Health effects of silica dust exposure – what do we need to do?

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On 28 March 2023, a satellite workshop, as part of the South Africa Sweden University Forum (SASUF) Research and Innovation Week 2023, was held at the University of the Witwatersrand School of Public Health. Ninety-five participants attended online from South Africa and several countries, and 28 attended in person. Prof. Tobias Chirwa, Head of the School of Public Health, welcomed all attendees. The workshop presentations and issues raised are summarised under the four themes of the workshop.

THEME 1: WHAT ARE THE SILICA-RELATED DISEASES AND WHY ARE THEY IMPORTANT?

Chaired by Dr Spo Kgalamono, Executive Director: National Institute for Occupational Health, National Health Laboratory Service, South Africa

Prof. Gill Nelson from the Wits School of Public Health set the scene with a short presentation about silica dust and silica-related health effects.

Overview of silica-related health effects and magnitude of the problem

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Millions of people are exposed to silica dust, worldwide, from a variety of industries, and silicosis rates remain high. The risk of developing silicosis is life long and continues after exposure has ceased. Silicosis data are available for some large industries but not for smaller businesses (usually unregulated), and artisanal and informal workers, which include women and children.

Quartz is the most common form of crystalline silica and the most common mineral in the earth's crust, so it is a component of most sand and rocks. Workers in many industries are exposed to silica dust. Aside from the well-known occupations, such as gold mining, construction, and artificial stone manufacture, those involved in tunnelling, denim jean production, jewellery production, hydraulic fracking, agriculture, and paint manufacturing (to name a few) are also potentially exposed to silica dust.

In the mining industry, silica dust is most prevalent in gold and coal mining, oil and gas mining, and shale and diatomaceous earth mining. Most affected are miners, drillers and crushing machine operators. In the construction industry, workers are exposed to silica dust from concrete, brick, granite, and tiles. Road working and stone working are also hazardous occupations. Exposure to silica flour is also a risk for silicosis as it comprises very fine grains of silica used in grouting, metal polish, abrasive cleaners, sandpaper, and toothpaste. Silica nanoparticles are produced on an industrial scale as additives to cosmetics, drugs, printer toners, varnishes, and food, and are being developed for biomedical and biotechnological applications such as cancer therapy, and drug delivery. Long-term toxicity due to accumulation of these nanoparticles is under investigation.

Although silicosis and silica-associated tuberculosis (TB) are the most common occupational lung diseases associated with silica worldwide, exposure also plays a role in connective tissue diseases, lung cancer, chronic obstructive pulmonary disease, and some types of pulmonary fibrosis and systemic diseases. All are preventable.

Challenges

- For some diseases, there is a clear dose-response relationship (e.g. simple silicosis). For others, the dose-response relationship is less clear (e.g. auto-immune diseases).
- All of the diseases, apart from silicosis, are associated with other exposures, e.g. chronic obstructive pulmonary disease (COPD) and cigarette smoking, TB, and HIV.
- For these other diseases, the association with silica dust exposure is often overlooked, e.g. chronic renal disease and rheumatoid arthritis.
- There are diagnostic challenges, particularly in distinguishing silicosis and TB.
- Many questions remain, e.g. what is the interactive effect of smoking and silica dust exposure on COPD and lung cancer?

Prof. Emeritus Rodney Ehrlich, from the University of Cape Town, joined online to discuss the interaction of silica dust exposure and tuberculosis, and addressed some pertinent questions.

Silicosis and tuberculosis – unanswered questions and research needs

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Although silicosis and tuberculosis were identified as closely related but distinct entities in the early 20th century, there are still many unanswered questions about their relationship and combined management. This brief overview is based on experience with gold miners from the South African mines, although the questions have global application.

What is the silica dust concentration threshold for increased risk of TB?

We do not know whether control of silicosis will also control the excess risk of TB due to silica.[1] Cohort studies are needed, which control for radiological silicosis, measure silica exposure accurately, and control for other confounders.

What is needed to better distinguish radiologically between silicosis, TB, and combined disease in individuals from populations with a high risk of both diseases?

Training on the International Labour Organization (ILO) Pneumoconiosis Classification is necessary but not sufficient. Training is needed on taking an informed occupational history and on the radiological appearances of post-TB (fibrosis, nodulation, cystic changes/bronchiectasis, lung distortion, pleural sequelae) and of active TB.[2] Development of training materials for involved clinicians and evaluation of such training are needed.

What is the optimal TB treatment regimen for active TB combined with silicosis?

Cohort studies have found a two-to-three times worse clinical outcome for silicotuberculosis than for TB alone.[3,4] Past clinical trials offer conflicting evidence on the optimal regimen and period of treatment (e.g. five to nine months).[5,6] Updated research using the latest regimens is needed.

Is TB preventive treatment (TPT) of individuals with silicosis realistic in low-resource settings?

There is limited and mixed evidence of the effectiveness of TPT in silicosis and the period of treatment.[7,8] South African national guidelines recommend TPT for persons with silicosis for three months (weekly rifapentine and isoniazid) or 12 months (daily isoniazid).[9] The extent of local implementation is unknown and questions regarding regimen, acceptability, feasibility, and coverage remain, particularly among ex-miners. Updated research using the latest shorter regimens is needed.

How frequently should individuals be examined for silicosis and silicotuberculosis?

Currently, active miners in South Africa are required by law to be examined annually while the Occupational Diseases in Mines and Work Act provides for ex-miners to be examined every two years. This latter provision has historically hardly been implemented in the case of black miners, many of whom do not live in South Africa.[10] Even with these limitations of access, the Medical Bureau for Occupational Diseases (MBOD), the state agency responsible for certifying occupational lung disease in miners, has struggled with large backlogs in recent years.[11] This raises the question of what frequency of examination of ex-miners is feasible, taking into account the need to determine eligibility for compensation in an impoverished population and to identify TB given a very high risk of active disease.

In populations with high burdens of silicosis and TB, what is the role of sputum examination using GeneXpert or equivalent?

Individuals with silicosis have four times the risk of TB than those with TB alone.[1] In populations with both disease burdens, the diagnosis of active TB is confounded by chest X-ray (CXR) abnormalities and chronic respiratory symptoms attributable to silicosis and post-TB. On the other hand, half of individuals with active TB may have no symptoms.[12,13] Xpert (and Xpert Ultra) have been shown to attain high sensitivity and specificity against TB culture.[14] Protocols are needed for the threshold for sputum examination when examining individuals from such populations, and for rational empirical treatment in the case of negative sputum tests.[2,14]

Can use of computer-aided detection systems for reading CXRs increase the ability to conduct such surveillance?

Computer-aided detection (CAD) is recommended by the World Health Organization (WHO) for CXR screening for active TB in high-risk groups, which includes workers exposed to silica dust.[15] Independently, CAD has been shown to achieve high performance metrics for identification of silicosis in miners.[16] Acceptability, feasibility, and costing studies of application of CAD for TB and silicosis in low-resource settings are needed.[17]

REFERENCES

1. Ehrlich R, Akugizibwe P, Siegfried N, Rees D. Silica exposure, silicosis and tuberculosis – a systematic review. BMC Public Health. 2021; 21:953. doi: 10.1186/s12889-021-10711-1.
2. Maboso B, Rees D, teWater Naude J, Goodman H. Ehrlich R. Difficulties in distinguishing silicosis and pulmonary tuberculosis in silica exposed gold miners – a report of four cases. Am J Ind Med. 2023; 66(4):339-348.
3. Escreet BC, Langton ME, Cowie RL. Short-course chemotherapy for silicotuberculosis. S Afr Med J. 1984; 66(9):327-330.
4. Hong Kong Chest Service/tuberculosis Research Centre, Madras/British Medical Research Council. A controlled clinical comparison of 6 and 8 months of antituberculosis chemotherapy in the treatment of patients with silicotuberculosis in Hong Kong. Am J Respir Med. 1991; 143(2):262-267.
5. Churchyard GJ, Kleinschmidt I, Corbett EL, Murray J, Smit J, De Cock KM. Factors associated with an increased case-fatality rate in HIV-infected and non-infected South African gold miners with pulmonary tuberculosis. Int J Tuberc Lung Dis. 2000; 4:705-712.
6. Rupani MP. A mixed-methods study on impact of silicosis on tuberculosis treatment outcomes and need for TB-silicosis collaborative activities in India. Sci Rep. 2023;13(1):2785. doi: 10.1038/s41598-023-30012-4.
7. Hong Kong Chest Service/Tuberculosis Research Centre, Madras/British Medical Research Council. A double-blind placebo-controlled clinical trial of three antituberculosis chemoprophylaxis regimens in patients with silicosis in Hong Kong. Clinical Trial. Am Rev Respir Dis. 1992; 145(1):36-41.

8. Cowie RL. Short course chemoprophylaxis with rifampicin, isoniazid and pyrazinamide for tuberculosis evaluated in gold miners with chronic silicosis: a double-blind placebo controlled trial. Tuber Lung Dis. 1996; 77:239-243.
9. South Africa. Department of Health. National Guidelines on the Treatment of Tuberculosis Infection. Undated (issued 2023). Available from: https://sahivsoc.org/Files/Health_Latent%20TB%20Infection_2023_web.pdf (accessed 18 May 2023).
10. Ehrlich R, Barker S, Tsang V, Kistnasamy B, Yassi A. Access of migrant gold miners to workers' compensation for occupational lung disease: quantifying a legacy of injustice. J Migration Health. 2021; 4:100065. doi: 10.1016/j.jmh.2021.100065.
11. Kistnasamy B, Yassi, A. Yu J, Spiegel SJ, Fourie A, Barker S, et al. Tackling injustices of occupational lung disease acquired in South African mines: recent developments and ongoing challenges. Global Health. 2018; 14(1):60. doi: 10.1186/s12992-018-0376-3.
12. Maboso BM, Moyo DM, Muteba KM, Govender VG, Barnes DF, Maama-Maime LBM, et al. Burden of disease among Basotho ex-miners in a large out-reach medical assessment programme. Occup Health Southern Afr. 2020; 26(4):145-152.
13. The First National TB Prevalence Survey. South Africa 2018. Short report. Available from: https://www.nicd.ac.za/wp-content/uploads/2021/02/TB-Prevalence-survey-report_A4_SA_TPS-Short_Feb-2021.pdf (accessed 18 May 2023).
14. Kendall A, Kamoga C, Kitonsa PJ, Nalutaaya A, Salvatore PP, Robsky K, et al. Empiric treatment of pulmonary TB in the Xpert era: correspondence of sputum culture, Xpert MTB/RIF, and clinical diagnoses. PLoS ONE. 2019; 14(7):e0220251. doi: 10.1371/journal.pone.0220251.
15. WHO Consolidated Guidelines on Tuberculosis. Module 2: Screening – Systematic Screening for Tuberculosis Disease. Geneva: World Health Organization; 2021. Licence: CC BY-NC-SA 3.0 IGO. Available from: https://apps.who.int/iris/bitstream/handle/10665/340255/9789240022676-eng.pdf (accessed 19 May 2023).
16. Ehrlich R, Barker S, Rees D, teWater Naude J, Kistnasamy B, Naidoo J, et al. Accuracy of computer aided detection of silicosis and pulmonary tuberculosis in ex-miners from the South African gold mines. Int J Environ Res Public Health. 2022; 19:12402. doi:10.3390/ijerph191912402.
17. Geric C, Qin ZZ, Denkinger CM, Kik SV, Marais B, et al. The rise of artificial intelligence reading of chest X-rays for enhanced TB diagnosis and elimination. Int J Tuberc Lung Dis. 2023; 27(5):367–372.

The topic of 'Silica dust exposure and lung cancer' was presented by Prof. Jill Murray (honorary associate professor in the Wits School of Public Health), with assistance from Dr Deepna Lakhoo from the National Institute for Occupational Health and the Wits School of Pathology.

Silica-associated lung cancer

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Worldwide, lung cancer is one of the most commonly diagnosed malignancies and is the leading cause of cancer mortality; for example, in the USA, it comprises 21% of all cancer deaths.[1] In the general population, tobacco smoke is the main risk for lung cancer and there is evolving evidence of increased risks due to smoking combined with other lung carcinogens. However, what is less well appreciated, both by the medical profession and the general public, is the contribution of occupational factors. The population attributable fraction of occupational lung cancer is reported to be as high as 15%.[2] Of the occupational exposures, asbestos is the most common, but there are many other workplace carcinogens, including arsenic, radon, polycyclic aromatic hydrocarbons, and silica.

In 1997, the International Agency for Research on Cancer (IARC) designated silica as a carcinogen[3] but, at that time, the carcinogenicity was questioned because of the absence of dose-response findings in studies, and the concern that confounding variables, in particular smoking, had not been adequately addressed.[4]

In 2012, the IARC performed an updated meta-analysis, which confirmed the carcinogenicity of silica and clearly demonstrated a positive exposure-response relationship.[5] These findings greatly contributed to the lowering of the occupational exposure limit (OEL) to 0.05 by the Occupational Health and Safety Administration (OHSA) in 2016.[6] However, a number of uncertainties remained, with implications for medical screening, prevention, setting of OELs, and lung cancer treatments. Is the presence of silicosis a necessary prerequisite to attribute lung cancer in an individual to silica exposure? What is the combined effect of silica and smoking? Is there a silica exposure threshold below which lung cancer will not occur? Is there an association with specific histological subtypes?

Subsequent research has shed light on these uncertainties. First, the risk of lung cancer is elevated in both those with and without radiological signs of silicosis,[7] and the effect of smoking is likely multiplicative[8] (see Figure 1). With regard to histological type, some studies have suggested an increased risk of all types of lung cancer,[8] while others have reported a strong association with small and squamous cell carcinomas[9] – subtypes that are less responsive to therapy than adenocarcinomas.[10]

As a result of relatively recent advances in lung cancer management, the outlook has shifted from one of nihilism to cautious optimism.[1] Subsequent to research conducted in the USA that showed that screening with low-dose computed tomography (LDCT) substantially reduced lung cancer mortality,[11] programmes targeted at current and former smokers have been widely instituted in well-resourced settings. There are no official screening programmes for lung cancer in South Africa. However, the South African Thoracic Society made broadly similar recommendations in 2019 with pointers to guide interpretation,[12] given the high local prevalence of tuberculosis. With regard to treatment, molecular profiling of tumours, undertaken in sophisticated pathology laboratories, is resulting in targeted, individually tailored therapy.[10]

There are several important implications for the management of silica-exposed populations in South Africa. Chest radiographs are the most widely used modality for silicosis diagnosis – but they not only miss half the cases of pulmonary silicosis using autopsy as the gold standard,[13] but also do not meet the requirements for lung cancer screening.[4] Studies are necessary to clarify the efficacy of LDCT screening in populations in which silicotuberculosis is not infrequent. Research directed at treatment should include a focus on the cells and genes activated by silica exposure to identify potential therapeutic targets. Primary prevention should aim not only to reduce exposure to silica, but also carcinogens, particular tobacco smoke. For workers with lung cancer, clear criteria for compensation need to be established. Finally, research is needed to evaluate the burden of silica-associated lung cancer in both mining and non-mining populations.

Risk is elevated in both silicotics and non-silicotics[7]

	SMR	95% CI
Silicotics	2.32	1.91–2.81
Non-silicotics	1.78	1.07–2.96

For the same silica dose, the cancer risk is higher in indivduals with radiological silicosis.

Risk of smoking is at least additive and likely multiplicative[8]

Exposure status	OR[7]	95% CI
Never smoker and never silica	1.00	
Never smoker and ever silica	1.02	0.87–1.19
Ever smoker and never silica	6.37	5.91–6.87
Ever smoker and ever silica	8.72	8.00–9.52

Figure 1. Silica dust exposure risks for lung cancer

REFERENCES

1. Siegel RL, Miller KD, Wagle NS, Jemal A. Cancer statistics, 2023. CA Cancer J Clin. 2023 Jan; 73(1):17-48. doi: 10.3322/caac.21763. doi: 10.3322/caac.21763.
2. Cocco P. Lung cancer and occupation. In: Feary J, Suojalehto H, Cullinan P, eds. Occupational and Environmental Lung Disease (ERS Monograph). Sheffield: European Respiratory Society; 2020. pp. 252–265.
3. International Agency for Research on Cancer. IARC monographs on the evaluation of carcinogenic risks to humans. Vol 68. Silica, some silicates, coal dust and para-aramid fibrils. Lyon: IARC; 1997. Available from: https://monographs.iarc.fr/wp-content/uploads/2018/06/mono68.pdf (accessed 7 August 2023).
4. Sato T, Shimosato T, Klinman DM. Silicosis and lung cancer: current perspectives. Lung Cancer (Auckl). 2018; 9:91-101. doi: 10.2147/LCTT.S156376.
5. IARC Working Group on the Evaluation of Carcinogenic Risks to Humans. Arsenic, metals, fibres, and dusts. IARC Monographs on the Evaluation of Carcinogenic Risks to Humans. 2012; 100(Pt C):11-465. Available from: https://europepmc.org/article/NBK/nbk304375.
6. United States. Occupational Health and Safety Administration. Occupational Exposure to Respirable Crystalline Silica; Final Rule. FR Doc No: 2016-04800. Federal Register. 2016; 81(58):16285-16890. Available from: https://www.govinfo.gov/content/pkg/FR-2016-03-25/pdf/2016-04800.pdf (accessed 7 August 2023).
7. Poinen-Rughooputh S, Rughooputh MS, Guo Y, Rong Y, Chen W. Occupational exposure to silica dust and risk of lung cancer: an updated meta-analysis of epidemiological studies. BMC Public Health. 2016; 16(1):1137. doi: 10.1186/s12889-016-3791-5.
8. Ge C, Peters S, Olsson A, Portengen L, Schüz J, Almansa J, et al. Respirable crystalline silica exposure, smoking, and lung cancer subtype risks. A pooled analysis of case-control studies. Am J Respir Crit Care Med. 2020; 202(3):412-421. doi: 10.1164/rccm.201910-1926OC.
9. Zhou Y, Zhang W, Wu D, Fan Y. The effect of silica exposure on the risk of lung cancer: A meta-analysis. J Biochem Mol Toxicol. 2023; 37(4):e23287. doi: 10.1002/jbt.23287.
10. Lindeman NI, Cagle PT, Aisner DL, Arcila ME, Beasley MB, Bernicker EH, et al. Updated molecular testing guideline for the selection of lung cancer patients for treatment with targeted tyrosine kinase inhibitors: guideline from the College of American Pathologists, the International Association for the Study of Lung Cancer, and the Association for Molecular Pathology. Arch Pathol Lab Med. 2018; 142(3):321-346. doi: 10.5858/arpa.2017-0388-CP.
11. National Lung Screening Trial Research Team. Reduced lung-cancer mortality with low-dose computed tomographic screening. N Engl J Med. 2011; 365:395-409. doi: 10.1056/NEJMoa1102873.
12. Koegelenberg CFN, Dorfman S, Schewitz I, Richards GA, Maasdorp S, Smith C, et al. South African Thoracic Society. Recommendations for lung cancer screening in Southern Africa. J Thorac Dis. 2019; 11(9):3696-3703. doi: 10.21037/jtd.2019.08.66.
13. Hnizdo E, Murray J, Klempman S. Lung cancer in relation to exposure to silica dust, silicosis and uranium production in South African gold miners. Thorax. 1997; 52(3):271-275. doi: 10.1136/thx.52.3.271.

THEME 2: SILICOSIS ELIMINATION PROGRAMMES

Chaired by Dr Vanessa Govender, Director: Masakhane Health, South Africa

Dr Meckie Achayo from MKUTA in Tanzania [A Response to Fight TB and HIV/AIDS in Tanzania], who is a Wits graduate, provided data about 'Silicosis elimination programmes in the non-mining industry – a global context'; he joined virtually from Dar es Salaam, Tanzania.

Silicosis elimination programmes in the non-mining sector: a global context

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Background

Elimination of silicosis has been on the global agenda since the 1930s. In 1995, the ILO/WHO Joint Committee on Occupational Health recommended countries to place elimination of silicosis high on their priority lists.[1] In the same year, the Global Programme for the Elimination of Silicosis (GPES) was initiated. Following this, countries such as Brazil, China, Chile, India, Thailand, Vietnam, and South Africa joined the programme and formed their own National Programmes for the Elimination of Silicosis (NPESs).[1]

Methods

A scoping review was conducted to explore silicosis elimination programmes in the non-mining industry, globally, through an extensive search for both scientific and grey literature published from 1995 to 2021. Of the 1 277 articles identified, 10 met the eligibility criteria (two journal papers, three reports, four presentations, and one fact sheet). Eight countries were represented: the Americas (Brazil, Chile, Peru), Asia (Vietnam, Thailand, China), Africa (South Africa), and Europe (Turkey).

Findings

Countries used four key strategies to implement their NPES activities:

1. Intra- and inter-national collaborations
2. Capacity building through training
3. Policies, guidelines, and silicosis prevention measures
4. Occupational health surveillance and prevalence studies

Intranational collaborations were initiated among government ministries as well as with occupational health and safety-related organisations. The Americas Silicosis Initiative (initiated in 2005) and the Work and Health in Southern Africa (WAHSA) programmes are good examples of regional collaborations.[2,3] In countries such as Brazil, Chile, and Peru, training was conducted on dust control technologies (control banding) and diagnosis of silicosis using the ILO's International Classification of Radiographs of Pneumoconioses.[2]

To ensure that prevention measures were adhered to, countries developed policies through their NPES. For example, Brazil banned the use of sand as a blasting agent and dry finishing of ornamental stones.[4] Chile developed a risk assessment guidance tool, the 'Qualitative Evaluation of the Risk of Exposure to Silica', for assessment and control of silica exposures in four high-risk industries: aggregate crushing, ceramics, tile making, and dental laboratories.[5] Surveillance and prevalence studies were identified as essential for the monitoring of trends of several indicators (e.g. the proportion of workers using protective personal equipment (PPE)).[6,7]

Challenges

Several challenges hindered progress of NPES activities across different countries. Some of these included:[1]

1. Insufficient political will
2. Insufficient access to information and knowledge
3. Shortage and/or inadequacy of human resources
4. Legislation shortcomings:
   a. Poor enforcement
   b. More focus on fact finding than problem solving
5. Shortage or inadequate allocation or re-allocation of financial resources
6. Insufficient primary prevention measures

Insights

There is a gap in reporting progress of the NPES and GPES, which may indicate a loss of momentum of global efforts to eliminate silicosis. While experiences from Switzerland, Germany, Finland, and France indicate that silicosis incidence can be reduced, there has been a resurgence in some countries e.g. Australia and Sweden.[8] Vigilance through surveillance is therefore needed to respond to new exposures and epidemics.

Food for thought

- Is the WHO and ILO target to eliminate silicosis by 2030 achievable?
- What are the best silicosis elimination strategies for the African non-mining industry, including the informal sector?
- What lessons can the non-mining industry draw from the mining industry?
- How can we translate strategies/experiences from countries such as Belgium and Switzerland to suit the southern African context?

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REFERENCES

1. World Health Organization. The Global Occupational Health Network: Elimination of Silicosis; 2007:1-20. Available from: https://studylib.net/doc/13783560/gohnet-the-global-occupational-health-network (accessed 8 August 2023).
2. Pan American Health Organization. Fact sheet – Elimination of Silicosis: Americas Initiative; 2009. Available from: https://www.paho.org/en/documents/fact-sheet-elimination-silicosis-americas-initiative (accessed 8 August 2023).
3. Hogstedt C, Elgstrand K, Ryan A, Naidoo RN, Rees D, Chitambo A, et al. The Work and Health in Southern Africa (WAHSA) Programme – overall experiences and the way forward. Occup Health Southern Afr. 2009;15(6a–WAHSA Special Issue):2-6. Available from: http://occhealth.co.za/index.php?p=issue&i=187 (accessed 8 August 2023).
4. International Labour Organization. National Programme on Elimination of Silicosis – Brazil; 2005. Available from: https://www.ilo.org/global/topics/safety-and-health-at-work/events-training/events-meetings/WCMS_110470/lang--en/index.htm (accessed 8 August 2023).
5. National Institute for Occupational Safety and Health, Finnish Institute of Occupational Health. Improving workers' health across the globe: advancing the global plan of action for workers' health. Cincinnati, OH: Department of Health and Human Services, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, DHHS (NIOSH). Publication No. 2016-118; 2016. Available from: https://www.cdc.gov/niosh/docs/2016-118/default.html (accessed 8 August 2023).
6. International Labour Organization. Silicosis Elimination Program in Thailand; 2005. Available from: https://www.ilo.org/wcmsp5/groups/public/---ed_protect/---protrav/---safework/documents/presentation/wcms_110488.pdf (accessed 8 August 2023).
7. International Labour Organization. Evaluation on five years of implementing the silicosis prevention project in Vietnam (1999-2003); 2005. Available from: https://www.ilo.org/safework/info/WCMS_110490/lang--en/index.htm (accessed 8 August 2023).
8. Fedotov IA. The ILO/WHO Global Programme for the Elimination of Silicosis (GPES). African Newsletter on Occupational Health and Safety; 2005; 15(3):56-58.

Moving abroad, Prof. Anna-Carin Olin (University of Gothenburg), who was visiting South Africa for the SASUF Research and Innovation Week, described the current situation with regard to silica dust exposure in Sweden.

Silica exposure in Sweden – past and current perspectives

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The exposure pattern to silica dust has changed dramatically in Sweden during the last decade. The mining sector has changed from having more than 1 000 small mines back in history; the number is now down to 15. Quarrying also used to be a big industry, employing more than 7 000 workers, but has decreased in size and currently employs around 1 200 workers. Much of the stonework is now exported, mainly to China, where poor working conditions have been described. Initiatives have been taken to strengthen procurements to include standards for the work environment for imported stone, but many anomalies still probably exist.

During the 1960s, there was a large campaign to reduce exposure to quartz in Swedish mines. This was as a result of analysis of data from the national silicosis register, which revealed that more than 4 500 workers – mainly employed in quarrying – had developed silicosis. The campaign was successful: exposure levels were dramatically reduced and morbidity decreased. Subsequently, there has been a gradual reduction in Sweden's preventive measures. The silicosis register was stopped in 1988, and legislation prescribing obligatory quartz measurements in specified workplaces was abandoned in 2019. This has resulted in a lack of knowledge about the current exposure situation in Swedish workplaces and an ignorance of the problems associated with silica exposure. Sectors where exposure to silica dust still seems to be a problem are construction and concrete manufacturing, which employ many workers.

Strong initiatives, from researchers in occupational and environmental departments in Sweden, have been taken to lower the current OEL for quartz from 0.1 to 0.05 or 0.025 mg/m^3, but efforts have been fruitless so far.

Moving back to South Africa, Jabulile Mhlophe (Department of Employment and Labour) gave an update on the silica dust and silicosis milestones.

South Africa's National Programme for the Elimination of Silicosis – where are we?

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In 2004, the Department of Employment and Labour initiated the National Programme for the Elimination of Silicosis. Two years later, in 2006, the National Working Group (NWG) and Provincial Working Groups (PWGs) were established to manage the programme, but lack of baseline data on the prevalence of silicosis in South Africa made it difficult for the working groups to achieve their mandates.

In 2009, the Council for Scientific and Industrial Research (CSIR) was commissioned to conduct a literature review on silica dust exposures of workers in the non-mining industry, especially in South Africa. The review revealed that there was no information regarding the most frequently recorded occupations where silicosis was listed as a contributory cause of death in the South African non-mining sector, although, from 1999 to 2004, the Occupational Medicine Clinic at the National Institute for Occupational Health (NIOH) diagnosed silicosis in workers from foundries and potteries, and from the refractory, engineering, stone crushing, construction, chemical, and glass industries.[1] The authors also stated that *"Lack of a comprehensive programme on worker exposure to silica dust and a commitment from the management on this type of programme is a problem in the non-mining industries".*[1] The same group collected 300 personal dust samples, using gravimetric dust sampling in six non-mining industries in Gauteng province. Silica dust exposures in the sandstone, ceramics, refractory, and foundry exceeded the OEL of 0.1mg/m^3.[2]

In the same year (2010), the Department of Employment and Labour embarked on an inspection of 208 silica dust producing companies in all the provinces to determine compliance with silica dust levels in terms of the Occupational Health and Safety Act of 1993. Only 54 companies (26%) were found to be compliant.[3]

In October 2020, the CSIR and the Wits Health Consortium were funded by the Department of Employment and Labour to conduct a study on the prevalence of silicosis in the non-mining sectors in South Africa, which is underway. The objectives of the study are:

1. To determine the prevalence of (and the number of workers diagnosed with) silicosis across industries from 2012 to 2018
2. To establish trends in the number of deaths from silica-related diseases per industry from 2012 to 2018
3. To develop a strategy and occupational health programmes that should be put in place to reduce exposure to respirable silica dust and to eliminate silicosis in South Africa by 2030

REFERENCES

1. Khoza NN, Grové T, Moraba M, Schutte PC. Level of exposure of workers to silica dust in the non-mining sectors in South Africa. Literature review. Centre for Mining Innovation, CSIR; 2009. Available from: https://www.labour.gov.za/DocumentCenter/Research%20Documents/SEIAS%20Reports/Level%20of%20exposure%20of%20workers%20to%20Silica%20dust%20in%20the%20non%20mining%20sectors%20in%20South%20Africa.pdf (accessed 21 August 2023).
2. Khoza N, Grové T. Determining the extent of exposure to silica dust of the workers in the non-mining sectors in South Africa: an exploratory study. Centre for Mining Innovation, CSIR; 2010. Available from: https://www.labour.gov.za/DocumentCenter/Research%20Documents/SEIAS%20Reports/Determining%20the%20extent%20of%20exposure%20to%20silica%20dust%20of%20workers%20in%20the%20non%20mining%20sectors%20in%20South%20Africa.pdf (accessed 21 August 2023).
3. Annual Report of the Department of Labour. Section 2. Information on predetermined objectives. Dept. of Labour; 2011. Available from: https://www.labour.gov.za/DocumentCenter/Reports/Annual%20Reports/Departmental%20Annual%20Reports/2011/PFMA%20Report_2011part2.pdf (accessed 22 August 2023).

Jabulile Mphlope was followed by Dr Thuthula Balfour (Minerals Council South Africa), who brought the audience up to date on the mining industry's progress on silicosis elimination.

Silicosis elimination in the South African mining industry

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The elimination of silicosis remains a priority in the South African mining industry as evidenced by the number of cases that are still reported annually. Although cases of silicosis declined by 86.5% from 2008 to 2021, there were still 240 cases reported in 2021. This is a significantly high number.

It is ironic that the first international conference on silicosis was convened by the ILO and the Transvaal Chamber of Mines, and paved the way to the adoption of a 1934 ILO convention that recognised silicosis as an occupational disease.

Over the years, South Africa has led research on silicosis. In a seminal study conducted in 2004, Gavin Churchyard et al. found an 18.3–19.9% prevalence of silicosis in 520 gold miners with mean service of 21.8 years, at quartz levels of 0.053 mg/m^3. With this and other evidence, better performance regarding the elimination of silicosis in the country would have been expected.

This irony is well articulated by Jock McCulloch in his book, *South Africa's Gold Mines and the Politics of Silicosis*, in which he states: *"The history of silicosis in South Africa is filled with paradoxes. The Rand mines were the first in the world to invest heavily in dust extraction technologies and instruments, such as the konimeter, to reduce risk. South Africa was the first state to recognise silicosis and tuberculosis as occupational diseases, and the gold mines were the first to use radiography to screen workers. Yet South Africa was unsuccessful in making the mines safe or in providing adequate compensation. The major paradox is between the intensity of public debate about silicosis and the invisibility of the disease burden."*[1]

There have been concerted industry initiatives from both the Mine Health and Safety Council (MHSC) and the Minerals Council South Africa to eliminate silicosis and other pneumoconioses. In 2003, through the MHSC, the industry adopted milestones, which were re-emphasised in 2013:[2]

- By December 2024, 95% of all exposure measurement results will be below the milestone level for respirable crystalline silica (RCS) of 0.05 mg/m^3.
- By December 2024, 95% of all exposure measurement results will be below the milestone level for coal dust respirable particulate of 1.5 mg/m^3 (< 5% crystalline silica).
- Using current diagnostic techniques, no new cases of silicosis, pneumoconiosis, or coal worker's pneumoconiosis will occur amongst previously unexposed individuals who joined the industry in 2009.

In 2007, the Minerals Council developed the Mining Occupational Safety and Health (MOSH) leading practice adoption system and rolled out several leading practices in mines, such as the fogger dust suppression system, footwall and sidewall treatment, scraper winch covers, multistage filtration system, and continuous real-time monitoring of airborne pollutants. The Minerals Council also established a milestone reporting system in 2015 to monitor progress towards achieving the milestones.

Consequently, the mining industry is on target to meet the milestone on RCS. In 2022, 6.3% of exposures were higher than 0.05 mg/m^3, lower than the aspirational target of 7%. A few cases of silicosis have, however, been diagnosed in novices who joined the industry after 2009. This is a cause for concern as it indicates previous high levels of exposures.

In conclusion, South Africa has the knowledge and ability to eliminate silicosis and all efforts should be directed at this task.

REFERENCES

1. McCulloch J. South Africa's Gold Mines and the Politics of Silicosis. Martlesham, Suffolk: Boydell & Brewer; 2012. Available from: https://www.jstor.org/stable/10.7722/j.ctt1x736n (accessed 14 August 2023).
2. South African Government. Mineral Resources on Occupational Health and Safety summit; 2016. Available from: https://www.gov.za/speeches/mine-health-and-safety-19-nov-2016-0000 (accessed 14 August 2023).

THEME 3: OCCUPATIONAL EXPOSURE LIMITS

Chaired by Prof. Cas Badenhorst, Anglo American and North-West University, South Africa

More technical presentations followed, starting with an online discussion by Prof. Derk Brouwer (University of the Witwatersrand), who pertinently asked the question: *"Should the current statutory OEL for silica be reduced to 0.05 mg/m^3?"* This question was further debated by Prof. Cas Badenhorst (North-West University) as he explained the challenges in reducing the statutory RCS OEL in the SA mining industry.

Will reducing the statutory OEL for silica to 0.05 mg/m^3 prevent new silicosis cases?

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OELs aim to protect workers from developing diseases due to a working lifetime of exposure to hazardous substances. Such limit values can be derived from toxicological animal studies where an outcome or point of departure is used as a starting point for extrapolation to human exposure, or from epidemiological studies. The first type of OEL assumes a 'standard worker and scenario', such as a 70 kg male performing light activities for 40 years for 40 hours per week. The second type of OEL uses (aggregated lifetime) exposure-disease outcome relationships to calculate a cut-off point as a limit value concentration. However, there is always a residual risk – partly due to the uncertainties associated with the methods. This means that exposure to the substance at the OEL concentration will never protect all workers from adverse health effects. For example, for RCS dust, the US Occupational Safety and Health Agency (OHSA) states that the residual risk for silicosis at an OEL of 0.05 mg/m^3 ranges from 0.7% to 4.3%.[1] Similarly, the EU Scientific Committee on Occupational Exposure Limits (SCOEL) assumes a silicosis prevalence of < 5% at that OEL concentration.[2]

In addition to the actual value of the OEL, there are statistical considerations regarding compliance testing. Presently, it is not feasible to measure exposures for every worker each day. In practice, the time-weighted average concentration over eight hours (TWA-8h) of a 'sample' of workers is measured periodically. This dataset is used to make inferences about the total population of workers. Consensus exists that a lognormal distribution can best describe the variation in concentrations of pollutants in workplaces. Moreover, the current approach uses the 95th percentile of the estimated distribution of concentrations for the 'population' as a test criterion. Taking this into account, it is essential to know how, in actual workplace practice, compliance with the OEL can ensure that the RCS TWA-8h concentrations for all of the workers does not exceed 0.05 mg/m^3. For a hypothetical dataset, 21 TWA-8h concentrations range from 0.023 to 0.05 mg/m^3 with a geometric mean (GM) of 0.035 mg/m^3 and a relatively low geometric standard deviation (GSD) of 1.27. For this dataset (with no data point exceeding 0.05 mg/m^3), the point estimate of the 95th percentile of the population from which this sample is drawn is 0.054 mg/m^3, and the probability of exceedance of 0.05 mg/m^3 is 81.7%.

In conclusion, the risk of developing silicosis will never be reduced to zero, due to the inherent variability of exposure and the uncertainty associated with both the OEL and its compliance testing (95th percentile of a sample). A 5% exceedance of an OEL is accepted, whereas an RCS OEL of 0.05 mg/m^3 implicitly accepts a 'residual' risk. Therefore, silicosis cannot be eliminated by a statutory OEL of 0.05 mg/m^3 (or even a lower value). However, the prevalence can be reduced to a societal 'accepted risk level', although this will only work (as long as every worker is not equipped with a real-time monitor every day) if the 95th percentile of the TWA-8h concentration distribution of each measurement campaign (sample) is below this threshold limit value.

REFERENCES

1. United States. Occupational Safety and Health Administration, Department of Labor. Occupational exposure to respirable crystalline silica – Literature review and preliminary risk assessment, OSHA 2010-0034; 2010. Available from: https://www.federalregister.gov/documents/2016/03/25/2016-04800/occupational-exposure-to-respirable-crystalline-silica (accessed 9 August 2023).
2. Recommendations from the Scientific Committee on Occupational Exposure Limits for Silica, Crystalline (respirable dust). SCOEL/SUM/94. European Commission; 2003.

Challenges in reducing the statutory RCS OEL in the SA mining industry

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OELs play a crucial role in assessing workplace exposures and their potential health risks. Ever since Kobert introduced the table of acute exposure limits in 1912,[1] numerous organisations worldwide have contributed to the global effort of establishing OELs. These limits serve as invaluable tools in understanding and managing occupational hazards.

The widespread adoption of OELs has led to a complex landscape of guidelines, influenced by various factors and organisations. The process of developing and setting OELs involves evaluating scientific data on health impacts, which can differ between bodies and jurisdictions. One significant factor contributing to variations in OELs is the consideration of feasibility, with health-based OELs being more

Table 1. Early history of institutional OEL development *

Decade first published	Type of OEL
1910s	US and South African limits (for crystalline silica/quartz only)
1920s	US Bureau of Mines exposure limits
	International Critical Tables
1930s	German exposure limits
	USSR Ministry of Labour MACs
1940s	American Conference of Governmental Industrial Hygienists (ACGIH) maximum allowable concentrations of atmospheric contaminants (preceding threshold limit values)
	American National Standards Institute standards
1950s	People's Republic of China's Provisional Hygienic Standards for the Design of Industrial Premises
1970s	US Occupational Safety and Health Administration (OSHA) permissible exposure limits (PELs)
	National Institute for Occupational Safety and Health (NIOSH) recommended exposure limits (RELs)
	Nordic Expert Group (NEG) for Criteria Documentation of Health Risks from Chemicals
	Deutsche Forschungsgemeinschaft (DFG) *Maximale Arbeitsplatz-Konzentration* (MAKs)
1980s	American Industrial Hygiene Association (AIHA) workplace environmental exposure limits (WEELs)
1990s	European Scientific Experts Group (now Scientific Committee on Occupational Exposure Limits [SCOEL]) binding occupational exposure limit values (BOELVs) and indicative occupational exposure limit values (IOELVs)

*Source: Deveau et al. 2015[2]

precautionary and regulatory-adjusted OELs incorporating non-health factors such as economics and technical feasibility.

These differences in OELs are seen not only between health-based and regulatory-adjusted values but also across jurisdictions with varying socioeconomic contexts and technological capabilities. The economic feasibility of reducing OELs for substances such as silica includes benefits for governments and employers. Governments can experience lower costs in medical treatment and tests, reduced insurance payments, and fewer incident investigations. Employers benefit from reduced costs associated with illnesses, fatalities, insurance payments, replacement workers, and training.

The economic feasibility of reducing OELs also considers costs associated with implementing engineering and administrative controls, conducting more frequent incident investigations, adopting new equipment and technologies, and complying with changes in codes of practice.[3] Additionally, there may be indirect costs related to productivity loss due to process elimination or substitution techniques, as well as the potential for complete work stoppages.

Overall, the economic feasibility of reducing OELs requires a comprehensive assessment of costs and benefits, considering the specific context and capabilities of each jurisdiction.

REFERENCES

1. Kobert R. The smallest amounts of noxious industrial gases which are toxic and the amounts which may perhaps be endured. Comp Pract Toxicol. 1912; 5:45.

2. Deveau M, Chen CP, Johanson G, Krewski D, Maier A, Niven KJ, et al. The global landscape of occupational exposure limits – implementation of harmonization principles to guide limit selection. J Occup Environ Hyg. 2015; 12 (sup1):S127-S144. doi: 10.1080/15459624.2015.1060327.

3. Claassen N, Du Plessis JL, Van der Walt J, Preis E, Girdler-Brown B, Ker-Fox J, et al. Review of the current airborne exposure limits as listed in Schedule 22.9(A). CoE 180607. Johannesburg: Mine Health and Safety Council; 2021. Available from: https://mhsc.org.za/wp-content/uploads/2022/05/CoE-180607-Milestone-5-Integrated-Report_Final.pdf (accessed 25 August 2023).

Mr Vijay Nundlall (Sibanye-Stillwater) expanded on Prof. Badenhorst's talk, by discussing current practices to reduce silica dust exposure in the South African mining industry.

Current practices to reduce dust exposure in the South African mining industry

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Vijay Nundlall focused on current practices in the South African gold mining industry to reduce exposure to silica dust. He described the processes that generate silica dust, and how the transportation of the broken rock influences where silica settles and how it is transported via the mine ventilation system. Some of the key interventions discussed were footwall treatment to keep dust trapped on the footwall, and dust filtration systems to remove silica from the ambient air and during rock tipping (transportation) processes. Watering down and the tools available, including automated spray systems, were also elaborated upon. The use of real-time dust monitors for trouble shooting problem areas, and for re-engineering work processes, was highlighted. Vijay emphasised the importance of awareness and education of employees about the dangers of silica dust, the control measures in place, and what employees can individually do to reduce their exposure to silica dust. He concluded with a description of internal dust management awards – created to influence behaviour – and the trends in silica dust exposure reduction over time with all interventions in place.

Staying in the mining industry, Dr Dipalesa Mokoboto (Department of Mineral Resources and Energy) asked, and responded to the question: *"Have the silicosis milestones for SA mining been achieved?"*

Summary on achievement of silicosis milestone in the South African mining industry

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The Mine Health and Safety Inspectorate (MHSI), and Mine Health and Safety Council (MHSC) – an entity of the MHSI – were both established in terms of the Mine Health and Safety Act (MHSA) No. 29 of 1996 as amended. Occupational lung diseases (OLDs) such as silicosis and tuberculosis are reported to the MHSI in line with the requirements of the MHSA. The MHSC, on the other hand, is responsible for setting milestones through its tripartite structures, during summits. Milestones on elimination of OLDs were set at a health and safety summit in 2014. The MHSC is responsible for monitoring and reporting on progress made on the milestones.

The milestones covered occupational hygiene and occupational medicine:[1]

1. By December 2024, 95% of all exposure measurement results will be below the milestone level for RCS of 0.05 mg/m^3 (these results are individual readings and not average results).
2. Using present diagnostic techniques, no new cases of silicosis, pneumoconiosis, or coal worker's pneumoconiosis will occur amongst previously unexposed individuals ('previously unexposed individuals' were regarded as those unexposed to mining dust prior to December 2008, i.e. persons entering the industry in 2009).

In terms of monitoring the occupational hygiene milestone to determine if 95% of the RCS measurements were below 0.05 mg/m^3, there was an improvement from 82.75% in 2014 to 91.1% in 2020. Thus, the milestone has not yet been reached; however, it is anticipated that 95% of all RCS measurements will be below 0.05 mg/m^3 by 2024.

For the occupational medicine milestone, six cases of silicosis were reported to the MHSI, which were confirmed as novice workers. The Medical Bureau for Occupational Diseases (MBOD) certified two of the cases as silicosis. Two additional cases were further investigated by the Minerals Council South Africa and silicosis was excluded in both. One was found to have miliary TB and the other had community acquired pneumonia.

A holistic review of the remaining two novice cases needs to be conducted to verify the diagnosis of silicosis. The validity of the diagnosis is influenced by the experience of the reader of the CXR, and the results of other examinations. Although the silicosis milestones for the South African mining industry have not yet been met, great achievements have been made.

REFERENCE

1. Mine Health and Safety Council. 2014 Occupational Health and Safety Summit Milestones. Available from: https://mhsc.org.za/sites/default/files/public/research_documents/2014%20OHS%20Summit%20Milestones.pdf (accessed 14 August 2023).

THEME 4: DETECTION AND MONITORING OF SILICA-RELATED DISEASES

Chaired by Dr Thuthula Balfour, Minerals Council South Africa

Three presentations were delivered under this theme. Dr Zodwa Ndlovu discussed the challenges and opportunities of the national silicosis surveillance programme. Prof. Emeritus David Rees from the Wits School of Public Health and Prof. Anna-Carin Olin from the University of Gothenburg spoke about the use of biomarkers in the diagnosis of lung fibrosis and silicosis.

National surveillance of silica-exposed workers – challenges and opportunities

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The concept of surveillance is well established. It is a systematic and ongoing process – not a once-off event. Occupational surveillance systems collect data on exposure measurements, disease, and demographic and occupational characteristics. Nowadays, these data are usually available in computerised, administrative databases. The data are analysed, interpreted, and disseminated to stakeholders for the prevention and control of adverse exposures and occupational diseases. Occupational disease surveillance is useful for the detection of exposures and disease, the monitoring of trends, the identification of workers who are at risk of developing disease, the provision of alerts or warnings of high risk, the provision of information to evaluate or monitor the effects on interventions, and for stimulating research.

The use of routine, administrative, compensation data for surveillance was illustrated using the example of the National Institute for Occupational Health's (NIOH's) Pathology Automation System database (PATHAUT). The database contains diagnoses of OLDs, including silicosis and TB, in deceased South African miners. Although the data are collected for autopsy compensation, they are used for OLD surveillance. The PATHAUT database is the only source of long-term data for OLD surveillance in South African mine workers. The surveillance information is contained in annual reports dating back to 1975, which are available on the NIOH website (https://www.nioh.ac.za/pathology-division-surveillance-reports/). The PATHAUT data have also been used extensively for research. Studies have described the magnitude and factors associated with silicosis trends[1,2] and alerted the industry to the risk of silicosis in platinum miners and female gold miners.[3,4]

There are other institutions that collect silicosis disease and silica exposure data that could be used to establish a national silicosis surveillance system for both the mining and non-mining industries. This will require collaboration among the relevant stakeholders. However, experience has shown that sustained commitment determines the success or failure of a surveillance system. Therefore, long-term commitment to provide adequate human and financial resources is key to the development of a sustainable national surveillance system.

REFERENCES

1. Nelson G, Girdler-Brown B, Ndlovu N, Murray J. Three decades of silicosis: disease trends at autopsy in South African gold miners. Environ Health Perspect. 2010; 118:421-426.
2. Nelson G, Murray J. Silicosis at autopsy in platinum mine workers. Occup Med (Lond). 2013; 63:196-202.
3. Ndlovu N, Nelson G, Vorajee N, Murray J. 38 years of autopsy findings in South African mine workers. Am J Ind Med. 2016; 59:307-314.
4. Ndlovu N, Richards G, Vorajee N, Murray J. Silicosis and pulmonary tuberculosis in female South African miners. Occup Med (Lond). 2019; 69:272-278.

Biomarkers for the detection of pathophysiological responses to silica

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Medical surveillance of workers for silicosis – fibrosis of the lung due to RCS – is typically done using CXRs. This method is imperfect because subradiological silicosis (disease unapparent on the X-ray) is common and, once apparent, shows incurable and established disease. Consequently, markers of pathophysiological responses to silica using methods other than CXRs have been of interest for decades.[1] These markers are broadly termed biomarkers or screening tests; meaning indicators of excessive exposure or the body's negative reaction to the exposure, or tests that provide a presumptive diagnosis of disease.

Some of the potential benefits of these tests are:

1. Biomonitoring to identify harmful RCS exposure

Measuring RCS is expensive and requires sophisticated equipment. An affordable biomarker that directs RCS measurement to worksites or jobs with potential over-exposure would be useful.

2. Screening for silicosis

CXRs and the competence to read them are limited in some countries with large numbers of RCS-exposed individuals. A simple screening test that identified individuals who require more sophisticated evaluation would reserve scarce resources for those needing them.

3. Diagnosis of silicosis

Subradiological silicosis, including early disease, would be diagnosable if a sensitive and specific test for the pneumoconiosis was available.

4. Triage for further investigation

A test that excluded silicosis (high negative predictive value) among exposed individuals would enable selection of only those with a risk of the disease to undergo chest imaging. In resource-scarce settings (informal mining, for instance) this targeting would be beneficial.

5. Identifying susceptible individuals

Only a proportion RCS-exposed people develop silicosis. Identifying those susceptible might stimulate interventions to prevent disease development.

All biomarkers and screening tests investigated so far have flaws[2] and there are reservations about their use. Nevertheless, their potential benefits are substantial and the search for reliable tests should continue.

REFERENCES

1. Gulumian M, Borm PJA, Vallyathan, Castranova V, Donaldson K, Nelson G, et al. Mechanistically identified suitable biomarkers of exposure, effect, and susceptibility for silicosis and coal-worker's pneumoconiosis: a comprehensive review. J Toxicol Environ Health. 2006; Part B 9: 357-395. doi: 10.1080/15287390500196537.

2. Austin EK, James C,Tessier J. Early detection methods for silicosis in Australia and internationally: a review of the literature. Int J Environ Res Public Health. 2021; 18:8123. doi: 10.3390/ijerph18158123.

Can we detect early adverse effects of inhaled respirable silica?

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Silica dust exposure is deposited in the very distal part of the small airways (i.e. airways < 2 mm in diameter). Here, silica induces a low-grade inflammatory response as the normal defence system cannot handle the long quartz structures. Long-standing inflammatory changes may slowly develop into silicosis in susceptible individuals, or into cancer.

The small airways have long been known as 'the silent zone of the lung'. This is based on the fact that early pathological changes are asymptomatic and, moreover, are not detected by routine clinical measures such as spirometry or CXRs. This explains why silicosis often goes undiagnosed, as shown in several studies, including those using mine workers' autopsy data in South Africa.[1]

This illustrates the need for better methods to identify early silicosis, i.e. secondary prevention. This need must, however, not detract focus from actions to reduce exposure and thus prevent the disease.

A method has been developed and validated in which a small amount of fluid is retrieved from the airway linings in the lung, in exhaled air: the PExA method™ (particles in exhaled air: www.pexa.se). Pathological processes in the small airways of the lung have been shown to alter the composition of the lining fluid. Hence, the sample provides a valid source of biomarkers for diseases affecting the small airways. Using the PExA method, a number of protein biomarkers have been identified for smoking-induced lung disease and, in post-COVID-19 patients, a profile of surfactant lipids has been identified that is suggestive of the development of lung fibrosis. More recently, preliminary findings in tunnel workers exposed to silica dust show that their lipid profiles in PExA samples are altered, proposing a 'pro-fibrotic' profile. As the PExA method is non-invasive, it is suitable for screening for the detection of early disease.

REFERENCE

1. Field N, Murray J, Wong ML, Dowdeswell R, Dudumayo N, Rametsi L, et al. Missed opportunities in TB diagnosis: a TB process-based performance review tool to evaluate and improve clinical care. BMC Public Health. 2011; 11:127. doi: 10.1186/1471-2458-11-127.

KEY POINTS FROM THE WORKSHOP

1. Silicosis is a problem in the mining industry in South Africa and is diagnosed in workers from other industries.
2. Although good progress has been made in reducing silica dust exposures in the gold mines, silica dust-related diseases persist.
3. Silica dust levels have been reduced in the South African gold mining industry, with the help of dust suppression and other controls, but not completely.
4. The silicosis milestones, set in 2014, have not yet been met.
5. There is need for comprehensive silicosis surveillance to monitor the trends and distribution of new cases in South Africa – in both workers and former workers – to assess progress towards silicosis elimination targets.
6. The target 0.05 mg/m^3 silica dust concentration is unlikely to provide complete protection against the development of silicosis, which means that the milestone of zero cases of silicosis will not be met.
7. Real-time monitoring of silica dust exposure is needed.
8. The setting of OELs is complicated and lowering the current OEL to 0.05 mg/m^3 will introduce complexities that need to be considered.
9. In Sweden, current silica dust exposure levels are unknown due to changes in legislation, which inhibit the measurement of silica concentrations in occupational settings; silicosis rates are probably underestimated.
10. South Africa is 'ahead of the game' by performing autopsies on deceased current and ex-mine workers; Sweden has no such programme.
11. New biomarkers for the early detection of pathological effects and disease need to be investigated.

Unanswered questions

1. Is there is a need for medical surveillance in the stone and sand industries?
2. What is the relevance of tuberculin skin testing in silica-exposed individuals? Is tuberculosis preventive treatment effective for silicosis in southern Africa?
3. What RCS OEL is protective against increased tuberculosis risk?
4. Should we spend resources on lung cancer surveillance and research in silica-exposed workers?
5. How can we address silica dust exposure and silicosis in artisanal and illegal mine workers?

Quotes from the workshop

1. *"We are all swimming in the same pool. Can we learn to be life savers and prevent exposed workers from developing silicosis?"* – Jabulile Mhlophe, Department of Employment and Labour
2. *"240 cases of silicosis are 240 too many."* – Thuthula Balfour, Minerals Council South Africa
3. *"We have known about silicosis for more than 150 years… let us not take another 150 years to eliminate it."* – Gill Nelson, Wits School of Public Health
4. *"Silicosis is not the only disease caused by silica dust exposure, and the lungs are not the only organs affected."* – Gill Nelson, Wits School of Public Health

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Authors can be contacted directly for copies of their presentations