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From: Paul.Wambach
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To: NIOSH Docket Office (CDC)
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Subject: 161-A - Occupational Exposure to Carbon Nanotubes and Nanofibers
Attachments: Comments to NIOSH Draft Current Intell Bulletin re Nanotubes Nanofibers 2-17-11 (2).doc

Attached are comments on the subject document submitted on behalf of the U.S. Department of Energy, Office of Health, Safety and Security.

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National Institute for Occupational Safety and Health Draft Current Intelligence Bulletin:
Occupational Exposure to Carbon Nanotubes and Nanofibers

General Comments:

With carbon nanotubes (CNT) and carbon nanofibers (CNF) having entered commerce, the need for the National Institute for Occupational Safety and Health (NIOSH) Bulletin to assist employers in preventing occupational disease is well supported by the summary of toxicology studies and risk assessment.

DOE believes that NIOSH's Recommended Exposure Limit (REL) of 7 $\mu g/m^3$ elemental carbon (EC) as an 8-hr TWA respirable mass airborne concentration measured by NIOSH Method 5040 *Diesel Particulate Matter 5040 (as Elemental Carbon)* is not advisable. That recommended REL is the lowest level that is technically feasible to measured, however, employers cannot implement effective exposure monitoring and control programs if they cannot measure levels below the REL.

The Bulletin on page 7 states that 7 $\mu g/m^3$ is a high estimate of the Level of Quantitation (LOQ)." The LOQ is generally understood to be the lowest concentration that can be reported with a defined, reproducible level of certainty. Analytic results less than the LOQ typically are reported as "less than the LOQ" or "non-detect," also referred to as censored results. Setting the REL at the analytic LOQ value is not practical. Exposure control programs require an action level that is lower than the REL. Employers must be able to measure exposures at an action level to have confidence that the REL is not being exceeded. NIOSH Method 5040 is not capable of measuring those lower levels.

DOE recognizes that a NIOSH method development initiative to lower the LOQ for Method 5040 is not within the scope of this Bulletin. DOE nonetheless respectfully suggests that NIOSH undertake that method development in order to increase the likelihood that a protective action level for CNTs and CNFs can be established used proactively to monitor and control exposures before the exposures exceed the REL.

Detailed Technical Comments:

1. On page 42 the bulletin says: *However, NIOSH recognizes that the REL may not be completely health protective, but its use should help to lower the risk for developing lung disease and assist employers in establishing an occupational health surveillance program that includes elements of hazard and medical surveillance. Until improvements in sampling and analytical improvements can be made in measuring airborne exposures to CNT and CNF, continued efforts should be made to reduce airborne concentrations as low as possible below REL by optimizing the sampling and analysis of exposures when possible (Appendix C).*

   NIOSH should acknowledge that compliance with the recommended REL is the highest feasible level of protection employers can provide and refrain from recommending reducing

exposures to levels as low as possible below the REL because employers will be unable to implement measures to reduce exposures to levels below the REL if they cannot measure those levels.

Exposure assessment methods should aim to limit both false negative and false positive errors that result in unnecessary expenditures of resources on preventive efforts that may have no value. The employer attempting to implement this recommendation would have to make a choice of which of these two types of errors to limit. False positive errors would be limited by taking protective actions only when exposures are above the REL, but because the REL is not a safe level; the false negative error rate would be unknown and uncontrolled. False negative errors could be limited by "continued efforts to reduce airborne concentrations as low as possible below the REL," however because levels below the REL cannot be measured, the false positive error rate would be unknown and uncontrolled. Managers responsible for worker health and safety will have difficulty in securing labor and line management support for protective actions when there is no monitoring or other objective data supporting their need or effectiveness.

2. On page 48, a paragraph that reads: *As part of the initial workplace hazard surveillance, NIOSH recommends identifying those workers with the highest potential for exposure to CNT and CNF [NIOSH 2009a], as well as the tasks and processes associated with those potential exposures. Performing targeted exposure sampling of workers involved in those tasks can be part of an overall exposure sampling strategy to protect workers' health. Although a specific sampling strategy has not been developed for evaluating workplace exposures to CNT and CNF, the same principles developed for the exposure measurement of other aerosols [e.g., NIOSH 1977; Leidel and Busch 1994] should apply to workers with potential exposure to CNT or CNF. When the goal of sampling is to determine whether or not worker exposures are being controlled below the REL, initial sampling efforts should focus on those workers thought to have the highest exposure concentrations (i.e., maximum risk worker) [NIOSH 1977; Leidel and Busch 1994]. This type of strategy may be more efficient and require fewer resources for identifying potential exposures above the REL, although periodic sampling of all workers or groups of workers (identified as having similar exposures) should also be performed. The periodic sampling will ensure that the targeted sampling groups include all workers with potential for exposures above the REL. In workplaces where the number of workers potentially exposed is small, consideration should be given to sampling all workers.*

   The employer must decide which workers and how frequently they should be monitored to determine compliance with the REL. The referenced publication (Leidel and Busch, 1994) Section 5.3 "Exposure Monitoring Strategies," answers this question through the application of hypothesis testing statistics to exposure monitoring results to guide decisions. On page 521 the authors state "Section 2.4 listed two major types of monitoring programs as possible objectives of exposure estimation. The first type is an exposure screening program, which is a limited exposure monitoring program designed to identify target populations of workers with other-than-acceptable exposure distributions for follow up periodic monitoring. The program uses an action level as a screening cutoff to identify appropriate target

populations for inclusion in a limited exposure surveillance program or a more extensive exposure distribution monitoring program. The latter program is a more extensive one intended to quantify exposure distributions of target populations."

Implementing the screening step requires an action level that is less than the exposure limit since the fact that one day's exposure is less than the REL does not guarantee that all other days' exposures are less than the REL. Appendix L of the NIOSH 1977 reference explains that the distance the action level should be from a limit is highly dependent on the amount of day-to-day variation in exposure. The action level should be at least 50 percent the REL even if day-to-day variation is very low (i.e., a geometric standard deviation [GSD] of 1.2 or less) and lower if variation is higher. For moderate variation with a GSD of 2, the action level should be 10 percent of the REL. The AIHA's, *Strategy for Assessing and Managing Occupational Exposures*[1], provides similar but more intuitive guidance as that provided by Leidel and Busch. On Page 89 of the AIHA text states, "If one measurement result is far below 10% of the Occupational Exposure Limit (OEL) threshold or well above 100% of the OEL, then it may be all the monitoring required to judge the exposure acceptable or unacceptable. If the exposure profile is highly variable or positioned within the range of 10% to 100% of the OEL, then more samples might be needed to adequately characterize the exposure profile."

If judgment or screenings identify target populations for more extensive exposure distribution monitoring program, then Leidel and Busch recommend initially collecting 6 to 10 samples per group and using lognormal probability plots or other parametric methods to estimate one-sided tolerance limits and other metrics used to guide decisions on the need for protective actions. If the lognormality of the data is in doubt, they advise much larger sample numbers per group (i.e., 30 to 60). Censoring casts doubt on the fit of data to a parametric model. In Appendix VIII of the AIHA book 20 percent to 50 percent censoring is characterized as medium, 50 percent to 80 percent as high, and 80 percent to 100 percent as severe. In a hypothetical minimally compliant exposure distribution with exactly 5 percent of exposures exceeding the REL and a GSD of 3, a reporting limit that is 50 percent of the REL would result in extreme (≈84 percent) censoring and require use of order statistics. A reporting limit that is 10 percent of the REL would reduce this to medium (≈33 percent) censoring, and use of parametric statistics would still be possible. Monitoring results from environments that are more clearly compliant with the REL would have higher percentages of censored results.

3. The Bulletin recommends an exposure assessment strategy that largely depends on having monitoring methods that can detect exposures that are 10 percent of the REL or lower even though, as described above, NIOSH Method 5040 is unable to detect exposures less than the REL. Censoring measurements at the REL limits the choice of strategies to only one of Leidel and Busch's recommended options, the use of nonparametric order statistics. Under most occupational exposure scenarios, order statistics are too inefficient to have much utility.

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[1] Ignacio, J.S. and W.H. Bullock, *A Strategy for Assessing and Managing Occupational Exposures*, Third Edition. AIHA Press, Fairfax, VA. 2006

Similarly, exposed groups large enough to produce enough representative samples to support the use of order statistics would be the exception rather than the rule. Under most circumstances, sampling all workers in all shifts would be the only possible method of determining the rate at which the REL is being exceeded.

4. The Bulletin provides recommendations to employers to guide decisions on whether additional protective actions are needed. Employers primarily should be concerned with avoiding errors that result in concluding that unsafe working conditions are safe. Exposure monitoring methods that are unable to detect levels less than the REL are ill suited to achieving this goal. A consequence of censoring measurements at the REL is that it will limit the use of the monitoring results to support studies of protective exposure levels. Monitoring results from compliant workplaces will be all, or nearly all, labeled nondetects. Even results from workplaces with mean exposure levels near the REL will be highly censored. If the medical surveillance recommended by the Bulletin identifies workers with health effects, it is unlikely that the highly censored monitoring data available would support analyses of the differences in exposure levels between those with health effects and those without even if the exposures had been extensively monitored.

5. Throughout the Bulletin, there is a statement that: "the LOQ for NIOSH Method 5040 is 7 $\mu g/m^3$." Users of the Bulletin may not understand precisely what NIOSH means by the term "LOQ." There is no standard definition that chemistry laboratories apply to reporting limits, and the limit of quantitation (LOQ) is not defined in the Bulletin or in referenced documents. For example, what NIOSH calls LOQ other laboratories might call LOD (limit of detection), DL (detection limit), IDL (instrument detection limit) , LQ (limit of quantitation), QL (quantitation limit), PQL (practical quantitation limit), EQL (estimated quantitation limit), MDL (method detection limit), or RL (reporting limit). Adding to the confusing variety of these terms is the different procedures and criteria used for their calculation. Most commonly the term LOQ is applied to a metric that conforms to the statistical concept L. A. Currie[2] called the quantifiable level and defined as the true concentration above which the relative standard deviation of the distribution of measured values is less than a specified value (e.g., 10 percent.). This number will depend on several variables, e.g., the concentration of the lowest calibration standard, condition of the analytical equipment, sample matrix, preparation method, number of replicates, etc., and varies over time for a laboratory for each analyte and method. The Bulletin's recommended use of the fixed number 7 $\mu g/m^3$ is not consistent with Currie's concept of a quantifiable level and how it is determined.

   The American Industrial Hygiene Association (AIHA), which provides the accreditation services used by most U.S. industrial hygiene laboratories, requires that "measurements below the method reporting limit shall be reported as "<" (less than) or not detected (ND) and reference the reportable limit."[3] AIHA defines reportable limit as "the lowest

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[2] L. A. Currie, Anal. Chem., 1968, 40, 586–593.

[3] LQAP Policy Document, Module 9, American Industrial Hygiene Association, Cincinnati, OH, www.aiha.org, accessed 1/4/2011.

concentration of analyte in a sample that can be reported with a defined, reproducible level of certainty."[4] This is very similar to the Currie definition above but includes the requirement that the limit be reproducible. To be a reproducible, laboratories base reporting limits in part on analyses of blanks and spikes, but also multiply their detectible limits with a factor to account for different sample matrices, interferences on field samples, instrument drift, etc., that would otherwise result in day-to-day variation in the reporting limits that they wish to avoid.

The Bulletin suggests that the 7 $\mu g/m^3$ value is the censoring point that NIOSH quality assurance programs have established for reporting results of analyses of full shift personal samples for diesel particulate. It is well suited to assessing diesel particulate exposures against a Mine Safety and Health Administration Permissible Exposure Limit of 160 $\mu g/m^3$. Publishing a REL of 7 $\mu g/m^3$ for CNT and CNF will make it a de facto reporting limit for other chemistry laboratories for CNT and CNF analyses. Labs must establish reporting limits before analyzing the first sample from a customer and will almost certainly choose to establish that they can meet the number NIOSH has shown to be feasible rather than attempt to establish a reporting limit that they could attain that would be lower than the NIOSH LOQ. The discussion in the Bulletin and Chapter Q of the NIOSH Manual of Analytical Methods suggests that lower censoring points for diesel particulate could have been validated had there been a need.[5] Use of a smaller filter, a size selective sampler that operates at a higher flow rate, and analysis of a larger portion of the sample filter media appear to be straight forward methods of lowering the censoring point. DOE respectfully suggests that NIOSH undertake to enhance Method 5040 to establish a lower LOQ and therefore lower censoring point for CNT and CNF analytic results.

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[4] LQAP Policy Document, Module 2A, American Industrial Hygiene Association, Cincinnati, OH, www.aiha.org, accessed 1/4/2011.

[5] Birch ME, "Monitoring of Diesel Particulate Exhaust in the Workplace" in *NIOSH Manual of Analytical Methods* http://www.cdc.gov/niosh/docs/2003-154/pdfs/chapter-q.pdf, accessed 2/1/201.