Comments of Dr. Woodhall Stopford of Duke University Medical Center.

You have asked for comments concerning your above summary. You based your Inhalation Reference Exposure Level (iREL) for respirable crystalline silica on the study of Hnizdo & Sluis-Cremer (1993), corrected for the average crystalline silica content they reported for South African gold mines. This study was supported by dose-response relationships between crystalline silica and silicosis noted by several studies, the availability of several long-term worker exposure studies at various concentration ranges and the observation of no adverse effect levels for respirable crystalline silica reported in some studies. I am concerned that you corrected the Hnizdo & Sluis-Cremer study without comment concerning the relationship between the dust exposures they measured in their study (combusted, acid-washed respirable dust) and your correction for silica in respirable dust; your choice of setting an iREL against dust that falls within a range that can deposit anywhere in the thoracic region as apposed to respirable dust; and the lack of discussion, or correction in your iREL assessment, for bias created by choosing a mass median aerodynamic diameter (MMAD) that is appreciably larger than used in the epidemiological studies you used for the development if the iREL such that excessively large crystalline silica content of samples representing the MMAD would be expected..

Comment 1. Correction of iREL for quartz content of respirable dust. Hnizdo & Sluis-Cremer (1993) base their risk assessment on exposure to acid washed and combusted respirable dust. They comment that this treatment results in respirable dust that is mainly made up of crystalline silica and silicates. They comment that respirable dust in South African gold mines contains an average of 30% quartz. This dust, however, likely represents untreated dust. Your correction, therefore, is likely to make your iREL unduly conservative. Without the correction, the iREL would be closer to that expected if you used the Hughes, et al. (1998) analysis. With the correction your iREL is closer to that you would expect if you use the Steenland & Brown (1995) analysis. You may want to either take USEPA's approach and base your iREL on a number of studies or comment on whether or not the likely error introduced by correcting for respirable quartz content of mine dusts is acceptable.

Response. *OEHHA is not applying a correction to the quartz exposures for various occupations determined by Hnizdo and Sluis-Cremer (1993): those authors' estimates are used unmodified. The confusion about the proper quartz level to be applied to the dust concentrations appears to have arisen as a result of an incorrect footnote to Table IV of the paper. OEHHA staff has reviewed the paper by Gibbs and Du Toit (2002) and related comments by Dr. Gibbs for possible application to the cREL derivation. The Gibbs and Du Toit proposal would change the estimate of percent quartz in the South African gold mine dust which is to be applied to Hnizdo's occupation-specific dust levels from 30% to 54%. As described in detail in the revised chronic REL summary, OEHHA staff reviewed pertinent publications from South Africa on the quartz content of gold mine dust and concluded that 30% was the appropriate value to use, and that the quartz levels calculated by Hnizdo and Sluis-Cremer are a reasonable estimate of conditions to which the miners they studied were exposed.*

The REL is based primarily on the results of Hnizdo and Sluis-Cremer (1993),which is considered the most reliable study, but a variety of other studies are also analyzed and presented as supporting evidence. This is consistent with US EPA practice and the commentator's suggestion.

Comment 2. Use of inhalable vs respirable dust for your iREL**.** ACGIH (1998) defines thoracic particulate mass as that dust with MMAD of 10 μm. They note that it is an appropriate descriptor for exposure to dusts from those materials that are hazardous when deposited anywhere within the airways and the gas-exchange region of the lungs. Materials that cause both airway irritation and lung effects, such as sulfur dioxide, would be appropriate to monitor using this parameter. On the other hand, they define respirable particle mass (respirable dust) as that dust with a MMAD of 4.0 μm. They note that this measurement should be used for those materials that are hazardous when deposited in the gas-exchange region. This latter definition is in accord with the International Organization/European Standardization Committee protocol for measurement of respirable dust. You have chosen to use an iREL based upon measurements of thoracic particle mass, instead of respirable dust. An iREL based upon the latter may be more appropriate. Hearl (1997) notes that measurements of respirable dust, as defined by ACGIH and ISO, are intended to apply to health-related sampling both in the workplace and general environment.

Raabe (1982) notes that "particle size-related standards are necessary to provide more meaningful measurements for both source emission control and environmental monitoring where the lung is the principal organ of concern…'[I]nhalable' particle sampling would tend to obscure the contribution to environmental aerosols of smaller, more respirable and stable particles that are of primary importance in potential risks to pulmonary and small bronchial airways." Respirable crystalline silica certainly falls in this paradigm: quartz particles that will produce silicosis are those that deposit in the smallest airways (bronchioles) and alveoli.

Your iREL is not only more appropriately represented by measures of respirable crystalline silica but will be strengthened by such a change. I have reviewed the industrial hygiene measures used as a basis for risk assessment for the relationship between exposure to crystalline silica and silicosis in the studies outlined in the table below and reviewed in your Chronic Toxicity Summary. In each instance measurements either were of respirable dust or silica or converted to respirable dust or silica. In most instances the norm was either the ACGIH or ISO standard where respirable dust collectors collected particles with a MMAD of 4.0 μm. In two studies respirable particle counts where the particle diameters were 5 μm or less were converted to respirable dust mass exposure without comparison to a cyclone which collected particles with a MMAD of 4.0 μm. In these instances the MMAD of the particles might be expected to be <6 μm, the MMAD of respirable particle counts above a geometric mean of 3 μm (Rando et al, 2001). An iREL based on a MMAD of 4.0 would be supported by studies upon which you based your iREL determination and would make your iREL a true health effects-based iREL.

Table: Respirable dust measurement methods in epidemiological studies relating exposure to risk of silicosis

Study	Quartz measurement	Median respirable mass fraction	Reference
Ontario hard rock miners	Cyclone and conversion of konimeter counts to respirable mass by comparison	4 µm	Muir et al '89, Verma et al '89
Gray iron foundry workers	Conversion of respirable dust counts to respirable mass and multiplication by bulk silica %	<6 µm	Rosenman et al '96
Diatomaceous earth workers	Cyclone, total dust and respirable dust counts with conversion of latter to respirable mass by comparison	4 µm	Hughes et al '98, Seixas et al '97
South African gold miners	Integrated respirable dust counts and surface area to get respirable mass	<6 µm	Hnizdo & Sluis-Cremer '93
Scotish coal workers	Integrated measurements of respirable dust and settled dust silica levels	4 µm	Miller et al '98
South Dakota gold miners	Respirable dust mass and conversion of respirable dust counts to respirable mass by comparison	4 µm	Steenland & Brown '95
Leadville miners	Assignment of representative respirable silica levels to respirable dust exposure measurements	4 µm	Kreiss & Zhen '96
Chinese tin miners	Cyclone and conversion of total dust mass to respirable mass by comparison	4 µm	Chen et al '01
Industrial sand workers	Cyclone and conversion of respirable dust counts to respirable mass by comparison	4 µm	Rando et al '01

Response. *OEHHA staff is proposing a chronic inhalation REL for respirable, crystalline silica. The Table provided by the commentator shows that respirable, as used in many epidemiological studies of silica, means a 50% cut point at 4 µm. Hnizdo and Sluis-Cremer (1993) based their study on similar silica particle measurements (< 6 µm). The implication for the cREL is that using the silica content of PM_{10} as the measurement of near-source ambient concentration resulting from Hot Spot facility emissions includes many larger silica particles that probably do not get into the deep lung and thus may not contribute to silicosis, but they inflate the Hazard Index. Following various public comments (including these), and discussion by the Scientific Review Panel, OEHHA has* *concluded that it is more appropriate to base the chronic REL on exposure to particles similar to those to which the subjects of the critical occupational studies were exposed, and which are known to cause silicosis. Therefore, as indicated in the revised summary, the chronic REL is specified as applicable to concentrations of crystalline silica particles having a size range similar to those measured in the occupational studies [respirable as defined by the occupational sampling method, most recently described in NIOSH (2003)].*

Comment 3. Relationship of crystalline silica content to MMAD of dusts**.** Quartz content of soil-related dusts (the major source of crystalline silica in rural and agricultural regions, USEPA 1996) increases as particle size increases. We (Stopford & Stopford, 1995) found that the quartz content of clay-containing soils that passed through a 45 mesh sieve (MMAD ranging from 7.7 to 58.9 μm) ranged from 17.5 to 52.0% while the quartz content of 4 μm fraction of these same soils ranged 1.3 to 3.4%, values averaging 14 fold less than for the course soil. Similarly, Davis et al (1984) when comparing the course (*sic*) (>2.5 μm cut) and fine (<2.5 μm cut) fractions of PM10 samples found that the quartz content of the course fractions averaged 4.9% while those of the fine fractions averaged 0.4%, 12 fold less than the average quartz content of the course fraction. USEPA (1996) re-analyzed this data and found that the quartz content of the fine fraction had a geometric mean concentration of 0.1% and that of the course fraction a geometric mean concentration of 7.2%. For the California cities in the Davis et al (1984) study, the respirable quartz content of the course fraction ranged from 1.9 to 6.0% and for the fine fraction from non-detectable to 1.0%. Chow et al (1993) found a similar relationship in analyzing the PM10 and PM2.5 silicon values in samples collected in cities in the San Joaquin Valley. The PM10 silicon values averaged from 5.2 to 8.7 $\mu g/m^3$ while PM2.5 silicon values averaged from 0.33 to 0.82 $\mu g/m^3$. PM10 samples have a MMAD of about 8 μm (McClellan & Miller, 1997). Using a MMAD of 10 μm would further exaggerate the crystalline silica content of environmental samples, unduly weighing the quartz content of the non-respirable fraction of samples collected to represent the 10 μm MMAD distribution. Basing your iREL for respirable quartz on a particle distribution with a MMAD of 4 μm would avoid this bias.

Response. *The chronic REL for crystalline silica will be applied to modeled or measured crystalline silica emitted from Hot Spots facilities, not to a measure of ambient PM. Thus any regulations based on the REL will take into account the specific characteristics of the source, and the varying silica content of urban, rural, or source-specific PM is not relevant to the development or application of the chronic REL.*

References

ACGIH. 1998 TLVs and BEIs. Threshold Limit Values for Chemical Substances and Physical Agents. Biological Exposure Indices. Cincinnati.

Chen W, Zhuang Z, Attfield MD, Chen BT, Gao P, Harrison JC, Fu C, Chen J-Q. Exposure to silica and silicosis among tin miners in China: exposure-response analyses and risk assessment. Occup Environ Med. 2001; 58:31-7.

Chow JC, Watson JG, Lowenthal DH, Solomon PA, Magliano KL, Ziman SSD, Richards LW. PM10 and PM2.5 compositions in California's San Joaquin Valley. Aerosol Sci Tech. 1993; 18: 105-28.

Davis BL ; Johnson LR ; Stevens RK ; Courtney WJ ; Safriet DW. The Quartz Content And Elemental Composition Of Aerosols From Selected Sites Of The EPA Inhalable Particulate Network. Atmos Environ. 1984; 18 (4): 771-82.

Hearl FJ. Industrial hygiene sampling and applications to ambient silica monitoring. J Exposure Anal Environ Epid. 1997; 7:279-89.

Hnizdo E ; Sluis-Cremer GK. Risk of Silicosis in a Cohort of White South African Gold Miners. Am J Ind Med. 1993; 24(4): 447-57.

Hughes JM, Weill H, Checkoway H, et al. Radiographic evidence
Of silicosis risk in the diatomaceous earth industry. Am J Respir Crit Care Med. 1998; 158(3):807-14.

Kreiss K; Zhen B. Risk of silicosis in a Colorado mining community. Am J Ind Med. 1996; 30(5):529-39.

McClellan RO, Miller FJ. An overview of EPA's proposed revision of the particulate matter standard. CIIT Activities 1997;17:1-22

Miller BG, Hagen S, Love RG, Soutar CA, Cowie HA, Kidd MW, Robertson A. Risks of Silicosis in Coalworkers Exposed to Unusual Concentrations of Respirable Quartz. Occup Environ Med.1998;55(1): 52-58.

Muir DCF ; Shannon HS ; Julian JA ; Verma DK ; Sebestyen A ; Bernholz CD. Silica exposure and silicosis among Ontario hardrock miners: I. Methodology.
Am J Ind Med.1989; 16(1):5-11.

Raabe OG. Comparison Of The Criteria For Sampling "Inhalable" And "Respirable" Aerosols. Ann Occup Hyg, 1982; 26: 33-45.

Rando RJ, Shi R, Hughes M, Weills H, McDonald AD, McDonald JC. Cohort mortality study of North American industrial sand workers. III. Estimation of past and present exposures to respirable crystalline silica. Ann Occup Hyg. 2001; 45:209-16.

Rosenman KD ; Reilly MJ ; Rice C ; Hertzberg V ; Tseng CY ; Anderson HA. Silicosis among foundry workers: Implication for the need to revise the OSHA standard
Am J Epid.1996; 144(9):.890-900.

Steenland K ; Brown D. Silicosis among gold miners: exposure--response analyses and risk assessment. Am J Pub Health. 1995; 85(10):1372-7.

Stopford CM, Stopford W. Respirable quartz content of farm soils. Appl Occup Environ Hyg. 1995; 10(3):196-9.

USEPA. National Air Quality and Emissions Trends Report, 1996. Office of Air Quality Planning and Standards, Research Triangle Park, NC. EPA 454/R-97-013 (1998).

Verma DK ; Sebestyen A ; Julian JA ; Muir DCF ; Schmidt H ; Bernholz CD ; Shannon HS. Silica exposure and silicosis among Ontario hardrock miners: II. Exposure estimates. Am J Ind Med. 1989; 16(1): 13-28.