Comprehensive investigation into the use of Refractory Ceramic Fiber Material (RCFM)

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1 INTRODUCTION

After an extensive literature study, comprising various scientific articles, internet resources, manufacturing specifications and other data regarding the use of refractory ceramic fiber material (RCFM) and the possible health effects the following summary can be made.

2 CHEMICAL STRUCTURE AND COMPOSITION

RCFM is part of a group that can be broadly classified as Synthetic Vitreous Fibers (SVF). Synthetic vitreous fibers are a group of fibers that doesn't have a crystalline molecular structure such as asbestos. Instead its structure can be described as amorphous having no crystalline molecular structure[1, 2, 3 and 7].

There are two broad categories of synthetic vitreous fibers namely wools and filaments. Wools can be classified as glass wool, rock wool, slag wool and refractory ceramic fibers (RCF). They are produced from the melting and blowing or spinning of calcined kaolin clay or a combination of alumina (Al_2O_3) and silica dioxide (SiO_2)[2]. A filament consists of continuous glass filaments.

A fiber is a long slender particle. According to the World Health Organization respirable fibers are particles with lengths greater than 5 µm, a diameter of less than 3 µm and an aspect ratio (ratio of length to diameter) of ≥ 3:1. The diameter of a fiber is an important property because very thin fibers are more easily suspended in air than thick fibers, and they can be breathed in and deposited deep in the lungs. Depending on the way that they are produced, fibers can have relatively large or small diameters. Generally speaking, glass wool, rock wool, slag wool, and refractory ceramic fibers have the smallest diameters, while continuous filament glass fibers have the largest diameters[1].

RCFM belong to the vitreous aluminosilicate fiber chemical family and exhibit a melting point of 1760°C. As produced all RCF fibers are vitreous materials, which do not contain crystalline silica. **Continued exposure to elevated temperatures may cause these fibers to devitrify and become crystalline.** The first crystalline formation namely mullite begins to occur at approximately 985°C. Crystalline silica called cristobalite formation may begin at temperatures of approximately 1200°C [4].

3 PHYSICAL CHANGES IN STRUCTURE/ COMPOSITION

Alumino-silicate fiber products have exceptional heat insulation properties and thus are used especially where high temperatures are reached for example furnaces in the steel making industry. **During the exposure to extreme temperatures it is possible for refractory ceramic fibers to devitrify.** This is a process whereby the amorphous structure of the fiber is replaced by a crystalline phase. **The crystalline silica presents itself as cristobalite and mullite after prolonged periods of exposure to extremely high temperatures in the region of 1300°C.** The possibility of crystalline silica exposure should be investigated especially during operations such as the removing of used refractories, which may have been exposed to extreme temperatures[4].

4 TOXICITY

Synthetic vitreous fibers can cause irritation of the eyes and skin known as “fiberglass itch”. They can also irritate the upper respiratory tract and parts of the lung, causing sore throat, nasal congestion and cough. The health effects regarding refractory ceramic fibers have been heavily debated[1, 14].

The cytotoxicity of different mineral fibers relates in part to their dimensions, surface characteristics and chemical composition. Cytotoxic refers to the effect that fibers have on the cell membrane and its permeability. **The cancerous contribution of these fibers are related to the fact that the cell function is altered leading to damaging**

products being released such as reactive oxygen metabolites; ROM's intervene with gene expression[9, 16] and cell energy metabolism. This is why fibers can be described as "cytotoxic"[5]. **Results of several animal experiments suggest that the effects of man-made vitreous fibers (MMVFs) differ from those induced by asbestos or quartz.**

How does one assess the actual damage of the cell membrane and other implications when taking toxicity into account? In a specific study done by the National Public Health Institute, Division of Environmental Health (article 2), erythrocyte haemolysis and lactate dehydrogenase (LDH) concentrations were studied. Erythrocyte haemolysis was an indication of the effect that these fibers have on the membranes of cells and LDH release would indicate cell membrane damage and destruction of energy-rich compounds. Excessive fiber-induced cell activation may induce fibrosis, which is the malignant transformation of cells. In the study conducted in article 2, it was found that Refractory Ceramic Fibers (RCF) investigated produced reactive oxygen metabolites and some haemolytic activity[5].

What contributes to the toxicity of an inhaled fiber? Its robustness and resistance to degradation in the respiratory tract. If one investigates the chemical characteristics on a microscopic level, RCF's are placed amongst the most durable SVF's. Inhaled RCF will be deposited in the alveolar region of the lungs and also persist there longer than a less durable fiber[15]. **NIOSH therefore recommends substituting a less durable fiber for RCF's in order to reduce the hazard for exposed workers[6].** Alkaline earth silicate wools are less biopersistent fibers and designed by several RCF producers within the Refractory Ceramic Fibers Coalition (RCFC), which must first undergo industry-sponsored testing before their selection and commercial use[1, 6].

5 HEALTH RISKS

There has been no increased incidence of respiratory disease in scientific studies examining occupationally exposed workers[1]. In animal studies, long-term laboratory

exposure to doses hundreds of time higher than normal occupational exposures has produced fibrosis, lung cancer and mesothelioma in rats and hamsters[12].

Target organs affected by RCFM exposure include the respiratory tract, which includes the nose and throat, the eyes and skin. These effects are mainly due to mechanical irritation and are of temporary nature[13]. It should be kept in mind that individuals may react differently to the same level of exposure.

Scientific literature does not clearly indicate whether RCFM exposure may lead to cancer, fibrosis or mesothelioma in humans, although a number of toxicological studies mainly conducted on hamsters and rats occur [6, 10] (a lot of them already completed), in order to identify any potential health effects from RCF exposure. The only definite is that ongoing research is necessary to provide clear answers[11, 14]. Research findings may not represent an accurate assessment of the potential for RCF to produce adverse health effects; RCF is thus classified as a **potential** carcinogen and not as a definite carcinogen. A lot of the tests have little relevance because they bypass many of the biological mechanisms that prevent fiber deposition or facilitate fiber clearance[1, 5].

Because of ceramic fibers similar application and appearance to asbestos, there has been some concern regarding the health effects associated with exposure to ceramic fibers. To further complicate matters is the fact that no definite answers exist regarding the safety of RCFM[2, 4 and 5].

6 RECOMMENDED EXPOSURE GUIDELINES

The recommended exposure guidelines (REG) are summarised in Table 2.

Table 2: Summary of Recommended exposure guidelines

Country / Organization	Based on	Value
Refractory Ceramic Fibers Coalition	"Less exposure is better" [11]	0.5 f/cc or f/mℓ (REG)
American Conference of Governmental Industrial Hygienists	Precautious	0.2 f/cc or f/mℓ (TLV-TWA)

As can be seen in Table 2, different views exist regarding a recommended exposure guideline. The REG proposed by the Refractory Ceramic Fibers Coalition have taken factors such as economic and practical feasibility into account. The American Conference of Governmental Industrial Hygienists (ACGIH) on the other hand has proposed a TLV-TWA but does not take economic and practical feasibility into account[1]. It is the conservative recommendation of this report to advise an Occupational Exposure Limit (OEL) of 0.2 f/cc, purely based on the fact that less exposure leads to less harm and thus implementing a safe working environment for all employees.

7 CONTROL MEASURES

To deal with this most organizations, authoritative bodies and governments approach the problem with a "less exposure is better" point of view. The following guidelines or standards have been proposed with regard to control measures.

Table 1: Various guidelines and standards as provided in different countries

Country	Authority	Standard / Guideline
USA [1]	Refractory Ceramic Fibers Coalition	Recommended work practices
Australian Commonwealth Government [3]	National Occupational Health and Safety Commission	National Code of Practice for the Safe Use of Synthetic Mineral Fibers
New Zealand [8]	Department of Labor	Health and Safety Guidelines for the selection and safe handling of synthetic mineral fibers
USA [2]	NIOSH	Recommendations for a Refractory Ceramic Fiber (RCF) Standard

The following is common topics in all of the above-mentioned standards and guidelines:

1. Engineering controls
2. Work practices
3. Respiratory protection
4. Sanitation and Hygiene

Control measures as well as PPE arrangements should follow the guidelines as provided by the Refractory Ceramic Fibers Coalition. These control measures are included in Section 8.

8 RECOMMENDATIONS

Taking into consideration the amount of ambivalent literature available regarding RCFMs the recommendations made will fall into two categories. The one category will be conservative and does not take economic and practical implications into account. The second recommendation will try to accommodate practical implications as well as economic considerations.

8.1 Conservative Recommendations

The conservative recommendation follows the guidelines provided by the “Voluntary product stewardship program (PSP) for refractory ceramic fiber (RCF) products” as outlined in their documentation, which has been incorporated herein.

8.1.1 Recommended work practices

The recommended work practices follows the guidelines set by Attachment III in the PSP. In the case where reference is made to a standard for which a South-African standard exist the latter shall apply.

8.1.2 Guidance for respiratory protection

Since no information is available regarding the current exposure to CRFs it is the recommendation of this report that a Half-face, air purifying respirator equipped with a NIOSH-certified P100 filter or equivalent be used when exposure to RCFs is evident.

8.2 Practical Recommendations

The following recommendations wants to engage all concerned parties with the establishment of guidelines based on the premise that guidelines must be practical in order to be effective. Factors such as economic viability must also be taken into account. Therefore it is the recommendation of this report that an OEL of 0.5 f/cc must be established. Furthermore extensive monitoring must be performed to access the current exposure of employees to RCFs. Control measures must be implemented on a "value-added versus resource investment" basis and not just on theoretical outcomes.

8.3 Proposed control measures

The following recommendations are made against the background of the literature study, South African legal requirements and our experience.

8.3.1 Medical surveillance

Medical monitoring represents secondary prevention and should not replace primary prevention efforts to control airborne fiber concentrations and workers exposures to RCFs. However compliance with a recommended exposure limit does not guarantee that all workers will be free from risk of RCF induced respiratory irritation or respiratory health effects. Therefore, medical monitoring is especially important, and employers shall establish a medical monitoring program. It is recommended that the following is included[1, 3]:

1. An initial medical examination including a physical examination of all systems with emphasis on the respiratory system and the skin. A spirometric test, chest X-ray as well as a standardized respiratory system questionnaire is advised.
2. Periodic medical examinations at regularly scheduled intervals.
3. More frequent and detailed medical examinations as needed on the basis of the findings from these examinations.
4. Written reports of medical findings.
5. Quality assurance and evaluation[2].

The periodic medical surveillance should be conducted at intervals not exceeding two years, or at intervals specified by an occupational medicine practitioner.

8.3.2 Induction

The induction of employees involves conveying information about the hazards and risks (health effects) associated with emissions released at this plant as well as the need and proper use of personal protective equipments. Legislation requires, after consultation with the Health and Safety Committee that before any employee is exposed or may be exposed to any Hazardous Chemical Substance (HCS) the employer must ensure that the employee is adequately and comprehensively informed and trained about the risks. The employee should thereafter be informed and trained at intervals as may be recommended by that health and safety committee, with regard to HCS Regulation.

The Training should cover the following aspects:

- Potential source exposure to hazardous chemical substances (HCS)
- Potential risks to health including signs and symptoms caused by exposure *(*including signs and symptoms)*
- Potential detrimental effect of exposure on his or her reproductive ability, if applicable
- Measures taken by the employers to protect an employee against any risk from exposure

- Precautions to be taken by an employee to protect himself against the health risks associated with such exposure, including the wearing and use of personal protective equipment
- Necessity, correct use, maintenance and limitations of personal protective equipment, facilities and engineering control measures provided
- Assessment of exposure, the necessity of personal air sampling and long-term benefits and limitations of medical surveillance
- Occupational exposure limit of substances being exposed to
- Importance of good housekeeping at the workplace and personal hygiene
- Safe working procedures regarding the use, handling, storage and labelling of the HCS at the workplace
- Procedures to be followed in the event of spillages, leakages or any similar emergency situation which could take place by accident
- Procedures for reporting, correcting and replacing defective personal protective equipment and engineering control measures
- A prohibition to enter or remain in an area where personal protective devices are required unless the person is authorized to do so and is wearing the required protection
- Prohibition to smoke, eat, drink or keeping food or beverages in a respirator zone

*** Author's inclusion**

It should be brought to the attention of employees that they have specific responsibilities while working with HCS. Every person who is or may be exposed shall obey a lawful instruction given by or on behalf of the employer or a self-employed person, regarding the:

- Prevention of an HCS from being released
- Wearing of personal protective equipment
- Wearing of monitoring equipment to measure personal exposure
- Reporting for medical surveillance and biological monitoring as required by Regulations

- Cleaning up and disposal of materials containing HCS
- Housekeeping at the workplace, personal hygiene and environmental and health practices

8.3.3 Occupational hygiene monitoring

Occupational hygiene monitoring should be conducted to determine personal exposure and to determine if any environmental pollution (contamination) does occur. It is recommended that not only total dust exposure is determined, but also in addition to fibre counting the approximate sizes of fibres are determined. This information would become very valuable in determining the potential risk associated with the different conditions under which work is performed.

8.3.4 Control at source

If at all possible removal of RCFM should be done using the wet method, using water or dilute solutions of any liquid soap. Spillages, specifically environmental spillages should be dealt with, using TSW.

8.3.5 Control along path

In order to ensure that employees, contractor and visitors do not enter the area without the necessary protection the area should be demarcation as a respirator zone/ area as indicated in Addendum A, by affixing the relevant safety (health) symbolic signs at all conspicuous places i.e. at all possible “entrances” towards the work area.

8.3.6 Control at employee

Apart from communicating the results of the survey to employees, employees should be prohibition to smoke, eat, drink or keeping food or beverages in a respirator zone.

Regarding the issuing of PPE, including respirators the following must also be ensured:

- The equipment must be correctly selected and properly used
- Employees must receive the information, instruction, training and supervision that are necessary with regard to the use of the equipment
- The equipment must be kept in good condition and efficient working order
- Reusable equipment may not be issued, to any person, unless the equipment have been properly decontaminated and sterilised
- Separate containers or storage facilities for respiratory equipment, when not in use, must be provided
- It must be ensured that all contaminated personal protective equipment is cleaned and handled in accordance with the following procedures, where the PPE is:
  - Cleaned on the premises of the employer, care shall be taken to prevent contamination during handling, transport and cleaning
  - Sent off the premises to a contractor for cleaning purposes the:
    (i) Equipment shall be packed in impermeable containers
    (ii) Containers shall be tightly sealed and have clear indication that the contents thereof are contaminated
    (iii) Relevant contractor shall be fully informed of the requirements of these regulations and the precautions to be taken for the handling of the contaminated equipment
- It must be ensured that no person removes dirty or contaminated PPE from the premises: Provided that where contaminated personal protective equipment has to be disposed of, it shall be treated as HCS
- Employees using personal protective equipment must be provided with:
  - adequate washing facilities which are readily accessible and located in an area where the facilities will not become contaminated, in order to enable the employees to meet a standard of personal hygiene consistent with the adequate control of exposure, and to avoid the spread of an HCS;

– two separate lockers separately labeled "protective clothing" and "personal clothing", and ensure that the clothing is kept separately in the locker concerned.

At this point in time a decontamination unit and the use of disposal overall are not recommended.

8.5 Restrictions to work

All work should immediately stop if the wind in the working environment exceeds 3,9 m/sec, unless a wet method is used during the process and the responsible person on site assesses the conditions as adequately under control.

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ADDENDUM A

<u>Figure 1:</u> Symbolic safety (health) sign for wearing respiratory protection