewart 2012].
    - The fact that older engines used indirect injection, which had higher DPM emissions than direct injection engines. Mining generally lagged behind on-road vehicles, in the introduction of cleaner engines, by a decade or more.
    - The fact that DPM measurement methods were not developed until the late 1980s, with REC measurement technology even later. This means pre-1985 emissions from mining

equipment must be estimated from later data for on-road vehicles—which will likely underestimate emissions from the mine diesels, due to the lag in introduction of better technology in mining. The HEI panel should address the question of whether the DPM emissions from diesel engines in mines are sufficiently different from on-road diesels, and whether it is appropriate to use the DEMS data for any quantitative estimation of lung cancer risk from ambient DPM that arises predominantly from on-road engines.

g) Another trade association representative submitted four large files. The first contained comments on IARC Monograph 105; together with the Global and Historical Perspective report; plus an eight-page letter from HEI to the IARC committee summarizing newer studies and their findings relevant to the carcinogenicity of diesel exhaust, and the differences between new-technology diesel engine (NTDE) exhaust and traditional technology diesel engine exhaust. The second file contained a literature review also submitted by another commenter (Hesterberg 2012), and two others containing several epidemiology studies (several, but not all, of which were also submitted as individual files by other commenters). [Studies], [Studies]. This commenter attributed the following points to the IARC monograph [Comments]:
   - The IARC Group 1 classification should not apply to NTDE. The new diesel engine technology has been shown to reduce particulate mass emissions by more than two orders of magnitude, and the human epidemiological studies reviewed in the IARC monograph were conducted before the introduction of the modern diesel engine technology. Most of the exposures in the relevant epidemiology studies occurred in the 1960s–1980s, with a few studies extending into the 1990s.
   - IARC uses the following terminology: diesel engines that are unregulated for particulate emissions are referred to as “traditional technology diesel engines,” those that are fitted with wall-flow particulate filters and oxidation catalysts and use ultra-low-sulfur fuel are “new technology diesel engines,” and those that fall in between are “transitional diesel engines.”
   - Diesel engines with diesel particulate filters had particulate emissions in the same range as gasoline engines.
   - “Exhaust after-treatment can contribute to substantial reductions in the activity of extracts of diesel engine particulate matter or exhaust semi-volatile organic compounds of expressed per unit of engine work or volume of emitted exhaust. No comparative data were available to the Working Group to evaluate the genetic and related effects of new technology diesel exhaust…[A]t the present time, new-technology diesel engines have not been evaluated thoroughly.”

h) Another commenter, from a trade coalition, urged caution in relying on the current published health effects science to support additional diesel engine regulations: the published science, stated the commenter, generally does not consider today’s far-cleaner diesel engines, fuels, and exhaust. This commenter submitted several studies along with comments (or abstracts) for some of them:
   - Crump 2012: This study reanalyzed DEMS exposure estimates using different assumptions about the relationship between CO and DPM exposures.

- Crump 2015: This study reanalyzed DEMS data while controlling for radon exposure. It found no association between diesel exhaust exposure and lung cancer in six alternative exposure estimates for underground miners, but did find an association when using the three original exposure estimates.
- Crump 2016: This study re-estimated DPM exposure using data on equipment use, horsepower, ventilation, and reductions in engine emissions. It found much lower trend slopes for association with lung cancer, which were not statistically significant.
- Gamble 2012: This literature review concludes that the weight of evidence is inadequate to confirm the diesel-lung cancer hypothesis.
- Hesterberg 2012: Studies of traditional diesel exhaust exposure show inconsistent evidence of exposure-response trends. NTDE is more similar to gasoline and natural gas engine exhaust in its particulate content.
- McClellan 2012a: Improvements from traditional diesel engines include better engine control, a better fuel injection system, enhanced exhaust cooling, use of ultra-low-sulfur fuel, wall-flow high-efficiency exhaust particulate filters, exhaust catalysts, and crankcase ventilation filtration. The composition of NTDE is qualitatively different and the concentrations of particulate constituents are more than 90% lower than for traditional diesel exhaust. The authors recommend that future reviews of carcinogenic hazards of diesel exhaust evaluate NTDE separately from traditional diesel exhaust.
- Mohner 2013a: Reanalysis of lung cancer risk in German potash miners while controlling for smoking and previous occupational history (e.g., uranium mining) found no statistically significant association between respirable elemental carbon exposure and lung cancer.
- Moolgavkar 2015: Analysis of the DEMS cohort by mine type and temporal factors such as duration of exposure found elevated lung cancer risk only in the limestone mine, with evidence of effect modification by attained age.
- Morfeld 2012: The causal associations between diesel exhaust exposure and lung cancer risk identified in the DEMS studies relied on surface versus underground work as a risk factor. This was not explained, and led the authors to hypothesize that high REC exposures were protective against lung cancer excess risks due to smoking. This article poses questions about mortality follow-up procedures and the reliability of the REC and smoking exposure estimates.
- In addition, this commenter submitted the following articles without commentary: [McClellan 2012b] (editorial letter), [Mohner 2016b] (letter suggesting reanalysis of the DEMS data), [Bofetta 2012], [Borak 2011]. The commenter also submitted two 2014 letters regarding a meta-analysis by Vermeulen (2014, not submitted to the docket): [Crump 2014 letter and Vermeulen response]. The first of these is a discussion by Crump of study limitations; the second is a response by Vermeulen.