

Relationship of Exposures to Crystalline Silica & Health Effects: An Epidemiologist View of the Controversy

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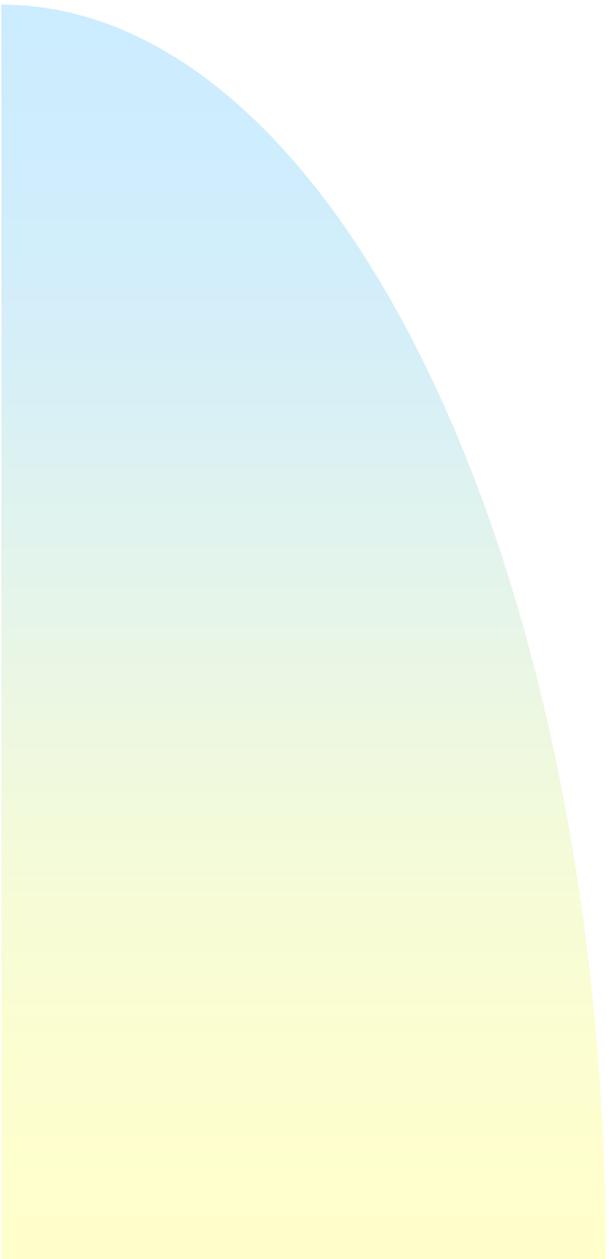
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May18, 2006, AIHA, Chicago, IL



Objectives for this Talk

- Describe the science of silica related chronic diseases, including introducing the "new" health effects
- Assess some risk assessments for SiO₂
- Discuss the impacts of Judge Janice Jack's 2005 ruling

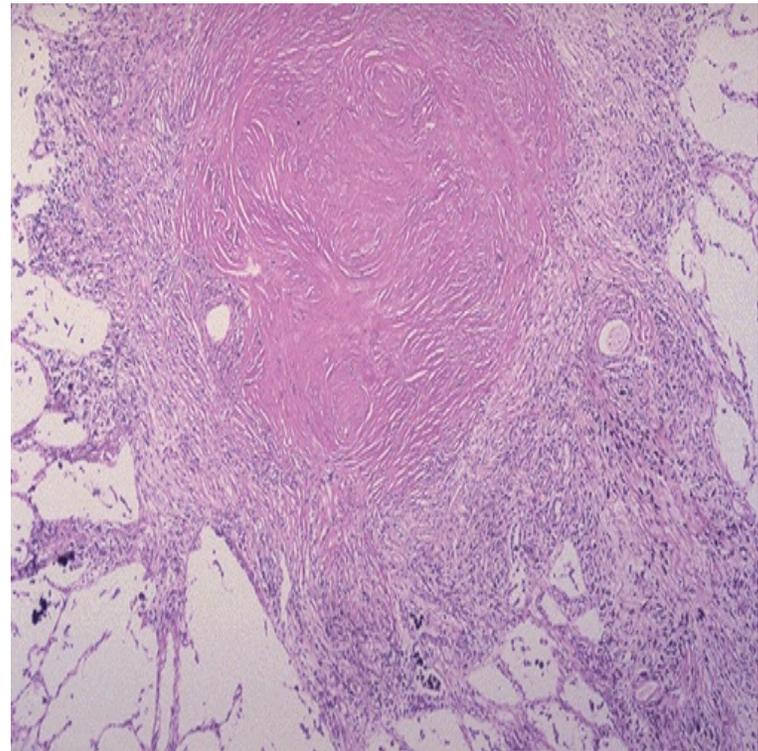
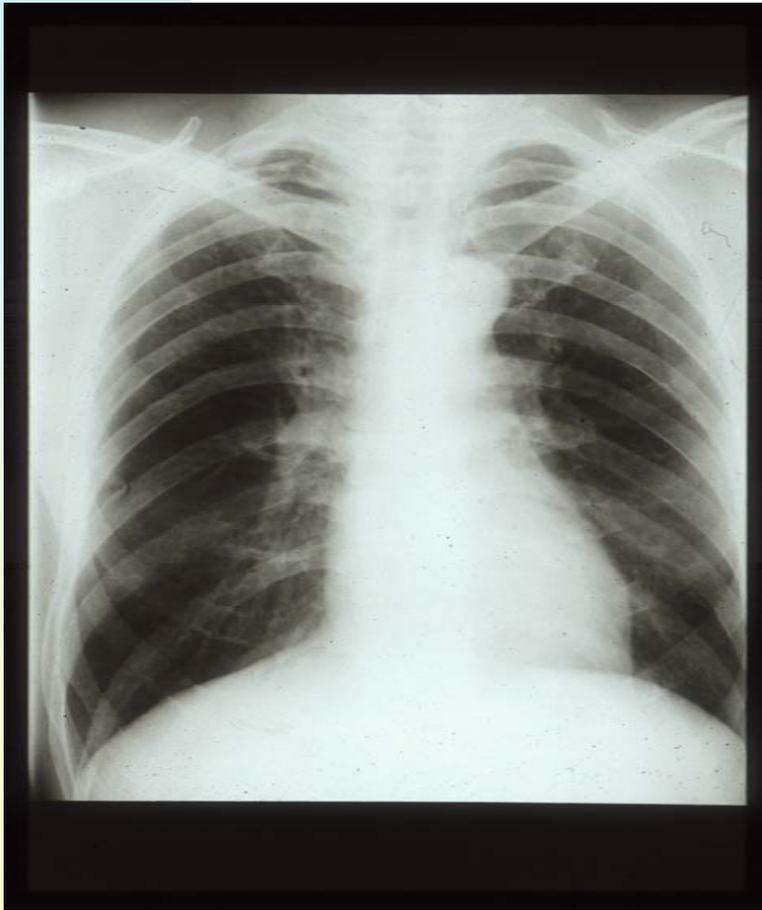
Introduction

- Crystalline silica (SiO_2) exposure causes silicosis, silico-TB, and *cor pulmonale*; ~300 deaths per year, though seriously underestimated in U.S.
- Current estimates 2 million U.S. workers, 100+ million workers world-wide exposed to SiO_2 mining, construction, metallurgy, ceramics, agriculture, sandblasting; OSHA is revising standard
- There is evidence since mid 1980s that workplace silica exposure leads to increased risk for multiple diseases, thus joining smoking, & asbestos as multipotential health hazards

Introduction--2

- In the light of Judge Jack's ruling, castigating plaintiffs attorneys for running "puppy mills" for screening silica exposed workers, all silica medical monitoring is being called into question
- Last month there were hearings in House of Representatives that implied ALL plaintiffs' experts and attorneys were using the same methods as in MDL cases
- OSHA is considering revising the national standard & examining risk assessments

Clinical picture of silicosis



What is Necessary for Diagnosis of Chronic Silica Diseases?

- Sufficient workplace exposure to silica dust (better if IH documented levels)
- X-ray evidence, biopsy or autopsy or other clinical evidence of chronic illnesses—silicosis, NMRD, lung cancer, kidney disease/autoimmune disease
- Disease symptoms—shortness of breath, difficulty walking on level ground, bloody sputum, other symptoms
- Rule-out other possible causes
- Judgment is always a factor in individual cases

Late 20th/21st Century SiO₂ Highlights

- 1997 OSHA, NIOSH, MSHA hold National Conference to Eliminate Silicosis
- 1997 ATS /ALA Occupational Health Expert Advisory Group Report on SiO₂
- 1997 IARC redefines SiO₂ as Group 1 (known human) carcinogen
- 2002 3rd International Symposium Silica, Silicosis, Cancer & Other Diseases, Italy
- 2004-2006 OSHA considering new PEL
- 2005 Judge Jack's Ruling in MDL

Consider the following

- In China every year since 1980 ~20,000 cases and 5,000 deaths from occupational lung diseases: ~ 2/3 silicotics.
- Thousands of Union Carbide workers were afflicted with silicosis during Gauley Bridge, leading to Congressional investigations and national outrage.
- 60 years after Gauley Bridge, in Midland-Odessa TX, 100s of Mexican men aged 30-49 suffered an epidemic of acute & accelerated silicosis from unprotected SiO₂ exposure to blast clean oil field pipe. OSHA showed SiO₂ dust levels >7 times PEL. No national publicity.

Oil pipe sandblasting



Illustration of actual workplace conditions in oilfield sandblasting in Texas in the early 1990s.

Consider more current issues--2

- From the work of Dr. Ken Rosenman at MSU, 953 workers (98% male) were diagnosed with silicosis in Michigan 1987-2004; employed >25 yr.; 43% are Afro-Am, & 54% are white, but the silicosis incidence was 12.6×10^5 for blacks vs. 1.8×10^5 for whites, thus Afro-Ams have **7 X** the risk. 25% had progressive massive fibrosis (PMF); 28% never smokers
- Nearly 80% of silicotics worked in foundries, and >25% had history of sandblasting. 54 worked <10 years, 37 began work in recent decades. The MI SENSOR program estimates for 2001 it detects only **~20% of every 100 true silicosis cases; 58% never applied for WC.**
- Relying on X-rays (greater than 1/0) means we will **miss 2 of 3 true cases**



Criteria for Cancer Causation for Silica Exposure and for Silicosis after 2nd IARC review

Point of evidence	Silica Exposed Workers	Workers with silicosis
Strong relative risk	++	+++
Dose-response gradient!	+++	+++
Consistent findings (w/ best IH^ data)!	++	++ ++
Controlled confounding!	++	++
Biological plausibility	++	±
Temporal cogency	++	++
Specificity	++	++
OVERALL COHERENCE	YES	YES

Research concerns

- IARC 10 cohort assessment of pooled lung cancer (1072 deaths) assessment, high quality sampling data and mortality follow-up: U.S. diatomaceous earth, industrial sand, gold, granite workers, Finnish granite, Chinese tin, tungsten, pottery, Australian gold, and South African gold miners

Figure 1
Spline Curve: Log Lung Cancer Rate Ratio vs.
Log Cumulative Exposure 15 yr lag

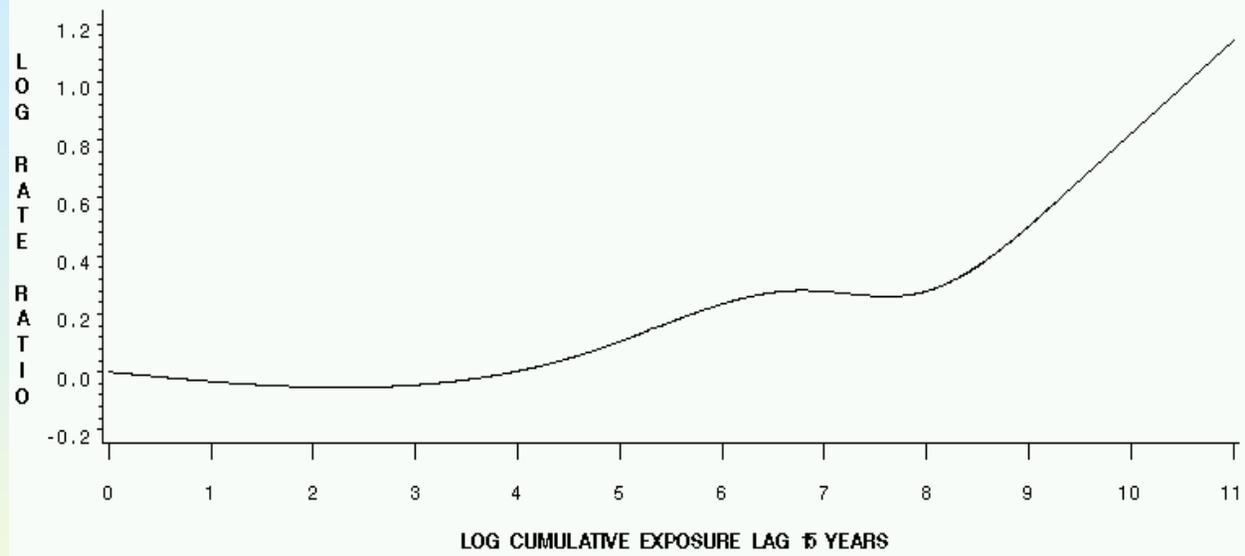
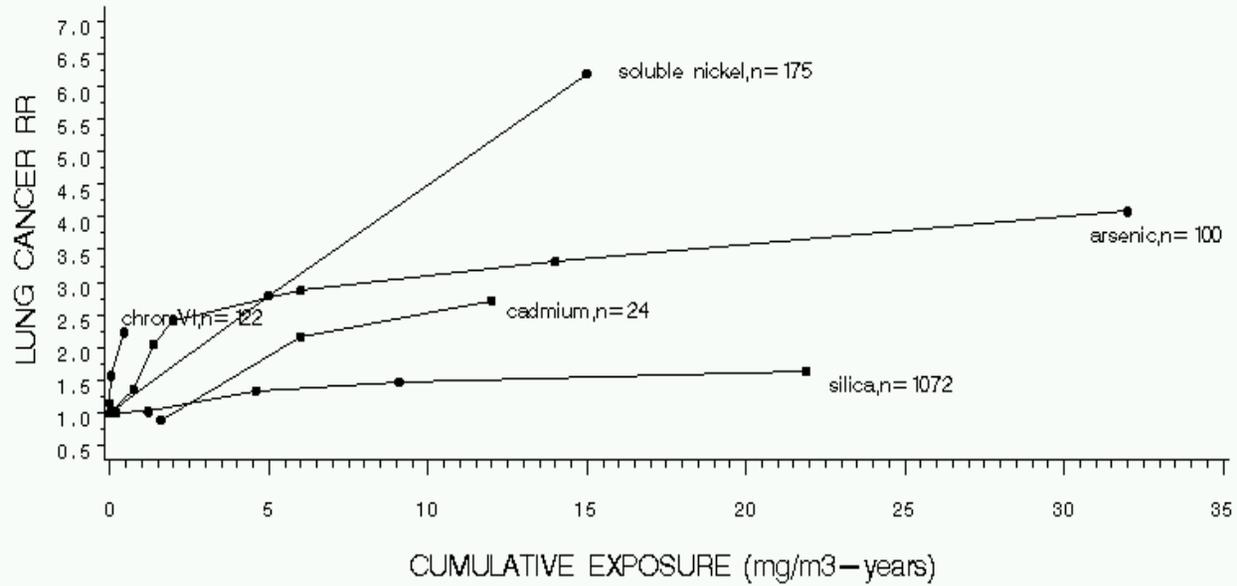


Fig. 2. Lung Cancer RR by mg/m³-years, Five Agents



* n refers to the number of lung cancer per study

Some nonlung cancers linked with SiO_2

- Stomach and/or gastrointestinal malignancies including
 - ◆ esophagus,
 - ◆ pharyngeal,
 - ◆ large bowel,
 - ◆ salivary gland
- Lymphatic cancers (leukemia, lymphomas)
- Skin cancers (among silicotics)
- Kidney cancers

What are the Autoimmune Diseases linked with SiO₂?

- Rheumatoid Arthritis
- Sjogren's Syndrome
- Scleroderma
- Systemic lupus erythematosus (SLE)
- Dermatomyositis
- Glomerulonephritis

What is the nature of the epidemiology evidence?

- 1999 Rosenman et al. reported MI silicotics had a greater prevalence for RA (RR=2.73; 95%CI 1.75,4.06);
- Scleroderma (RR=15.65; 95%CI 0.21, 87.03);
- SLE (RR=11.37; 95%CI 0.15, 63.23).
- Epidemiologists worry about small numbers of subjects except RA

What is the nature of the evidence (2)?

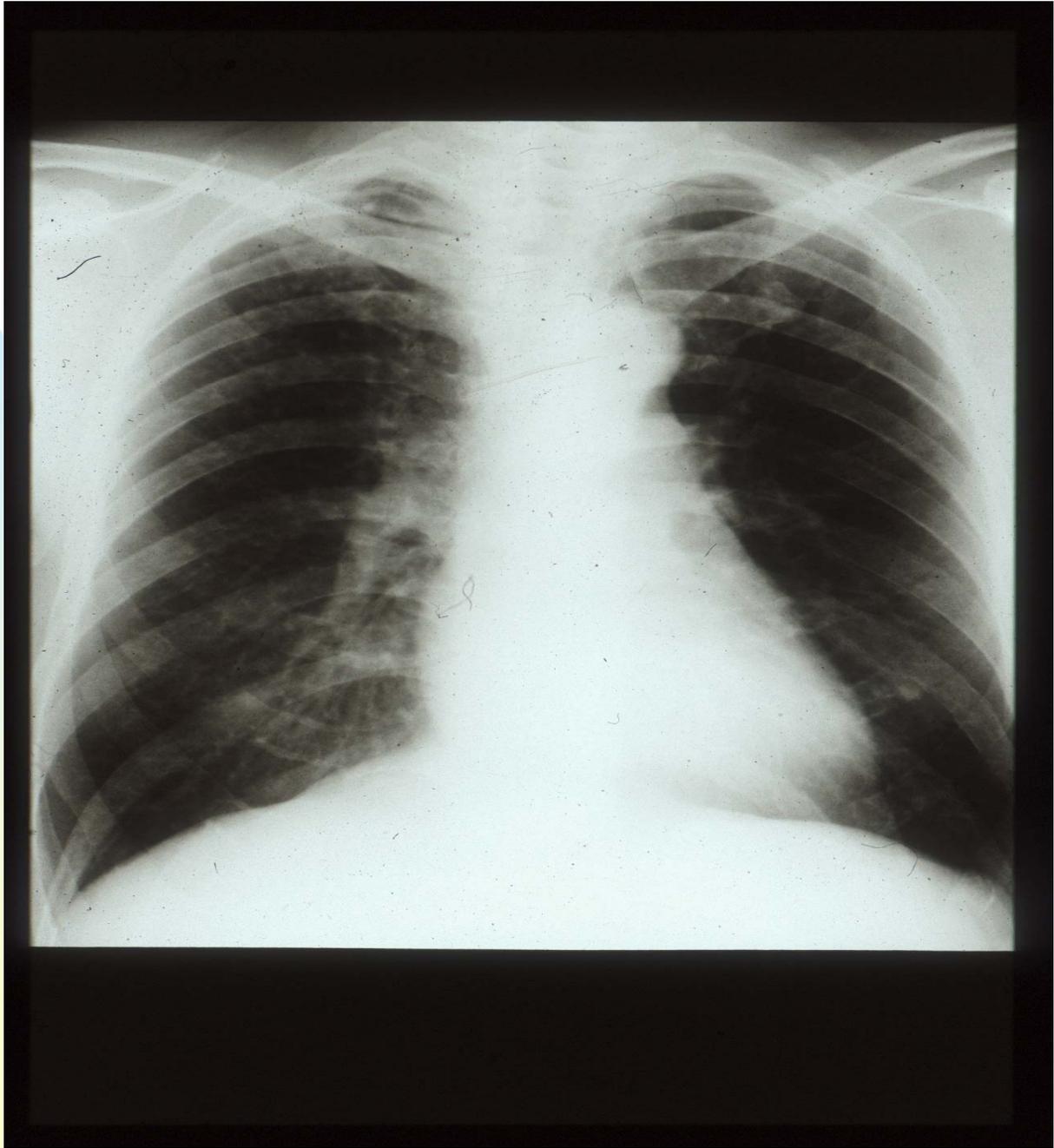
- Calvert et al , SD 1997 SIR of 4.22 (95% CI 1.54, 9.19) for glomerulonephritis gold miners,
- Parks et al.,NC, SC, 2002 found SLE patients had increasing risk for categories of industrial exposure that extended to employment in agriculture. Parallel exposure-response for males, females, Afro-Americans and whites; found smoking and SiO₂ exposure interaction for SLE

What is the nature of the evidence (3)?

- Steenland et al. (2001) and Steenland (2005) provide compelling evidence of silica's effect on kidney disease producing a lifetime risk of 140/1000 workers at current OSHA standard
- Steenland (2005) demonstrates that excess exposure leads to multiple disease risks, and OSHA standard (to protect workers for a lifetime at 1/1000 risk) is no longer functioning effectively

Some progress has happened, but.....

- Controlling SiO₂ w/wet methods began in VT granite quarries and other settings in the 1940s--lead to reduction in the risk of chronic silicosis
- After WW II, U.K. & EEU banned silica sand for abrasive blasting, & in many nations, risk of silicosis declined. In 1970s there was U.S. proposal to follow Europe, but was not adopted by OSHA, but perhaps this needs to be revisited
- From public health view, the easy-to-prevent diseases--silicosis and silicoTB--replaced by 'newer' conditions: lung (& other) cancers, autoimmune and kidney diseases,-- harder to diagnose, treat, and monitor.



Lifetime silicosis risk; 1/1000 is usual concern level

Table 1. Silicosis morbidity. Lifetime risk, ILO category 1/1 or higher (small opacities on radiograph)

study	Followup after employment	Lifetime risk at 0.1 mg/m ³ for 45 yrs
Muir et al. 1989	No	2%
Rosenman et al. 1996	No	3%
Ng and Chan 1994	Some	15-20%
Steenland and Brown 1995	Yes	47%
Hnizdo and Sluis-Cremer 1993	Yes	77%
Kreiss and Zhen 1996	Yes	92%
Chen et al. 2001	Yes	55%

Nonsilicosis lung diseases from SiO₂ exposure--with and without silicosis

- Chronic bronchitis
- Emphysema
- Other nonmalignant respiratory disease
- TB, and silico-TB

Current OSHA standards

- 0.1 mg/m³ for 100% respirable SiO₂
- 0.05 mg/m³ for 100% cristobalite/tridymite; NIOSH REL since 1974
- Standard not changed since OSHA adopted ACGIH TLV from 1968-1970
- Despite likely underdiagnosis, risk of silicosis appears to be declining in U.S.
- No regulation of silica as carcinogen
- Extrapolation of silicosis risk suggest ~40%+ of workers will have silicosis assuming 45 year working career at current standard in U.S.

Non U.S. situation

- WHO/ILO trying to improve less-industrialized countries diagnosis and prevention of silicosis
- EEU & Australia have discussed lowering current standards, though only Scandinavia has done so
- NIOSH has collaborated with IARC on pooling of data project that was discussed

NIOSH risk assessments

- Likely NIOSH risk extrapolations to be used by OSHA because of high quality and actual dust measurements; LC RR=2.15; NMRD RR=5.35
- Used excellent data from DE cohort (Checkoway et al.) using a variety of extrapolation models, adjusting for time, age, Hispanic ethnicity, lagged by 10 years, AND 6000+ SiO₂ dust measurements (no evidence asbestos confound)
- Examined mortality from lung diseases other than lung cancer, X-ray evidence of silicosis, and lung cancer deaths, including IARC pooled analysis

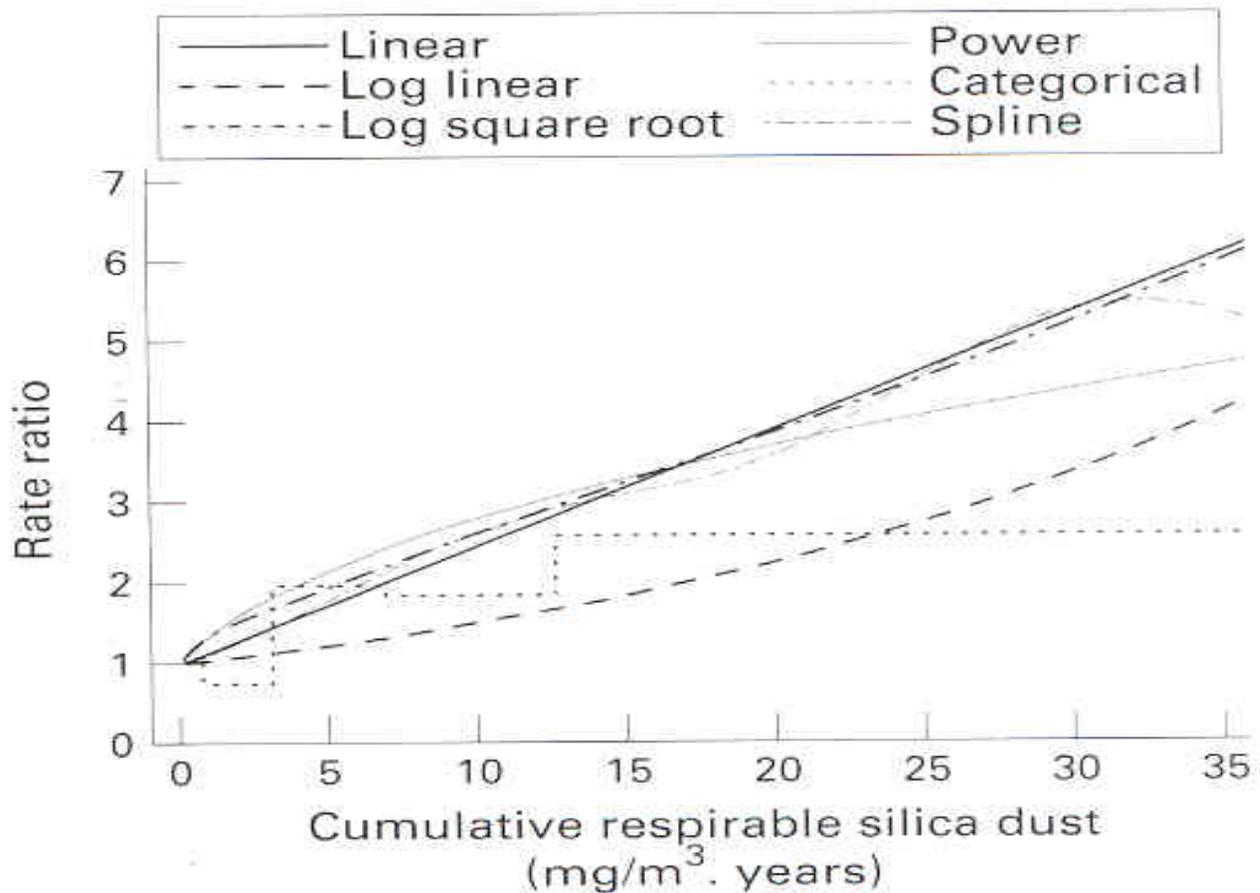


Figure 1 Rate ratio of mortality from lung cancer by cumulative exposure to silica. Poisson regression models with external adjustment for United States rates of death from lung cancer, 10 year lag.

Table 2 Predicted excess lifetime risks† of mortality from lung cancer assuming 45 years of respirable crystalline silica dust exposure (lagged 10 years) based on Poisson regression linear relative rate model with external adjustment‡*

<i>Concentration (mg/m³)</i>	<i>White men</i>	<i>White women</i>	<i>Black men</i>	<i>Black women</i>	<i>Total population</i>
0.001	0.4	0.2	0.4	0.2	0.3
0.005	1.9	1.1	1.9	0.9	1.5
0.01	3.8	2.2	3.7	1.7	2.9
0.02	7.6	4.4	7.4	3.4	5.9
0.03	11	6.7	11	5.2	8.8
0.04	15	8.9	15	6.9	12
0.05	19	11	18	8.6	15
0.06	23	13	22	10	18
0.07	26	15	25	12	20
0.08	30	18	29	14	23
0.09	34	20	33	15	26
0.10	37	22	36	17	29

*Excess risk estimates are for 1000 workers. For example, the excess lifetime risk of lung cancer for white men at 0.05 mg/m³ of silica is 19 deaths per 1000 workers.

†Assuming that workers were exposed to a constant silica concentration for 45 years between the ages of 20 and 65, and accumulating annual risks up to age 85.

‡US 1992 lung cancer mortalities.

evaluated. The linear relative rate model (1.1 (1.0

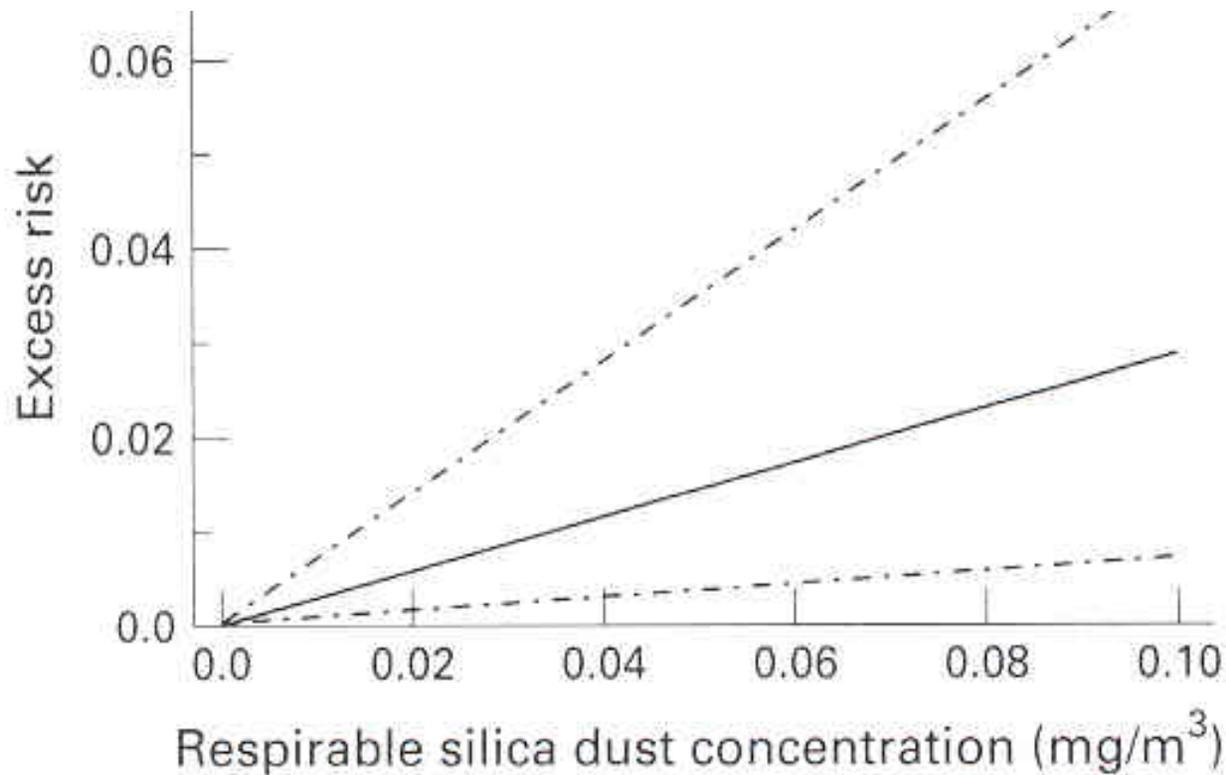
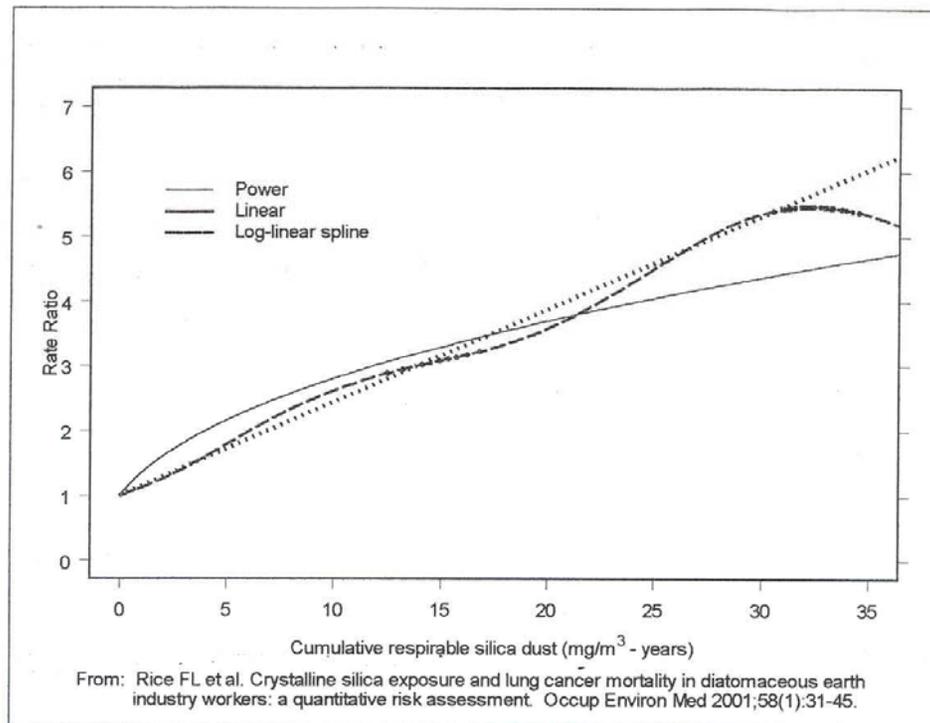


Figure 2 Estimated excess risk of lung cancer associated with up to 45 years of occupational exposure to respirable crystalline silica dust based on the linear relative rate model with a 10 year lag and United States total population mortality. (Two sided 95% CIs are also shown.)

Lung cancer Findings

- Linear relative rate model (LRRM), Poisson regression, gave best fit
- LRRM lung cancer rate ratio ~1.6 for mean cumulative SiO₂ exposure, and rate ratio of 5.4 and 6.0 at maximum SiO₂
- At 0.05 mg/m³ (NIOSH REL), estimate lifetime excess lung cancer risk is ~2/100 for white and black males--20 times greater than 1/1000 for cancer

Figure 1. Lung Cancer mortality rate ratios predicted from Poisson regression models by cumulative silica exposure (using a 10 year lag).



Other findings of relevance to risk assessment

- Linear relative rate model for lung disease other than cancer (LDOC) shows best fit (10 year lag)--figure 2
- Radiographic silicosis best fitting were power models which were supra-linear-- figure 3
- Estimated excess lifetime risks for lung cancer =29/1000 for LDOC=100/1000; and for radiographic silicosis 140/1000
- For kidney disease 140/1000 for a 45-year working lifetime

Figure 2. Lung diseases other than cancer (LDOC) predicted rate ratios from Poisson regression models by cumulative silica exposure.

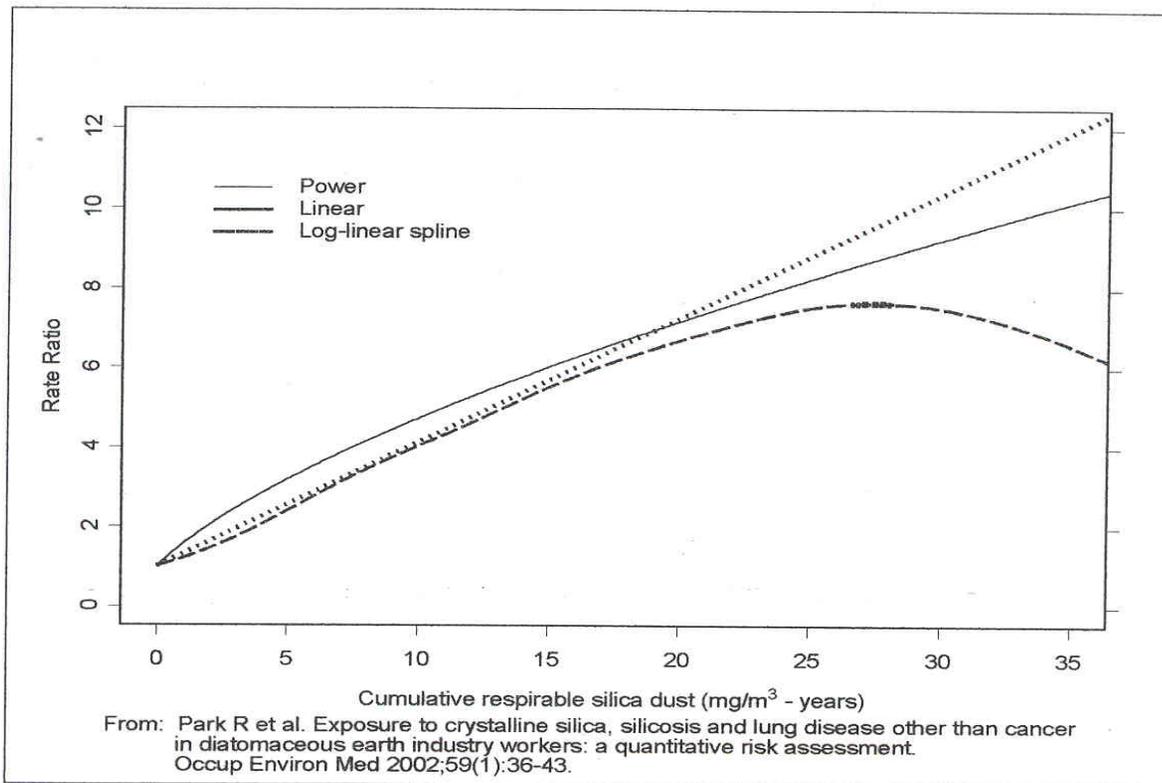


Figure 3. Radiographic silicosis predicted rate ratios from Poisson regression models by cumulative silica exposure.

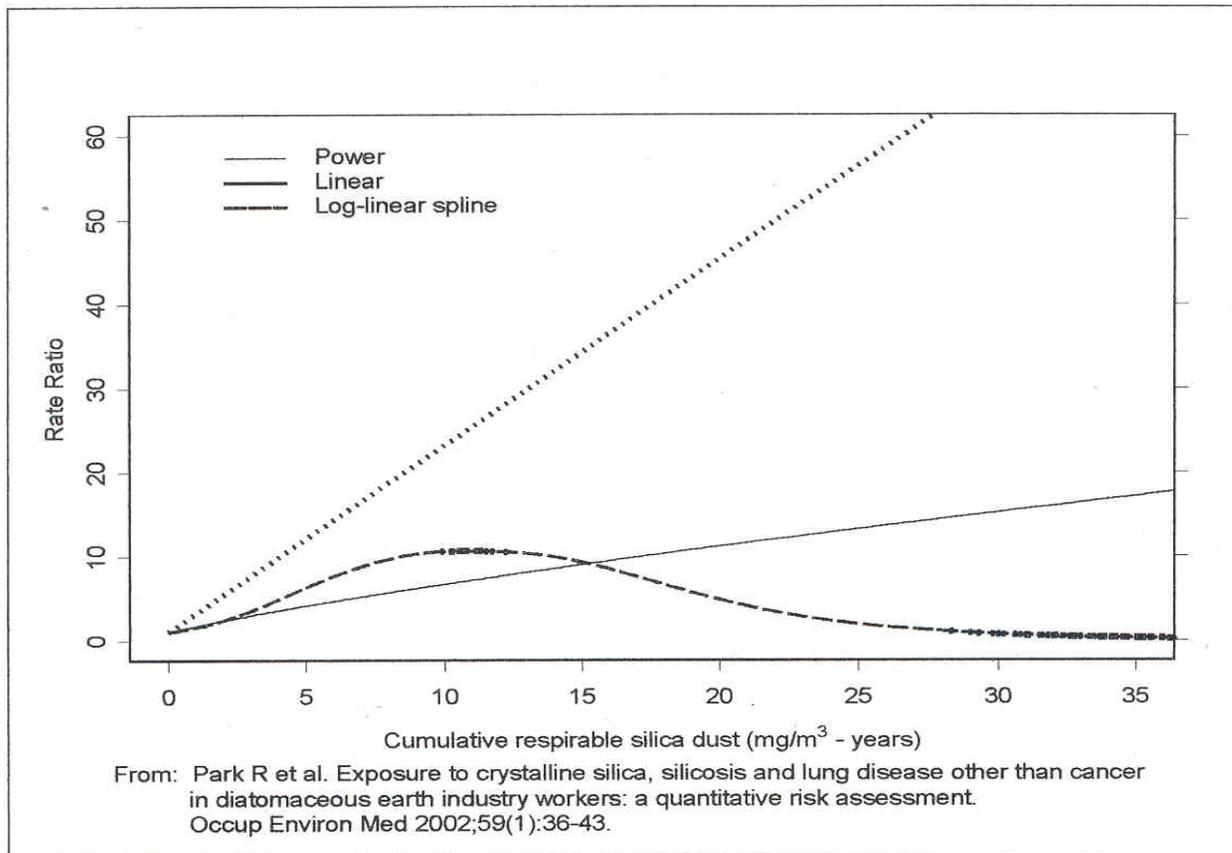
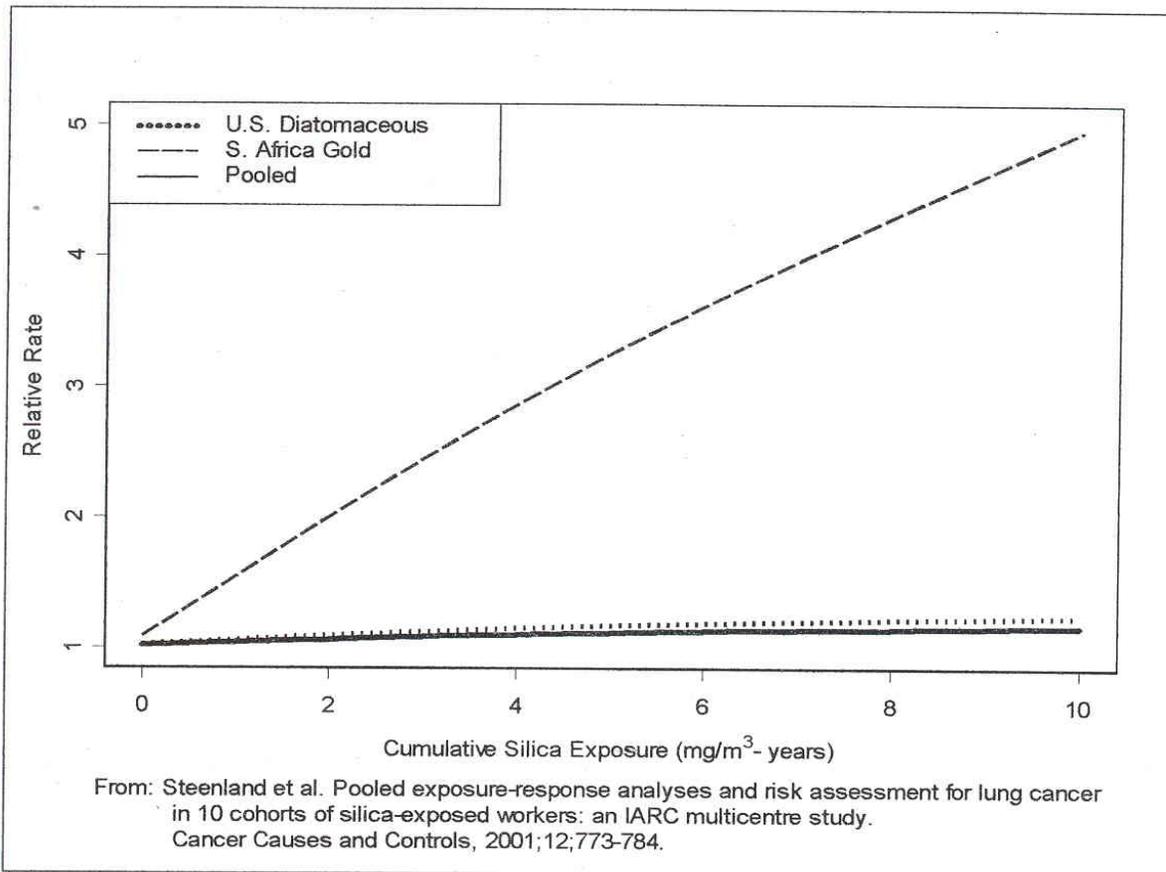


Figure 4. Results from pooled analysis of lung cancer and cumulative silica exposure, and comparison of results from models fitted to U.S. diatomaceous earth workers and South African gold miners.



New Policy and Litigation Issues

- CA has adopted in 2005 a new ambient silica air toxic regulation for local Air Pollution Control Districts—3 ug/m³:http://www.oehha.org/air/chronic_rels/silica_final.html
- In addition to OSHA considering revisions to PEL, Consumer Product Safety Commission (CPSC) conducting risk assessment for playground sand to protect children
- In the past 3 years new bloom of occupational silica litigation primarily in Mississippi, Texas, and Pennsylvania—Judge has thrown out several 1000s of MDL cases because of MDs reuse of asbestos cases

What This Means for Future Occupational Health Professionals

- Currently there is strong justification for new dust standards for respirable crystalline silica based on excess risk for silicosis, lung cancer and kidney disease
- Strong rationale for new research and clinical training & surveillance, including industrial hygiene links, determination of surface characteristics & particle sizes
- Strong basis to develop industry & union & legal leadership collaborations nationally, with particular focus on immigrant and minority workers who need improved education and outreach on silica's health hazards

What epidemiology research needs to be done NOW?

- Increase focus on interactive effects of smoking, and other hazards, including radon in mines, PAHs in foundries, asbestos, and arsenic WITH SiO₂
- Support SiO₂ prevention efforts, and make dust control highest corporate investment priority
- Expand outreach to minority and Spanish-speaking workers in many of the dusty industries because this appears essential for effective prevention

New Policy and Litigation Issues

- In the past 2-3 years new bloom of occupational silica litigation primarily in Mississippi, Texas, and Pennsylvania—next asbestos??
- With Judge Jack's ruling, there needs much more careful understanding of what a silica case is, though care must be taken so minority & immigrant workers are not denied access to legal system.
- The system is broken: no enforcement; delayed new standards; significant reduction to redress in our legal system; employers and workers no engaged in protecting corporate and individuals' health

Conclusion

- Greater evidence for silica's multipotential toxicity in producing silicosis, autoimmune diseases, kidney ailments, & lung cancer
- Research continues to be needed to understand the detected risks, and refine the risk assessments
- Many in the corporate world know silica standards need to be improved and have adopted improved goals disregarding current OSHA regulations
- Litigation will still require experts in medicine, epidemiology, industrial hygiene, & risk assessment
- Impact of Judge Jack's ruling is still to be determined, though current situation appears gloomy because of politics
- If OSHA proposes new, improved standards, expect court battles

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