April 1, 2025

Review of Selected Literature Relevant to the Production of Natural and Engineered Stone Countertops and Adverse Health Effects

Part 2: Selected Clinical, Surveillance/Epidemiology and Biomarker Studies

List of Abbreviations

ACE - angiotensin-converting enzymes
AL – Action Level
ANA - antinuclear antibodies, found in patients with autoimmune diseases and silicosis
AS***** - Artificial Stone = engineered stone (ES) = artificial silica conglomerates
BALF - Bronchoalveolar lavage fluid
Cal/OSHA – California Division of Occupational Safety and Health
COPD - Chronic obstructive lung disease
CT chest – Computed Tomography scan of the chest
CXR – Chest X-ray
DLCO (TLCO) – Diffusing Capacity (or Transfer Factor) of the Lung for Carbon Monoxide
ENA - Extractable Nuclear Antigen
ES* – Engineered stone
FEV1 – Forced Expiratory Volume in one second
FVC – Forced Vital Capacity
HRCT – High-Resolution Computed Tomography scan of the chest
PAP – Pulmonary Alveolar Proteinosis
PEL – Permissible Exposure Limit
PFT – Pulmonary Function Test
PMF – Progressive Massive Fibrosis
RCS – Respirable Crystalline Silica
TB – Tuberculosis
TLV – Threshold limit value

*****The terminology used by individual authors was employed when summarizing their publications.

Table of Contents

Foreward from NSI and ISFA

On March 25, 2016, the Occupational Safety and Health Administration (OSHA) published a final rule regulating occupational exposure to respirable crystalline silica (silica) in general industry: 29 C.F.R. § 1910.1053 Occupational Exposure to Respirable Crystalline Silica.
{link: https://www.osha.gov/silica-crystalline/general-industry-maritime}

In 2019, the Centers for Disease Control (CDC) published a Morbidity and Mortality Weekly Report (MMWR): Severe Silicosis in Engineered Stone Fabrication Workers — California, Colorado, Texas, and Washington, 2017–2019 which highlighted 18 cases of silicosis in countertop workers from four U.S. States.
{citation link: Rose C, Heinzerling A, Patel K, et al. Severe Silicosis in Engineered Stone Fabrication Workers — California, Colorado, Texas, and Washington, 2017–2019. MMWR Morb Mortal Wkly Rep 2019;68:813–818. DOI: http://dx.doi.org/10.15585/mmwr.mm6838a1.}

The above information, along with cases of silicosis in countertop workers outside the U.S., has prompted increased focus and research into silicosis cases and silica exposures amongst countertop workers. With a growing number of studies and reports emerging - ranging from material-specific and workplace exposure studies, case series of silicosis, surveillance studies of countertop workers, and review articles /commentaries, NSI and ISFA partnered together to employ professional services from Yale Occupational and Environmental Medicine to review available medical and scientific publications to help determine which studies are most applicable and helpful for our collective members and for the industry at large. The report that follows is a summary of the most relevant sixty-nine clinical and surveillance publications available as of late-2024.

As stated in the executive summary, major findings of this review include:

- Similarities of clinical silicosis cases, despite variations in population, ethnicities, healthcare systems, and socio-political factors.
- Surveillance /epidemiology studies of countertop workers that assess work exposures and the risk of silicosis are limited, but available studies commonly report dry cutting with hand tools as an important risk factor.
- OSHA-mandated medical surveillance (chest X-ray and spirometry) can miss early-stage detection of silicosis.
- There is an urgent need for medical surveillance data from workplaces with effective engineering controls to assess the extent of ES silicosis and the adequacy of current protective measures.

It is the hope of both NSI and ISFA that this review is helpful in providing a better understanding the importance of employee medical surveillance to detect possible early cases of silicosis, and also to provide more data to evaluate the effectiveness of current protective measures in reducing employee exposures to RCS and the risk of developing silicosis.

Executive Summary

This review summarizes 69 publications related to the human health effects of occupational exposure to engineered stone (ES) published from 2010 through 2024, including 20 clinical studies that highlight the clinical features of silicosis linked to ES and 14 surveillance / epidemiology studies that assess the prevalence of silicosis in these ES workers. This rapidly expanding literature has prompted numerous reviews, commentaries, and letters to the editor, which are cited in the final section. Articles within each section are described in chronological order of date of publication, from earliest to most recent.

Engineered Stone-Associated Silicosis - Clinical Presentation, Diagnosis, Treatment, Risk Factors

Since the initial reports from Spain in 2010, a growing number of cases of silicosis associated with ES have been documented across multiple countries, including Israel, Italy, Spain, the United States, Australia, China, and the United Kingdom. These clinical cases exhibit notable similarities despite variations in populations, ethnicities, healthcare systems, and socio-political factors. In comparison to "traditional" silicosis, silicosis associated with ES typically presents at a younger age (30s-40s years), with a shorter duration of exposure, more advanced silicosis, more rapid progression and higher mortality. Also common, cases frequently occur in vulnerable populations who work in relatively small workplaces (< 20 employees) with limited engineering controls. The clinical spectrum ranges from simple silicosis to progressive massive fibrosis (PMF), silico-proteinosis and death.

The diagnosis is usually based on a history of regular work exposure to ES dust (and potentially also natural stone) for several or more years and chest imaging findings consistent with silicosis, with chest CT scans outperforming X-rays in detecting silicosis. Delayed diagnosis until disease is advanced is also common, as is an initial "index case" leading to the recognition of additional cases from the same workplace. Conditions that co-exist with silicosis, such as infection, autoimmune diseases, autoimmune markers and chronic obstructive lung disease, are common and further complicate diagnosis. Dry cutting of stone and infrequent use of respirators are frequently reported, implicating high exposures to RCS as the primary cause of these outbreaks.

Studies that describe prognosis indicate that ES-associated silicosis can progress despite cessation of exposure, and treatment options are limited, with lung transplantation an option for end-stage disease.

Surveillance and Epidemiology

Published reports of medical surveillance of ES workers or more formal epidemiology studies are limited. The best estimates of the prevalence of ES silicosis come from Australia, which instituted an extensive surveillance program of stone workers after initial cases of ES silicosis were identified. Over 2,000 ES workers in Queensland and Victoria Australia have undergone medical surveillance, many with chest CT scans, revealing silicosis prevalence rates of 20–25%. Smaller-scale surveillance studies in the US and other countries (typically 10-50 workers from 1-2 workplaces after cases identified) have reported prevalence rates ranging from 12% to over 50%, with dry cutting with hand tools the most commonly cited risk factor.

Biomarker and Miscellaneous Studies

Clinical investigators are exploring biomarkers that may facilitate diagnosis or treatment. However, these studies remain largely experimental.

Reviews and Commentary

The surge in ES silicosis cases has prompted widespread concern, with at least 29 reviews, letters, and commentaries, commonly with titles such as a "preventable tragedy" and an "emerging epidemic". These publications emphasize the urgent need for improved exposure controls, regular medical surveillance, and systematic case reporting. Some raise the question of banning ES, similar to Australia.

Overall Key Findings Most Relevant to NSI and ISFA

1) Cases of silicosis associated with ES are increasingly being documented, often with severe disease.
2) Dry cutting of ES stone with hand tools, without adequate exposure controls, is likely a key risk factor.
3) OSHA-mandated medical surveillance (chest X-ray and spirometry) can miss early-stage silicosis.
4) To date, most surveillance studies have focused on workplaces with known cases of silicosis and inadequate engineering controls, which can skew prevalence rates higher.
5) Published surveillance data from workplaces with effective engineering controls is urgently needed to assess the extent of ES silicosis in this industry and the adequacy of current protective measures.

Clinical Studies of Engineered Stone Silicosis

Title: Silicosis: a disease with an active present

Citation: Martinez C, Prieto A, Garcia L, Quero A, Gonzalez S, Casan P. Silicosis: a disease with an active present. Arch Bronconeumol. Feb **2010**;46(2):97-100.

Location/Country: Spain

Study Type and Description: Report of 3 cases of silicosis in young male workers in Spain who installed panels / countertops made of artificial silica conglomerates for 17 years. The 3 cases (2 simple silicosis, 1 complicated silicosis) were identified during routine periodic examination.

Key findings:
Case 1: 32-year old male with dyspnea with exertion. Lung function showed restriction and reduced DLCO. Chest x-ray nodular opacities 2/2 profusion in both lungs. HRCT confirmed opacities and progressive massive fibrosis (PMF).
Case 2: 34-year-old male patient. CXR with diffuse nodular opacities with 2/1 profusion, adenopathy. Lung function was normal.
Case 3: 37-year-old male patient, asymptomatic. Nodular opacities with ½ profusion. Lung function was normal.

The authors note that the material was composed of a high percentage of crystalline silica (70 to 90%) combined with other components (glasses, feldspars, pigments, etc.) bound with synthetic resins, which was mainly cut dry in closed spaces without controls or respiratory protection. The diagnoses were made based on clinical presentation and chest imaging typical for silicosis and an occupational history of substantial silica exposure.

Conclusions of Authors: The authors highlight the risks of working with artificial silica conglomerates. They also noted the young age of the workers and the importance of an occupational history for diagnosis.

Relevance to the Industry: This likely is the earliest published report of silicosis in artificial stone workers and is notable for the workers' relatively young ages.

Title: Silicosis in Quartz Conglomerate Workers

Citation: Garcia Vadillo C, Sanchez Gomez J, Romero Morillo J. Silicosis in Quartz Conglomerate Workers. Arch Bronchoneumol. **2011**;47(1):53.

Location/Country: Spain

Study Type and Description: Letter to the editor in response to Martinez 2010 above. This brief report describes 6 additional cases of silicosis (diagnosed in 2009 to 2010 in Spain) in workers from 3 different companies who handled artificial quartz conglomerate countertops. The diagnosis was made based on radiological findings, restrictive pattern spirometry and occupational history. Lung biopsies on the first 4 patients confirmed the diagnosis.

Key findings: The mean age of the 6 workers was 29 years (range 26 – 37 years) with a mean of 9 years of exposure (range 5 – 12 years). All 6 had reduced lung function and chest CT scan findings typical for silicosis.

Conclusions of Authors: the young age and short period of exposure of the patients could indicate high toxicity of the material or insufficient preventative measures. They note that *"The findings mandate a rigorous assessment of the preventive measures, as well as active evaluation of the workers in these industries."*

Relevance to the Industry: One of the earliest reports of silicosis in artificial stone workers. The cases are notable for the workers' young ages and short duration of employment.

Title: Artificial stone silicosis [corrected]: disease resurgence among artificial stone workers.

Citation: Kramer MR, Blanc PD, Fireman E, Amital A, Guber A, Rhahman NA, et al. Chest**. 2012;**142(2):419-24.

Location/Country: Israel

Study Type and Description: This was a retrospective analysis of silicosis patients referred to the only lung transplant center in Israel from 1997 to 2010. Cases underwent standardized evaluation, including occupational history, PFT, a 6-minute walking test, cardiopulmonary exercise testing, and CT chest imaging. Fiberoptic bronchoscopy and video-assisted thoracoscopic surgery were performed based on clinical context. All but 2 cases had lung biopsy, and those that underwent lung transplantation had histological examination of explanted lung tissue. Cases were classified into accelerated disease with PMF or chronic silicosis. Samples of artificial stone were also analyzed for silica content by X-ray diffraction methods. Cases were followed for a median of 23 months after lung transplantation.

Key Findings: Of 25 patients diagnosed with silicosis, 15 (60%) were determined to be potential candidates for lung transplantation, and 10 cases (40%) underwent lung transplantation.

All cases worked with the same synthetic stone material (SDS >85% crystalline silica) for use in kitchens and other countertops, dry cutting without dust suppression or respiratory protection for an average of 10-12 hours / day. All had moderate-to-severe restrictive defects on PFTs, and most were on supplemental oxygen.

Conclusions of Authors: Unusually high incidence of advanced silicosis linked to a specific, relatively new engineered product with a high silica content. Recognition, reporting, and identification of disease clusters are critical for the prevention of silicosis. Enforcement of occupational regulations could have prevented this tragedy. Public health interventions should be undertaken to prevent future occurrences.

Key strengths: This is the first major publication reporting rapidly progressive advanced silicosis in artificial stone workers. Given only one lung transplant referral center, the authors likely evaluated most cases of advanced silicosis diagnosed over this time period.

Relevance to the Industry: That exposure to artificial stone with high silica content can result in severe advanced silicosis was published in a major US medical journal in 2012.

Title: Notes from the field: silicosis in a countertop fabricator - Texas, 2014

Citation: Friedman GK, Harrison R, Bojes H, Worthington K, Filios M, Centers for Disease C, et al.. MMWR Morb Mortal Wkly Rep. **2015**;64(5):129-30.

Location/Country: Texas, USA

Study Type and Description: This case report describes a 37-year-old non-smoker Hispanic male with silicosis and progressive massive fibrosis. He worked as an ES stone fabricator for 10 years, with conglomerate or quartz (70-90% crystalline silica). He initially presented to primary care with 2-years of persistent cough and exertional dyspnea.

Key Findings: PFT showed combined obstructive/restrictive defects and decreased diffusion capacity. CXR showed large opacities with 3/2 profusion, q/r bilateral upper and middle lobe rounded opacities. Patient was on oxygen, being considered for possible lung transplantation

Conclusions of Authors: The increased use of quartz surfacing materials poses a new risk for silica exposure. Healthcare providers must be aware of quart surfacing materials as a source of silica exposure, advise reassigning patients to limit exposure, and report cases to their public health agencies.

Relevance to the Industry: This likely is the earliest reported case of engineered stone silicosis in the U.S.

Title: Silicosis in Workers Exposed to Artificial Quartz Conglomerates: Does It Differ From Chronic Simple Silicosis?

Citation: Paolucci V, Romeo R, Sisinni AG, Bartoli D, Mazzei MA, Sartorelli. Arch Bronconeumol. **2015**;51(12):e57-60.

Location/Country: Italy

Study Type and Description: A report of 3 cases of silicosis in Italian workers exposed to quartz conglomerates. The diagnosis was based on exposure history, HRCT, and analysis of bronchoalveolar lavage fluid (BALF).

Case 1: A 44-year-old male non-smoker worked for 24 years in a small stone company cutting, polishing, and home installation of countertops. IH sampling showed very high RCS levels (> 0.5 mg/m^3). CXR revealed diffuse small nodules. HRCT showed well-defined, rounded, grade 2 opacities. ANA, anti-ENA, ACE and Quantiferon were normal / negative. BALF showed pigmented alveolar macrophages and a low number of birefractive bodies.

Case 2: A 50-year-old male non-smoker employed by the same company for 30 years had a CXR typical for silicosis (nodular q-p opacities with 2/2 profusion, mainly in upper and middle lung zones). HRCT showed diffuse well-defined rounded grade 2 opacities. He was assigned to different tasks to prevent further exposure, but the opacities on his imaging worsened. ANA and anti-ENA were normal. Quantiferon testing was negative.

Case 3: A 55-year-old male nonsmoker worked in a small ornamental stone company cutting quartz conglomerate countertops with a water-jet system and installing countertops. No protection was used during home installation. His CXR showed nodular p-p opacities with 1/0 perfusion, mainly in the upper lung zones. HRCT showed well-defined rounded grade 1 opacities with profusion grade 4.

Conclusions of Authors: In Cases 1 and 2, exposure to silica was > 20 times higher than ACGIH TLV and both were diagnosed with severe accelerated silicosis.

Relevance to the Industry: Likely the first cases reported in Italy. 2/3 cases had severe accelerated silicosis.

Title: Outbreak of autoimmune disease in silicosis linked to artificial stone.

Citation: Shtraichman O, Blanc PD, Ollech JE, Fridel L, Fuks L, Fireman E, Kramer MR. Occup Med (Lond). **2015**;65(6):444-50.

Location/Country: Israel

Study Type and Description: Record review of artificial stone silicosis patients in Israel for autoimmune disease. The study included all 40 patients with artificial stone silicosis who had been referred to Israel's only lung transplantation center from 1997 – 2012. The authors collected demographic information, medical histories, physical exams, radiographic assessments, and pulmonary function tests, and assessed autoimmune disease based on record review. Clinical and serological findings were used to diagnose a specific autoimmune disease.

Key Findings: 9 of the 40 patients (23%) had an autoimmune disease (about 7.5 times expected): 3 had systemic sclerosis, 2 had rheumatoid arthritis, 2 had mixed connective tissue disease, 1 had Sjogren's syndrome, and 1 had polymyositis anti-synthetase syndrome. Three of the 9 also had silicoproteinosis, considered an autoimmune disease. Age and cumulative smoking were not associated with autoimmune disease. All had a history of at least 6 years of silica exposure.

Conclusions of Authors: The findings demonstrate a strong link between silicosis and autoimmune disease. Clinicians should assess for autoimmune disease in patients with silica-related lung disease and assess for silica exposure in those with autoimmune disease.

Key Strengths and Weaknesses: The one national lung transplant center likely caught most cases of severe lung diseases. However, greater severity of disease in those referred could have increased the likelihood of autoimmune disease, so cannot generalize to less severe silicosis. The timing of onset of autoimmune disease relative to the onset of silicosis symptoms or diagnosis was not provided. The findings are consistent with other studies that have documented a high prevalence of autoimmune disease and autoimmune markers in patients with silicosis.

Relevance to the Industry: High. Workers with silicosis are at increased risk of autoimmune disease.

Title: Radiological Evaluation of Artificial Stone Silicosis Outbreak: Emphasizing Findings in Lung Transplant Recipients.

Citation: Grubstein A, Shtraichman O, Fireman E, Bachar GN, Noach-Ophir N, Kramer MR. J Comput Assist Tomogr. **2016**; 40(6):923-7.

Location/Country: Israel

Study Type and Description: This study describes the radiological features of artificial stone silicosis and correlates Chest CT severity scales with PFTs. 82 patients diagnosed with artificial stone silicosis (based on NIOSH guidelines) referred to Israel's lung transplantation center from 1997 to 2015, and had PFTs and chest CT scans were included. 13 patients underwent lung transplantation (LTX). CT scans were evaluated by two radiologists.

Key Findings: Mean age was 47 years, with mean exposure of 19.8 years, 78% smoking history. PMF was diagnosed in 85% of those with LTX (11 of 13) **and** 40% (20 of 69) without LTX. Chest CT severity grade and PFT findings were inversely significantly associated. CT scans showed a number of patterns including centrilobular and perilymphatic nodules, lymphadenopathy $\pm$ calcification, emphysema, conglomerate masses (PMF), and less commonly ground-glass opacities and traction bronchiectasis. Silicoproteinosis was pathologically confirmed in 2 patients with LTX.

Conclusions of Authors: This study emphasizes the role of chest CT findings in diagnosis, assessing diseases severity, and guiding clinical decisions.

Relevance to the Industry: Chest CT is important for diagnosis of silicosis and assessment of disease severity.

Title: Complicated silicosis resulting from occupational exposure to engineered stone products.

Citation: Matar E, Frankel A, Blake LKM, Silverstone EJ, Johnson AR, Yates DH. Med J Aust. **2017**;206(9):385-6.

Location/Country: Australia

Study Type and Description: A case report of a 54-year-old male who presented with a 6-year history of chronic cough and exertional breathlessness. At age 35 he started a job fabricating artificial stone (>80% crystalline silica) benchtops, which included cutting, grinding, finishing, and installing benchtops. He reported hardly ever using water for dust suppression and limited protection.

Key Findings: Patient was diagnosed with progressive massive fibrosis. PFTs showed restriction with reduced DLCO. Chest CT showed bilateral calcified fibrotic masses in the upper zones with volume loss, distortion and calcified mediastinal lymphadenopathy. Lung and lymph node biopsy showed numerous silicotic nodules. Patient continued to worsen, developed bilateral pneumothoraces and was listed for lung transplantation.

Conclusions of Authors: Recent outbreaks of silicosis have been associated with the manufacture of ES kitchen and bathroom benchtops. Medical practitioners should be aware that cutting and installing these engineered stone products can be hazardous. This case reaffirms the need for vigorous enforcement of dust reduction regulations and respiratory protection in the engineered stone industry.

Relevance to the Industry: Likely first published case report of ES silicosis in Australia.

Title: Artificial Stone-Associated Silicosis: a rapidly emerging occupational lung disease

Citation: Hoy RF, Baird T, Hammerschlag G, Hart D, Johnson AR, King P, et al. Occup Environ Med. **2018**;75(1):3-5.

Location/Country: Australia

Study Type and Description: Case series of 7 Australian workers with Artificial Stone (AS)-associated silicosis. Information included: occupation history, PFT, chest imaging, and histopathology when available. The diagnosis was based on history of silica exposure, chest imaging consistent with silicosis, and lung histopathology.

Key Findings: Between 2011 and 2016, 7 cases of AS-associated silicosis were identified. All were male, ages 26-61 years (median 44 years) and were employed in benchtop fabrication businesses that primarily used ES and had poor dust control measures. Two were non-smokers and 4 were foreign-born. None had education about respirator use or employer-based health surveillance. Median duration of exposure was 7 years (range: 4-10 years). All presented with cough and progressive exertional dyspnea for 0.5-3 years. Six cases had findings consistent with PMF (bilateral upper lobe fibrosis, volume loss with confluent mass-like densities consistent). 5 cases had lung biopsies with findings of histiocytic inflammatory infiltrate and nodules, 3 cases birefringent particles within histiocytes noted. 3 cases had bronchoalveolar lavage (31-54% Lymphocytes) and 1 case underwent double lung transplantation. PFTs showed restrictive spirometry patterns with rapid lung function decline (386 ml/year vs. expected 36 ml/year).

Conclusions of Authors: This series of silicosis in Australian workers further demonstrates the risk-associated high silica content artificial stone. The frequency of reported cases of silicosis associated with artificial stone work is increasing significantly. AS-associated silicosis is characterized by a shorter latency and more rapid loss of lung function than chronic silicosis. Urgent action is required to increase awareness of the risk of silicosis in the benchtop fabrication industry. Better measures are needed to control dust levels, monitor and protect workers in this industry.

Relevance to the Industry: One of the earliest reports from Australia of ES silicosis, several with severe progressive disease.

Title: Stonemasons with silicosis: Preliminary findings and a warning message from Australia.

Citation: Newbigin, K, Parsons R, Deller D, Edwards R, McBean R. Respirology. **2019**;24:1220-1221.

Location/Country: Australia

Study Type and Description: Research letter describing chart review of 78 Queensland stonemasons with silicosis who were participants in a new government-funded silicosis health screening program that was instituted in 2018 after several cases of silicosis associated with Artificial Stone (AS) were diagnosed. Of 141 silicosis claims among 659 screened stonemasons, the authors describe 78 subjects with silicosis who had at least one high-exposure risk factor: Use of AS > 50% of the time, PPE <50% of the time, or dry cutting >50% of the time. Diagnosis of silicosis was made by the treating respiratory physician based on: history of exposure to AS, spirometry, radiograph (CXR) and /or high-resolution computed tomography (HRCT).

Key Findings: The 78 stone masons with silicosis were all male with a mean age of 34 years (range 23 – 63 years) and mean stone work tenure of 13 years (range 2 – 45 years). 90% worked mostly with artificial stone, 87% used dry cutting techniques, and 68% reported all three high exposure risk factors. 46% were diagnosed with accelerated silicosis and 54% with chronic silicosis by their treating respiratory physician. Of the 67 who had a CXR ILO reading, 21% had progressive massive fibrosis (PMF) and 43% had a normal CXR (ILO 0) but HRCT findings consistent with silicosis. RCS levels were as high as 0.69 mg/m^3 when using wet cutting techniques, suggesting much higher levels when dry cutting.

Conclusions of Authors: The large number of stonemasons (78) with silicosis, 21% with PMF identified in Queensland within a year after instituting health screenings, suggests a potentially large health crisis across Australia. The authors stress the importance of RCS dust mitigation and also recognition of silicosis by medical professionals.

Relevance to the Industry: The report provides early results of health screenings of stonemasons in Queensland. A large number of cases of AS silicosis, many with advanced disease, and workplace risk factors are described. Use of AS >50% time, dry cutting techniques >50% time, and/or PPE <50% time results in a high risk for silicosis.

Title: Severe Silicosis in Engineered Stone Fabrication Workers - California, Colorado, Texas, and Washington, 2017-2019

Citation: Rose C, Heinzerling A, Patel K, Sack C, Wolff J, Zell-Baran L, et al. MMWR Morb Mortal Wkly Rep**. 2019;**68(38):813-8.

Location/Country: USA

Study Type and Description: This is a case series of 18 cases of silicosis among workers in the stone fabrication industry in California, Colorado, Texas, and Washington. Cases were identified through independent investigations in each state and confirmed with CT chest or lung biopsy.

California: A 37-year-old Hispanic man, who had worked in a stone countertop fabrication company between 2004 and 2013 dry cutting, grinding and polishing mainly artificial stone, was diagnosed with silicosis in 2012 based on CT scan findings. PFT showed restrictive defects and reduced diffuse capacity; lung biopsy was consistent with silicosis. Anti-SCL-70 and ANA were positive, and he was also diagnosed with scleroderma. Cal OSHA 2009 inspection found RCS levels up to 22 times the PEL (in 2009) of 0.1 mg/m^3. He was hospitalized at age 37 in 2019, at which time came to attention of CA Dept of Public Health, and died from silicosis at age 38 yrs.

5 additional cases of silicosis were found in Hispanic workers (ages 35-39 years) from the same company. Case 2 died in 2018 at age 36 yrs. Lung tissue at autopsy showed silicotic nodules and alveolar proteinosis. He had a history of rheumatoid arthritis with positive RF and anti-CCP. Case 3 was a former worker diagnosed in 2018. Three additional cases, current workers, were identified by medical surveillance, confirmed with CT scan.

Colorado: 7 cases of silicosis were identified from review of patient medical records of a Colorado physician specializing in occupational lung disease. All were Hispanic employees of stone fabrication companies. Two were female. 5 cases reported cutting, grinding, and polishing mainly engineered stone (ES), and 2 cases performed housekeeping duties. All 7 had Chest CT findings consistent with silicosis, 3 had also been diagnosed with rheumatoid arthritis with positive autoimmune antibodies, 2 had latent tuberculosis, and 4 cases underwent lung biopsy which confirmed the diagnosis. 5 of 6 with repeat chest imaging showed progression of silicosis over time. All were removed from silica exposure.

Texas: Four cases of silicosis, ages 40-59 years, were diagnosed in 2019 among workers at an ES countertop manufacturing and fabrication facility based on Chest CT scan. Three worked as fabricators and one worked in ES slab casting. Two had moderate to severe restriction on PFTs.

Washington: A 38-year-old Hispanic male who worked for 6 years cutting and polishing natural and ES countertops was diagnosed with silicosis with progressive massive fibrosis (PMF). Chest CT was consistent with silicosis and lung biopsy showed fibrosis with polarizable particles. PFT showed severe restrictive defect and reduced DLCO (32%). Patient was referred for lung transplantation.

Overall: 18 cases of silicosis, including 2 fatalities, were reported among stone fabrication workers in 4 states. Most were < 50 years, many with advanced disease. All had Chest CT scans which were consistent with silicosis. The diagnosis was delayed in some, especially when concurrent autoimmune disease. Five underwent lung biopsy, which confirmed silicosis.

Conclusions of Authors: This report of 18 cases of silicosis among ES fabrication workers, many with severe disease, highlights the urgent need for silica dust exposure reduction, regulatory enforcement, and enhanced medical and public health surveillance for silicosis. The authors also note that public health agencies should be notified of cases and that the findings suggest that there may be many more U.S. cases not yet identified.

Relevance to the Industry: This is the first major report of multiple cases of silicosis among ES fabrication workers in the U.S. The cases, from 4 states, are notable for 2 fatalities and many others with severe disease. Autoimmune disease and/or latent TB were common. The 6 cases from CA are included in Fazio et al. 2023.

Title: Artificial stone-associated silicosis: clinical-pathological-radiological correlates of disease

Citation: Levin K, McLean C, Hoy R. Respirol Case Rep. **2019**;7(7):e00470.

Location/Country: Australia

Study Type and Description: A case report of two Australian artificial stone (AS) workers who underwent lung transplantation for AS-associated silicosis.

A 47-year-old male stone fabricator for 9 years, who dry cut and grinded AS with minimal exhaust ventilation, presented with weight loss and worsening dyspnea. Lung function was reduced (FEV1 and FVC 40%, DLCO 54%) and declined further 22 months later. ANA was positive, other serology negative. Chest CT demonstrated changes consistent with PMF and also diffuse ground glass opacities. He underwent lung transplantation. Explanted lung showed dense fibrosis with silicotic nodules, progressive massive fibrosis (PMF) and also extensive alveolar proteinosis.

A 36-year-old male nonsmoker worked for 6 years fabricating AS benchtops, using hand tools without wet suppression and with minimum ventilation. He presented with worsening dyspnea and cough. Chest CT showed changes consistent with silicosis with progressive upper lobe fibrosis with hilar consolidation and ground glass opacities. PFT showed restrictive defects (FEV1 38% predicted, FVC 30% predicted, and TLCO 11% predicted). He underwent bilateral lung transplant. The explanted lung showed extensive parenchymal destruction, fibrosis with coalescing silicotic nodules, and also alveolar proteinosis, features of silicoproteinosis.

Conclusions of Authors: Both patients with severe accelerated silicosis had findings of both silicoproteinosis and chronic fibrotic / nodular silicosis (PMF) within the same lung. The histopathology correlated with chest imaging findings. The authors note that silicoproteinosis differs from chronic silicosis, with findings more consistent with pulmonary alveolar proteinosis (PAP), which could have implications for diagnosis and treatment.

Relevance to the Industry: Artificial stone silicosis can progress rapidly and have variable features of silicoproteinosis (PAP), chronic silicosis and PMF in the same lung.

Title: Artificial stone-associated silicosis in China: A prospective comparison with natural stone-associated silicosis.

Citation: Wu N, Xue C, Yu S, Ye Q. Respirology. **2020**;25:518-24.

Location/Country: China

Study Type and Description: This study compared 18 patients with artificial stone (AS) silicosis and 63 patients with natural stone silicosis, all diagnosed in 2018 in China, and followed for 6-12 months.

Key Findings: The 18 AS-associated silicosis patients, compared to the 63 with natural stone silicosis, were younger (36 vs. 52 years), had fewer years of exposure (6 vs. 14 years), shorter duration of time from exposure to illness (6 vs 29 years), more likely to have complicated silicosis (77% vs. 39%), more rapid decline in lung function (FEV1 and FVC >500 ml/year vs < 100 ml/year), be lung transplant candidates (39% vs 3%) and had higher mortality (28% vs 0%). 4 artificial stone dust samples collected from one workplace all had silica content above 90%.

Unique study aspects: Comparison of patients diagnosed with AS vs. natural stone silicosis.

Conclusions of Authors: AS silicosis is characterized by short latency from exposure to disease presentation, rapid radiological progression, accelerated decline in lung function and high mortality.

Relevance to the Industry: High. This paper highlights notable differences comparing artificial vs. natural stone silicosis, with artificial stone silicosis having more severe disease and more rapid progression.

Title: GM-CSF antibodies in artificial stone associated silicoproteinosis: A case report and literature review.

Citation: Khan SNS, Stirling RG, McLean CA, Russell PA, Hoy RF. Respirol Case Rep. **2022**;10(9):e01021.

Location/Country: Australia

Study Type and Description: Case report of a 26-yr old male stone benchtop fabricator who was diagnosed with silicoproteinosis, a form of 2nd pulmonary alveolar proteinosis (PAP) and a review of the relevant literature. PAP can be primary or autoimmune, related to elevated GM-CSF autoantibodies, or secondary, caused by conditions that impair macrophage function, such as acute inhalational exposure to silica.

Key Findings: The patient, a former smoker worked grinding and cutting artificial stone without water suppression and with limited respiratory protection for 8 years. His DLCO was 60%. HRCT showed "crazy paving", diffuse ground-glass opacities with septal thickening, a pattern seen in PAP. Lung biopsy was consistent with PAP. His GM-CSF-Ab was elevated, seen in autoimmune PAP and also in some cases of 2nd PAP. The patient was diagnosed with silico-proteinosis based on his occupational history, pathology, and imaging findings. Over 2 years away from exposure, his lung function was stable, and his HRCT scan showed a reduced crazy pacing pattern.

Conclusions of Authors: The authors discuss the pathogenesis of silicoproteinosis and the potential role of GM-CSF antibodies. Inhalation of high levels of crystalline silica can directly impair alveolar macrophage function and may also induce GM-CSF-antibodies.

Relevance to the Industry: Silicoproteinosis, a form of secondary PAP that develops after exposure to high levels of silica dust, is being reported in artificial stone workers, an indication of high inhalational exposures to silica. Such patients can have elevated GM-CSF-Ab levels, which thus does not rule out the diagnosis of silicoproteinosis. Silicoproteinosis usually progresses rapidly and can have a high mortality. Rarely patients can stabilize or improve away from exposure, as happened with this patient, although the longer-term prognosis remains unclear.

Title: Demographic, exposure and clinical characteristics in a multinational registry of engineered stone workers with silicosis

Citation: Hua JT, Zell-Baran L, Go LHT, Kramer MR, Van Bree JB, Chambers D, et al. Occup Environ Med. 2022; 79:586-93.

Location/Country: Israel, Spain, Australia, USA

Study Type and Description: This cross-sectional study, using data from the Engineered Stone Silicosis International (ESSI) registry, compared demographic, exposure, and clinical characteristics among 169 engineered stone (ES) workers with silicosis from 4 countries: Israel (125), Spain (20), Australia (14), and USA (10). ES workers aged > 18 years with a physician diagnosis of silicosis between 2001 and 2021 were included.

Key Findings: Participants with ES silicosis were predominantly male (98.8%), with a mean age of 51.7 years (range 26-81) and work tenure of 19.9 years (range 3-48), with 66% current or former smokers. Overall, 32.5% of workers had progressive massive fibrosis on chest imaging, of whom 18.5% reported ≤10 years of work tenure. 62% had simple silicosis, 74.6% had mediastinal / hilar lymphadenopathy and 15.4% had ground glass opacities, findings suggestive of alveolar proteinosis. Lung function impairment was common including: restriction (38% reduced TLC), reduced diffusion capacity (46%) and hypoxemia (23.5%), and 21.4% were diagnosed with an autoimmune disease or abnormal autoimmune serology. Chronic kidney disease was reported in 10%. Cases from the 4 different countries were generally similar, except that Australian cases were younger and employed in ES work for fewer years, likely reflecting less severe cases detected sooner due to medical surveillance.

Conclusions of Authors: There is a substantial emerging population of ES workers worldwide with severe irreversible silicosis and co-morbid conditions, including autoimmune disease. The authors highlight the urgent need for improved medical surveillance and better workplace exposure controls to prevent ES-induced silicosis.

Relevance to the Industry: Outbreaks of advanced silicosis with similar features in 4 countries highlight the growing epidemic of ES silicosis and the authors conclusions above.

Title: Silicosis Among Immigrant Engineered Stone (Quartz) Countertop Fabrication Workers in California.

Citation: Fazio JC, Gandhi SA, Flattery J, Heinzerling A, Kamangar N, Afif N, et al. JAMA Intern Med. 2023; 183:991-8.

Location/Country: USA

Study Type and Description: This large case series describes the clinical, socioeconomic, and occupational characteristics of 52 patients diagnosed with silicosis associated with fabrication of engineered stone (ES) in California. Cases were identified between 2019 and 2022 through statewide surveillance by the California Department of Public Health (CaDPH). Silicosis was defined based on NIOSH criteria (history of occupational exposure and either imaging or pathological finding consistent with silicosis). Those with a primary occupation of stone countertop fabricator and who regularly worked with ES were included. Medical records were reviewed and patients or next of kin were contacted to obtain further medical and occupational information.

Key Findings: 52 patients from 22 companies were identified with ES-associated silicosis, with 71% cases identified in Los Angeles County. The cases were diagnosed between 2010 and 2022, most after 2019. Median age at diagnosis was 45 years and all but 1 were Spanish-speaking Latino immigrant men. The median work tenure was 15 years, with 48% continuing to work after diagnosis. 45% reported water suppression to control silica dust, 49% reported working in a shop with < 10 employees, and 49% in a shop with 10-50 employees.

48% initially presented to an emergency department and 137% to primary care or urgent care. Delayed diagnosis occurred in 58%, most commonly due to alternative initial diagnoses, such as bacterial pneumonia (30%) or tuberculosis (27%), with only 1 confirmed case of active TB. 10% had non-tuberculosis infection. 65% were never smokers; 36% were current or former smokers, with median of 3.5 pack-years.

At diagnosis 38% had chest CT scans demonstrating progressive massive fibrosis (PMF). Lung function testing showed that 55% had restrictive defects, 14% mixed restrictive and obstructive defects, 2% only an obstructive defect, and 46% reduced DLCO. Six (12%) had an autoimmune disease: rheumatoid arthritis (4), scleroderma (1), and myositis (1). ANA was positive in 11/19 (25%) and rheumatoid factor positive in 4/16 (25%).

Of the 52 cases, at the time of publication, 10 (19%) had died due to silicosis at mean age of 46 years, 6 (12%) were alive with resting hypoxemia (1 post-transplant), 11 (21%) were referred to transplantation, and 3 (6%) underwent lung transplantation. 19% were uninsured, 52% had Medi-Cal, 15% had private insurance, and only 13% had worker's compensation.

Conclusions of Authors: The authors conclude that ES countertop fabrication workers in CA with silicosis are notable for: having occurred primarily in young Latino immigrant men, many presented with severe disease and a delay in diagnosis, and some were fatal. They highlight the urgent needs to protect ES workers from exposure to silica dust, and for medical surveillance and timely diagnosis. They also highlight the need to report cases to public health authorities and for provision of needed medical care.

Relevance to the Industry: This is the largest report of ES-associated cases in the U.S, which was published in JAMA, Journal of the American Medical Association, one of the most highly regarded and widely read general medical journals worldwide. The article received substantial publicity on local and national news, increasing awareness of ES silicosis and prompting regulatory attention, including CAL/OSHA's more stringent Emergency Temporary Standard for silica, which became a permanent Silica Standard in CA.

The identification of this large number of cases of ES silicosis, most in the Los Angeles area, was likely facilitated by resources not available in many U.S. States, including California's active Department of Public Health (CADPH) and Occupational Health Branch, local pulmonologists with awareness of silicosis, reporting of cases of silicosis and public health follow-up, and availability of medical care for undocumented persons. Additional cases of ES stone silicosis in CA have been reported since this publication.

Title: Clinical efficacy of tetrandrine in artificial stone-associated silicosis: A retrospective cohort study

Citation: Wu WH, Feng YH, Min CY, Zhou SW, Chen ZD, Huang LM, et al. Front Med (Lausanne). **2023**; 10:1107967.

Location/Country: China

Study Type and Description: A retrospective cohort evaluating the efficacy of tetrandrine, an anti-fibrotic drug developed in China, in patients with artificial stone (AS)-associated silicosis. 89 patients were selected from 284 patients with AS silicosis. Patients with infections, TB, mycobacterium, and pneumothorax were excluded. Patients who agreed to be treated with tetrandrine (n=47) were compared to 42 controls who did not want the treatment. Changes in HRCT, pulmonary function, and clinical symptoms in both groups were compared pre- and post-treatment. Participants mean age (37-8 yrs), years of exposure (6-7 yrs), and smoking (about 45% never smokers) were similar in the 2 groups. More patients in the treatment group vs control had PMF (34% vs 19%.

Key Findings: Much of the data is difficult to interpret as presented. The authors report that after treatment for 3–12 months, 57%–65% in the treatment group showed improvements in HRCT imaging, while there was no improvement in the control group ($p < 0.05$). Disease progression occurred in 0%–17% of patients in treatment group after 3–12 months of treatment compared with 44%–92% of patients in the control group ($p < 0.05$). After 3 months of treatment, FVC, FEV1, and DLCO significantly improved in the treatment group, but not in the control group. However, after 6 months of treatment, lung function changes in the treatment group were non-significant. Clinical symptoms (cough, dyspnea, chest tightness, chest pain) were reported to be significantly improved in the treatment group, but not in the control group. The main adverse effects noted in the treatment group was facial pigmentation (19.2%).

Conclusions of Authors: Tetrandrine can control and delay the progression of AS-associated silicosis fibrosis, with improved chest HRCT imaging and pulmonary function.

Study Limitations: The participants were not randomized to treatment and control groups and the study does not appear to be blinded as to who was on Tetrandrine vs placebo, limiting interpretation of the results.

Relevance to the Industry: The large number of ES silicosis patients (284) seen at 1 hospital in Shanghai, China, as well as their young age and disease severity are notable, and consistent with studies in other countries. As there is no effective treatment for silicosis, there is an interest in antifibrotic agents. The findings that Tetrandrine may slow the progression of silicosis, while preliminary, support further evaluation of antifibrotic agents in patients with ES silicosis.

Title: Successful lung transplantation for artificial stone-associated accelerated silicosis: a case report.

Citation: Hsu SC, Chen YJ, Fan HY, Wang CW, Lee HJ, Tsao YC. Ind Health. **2024;**62(3):209-14.

Location/Country: China

Study Type and Description: A case report of a 43-year-old male Chinese artificial stone fabricator who underwent lung transplantation. The patient presented with productive cough and dyspnea and was diagnosed with silicosis after undergoing CXR, PFTs, and HRCT. He processed kitchen countertops for 9 years. Workplace assessment noted ventilation and exhaust equipment. He used a surgical mask occasionally.

Key Findings: PFT showed moderate restrictive lung disease which worsened over time. CXR also showed disease progression and HRCT showed PMF**.** His lung function improved after lung transplantation.

Conclusions of Authors: Accelerated silicosis can occur after exposure to high concentrations of respirable crystalline silica. Adequate protective measures, including environmental monitoring, wet dust systems, local exhaust ventilation, and personal protective equipment are needed.

Relevance to the Industry: This single case report is similar to other reports of patients with severe progressive ES silicosis that have undergone lung transplantation.

Title: Artificial stone silicosis: a UK case series

Citation: Feary J, Devaraj A, Burton M, Chua F, Coker RK, Datta A, et al. Thorax. **2024**;79(10):979-81.

Location/Country: UK

Study Type and Description: Case series of the first 8 reported cases of artificial stone (AS) silicosis in the United Kingdom (UK). The 8 men were referred to a single occupational lung disease clinic and diagnosed with artificial stone silicosis based on occupational histories and clinical, radiological, and pathological features.

Key Findings: Median age of the 8 cases was 34 years with median exposure to stone dust 12 years (4 – 40 years). Four were exposed for only 4-8 years and reported 50 – 100% use of AS. Six were born outside the UK and 7 were current or former smokers. All worked for companies with < 10 employees, cutting / polishing countertops with dry methods and inadequate respiratory protection. None were under RCS health surveillance. Four were diagnosed with simple silicosis, 3 with complicated silicosis, and 1 with acute silicoproteinosis. Spirometry results ranged from 23% - 117% predicted and DLCOs from 41% - 129% predicted. Six underwent mediastinal lymph node biopsy: 5 had non-caseating granulomata and 3 birefringent crystals under polarized light. Blood tests showed: 4/7 had elevated serum ACE, and 3/5 positive ANA. Patient Status: 1 deceased, 2 referred for lung transplant, 1 lost to follow up. Three continued working with RCS exposure, 1 without further RCS exposure, and 2 were not working.

Unique study aspects: The cases are notable for the severity of disease, their detailed clinical evaluation, and all were from a single occupational lung disease clinic.

Conclusions of Authors: Current UK Health and Safety Executive (HSE) workplace guidance for RCS is inadequate. Strategies, such as mandatory reporting of AS silicosis, regulations focusing on small companies, and a ban on AS should be considered.

Relevance to the Industry: The findings are consistent with other studies showing younger age, shorter duration of exposure and severe disease in patients with AS silicosis. The report from the UK, a country with a National Health Service, universal access to medical care, and relatively strong Occupational Health standards, is notable, and suggests that inadequate workplace controls and under-recognition of silicosis cases likely occurs across different healthcare systems and workplace health and safety legislation.

Title: Chest X-ray has low sensitivity to detect silicosis in artificial stone benchtop industry workers.

Citation: Hoy R, Jones C, Newbigin K, Abramson M, Barnes B, Dimitriadis C, Ellis S, Glass D, Fwini S, Hore-Lacy F, Jimenez-Martin J, Pasricha S, Pirakalathanan J, Sieminowics M, Walker-Bone K, Sim M. Respirology. **2024**;29:785-794.

Location/Country: Australia

Study Type and Description: The objectives of this study were to: 1) investigate inter-reader agreement in interpretation of chest x-rays (CXR) and high-resolution computed tomography (HRCT) between radiologists, and 2) determine the sensitivity and specificity of CXR compared to HRCT to detect early silicosis. Data from 110 artificial stone (AS) benchtop workers who participated in silicosis screening in Australia, and had paired CXR and HRCT was utilized. Participants were evaluated by a respiratory physician regarding the diagnosis of AS silicosis. Radiologists were provided de-identified CXR and HRCT images that were not paired. Two radiologists out of a panel of 7 reviewed each CXR and HRCT independently according to ILO and ICOERD classifications and provided an overall opinion regarding radiological features compatible with silicosis (definite vs. probable vs. indeterminate vs. normal).

Key Findings: Participants had a median age of 40.3 years and a median duration of work in the stone benchtop industry of 13 years. 37% were never, 30% former, and 33% current smokers; 81.5% were fabricators, 18.5% were installers, and 50% reported working in an environment with dry processing. There was a high inter-reader agreement between radiologists on CXR b-read (87.3%) and the presence or absence of silicosis on HRCT (90.0%). Of note, CXR was positive for silicosis in 27/110 (24.5%) workers and HRCT positive in 40/110 (36.4%). Of the 83 with a negative CXR (ILO category 0), 15 (18.1%) had silicosis on HRCT. CXR had low sensitivity (48%) but had high specificity (97%) compared to HRCT in detecting silicosis in AS benchtop workers. HRCT also better identified other clinically relevant findings such as lymphadenopathy and emphysema.

Conclusions of Authors: CXR lacks sensitivity to detect early stages of silicosis. HRCT can better detect silicosis and identify other clinically relevant findings. Using CXR for medical surveillance would underestimate the prevalence of silicosis and could provide false reassurance and delay appropriate management.

Relevance to the Industry: This well-designed study clearly demonstrates that CXR is less effective in identifying early silicosis than HRCT. It also demonstrates that CXR is effective at identifying advanced silicosis. While OSHA currently mandates a CXR and not HRCT for medical surveillance of silica-exposed workers, this study demonstrates advantages of performing HRCT vs CXR. HRCT would provide greater accuracy for assessing whether silicosis was present pre-placement, and for assessing the effectiveness of workplace measures to control silica exposures. It would also be more effective at identifying other medically relevant conditions.

Surveillance – Epidemiology Studies

Title: Prevalence of silicosis in a marble factory after exposure to quartz conglomerates.

Citation: Pascual S, Urrutia I, Ballaz A, Arrizubieta I, Altube L, Salinas C. Arch Bronconeumol. **2011**;47:50-1.

Location/Country: Spain

Study Type and Description: A brief report describing a small surveillance study of 11 workers in a family-owned marble business who worked mostly with a product made up of 90% silica, less frequently with natural stone. The workers cut and polished stones in a 500 m^2 workspace with several dust extraction systems and sliding exterior doors that were nearly always open. Office workers with no direct contact with stone dust were excluded.

Key Findings: Six of 11 (55%) workers were diagnosed with silicosis, 1 with progressive massive fibrosis (PMF). Four workers used machines equipped with a waterjet cutting system, and 7 workers performed home installation that may have used dry cutting without respiratory protection or water suppression. Five of 6 cases were assemblers/ installers, and 1/6 cases used waterjet-equipped machines. Mean exposure was 10 hours daily for 12.5 (range 7-14) years.

Conclusions of Authors: The authors highlight the high risk of developing silicosis in workers who handle quartz conglomerates (engineered stone), especially installers who do not use water dust suppression. They note that it is essential to use adequate respiratory protection when processing materials with high levels of silica, especially during home installation.

Relevance to the Industry: While only 11 workers, this is likely the earliest surveillance data on quartz conglomerate workers. Although very small numbers, the study documents a high prevalence of silicosis. Also notable, 5/6 of the silicosis cases occurred in assemblers/ home installers.

Title: Outbreak of silicosis in Spanish quartz conglomerate workers.

Citation: Perez-Alonso A, Cordoba-Dona JA, Millares-Lorenzo JL, Figueroa-Murillo E, Garcia-Vadillo C, Romero-Morillos J. Int J Occup Environ Health. **2014;**20(1):26-32.

Location/Country: Spain

Study Type and Description: Description of epidemiological and clinical characteristics of a silicosis outbreak in Cadiz, Spain. Cases were men working in stone cutting, finishing and installing countertops and diagnosed with silicosis from 2009 to 2012 using high-resolution CT (HRCT) scans. The number of workers employed, which changed over time, was estimated based on census data. Telephone interviews and medical record reviews were conducted on all cases.

Key Findings: 46 engineered stone (ES) workers were diagnosed with silicosis based on Chest CT scan findings: 42/46 (91.3%) with simple silicosis and 4/46 (8.7%) with complicated silicosis. Median age at diagnosis was 33 years (26% under 30 years) and median length of employment was 11 years. 9/46 (19.6%) cases had normal chest x-ray, but HRCT findings were consistent with silicosis. Most - 38/46 (82.6%) - were never or ex-smokers, and had mild or no symptoms. The 46 cases came from 12 small family industries. The prevalence of silicosis ranged from 20% (46/224) to 56% (46/82) depending on the estimated number of employees (ranging from 82 in 2000 to 224 in 2008).

Workers reported inadequate dust control measures and many did not have periodic medical examinations and chest x-rays. One worker died at 33 years old.

Unique study aspects: One of the earliest reports of an outbreak of ES silicosis and estimated prevalence among ES exposed workers.

Conclusions of Authors: Increased use of conglomerate / ES countertops with high silica content increased silicosis incidence in Cadiz, Spain.

Key Strengths and Weaknesses: The study used active surveillance to identify cases and solicited other potential cases during interviews with known cases. The evaluation of cases was consistent, including occupational history and HRCT for diagnosis. However, the denominator was hard to determine with an increase in work force size over time and all workers were not evaluated.

Relevance to the Industry: Early report (2014) of a large cluster of cases of ES silicosis in a region of Spain, and likely high prevalence of silicosis among exposed stone workers (> 25-30 %).

Title: Silicosis in finishing workers in quartz conglomerates processing.

Citation: Guarnieri G, Salasnich M, Lucernoni P, Sbaraglia M, Putzu MG, Zuliani P, et al. Med Lav. **2020**;111:99-106.

Location/Country: North-Eastern Italy (Padua, Treviso, Turin)

Study Type and Description: The goal of the study was to describe the incidence, clinical and radiographical characteristics of silicosis detected in quartz conglomerate finishing workers. From 2016 to 2019, 45 workers from 11 ornamental stone companies were recruited and underwent medical screening, which included occupational history, respiratory symptoms, spirometry, DLCO, CXR, and HRCT. Silicosis was diagnosed based on silica exposure and HRCT findings. Trans-bronchial biopsy was performed on those with radiological signs of silicosis. Exposures were estimated using RCS air monitoring data and multiplying the time-weighted average (TWA) level by the years of exposure.

Key Findings: The 11 companies fabricated (cutting, polishing) quartz conglomerate countertops since 2008. All had all exhaust ventilation; 2 used wet methods for finishing**.** RCS 8-hr TWA levels were very high prior to 2016 (260 – 744 ug/m^3, 5-15 times current OSHA PEL (50 ug/m^3), and less < 100 ug/m^3 after interventions (wet methods, exhaust ventilation). 24 workers from 7 of the 11 companies were diagnosed with silicosis.

<u>Silicosis (n=24/45; 53%):</u> mean age of 43 years (range 25-57) with mean exposure duration of 9.4 years (range 3.5-20), cumulative silica exposure 4300 ug/m^3/y, 79% did not use PPE, most (71%) were asymptomatic, 63% had normal CXR. All had HRCT findings consistent with silicosis, such as multiple small nodules, large opacities, and /or ground glass pattern. 5/24 (21%) had accelerated silicosis. Twenty underwent transbronchial lung biopsy. All had histologic features consistent with silicosis and numerous particles of crystalline silica.

<u>No silicosis (n=21/45; 47%):</u> mean age 45 (range 33-54), duration of exposure 11.6 years (range 8-15), cumulative silica exposure 2200 ug/m^3/y, 45% did not use PPE, most (67%) were asymptomatic, 4/21 had abnormal CXR.

Respiratory symptoms, spirometry, and CXR, normal in many, had low sensitivity to detect silicosis. DLCO was more sensitive than spirometry.

Conclusions of Authors: High incidence of silicosis (> 50%) in stone finishing workers exposed to quartz conglomerate dust with high silica content**.** DLCO and HRCT should be used in screening workers with high silica exposure.

Key Strengths and Weaknesses: Workers from 11 companies were recruited. Standardized testing, including HRCT was used to diagnose silicosis and silica exposure data, more than most studies, is provided. What % of eligible workers participated is not given. It is unknown if the workers recruited were representative of the larger group. The authors refer to results as "incidence" of silicosis. However, given the study is cross-sectional, the findings indicate prevalence.

Relevance to the Industry: The study finds a very high prevalence of silicosis (>50%) in quartz conglomerate workers dry cutting with exposure to very high silica exposures (5-15x OSHA PEL). The prevalence of silicosis in these workers could increase further with time. Consistent with other studies, the authors note that CXR and spirometry can miss cases of silicosis and recommend HRCT. They study does not address the prevalence of silicosis with implementation of recommended engineering controls.

Title: Radiographic Screening Reveals High Burden of Silicosis among Workers at an Engineered Stone Countertop Fabrication Facility in California.

Citation: Heinzerling A, Cummings KJ, Flattery J, Weinberg JL, Materna B, Harrison. Am J Respir Crit Care Med. **2021**;203:764-6.

Location/Country: California (CA), USA

Study Type and Description: Report of silicosis screening of 43 current fabrication workers at a CA engineered stone (ES) countertop fabrication company with 3 former workers diagnosed with silicosis, including 2 fatalities. Screening included spirometry, chest x-ray (CXR) with certified B read. An earlier CA Division of Occupational Safety and Health (Cal/OSHA) inspection at this company (2009) had shown exposures up to 22 x PEL (100 ug/m^3). Another inspection in 2019, when the PEL was 50 mg/m^3, also showed inadequately controlled silica exposure.

Key Findings: The 43 workers screened were all Hispanic men with a median age of 37 years. 5/43 (12%) employees were diagnosed with silicosis; their median age was 40 and their jobs included cutting, fabricating and laminating. Median duration of employment for 4 of the 5 silicosis cases was 14.9 years compared to 6.5 years for 32 of the 38 workers without silicosis (some data was missing). 3 silicosis cases had restrictive spirometry pattern. An additional 5 employees with negative CXRs also had restrictive spirometry patterns.

Conclusions of Authors: 12% of the company's fabrication workers were diagnosed with silicosis, but there may be more cases since only current employees were screened and chest CT scans were not performed.

Key Strengths and Weaknesses: Medical surveillance was performed on all 43 current fabrication workers at the company following identification of silicosis cases. As noted by the authors, lack of chest CTs and worker turnover may have resulted in underdiagnosis.

Relevance to the Industry: Highlights the importance of medical surveillance for ES workers and likely under recognition of silicosis cases. How representative these findings are is not known.

Title: Identification of early-stage silicosis through health screening of stone benchtop industry workers in Victoria, Australia

Citation: Hoy RF, Glass DC, Dimitriadis C, Hansen J, Hore-Lacy F, Sim MR. Occup Env Med. **2021**;78:296-302.

Location/Country: Australia

Study Type and Description: Description of the findings of a health surveillance program for current and former workers exposed to artificial stone (AS). A primary evaluation was performed on 587 workers of an estimated 1400 workers, including a questionnaire, physical exam, chest x-ray (CXR) with B read, and lung function testing. If the worker had abnormal findings or a history of high exposure, they underwent a secondary evaluation, including a high-resolution CT (HRCT) and an assessment by a respiratory physician.

Key Findings: 239/587 (41%) completed the secondary evaluation after the first 12 months. 86 of these 239 (36%) workers were diagnosed with silicosis based on CXR or HRCT, occupational history, and exclusion of other diseases. 65/86 (76%) had simple silicosis (nodules < 10mm) and 23.4% had complicated silicosis. 36% of those with simple silicosis were identified with HRCT, but not on CXR, whereas 100% of complicated cases were identified on CXR. Antinuclear antibodies (ANA) were detected in 37% with silicosis and 24% without silicosis.

The 86 silicosis cases were all men, mean age 41.8 years, 67% were ever smokers, majority of time was spent dry processing AS. 85% primarily worked in the shop and 15% worked as installers. Duration of work was similar for simple and complicated silicosis. 22 cases had < 10 years duration of work. The surveillance program captured more cases than relying on worker's compensation claims.

Conclusions of Authors: 36% of workers who completed full evaluations were diagnosed with silicosis. There is a high risk of silicosis in AS benchtop workers and medical surveillance is recommended for these workers.

Key Strengths and Weaknesses: Data is from a large well-designed industry-wide medical surveillance program of AS benchtop workers with consistent medical follow-up by an experienced occupational pulmonary specialty program. As noted by the authors, exposure assessment was based on workers' questionnaire data.

Relevance to the Industry: This study demonstrates a high prevalence of silicosis in AS workers. CXR identified all complicated silicosis cases, but missed 36% of workers with simple silicosis. The high prevalence of ANA suggests risk for autoimmune diseases in these workers.

Title: Silica exposure estimates in artificial stone benchtop fabrication and adverse respiratory outcomes.

Citation: Glass DC, Dimitriadis C, Hansen J, Hoy RF, Hore-Lacy F, Sim MR. Ann Work Expo Health. **2022**;66:5-13.

Location/Country: Australia

Study Type and Description: This study analyzed data gathered from respiratory health screening (RHS) of stonemasons, conducted by WorkSafe Australia. Stonemasons had the opportunity to undergo a screening, consisting of a chest X-ray (CXR) with B read, questionnaire, and respiratory function testing. Self-reported information on job tasks, type of stone, dry work, and duration of work were used to create job exposure categories and estimate respirable crystalline silica (RCS) exposure duration, intensity and cumulative exposure. The study investigated whether job category and the silica exposure variables were associated with specific adverse respiratory outcomes.

Self-reported job task information was used to create five job exposure categories: Installer, Factory worker-CNC, Factory worker-machinist, other job with direct or secondary exposure, other job with minimal secondary exposure. Self-reported proportion of time working with artificial stone (AS), doing dry work, near someone else doing dry work were used to estimate intensity of RCS exposure. Weighted cumulative exposure was calculated by multiplying the job exposure intensity by duration for each job category and then summing the results for all jobs held.

Multivariate logistic regression was used to investigate associations between silica exposure variables and respiratory outcomes, adjusted for age, gender, and smoking.

Key Findings: From 557 workers who participated in the RHS, 407 agreed to contribute their data and 324 had complete records. Most were men, median age was 36 years, median duration of exposure was 6.8 years, and 45% were never smokers. Almost half were machinists, 23% were predominantly installers and 9% were CNC machinists.

Exposure intensity and cumulative exposure were associated with increased odds of an ILO category >=1 and with dyspnea. Exposure duration was also associated with increased odds of an ILO category >=1. In multivariate analysis job type (machinists) was associated with ILO profusion category. Exposure categories were not associated with respiratory function or symptoms.

Conclusions of Authors: RCS exposure intensity (% time spent dry cutting AS) and duration of this work predicted adverse respiratory outcomes. Dry cutting AS should be prohibited to reduce RCS exposure and risk of disease.

Key Strengths and Weaknesses: This study developed estimates of RCS exposure intensity and duration based on self-reported information on job tasks, type of stone, and work duration that predicted ILO $\geq$ 1. As the authors note, job histories were incomplete and quantitative exposure data limited. Given CXR, respiratory function and symptoms are insensitive tools to assess silicosis, in the future chest CT scans may be a better way to assess RCS exposure metrics.

Relevance to the Industry: This study develops a useful practical qualitative exposure metric that links intensity and cumulative RCS exposure to adverse respiratory health outcomes.

Title: An outbreak of work-related asthma and silicosis at a US countertop manufacturing and fabrication facility

Citation: Tustin AW, Kundu-Orwa S, Lodwick J, Cannon DL, McCarthy RB. Am J Ind Med. **2022**;65(1):12-9.

Location/Country: USA

Study Type and Description: This study describes a cluster of respiratory disease (work-related asthma [WRA] and silicosis) and also medical surveillance in a countertop manufacturing and fabrication plant where workers both produced and cut/processed engineered stone (ES). OSHA investigated the plant in 2016 after a worker reporting work-related respiratory symptoms. Personal air sampling for silica (RCS) and phthalic anhydride (PA) was conducted as well as screening questionnaires and interviews. Seven casting department workers with work-related respiratory symptoms were assessed by the company's occupational medicine physician including a medical history, physical exam, and spirometry. An OSHA screening questionnaire was completed by a convenience sample of 64 workers on one day, and medical surveillance was performed on 12 workers (7 fabrication department, 5 casting department).

Key Findings: Due to evaluations of different workers at different time periods the findings are challenging to summarize. In the Casting department 5 of 7 workers who sought care for respiratory symptoms were diagnosed by the company's physician with WRA and another 11 had suspected WRA based on questionnaire responses. All 7 were reassigned jobs and referred to a pulmonologist. 6/6 chest x-rays were normal. 1 of 6 personal air samples for PA were above the PEL of 12 mg/m^3.

In the Fabrication department, 6 of 11 (54%) personal air samples for RCS were above the PEL of 50 ug/m^3 (range 129 – 487 ug/m^3) and 2 of 11 were above the AL of 25 mg/m^3.

On the screening questionnaire of 64 workers 38.7% of workers reported a cough and 19.6% reported chest tightness; with no significant difference in symptom prevalence between casting and fabrication workers. Limited dust controls and respiratory protection were noted in both departments.

Medical surveillance of 12 workers identified 4 (33.3%) with silicosis based on chest CT findings.

Unique study aspects: Diagnosis of cases of both WRA and silicosis in a plant that both produced (casting department) and cut (fabrication department) ES. Air sampling confirmed elevated PA and RCS levels. The authors note that overexposures of silica and PA were consistent with other US employer data in the OSHA national database.

Conclusions of Authors: ES workers can develop asthma and/or silicosis. Workers exposed to asthmagens (PA and epoxy resins) are at increased risk for occupational asthma. Such exposures are most likely to occur in manufacturing ES before the material is cured. Employers should implement protective measures to reduce exposures and should also perform medical surveillance.

Relevance to the Industry: Silica is not the only exposure of concern in this industry. Artificial stone workers can also be exposed to chemicals and sensitizers, such as epoxy resins and PA, that can increase risk for occupational asthma. Medical surveillance can identify work-related respiratory disease before workers self-report symptoms.

Title: Predictors of psychological stress in silica-exposed workers in the artificial stone benchtop industry

Citation: Hore-Lacy F, Hansen J, Dimitriadis C, Hoy R, Fisher J, Glass D, et al. Respirology. **2022**;27:455-61.

Location/Country: Australia

Study Type and Description: Cross-sectional study of 556 silica-exposed artificial stone (AS) workers to assess psychological stress levels using the Perceived Stress Scale (PSS-10), a validated self-administered questionnaire that measures self-perceived stress. These workers are part of the previously reported Australian cohort of AS workers undergoing health surveillance for silicosis (Hoy et al. 2021).

Key Findings: 547 (98%) of the AS workers had complete PSS-10 data, 10% used an interpreter, and 18% self-reported history of anxiety or depression. PSS-10 scores were significantly higher for the following categories: those who had an mMRC dyspnea score > 0, had left the AS stone industry**,** had a diagnosis of anxiety or depression, and longer exposure duration (5 – 14 vs 0 – 4 years). PSS-10 scores were significantly lower for those born outside of Australia or had used an interpreter.

Unique study aspects: Assesses psychological stress in AS workers whereas most research has been focused on the severity of silicosis and/or associated medical conditions.

Conclusions of Authors: Dyspnea is a significant predictor of stress in AS workers and can be used to identify those who may need more support. It is.

Relevance to the Industry: Artificial stone workers, especially those with dyspnea who have left the industry, experience greater psychological stress. The PSS-10 was completed at the initial assessment and does not necessarily represent stress at other time points. Whether the findings are applicable to workers in other countries with different social and economic structures is unclear.

Title: Notes from the Field: Surveillance of Silicosis Using Electronic Case Reporting – California, December 2022-July 2023

Citation: Flattery J, Woolsey C, Epstein-Corbin M, Blackley DJ, Harrison RJ, Cummings KJ. MMWR Morb Mortal Wkly Rep. **2023**;72(46):1275-6.

Location/Country: USA

Study Type and Description: This study evaluated the utility of electronic case reporting (eCR) for identifying cases of silicosis in California (CA). eCR is a rapid reporting mechanism initially developed to use electronic health records (EHRs) to report cases of infectious diseases such as COVID-19 to public health agencies in real time using established criteria. Additional criteria or conditions, such as silicosis, can be added to the reporting criteria, which the CA Department of Public Health (CDPH) did. From October 2022 to July 2023, the CDPH received 41 eCRs for silicosis. Medical records were reviewed to assess the accuracy of these silicosis eCRs.

Key Findings: Among the 41 eCRs for silicosis**,** 35 (85%) were identified as either confirmed cases (19, 46%) or clinically compatible (probable) cases (16, 39%) that lacked confirmatory information, such as imaging or occupation. Six (15%) of the 41 eCRs were considered unlikely cases based on medical record reviews**.** Nine of the 41 eCRs (22%) were also identified as silicosis through other reporting sources (hospital discharge records, direct referrals), while most, 32 (78%) of the 41 persons reported to CDPH through eCRs were not identified through other sources. At least 7 (37%) of the 19 confirmed cases of silicosis were associated with fabrication of (ES) countertops**.**

Unique study aspects: This study modified an eCF system initially developed to identify cases of infectious diseases to identify cases of silicosis, an important approach that could greatly enhance reporting of cases of silicosis and other work-related diseases.

Conclusions of Authors: The authors conclude that the demonstrated the utility of eCR in improving reporting of silicosis cases as 78% of the potential cases it identified were not reported elsewhere and only 15% of cases identified were considered unlikely silicosis. They note that other public health jurisdictions throughout the US could similarly add silicosis reporting criteria and that improved reporting of silicosis cases could lead to more effective prevention.

Relevance to the Industry: The lack of public health reporting of silicosis (and other occupational diseases) greatly hinders the recognition and prevention of such diseases. eCR is a promising practical public health approach to identify silicosis cases by modifying an existing eCR infrastructure. More widespread implementation of such an electronic reporting system could help address an important question, the extent of engineered stone silicosis in the U.S.

Title: Prevalence and risk factors for silicosis among a large cohort of stone benchtop industry workers.

Citation: Hoy RF, Dimitriadis C, Abramson M, Glass DC, Gwini S, Hore-Lacy F, et al. Occup Environ Med. **2023**; 80(8):439-46.

Location/Country: Victoria, Australia

Study Type and Description: Data from a large voluntary government funded screening program of stone benchtop workers in Victoria, Australia was used to assess the prevalence and risk factors for silicosis in these workers. Workers were recruited by media campaigns and work-place visits. The primary evaluation (questionnaire, physical exam, chest x-ray (CXR) with B read, and respiratory function testing) was performed on all workers. If the worker had an abnormal result, significant symptoms, or a history of high exposure, they underwent a secondary evaluation with a high-resolution computed tomography scan (HRCT) chest , blood tests, and an assessment by a respiratory physician. Silica exposure categories (low, med, high, very high) were estimated based on occupational questionnaire responses regarding exposure to dry processing.

Key Findings: 544 workers underwent a primary screening, and 414 (76%) underwent a secondary evaluation. 117 (21.5%) of all workers screened; 28.3% of those who underwent a secondary evaluation) were diagnosed with silicosis based on HRCT, occupational history, and exclusion of other diseases. 96 (82%) workers were diagnosed with simple silicosis (pulmonary nodule 10 mm diameter or less) and 21 (18%) with complicated silicosis. All cases were male, 58% were migrants, and the median age was 42 years. 95% worked with artificial stone (AS) and 86.2% reported exposure to dry processing of stone (either direct dry work or bystander).

Silicosis cases were associated with a longer duration of exposure (12 vs. 8 years) and with high / very high (vs low / med) estimated silica exposure categories, based on frequency and duration of exposure to dry processing. Older age, lower BMI, and positive smoking history were also significantly associated with having silicosis.

While most silicosis cases had normal lung function, complicated silicosis was significantly associated with lower FEV1, FVC and DLCO compared to those with simple silicosis. About 40% of simple silicosis cases had no evidence of silicosis on CXR but findings of silicosis on HRCT, suggesting that CXR is not adequate for screening. All workers with complicated silicosis had ILO category CXR of $\geq$ 1.

Unique study aspects: Government support of large scale 2-step screening program of Australian stone benchtop workers using standardized protocols (diagnostic testing, questionnaires) and consistent diagnostic criteria.

Conclusions of Authors: The authors conclude that the prevalence of silicosis is high in the benchtop industry, that dry processing of AS is common, and high / very high silica exposure categories are associated with increased risk of silicosis. The authors also conclude that HRCT is better than chest x-ray and respiratory function tests at detecting especially early stage silicosis, and is thus preferred for screening AS benchtop workers. The authors note that urgent action is needed to protect workers, including screening and implementation of effective hazard controls, including the cessation of dry processing and the elimination of very high silica content AS.

Key Strengths: Large industry-wide medical surveillance program of AS benchtop workers (estimated 40% of those eligible) with standardized medical evaluation, including chest HRCT, evaluation by a single experienced occupational pulmonary specialty program, and use of detailed questionnaires to estimate silica exposures.

Comparison to Other Studies: This Australian study (along with related studies from this group) is the best available data on the prevalence of silicosis in AS workers. Compared to other reports of AS workers, this study found a lower prevalence of severe cases, likely related to earlier detection from comprehensive medical screening of a large fraction of all current AS workers.

Relevance to the Industry: The Australian data has documented a high prevalence of silicosis in AS workers, dry work as an important risk factor, and that HRCT can identify cases of simple silicosis not seen on CXR. A large fraction of total eligible workers has participated, reducing the chance of selection bias, such as participation of workers from establishments with fewer dust controls.

Title: Active Surveillance of Engineered Stone Workers Facilitates Early Identification of Silicosis: A Discussion of Surveillance of Occupational Lung Diseases

Citation: Gandhi SA, Heinzerling A, Flattery J, Fazio JC, Alam A, Cummings KJ, et al. New Solut. **2023**; 33:119-129.

Location/Country: USA

Study Type and Description: This publication describes 18 early cases of silicosis associated with engineered stone (ES) that were identified through silicosis surveillance efforts performed by the California Department of Public Health (CDPH), Occupational Health Branch (OHB). Passive surveillance cases were identified from review of hospital discharge diagnoses. Active surveillance was considered any case identified through employer-initiated medical testing or ES silicosis outreach-prompted reporting. The diagnosis was confirmed by record review and a history of ES exposure. Outcomes were categorized as alive without lung transplant, deceased, or post lung transplant.

Key Findings: 18 cases of silicosis associated with ES were identified between 2006 and 2020; 11 (61%) were identified from active surveillance, and 7 (39%) from passive surveillance, hospital discharge data. The cases were all male, 89% Latino, median age at diagnosis was 40 years, with median 14.5 years of exposure. Passive surveillance cases compared to active surveillance cases had more severe disease, including worse lung function, and were more likely to be deceased or undergone lung transplantation. The article also discusses more broadly the challenges and benefits of different approaches to surveillance for occupational lung diseases.

Conclusions of Authors: The authors conclude that passive surveillance, relying on hospital data and an informal provider referral system, delays the diagnosis of silicosis and identification of the work connection, resulting in identification of disease at a more advanced stage. Such passive surveillance likely also misses cases. Enhanced public health surveillance, including making silicosis a mandatory reportable disease, would greatly improve the detection of ES silicosis and facilitate primary preventive interventions to reduce workplace silica exposures and prevent future cases. They also note that enhancing active surveillance of ES workers would also enable "secondary prevention", by identify cases earlier in the disease process, enabling mitigation of disease progression or better treatment.

Key Strengths and Weaknesses: The manuscript provides an excellent discussion of different approaches to surveillance of workers at risk for ES silicosis and occupational lung diseases more broadly. Limitations and strengths of different surveillance approaches are discussed. The OHB's occupational health expertise and efforts at medical surveillance for ES silicosis is a key strength. Similar surveillance efforts would likely be challenging for most other state health departments to implement.

Relevance to the Industry: The findings suggest unrecognized cases of ES silicosis exist, consistent with other studies. The authors highlight the great need for enhanced active surveillance for ES associated silicosis in the U.S., including medical surveillance of current and former workers and enhanced public health surveillance efforts, including mandatory reporting of silicosis to local health departments.

Title: Autoimmune diseases, autoantibody status and silicosis in a cohort of 1238 workers from the artificial stone benchtop industry.

Citation: Tomic D, Hoy RF, Sin J, Jimenez Martin J, Gwini SM, Barnes H, et al. Occup Environ Med. **2024**;81:388-94.

Location/Country: Victoria, Australia

Study Type and Description: The objective of this cross-sectional study was to ascertain the prevalence of autoimmune disease and selected autoimmune markers [Antinuclear antibodies (ANAs), extractable nuclear antigens (ENAs), and RF] in workers exposed to artificial stone (AS) in the stone benchtop industry, and assess associations with silica exposure, silicosis and other risk factors. Data from the Australian silicosis screening program (Hoy OEM 2023) was used. Respirable silica exposure (RCS) was categorized (low to very high) based on reported work duration and intensity of dry processing. ENAs include antibodies to Ro, RNP, Scl-70 and other nuclear proteins.

Key Findings: 1238 ES workers underwent screening for silicosis. Workers were mostly male (93.3%) with a median age of 36.5 years and a median duration of 7 years stone work. 24.3% were diagnosed with silicosis. 4% (50/1238) were identified as having a possible autoimmune disease, 0.9% (11/1238) had a 'confirmed' autoimmune disease, and 7 of the 11 with autoimmune disease were also diagnosed with silicosis. The most prevalent autoantibody detected was ANA (24.6% of participants), with ENAs detected in 4.6% and RF in 2.6%. Autoantibodies were detected more frequently among those with very high vs. low estimated RCS exposure.

Conclusions of Authors: The prevalence of autoimmune markers, especially ANA (24.6%) was higher than expected for the general population, and were associated with high RCS exposures and silicosis, as well as age and smoking. After a mean of only 7 years of RCS exposure 0.9% of stone benchtop workers had clinical autoimmune disease, over half of whom (7 of 11) were also diagnosed with silicosis. The authors recommend screening for autoimmune disease in workers exposed to RCS and also that those diagnosed with autoimmune disease be asked about RCS exposure.

Unique features / comparison to literature: The study presents important new information on the prevalence of autoimmune disease / markers and risk factors in this well characterized Australian cohort of AS benchtop workers with substantial RCS exposures. The findings are consistent with other studies showing a high prevalence of autoimmune disease / markers is those with silicosis. The findings also support the more limited literature that silica exposure (even without silicosis) increases the risk of autoimmune disease. Other studies have found substantially higher prevalences of autoimmune markers and disease in those with silicosis, likely reflecting more severe silicosis and/or longer duration of silica exposure.

Relevance to the Industry: Substantial RCS exposure (with and without silicosis) increases the risk of autoimmune markers and autoimmune disease. The findings are consistent with other studies and suggest that RCS exposures likely cause both silicosis and autoimmune diseases, and that autoimmune disease may present before a patient develops silicosis. The findings support screening for autoimmune disease in workers with exposure to RCS. They also support asking patients presenting with autoimmune disease about work exposures to RCS. Thus autoimmune diseases that develop in workers with significant RCS exposures may be considered occupational diseases.

Title: Psychometric properties of the Perceived Stress Scale (PSS-10) in silica-exposed workers from diverse cultural and linguistic backgrounds.

Citation: Hore-Lacy F, Gwini S, Glass DC, Dimitriadis C, Jimenez-Martin J, Hoy RF, et al. BMC psychiatry. **2024**;24(1):181

Location/Country: Victoria, Australia

Study Type and Description: Evaluation of the psychometric properties of the Perceived Stress Scale (PSS-10) in artificial stone (AS) workers participating in a voluntary medical surveillance program. An earlier study in this population (Hore-Lacy et al., 2022) showed that those who were born overseas (45%) and those who used an interpreter (10%) had lower perceived stress scores. 682 workers had completed the PSS.

Key Findings: This study evaluated the PSS-10 tool previously used to assess perceived stress in silica-exposed workers. Internal consistency: items within the PSS-10 were closely related for all participants and remained high for subgroups of gender, country of birth, interpreter use, and language spoken at home. Validity: PSS-10 performed well for both sexes, moderately well with country of birth and language spoken at home, and less well for interpreter use.

Conclusions of Authors: The PSS-10 showed reasonable internal consistency and good validity in general, but its performance with an interpreter and with non-English speakers was weaker. Tools validated in this population are recommended for future studies.

Relevance to the Industry: Testing of the PSS-10 showed weaker validity among those who required use of an interpreter. Future studies that include large numbers of non-English speaking migrant workers, should use translated and validated instruments.

Title: Dose-response relationship between lung function and chest imaging response to silica exposures in artificial stone manufacturing workers.

Citation: Chen CH, Tsai PJ, Chang WW, Chen CY, Chen CY, Yates D, et al. Environ Health. **2024**;23(1):25.

Location/Country: Taiwan

Study Type and Description: This cross-sectional surveillance study assessed RCS exposures, respiratory symptoms and spirometry abnormalities in 65 employees involved in the production, cutting, and polishing of artificial stone (AS) products at 2 plants in Taiwan. Twenty employees also had CXR, CT scan and DLCO performed.

Plant A (57 workers) produced AS slabs from raw materials (quartz, resin, additives), with tasks that included unloading raw materials, mixing materials, spreading mix into molds, curing the material, and cutting the cooled slabs. Plant B (8 workers) was limited to cutting and grinding processes. 65 area respiratory dust samples were collected from different areas of the plants (such as unloading raw materials, mixing, cutting, grinding, research, administration). Personal exposures were calculated based on time spent in the area and expressed as 8-hr TWA. Cumulative exposure was determined by multiplying individual exposure levels (8-hr TWA) by tenure, resulting in units of mg/m^3-year. PFTs and chest imaging were performed per standard guidelines. Relationships between silica exposure, symptoms, lung function and chest imaging were explored. Whether patients were diagnosed with silicosis was not noted. Twenty participants (19 with high-exposure jobs and 1 supervisor – low exposure job) had chest Xray, CT scans and DLCO testing (authors note this was due to financial constraints).

Key Findings: The median RCS level was 0.168 mg/m^3, with raw material operator (10 employees) having the highest exposures (2.88 mg/m^3). Handling materials, unloading and missing also had high exposure**.** Administration, research and development (19 employees) had the lowest exposures. The 65 workers (mean age 42 years) were divided into low RCS exposure group (28 workers with mean 0.02 mg/m^3, cumulative per year 0.15 mg/m^3) and high RCS exposure group (37 employees with mean 1.12 mg/m^3, cumulative per year 6.23 mg/m^3), with similar mean tenure (6.0 years). Grinding, polishing, and cutting operations were reportedly performed with water suppression. Participants reported using respiratory PPE, but an onsite visit revealed low compliance, and only 22% of workers in the high exposure group had been fitted.

Of the 19 high exposure workers who had a more extensive work-up, 2/19 (10.5%) had abnormalities noted on CXR and 12/19 (63%) had abnormalities on CT scan with 9/19 (47%) having round opacities considered more definitive of silicosis and 9/19 (47%) had an impaired DLCO. The authors do not classify workers as having silicosis, but these findings suggest a prevalence of silicosis among the high exposure workers of at least 47%.

The authors perform extensive analyses assessing the various relationships between exposure, lung function and imaging. High-exposure workers reported more chronic phlegm production and had more ventilatory impairment on spirometry in a dose-dependent fashion. Respiratory symptoms, lung function, and chest x-ray combined provided good sensitivity and specificity for predicting chest CT abnormalities.

Conclusions of Authors: Lung function and chest CT abnormalities are common in AS workers. For high-exposure individuals, abnormalities on health screening should prompt chest CT to facilitate detection of silicosis.

Strengths and weaknesses: The presentation of the data is confusing, and the authors appear to avoid diagnosing silicosis (or noting the diagnosis) in workers who undoubtedly have silicosis. The authors minimize their key findings, which is the extremely high levels of RCS found, both in manufacture and cutting of the AS slabs, and the likely very high prevalence of silicosis, at least 47% of highly exposed workers.

Relevance to the Industry: This is one of the few studies of workers involved in the manufacture of AS slabs, and also includes workers who cut AS slabs. While the data are challenging to interpret, the findings are notable for very high RCS exposures, with the highest levels in the raw material operators who mix dry stone dust and resin. High levels were also found for supervisors and facilities managers, suggesting high background RCS levels, and for cutting and grinding machine operators, despite reported use of water suppression. The apparently high prevalence of silicosis, especially given mean duration of exposure of only 6 years, is concerning. The findings raise concern of additional cases of silicosis related to the manufacture of AS, especially as production increases world-wide.

Selected Biomarker Studies

Title: Serum angiotensin converting enzyme elevation in association with artificial stone silicosis

Citation: Hoy RF, Hansen J, Glass DC, Dimitriadis C, Hore-Lacy F, Sim MR. Respir Med. **2021**;177:106289.

Location/Country: Australia

Study Type and Description: Cross-sectional evaluation of serum angiotensin converting enzyme (sACE) and silicosis in 179 exposed artificial stone benchtop workers in Australia. These workers underwent medical assessments, as previously described in Hoy et al. (2021), including sACE levels, which are typically elevated in patients with granulomatous diseases, such as sarcoidosis.

Key Findings: 60 workers (34%) were diagnosed with silicosis (44 simple, 16 complicated). Another 12 had possible silicosis and another 16 had lymphadenopathy without silicosis. The median sACE value was lowest in those with no silicosis (32.0 U/L), highest in those with simple and complicated silicosis (64.1 U/L and 70.0 U/L, respectively), and intermediate in those with lymphadenopathy (43.0 U/L) and possible silicosis (42.6 U/L). Age at diagnosis, duration of exposure, and work location were not significantly associated with sACE levels.

Conclusions of Authors: In a cohort of silica exposed artificial stone workers, sACE levels were higher in those diagnosed with silicosis compared to those without disease and highest in those with complicated silicosis. sACE could potentially be a prognostic biomarker for silicosis.

Key Strengths and Weaknesses: The study utilizes a well-characterized workers exposed to RCS**.** As the authors note, sACE is not specific to silicosis and is elevated in other granulomatous diseases. It is unclear what was considered a normal and elevated sACE level.

Comparison to Other Studies: Consistent with other studies that have shown sACE elevated in silicosis.

Relevance to the Industry: sACE levels can be elevated in silicosis, sarcoidosis and other granulomatous diseases. Given lack of specificity sACE currently has limited clinical utility.

Title: Excess iron promotes the emergence of foamy macrophages that overexpress ferritin in the lungs of silicosis patients.

Citation: Aloe CA, Leong TL-T, Wimaleswaran H, Papagianis PC, McQualter JL, McDonald CF, et al. Respirology. **2022**;27:427-36

Location/Country: Australia

Study Type and Description: This study aimed to determine if excess iron in silicosis patients is primarily responsible for elevated ferritin levels and if this acute phase reactant is stimulated early in the disease process. Cases and controls were recruited from stone benchtop industry workers in Australia. Cases were patients with radiological changes characteristic of silicosis, and controls were those without radiological disease and normal PFT who were referred for bronchoscopy based on a chronic cough. Cases were stratified into simple and complicated silicosis groups based on Chest CT findings. Peripheral blood, bronchoalveolar lavage, and transbronchial biopsies (for cases) were analyzed.

Key Findings: 23 participants were recruited: 18 with silicosis (8 with simple silicosis, 10 with complicated silicosis) and 5 controls**.** Blood ferritin, iron, and total iron-binding capacity had significant differences when comparing cases to control, but no statistical difference when comparing simple silicosis to complicated silicosis cases**.** There were no differences in other blood tests (WBC, lymphocytes, ESR, CRP, liver enzymes except for ALT) or BAL macrophages when comparing cases to controls.

Conclusions of Authors: Blood ferritin levels were increased in patients with silicosis, with the highest level in simple silicosis**.** Markers of inflammation and liver dysfunction were not increased in those with silicosis.

Relevance to the Industry: Limited relevance at this time. The authors suggest that ferritin, iron, and TIBC levels can be markers of early silicosis. These findings are interesting, but their clinical relevance is unclear.

Title: Inflammatory indices obtained from routine blood tests show an inflammatory state associated with disease progression in engineered stone silicosis patients.

Citation: Garcia-Nunez A, Jimenez-Gomez G, Hidalgo-Molina A, Cordoba-Dona JA, Leon-Jimenez A, Campos-Caro A. Sci Rep. **2022**;12:8211.

Location/Country: Spain

Study Type and Description: Study of inflammatory-type blood biomarkers among a previously reported (Leon-Jimenez et al., 2020) Spanish cohort of ES fabrication workers with silicosis (n=91), 53 with simple silicosis and 38 with progressive massive fibrosis (PMF) and 22 healthy controls (hospital workers). All silicosis participants were male and 6-7 years after removal from work. Patients were excluded if they had active infection, kidney, liver or autoimmune disease, or used immunosuppressive drugs. Blood samples were analyzed for fibrinogen, C-reactive protein, lactate dehydrogenase (LDH), angiotensin converting enzyme (ACE), rheumatoid factor, and alkaline phosphatase. Several systemic inflammatory indices that are not routinely used clinically were measured/calculated: neutrophil-to-lymphocyte ratio (NLR), lymphocyte-to-monocyte ratio (LMR), platelet-to-lymphocyte ratio (PLR), several systemic markers of inflammation (SIRI, SII, and AISI).

Key Findings: LDH, fibrinogen, and ACE levels and the systemic inflammatory indices were significantly increased in both silicosis groups compared to the control group. C-reactive protein, rheumatoid factor, and alkaline phosphatase did not differ between any groups. Combining several indices showed sensitivity and specificity levels nearing 100% in distinguishing PMF from healthy controls.

Conclusions of Authors: Biomarker results suggest chronic inflammation in these ES silicosis patients, but individual markers cannot distinguish disease severity.

Key Strengths and Weaknesses: Analysis of a number of non-specific markers in a large group of ES silicosis patients. The control group (hospital workers) likely differed demographically from the silicosis population. The biomarkers studied are not specific to silicosis; they can be elevated in a number of chronic diseases. Most of the inflammatory indices described are not clinically routinely used in the U.S.

Relevance to the Industry: Limited relevance at this time since these markers are not specific for silicosis and not used in current clinical practice.

Title: Plasma cytokine profiling reveals differences between silicotic patients with simple silicosis and those with progressive massive fibrosis caused by engineered stone

Citation: Campos-Caro A, Jimenez-Gomez G, Garcia-Nunez A, Hidalgo-Molina A, Leon-Jimenez A. Int J Mol Sci. **2023**;24(2).

Location/Country: Spain

Study Type and Description: Cross-sectional study to assess plasma cytokine levels in the same cohort of 91 Spanish silicosis patients as described in the study above: 53 with simple silicosis (SS) and 38 with progressive massive fibrosis (PMF). The control group was 22 healthy hospital workers with no history of exposure to silica dust. There were no statistically significant differences among the 2 exposure groups in age, duration of exposure, years since cessation of exposure (average 6-7 years), or smoking status. Venous blood was analyzed for multiple cytokines: FGF-basic, Eotaxin, G-CSF, GM-CSF, IFN-γ, IL-1β, IL-1RA, IL-2, IL-4, IL-5, IL-6, IL-7, IL-8, IL-9, IL-10, IL-12 (p70), IL-13, IL-15, IL-17A, IP-10, MCP-1, MIP-1α, MIP-1β, PDGF-BB, RANTES, TNF-α and VEGF.

Key Findings: There were significant differences in cytokine values comparing controls to silicosis patients, but not between the 2 silicosis groups (SS and PMF).

Conclusions of Authors: A panel of cytokines may have future utility as a biomarker of severity and selecting therapeutic drugs.

Key Strengths and Weaknesses: The study analyzed a large panel of blood cytokines in ES silicosis patients. Variable cytokine levels can be seen in other diseases and are not specific for silicosis. The control group of healthy hospital workers is unlikely comparable, as noted in the prior study.

Relevance to the Industry: Limited relevance at this time since these markers are not currently being used in practice and most are not specific to silicosis.

Selected Miscellaneous Relevant Articles

Title: Silicosis appears inevitable among former denim sandblasters: a 4-year follow-up study

Citation: Akgun M, Araz O, Ucar EY, Karaman A, Alper F, Gorguner M, Kreiss K. Chest. **2015**;148(3):647-54

Location/Country: Turkey

Study Type and Description: This is a 4-year follow-up study of former denim sandblasters initially studied in 2007. *(Akgun M et al. An epidemic of silicosis among former denim sandblasters. Eur Respir J. 2008; 32: 1295 - 1303).*

Key findings: Among the original 145 former sandblasters, 83 were reassessed 4 years later (in 2011). At follow-up, 9 (6%) sandblasters had died (mean age 24 years). Among the 74 living sandblasters (mean age 27 years), the proportion with silicosis had increased from 55% to 96%. 82% had radiographic progression and 66% had loss in lung function ($\geq$ 12% decline in FVC). Mean duration of exposure had been about 3 years with a mean latency (time since beginning exposure) < 11 years, and all remained away from further exposure to silica.

Conclusions of Authors: The authors concluded that almost all former sandblasters will develop silicosis and that progression of disease is expected over time, despite their short duration (mean 3 years) and cessation of exposure. They note inadequate compensation for the workers and the need for Global measures to prevent silicosis in other workers in this industry.

Relevance to the Industry: High. Silicosis can develop and progress after removal from exposure. These findings are consistent with the broader literature on silicosis and other occupational pneumoconioses. This study raises concern that the prevalence of silicosis in ES workers may increase over time. It also supports the need for continued medical surveillance for silicosis after workers leave the industry.

Title: Outbreak of silicosis in workers producing artificial stone skirting boards

Citation: Ronsmans s, Goeminne P, Jerjir N, Nowé V, Vandebroek E, Keirsbilck S, Nemery, B. Chest. 2022; 162: 406-409.

Location/Country: Belgium

Study Type and Description: This detailed research letter describes an outbreak of silicosis that occurred in a plant producing novel silica-based composites, a product similar to artificial stone (AS), to make skirting boards, tiles to protect floors – walls for the food/pharmaceutical industry. Four workers who had worked for 7 to 27 years at the company were diagnosed with silicosis after referral to a specialized occupational clinic.

Key Findings: Thorough work up including Chest CT scan, lung biopsy, and longitudinal spirometry identified 4 previously unrecognized cases of silicosis at variable stages. Chest CT scans showed findings consistent with simple silicosis to progressive massive fibrosis (PMF). Using past spirometry data from health surveillance, FEV1 showed an accelerated decline (98 to 221 mL/year vs expected 30 mL/ year). Lung or mediastinal lymph node biopsy showed a spectrum from early granulomatous reactions to typical chronic silicotic nodules, and ¾ had birefringent particles in the tissues examined. High respirable silica (RCS) levels were measured in the workplace, exceeding the Belgian TLV (0.1 mg/m^3). Despite periodical health surveillance, including annual spirometry, the cases were not detected earlier, and no chest radiography was done.

Conclusions of Authors: The authors conclude that the 4 cases of silicosis demonstrate that the hazards of AS production/processing reach beyond the kitchen/ bathroom countertop industry. This outbreak occurred despite periodic medical surveillance. They also highlight that silicotic lesions may be difficult to differentiate from sarcoid-like granulomas.

Relevance to the Industry: Example of a silicosis outbreak associated with exposure to an ES product that is similar to ES countertops. Of note, medical surveillance was performed, but unfortunately did not detect the cases. Accelerated declines in lung function over time were not recognized by those performing medical surveillance and chest imaging was not performed. Earlier detection would have enabled intervention of better protective measures.

Selected Reviews, Commentary, Letters to the Editor

Review Articles (and 1 Position Statement)

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Commentary, Letters, Medical News

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