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Reasons for not using respiratory protective equipment and suggested measures to optimize use in the Norwegian silicon carbide, ferro- and silicon-alloy industry.

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Abstract

Previous studies have shown that there is an increased risk for pulmonary diseases such as Chronic Obstructive Pulmonary Disease (COPD) among workers in in the Norwegian Silicon carbide, ferro- and silicon-alloy industry. One of the main aims in the ongoing DeMaskUs study is to reduce the risk for respiratory disease for workers in these industries through optimizing the use of respiratory protective equipment (RPE). A step towards that goal is to identify reasons why RPE is not always used in situations where such use is required. A questionnaire containing 174 items addressing different issues relevant to assessing protective behaviour was distributed to 1254 workers from 13 different plants/work sites. The responses showed that 80% of the respondents do not always use respiratory protective equipment (RPE) in exposed or mandatory areas. Additionally, the respondents were asked to identify specific reasons for not wearing RPE in mandatory situations. Comfort issues, practical, logistical and technical issues were among the reasons that were listed. Here we summarize the answers from the workers and suggest practical measures that can be taken to meet the requests and increase the use of RPE in situations where such use is required.

INTRODUCTION

The metal alloy industry has been an important part of the community structure at many locations in Norway since the first smelters were established in the early 1900s. Today it is still one of the largest land-based industries in Norway (Statistics Norway, 2017). However, working in this industry has been associated with an increased risk of developing respiratory illness, such as asthma, chronic obstructive lung disease (COPD) and lung cancer (Bugge, Kjærheim et al., 2012, Johnsen, Kongerud et al., 2008, Johnsen, Søyseth et al., 2008, Søyseth, Johnsen et al., 2012). Substantial amounts of gas, dust and fumes, including nano-sized dust particles, in the work atmosphere (Føreland, Bye et al., 2008, Kero, Grådahl et al., 2017, Kero, Naess et al., 2015, Skogstad, Føreland et al., 2006) has been linked to an observed increased respiratory health risk (Bugge, Føreland et al., 2011, Føreland, Bye et al., 2008, Johnsen, Bugge et al., 2013). The recognition of this causality has led to increased awareness towards dust- and fume reducing measures. Through engineering controls such as improved ventilation, adjustment of manual procedures to more automatic processes, water and air curtains to reduce emissions from the smelting process and so on, work atmosphere in the smelters has, generally, improved considerably.

There are, however, still situations and areas of the smelter premises where there is a need to reduce workers' exposures using respiratory protective equipment (RPE). There exist a wide range of different respiratory protective equipment (RPE) based on different technologies, depending on what the equipment is meant to protect the wearer against. In the Norwegian smelter industry, filtering RPE (disposable filtering half masks, half face masks with reusable filters, full face filtering masks, powered air respirators) that protects against particles, including nano-sized particles, and gases such as sulphuric gases are often used. Supplied air respirators (compressor/hose or self-contained breathing apparatus are used in situations where supply of clean air is needed. Unfortunately, previous studies focusing on RPE use in other industries and occupations, such as construction, manufacturing companies, health care, nuclear fuel industry, farming and hazardous waste management (Bryce, Forrester et al., 2008, Carpenter, Lee et al., 2002, Guseva Canu, Faust et al., 2013, Han and Kang, 2009, MacFarlane, Chapman et al., 2008, Mitchell and Schenker, 2008, Salazar, Connon et al., 2001, V.W.Y. Tam, 2008) have shown that compliance with RPE use regulations or needs is not optimal. A table summarizing compliance rates from 5 different industrial categories shows a range from 13 to 72 % compliance (Fukakusa, Rosenblat et al., 2011). Anecdotal information and occasional observations from the Norwegian metal alloy industry give reason to believe that this is the case also for smelter workers. In some of the previously mentioned studies, specific reasons for not complying with the regulations was identified. Discomfort from sweating, thermal stress, difficulty breathing, communication and vision difficulties, a perception that they did not need RPE and poor fit were reported as reasons for not wearing RPE (Guseva Canu, Faust et al., 2013, Han and Kang, 2009, Salazar, Connon et al., 2001). Through identifying factors that negatively affect RPE-use, meaningful measures can be made to change the behaviour and increase compliance.

A survey among Norwegian smelter workers was undertaken to identify the current status of RPE use, and to identify reasons for not using RPE in situations where such use otherwise is mandatory or needed in a preventive perspective. In this paper we summarize the answers, and propose practical measures that can be taken to improve the RPE-use. The presented data originates from a larger study called DeMaskUs, which focuses on different aspects related to exposure to ultrafine, nano- sized particles in the metal alloy industry. The data presented in this paper is derived from the questionnaire-based cross-sectional part of the DeMaskUs study. This part of the study included 13 ferro silicon, silicon, ferromanganese, silicomanganese and silicon carbide smelters in Norway.

MAJOR SECTION

Method

Pen and paper questionnaires were individually enveloped and sent to employees at 6 smelters (n=701). The letters contained a questionnaire, paid-postage return-envelope, project information, including information about lottery prizes. A dedicated contact person within the HSE department at the respective plants distributed these to the employees.

A link to a web-based version of the questionnaire was distributed to employees by email addresses received from a dedicated contact person within the Health, Safety end Environment (HSE) department at 7 additional smelters (n=553). Project information, information regarding participation and prizes was included in the email. Participants had a chance to win a gift certificate of approximately 80 EUR.

Prizes were used to increase likelihood of participation and adherence to the study. Returned paper questionnaires were optically read at the Clinical Research Department at the University Hospital of Northern Norway, and all data was entered into an SPSS-file for analysis.

Participants and recruitment
Participants were recruited to the project in close cooperation with the silicon carbide producers and member companies of The Norwegian Ferroalloy Producers Research Association. Criteria for participating were present employment in the smelting industry and being 18 years or older. Anyone, working in an area where exposure to dust, fumes and gases was a risk factor, was of interest for this project. Recruitment of participants was organized through the HSE personnel at the different plants.

Questionnaire
The questionnaire consisted of 174 items in total, divided in to 9 topics or scales: Demographics, work and employment history, exposure knowledge, RPE use, self reported health, Theory of planned behavior (TPB) factors (attitudes, norms, perceived control, and intention) (Ajzen, 1985; 1991; Fishbein and Ajzen, 2009), a short scale for safety climate (Hahn and Murphy, 2008), Work Experience Measurement Scale (Nilsson, 2010; Nilsson et al., 2013) and Temperament and Character Inventory (Cloninger et al. 1993)

Demographics, single items and scales in the questionnaire were developed through different methods, including interviews in focus groups, scale development pilot questionnaires, translation & back-translation (Sperber, 2004) and selection of items based on scientific discussions in the research group.

A pilot questionnaire was administered to one plant for testing. 85 questionnaires were distributed with a response rate of 46% (n = 39). Problematic items were re-worded, otherwise revised or removed to optimize the final questionnaire.

In the current paper, the presented data originates from 2 demographic, 2 work- and exposure related items and 3 items regarding the worker's use of respiratory protective equipment. The answer alternatives in the questions with several answer options were chosen based on results from the focus group interviews and the pilot questionnaire:

- Gender (male or female)
- Age (number of years)
- "*Which of the following categories would best describe your work*? *Choose only one option"* 3 options were given: *production/maintenance, management (all levels including shift management) or other (administration, warehouse, cantina etc.)).*
- "*Which of the following factors are you exposed to on a regular basis (more often than once a week) through your work? You can choose several alternatives*" 15 alternatives were given, and the participants ticked one or more boxes for the answers that represented their situation: *Quartz dust, Polycyclic aromatic hydrocarbons (PAHs), FeSi dust, Si dust, Manganese dust, SiC dust, CO gas, CO_2 gas, sulfuric gases, welding fumes, noise, strong electromagnetic fields, diesel exhaust, none of these, other*.
- *"If you have used respiratory protective equipment during the last year, which of the following will best describe the type(s)? You can choose several alternatives"* 6 alternatives were given: *Disposable filtering half masks, Half face masks with reusable filters, full face filtering masks, powered air filtering respirators, supplied air respirators (compressor/hose or self-contained breathing apparatus).*

- *Q1: "It may be that you do not always use RPE, even in situations that you know you should do so. What is the main reason(s) for not using RPE?"* 8 alternatives were given, and the participants ticked one or more boxes for the answers that represented their situation: *I always use RPE, It is unpractical to use, It is uncomfortable to wear, It makes breathing heavy, RPE is not accessible to me, No one else around me is using RPE, It does not offer me good protection, Other reasons*. There was also an open answer field where participants could specify "Other reasons" for not wearing RPE
- *Q2: "What percentage of the time spent in mandatory or exposed (gases/dust/fumes) areas do you use RPE?"* This question was answered by indicating a percentage (number between 0 and 100) by marking a cross on a continuous scale shaped as a dotted line.

Results

565 workers answered parts of or the whole the questionnaire (410 paper- and 157 online surveys, with a response rate of 58% and 28% respectively). Total response rate was 45.2%. 89% (n=493) were males with an overall mean age of 44.5 (range 18-69).

To assess whether use of RPE was relevant for the individual worker, we asked for a description of their work and assumed frequent exposure factors in the work atmosphere. 549 persons answered the question regarding the area of work: 77% (n=425) of the respondents reported working in production and maintenance, 17% (n= 91) in management and 6% (n=28) answered "other" (i.e. general administration, the cantina or warehouse). 491 persons answered the question regarding frequent exposures in their work atmosphere. Only 1,8% (n=10) of the respondents stated that they were not exposed to any of the listed exposure factors (3 from production/maintenance, 4 from management, 3 from "Other"). Hence, RPE use at some point during their workweek was assumed relevant for 98% of the respondents.

Table I: A summary of the answers to the question "*Which of the following factors are you exposed to on a regular basis (more often than once a week) through your work?* Only exposure factors that were relevant for RPE use (gases, dusts and fumes) are shown here. Each person could give more than one answer. Percentage and exact number of persons answering affirmative to each exposure factor is given in the table.

n, total = 567	*Affirmative answers*	
Type of exposure	% of total n	n
Quartz dust	41	231
PAHs	19	106
SiC dust	16	92
FeSi dust	31	174
Si dust	41	230
Mn dust	48	272
Welding fumes	20	113
Diesel exhaust	35	196
CO gas	48	271
Sulphuric gases	26	148
CO_2 gas	18	100
Other	5	30
None	1,8	10

To identify the types of respirators used by the smelter workers, we asked the question "*If you have used respiratory protective equipment during the last year, which of the following will best describe the type(s)?*" The results are shown in table II. The most commonly used respirator type is the disposable filtering half face masks, which is used by 79% of the respondents.

Table II: Answers to the question *"If you have used respiratory protective equipment during the last year, which of the following will best describe the type(s)?"* Each person could give several answers.

		Total n = 502
Respirator type	n	% of total n
Disposable respirators	447	79
Reusable half face respirators	90	16
Full face filtering respirators	73	13
Powered air filtering respirators	96	17
Supplied air respirators	40	7

Reasons for not wearing RPE in mandatory or exposed situations were specified through choosing one or more of the alternative answers to the question Q1: *"It may be that you do not always use RPE, even in situations that you know you should do so. What is the main reason(s) for not using RPE?"*. Each person could tick off several boxes. As shown in table III, 30% answered that they always use RPE. Also, 15% answered that "Other reasons" were decisive for not wearing RPE even in situations they knew they should do so.

Table III: Answers to the question Q1 *"It may be that you do not always use RPE, even in situations that you know you should do so. What is the main reason(s) for not using RPE?"*. Each person could tick several boxes. Responses are presented as % of total n and exact number of affirmative answers for each statement.

n, total = 567	*Affirmative answers*	
Reason not to wear RPE	**% of total n**	**n**
I always use RPE	30	175
It is unpractical to use	26	147
It is uncomfortable to use	24	133
Wearing RPE makes breathing heavy	22	122
RPE is not accessible to me	14	80
No one else around me uses RPE	6	35
It does not offer me good protection	2	12
Other	15	83

96 persons provided written comments as an additional answer to Q1. Table IV summarizes the free text specifications. 23 persons commented that *Condensation and/or mismatch with protective goggles was a main reason not to wear RPE, while* 21 of those who gave comments wrote that forgetfulness, laziness or other excuses such as *"it is just a quick job task*", was a main reason for not wearing RPE in exposed areas. 19 persons had made an assessment that *RPE was not needed in the areas where they worked*, and another 17 respondents reported that having *difficulties communicating* was a reason not to wear RPE. *Heat stress* and *discomfort from sweat* were also mentioned by a smaller number of people (n=8). Health issues such as skin rash, itching and incompatibility with

respiratory illness was revealed as issues behind suboptimal RPE use for 3 of the responders. Finally, dissatisfaction with how health- and safety-issues were resolved by the management, such as a lack of focus on exposure reducing measures and lack of responsibility and motivation for RPE use were mentioned by additional 3 respondents as reasons for not wearing RPE in exposed situations.

Table IV: A summary and categorization of the written comments to the question Q1: *"It may be that you do not always use RPE, even in situations that you know you should do so. What is the main reason(s) for not using RPE?"*

Total n = 96

Statements, reasons to not use RPE	Number of persons giving the particulate statement
Condensation, mismatch with protective goggles	23
Excuses, forgetfulness and laziness	21
"It is not needed in the areas where I work"	19
Communication issues	17
Heat stress and sweat	8
Health issues (dermal or respiratory issues)	3
Administrative or organizational issues	3
Practicalities	2

Table V shows the distribution of the answers to the question Q2. 502 persons answered this question. 28% (n=141) of the respondents reported that they used RPE 100% of the time in areas where this is needed or mandatory.

Table V: Responses to the question Q2: *"What percentage of the time spent in mandatory or exposed (gases/dust/fumes) areas do you use RPE?"*. The response is shown as number and % of the respondents indicating RPE use within a given interval, either 0-24%, 25-49%, 50-74%, 75-99% or 100% of the time spent in exposed/mandatory areas. Total n for this item=502

total n =502

% of the time that RPE is used in mandatory/exposed areas	Number of respondents	% respondents
0-24	40	8
25-49	32	6
50-74	76	15
75-99	213	42
100	141	28

Discussion

This paper describes for the first time, the extent of RPE use among Norwegian smelter workers, which types of respiratory protective equipment that is used, and specific reasons to neglect RPE use despite recommendations. The response rate (45.2% in total, 58% for the paper form questionnaires and 28% for the web-based version) is acceptable and relatively high in this context, also compared to similar studies (Fukakusa, Rosenblat et al., 2011, Guseva Canu, Faust et al., 2013).

In this study, RPE use was measured through self-reporting from the respondents through 3 questions. One question clarified what types of respirators that were in use and to what extent (Table II). It is clear from these results that disposable filtering half face masks are by far the most commonly used RPE type, but reusable filtering half- and full face masks are also regularly used as well as powered air filtering masks.

Supplied air systems were not so commonly used (6% of the respondents). Furthermore, the respondents were asked to assess the proportion of the time they used RPE when they were in exposed areas or under regulations to do so. The question (Q2) was phrased *"What percentage of the time spent in mandatory or exposed (gases/dust/fumes) areas do you use RPE?"* The question was formulated in order to be valid for all respondents in the study, regardless of employer. The different smelters have different regulations regarding RPE use. Some have mandatory areas based on risk assessments that have indicated the need for RPE; others have a risk/situation based regulation, but all smelters have situations where the workers are under regulations to use RPE. The question was asked with the purpose to quantify the *actual* RPE use in work situations where the workers were under such regulations and knew that they should use RPE. Ideally, all workers should have answered the question by indication 100% compliance. Indeed, 141 respondents (28%, table V) indicated that they used RPE at all times in such areas. To the question (Q1) *"It may be that you do not always use RPE, even in situations that you know you should do so. What is the main reason(s) for not using RPE?",* one answer option was *"I always use RPE".* 175 persons chose this answer (30% of the total n). 35 more persons gave this answer than the 141 that indicated 100% compliance in *Q2.* Looking further into the responses from the 175 individuals that answered "I always use RPE", we found that 12 of the 175 did not answer Q2. Of the remaining 163 respondents, 95 answered in Q2 that they use RPE 100% of the time. The remaining 68 respondents that answered that they *always use RPE* in Q1 modified their statements in Q2, where their answers ranged from using RPE 20%-99% of the time. Further analyses can possibly reveal rationale behind the observed discrepancy for these individuals, but that is beyond the scope for this particulate paper. Nevertheless, based on the answers in Q1 and Q2 we can be quite sure that approximately 20% (95 of 567) of the respondents use RPE in all necessary situations, and furthermore, that 80% of the respondents do not always use RPE. There was however a noteworthy variation in the degree of non-use of reported RPE in Q2. Most respondents say that they use RPE more than 75% of the time (42% of the respondents indicated 75-99% compliance with the regulations). There was nevertheless a total of 14 % of the respondents that answered that they used RPE less than 50% of the time, and as many as 8% use RPE less than 25% of the time in exposed or mandatory situations.

The fact that a substantial share of the work force do not use RPE in exposed situations is concerning, considering the substantial amount of literature supporting the connection between inhaling dust, fumes and gases in Norwegian smelters, and respiratory morbidity (Bugge, Føreland et al., 2011, Johnsen, Bugge et al., 2013, Johnsen, Kongerud et al., 2008, Johnsen, Søyseth et al., 2008, Søyseth, Johnsen et al., 2012). Exposure reducing measures such as improved ventilation, air- or water curtains to separate the workers from the dust and fume-source, cleaning procedures, re-structuring of the production premises etc. have led to valuable improvement in the working atmosphere in Norwegian smelters the last decades. However, there are still specific work tasks and areas of the plants where exposure levels are potentially hazardous, and RPE use is indicated.

One reason for the lack of compliance with RPE use regulations could be reduced awareness of work place hazards among workers. However, as shown in table I, 98% of the respondents indicate that they are exposed on a regular basis to one or more potentially hazardous substances in their work atmosphere. In that regard, there is good reason to assume that lack of awareness of exposure is not an issue, and that the workers do know that protective measures during their workday may be necessary. Analyses to reveal whether the exposure scenarios that the respondents have reported

are in accordance with the actual exposure scenarios at the different sites is beyond the scope of this particulate paper, and will not be explored further here. Nevertheless, our data indicate that as many as 80% do not always use RPE in situations where they may be exposed, even if they report that they are exposed to potentially hazardous dust, fumes and gases on a regular basis. Hence, there is room for improvement and further investigation.

To be able to choose the most efficient strategy to improve the RPE use, reasons not to use RPE was identified through Q1. 50% of the respondents answered that RPE is uncomfortable to wear and that it is unpractical to use (24% and 26% respectively) (Table III). Comfort issues are often related to heat stress while wearing RPE (half face filtering masks mainly) during heavy work or in hot areas. If half face filtering masks are used, the respirator often becomes moist and damp inside. Also, if there is a silicon cuff or other silicon/silicon like parts in direct contact with the skin, it tends to increase the discomfort and even provoke itching or skin rash, as indicated by some respondents (Table IV). According to our experience, RPE manufacturers are constantly improving their products to optimize user comfort, practical issues and safety. However, improvement of one of the properties; user comfort, safety or practicalities, may lead to deterioration of one of the other, and the perfect combination is not easy to find. One example is the powered air purifying respirators (PAPR). PAPRs are considered safe and comfortable and 17% of the responders said that they use this kind of RPE (table II). However, the use of PAPRs offers practical challenges for workers that operate near extreme heat, in confined spaces or during work tasks that demand extensive movements because of the size and shape of the motor, hoses and the visor. To our experience, these workers tend to choose other, less safe options, or less comfortable options, which may finally result in not wearing RPE at all. Herein lays a future challenge for RPE designers.

"Wearing RPE makes breathing heavy" was selected by 22% of the respondents as a main reason not to wear RPE (table III). Breathing will become difficult if the unpowered filtering RPE has a clogged particle filter. Information about this effect and encouragement to change filters or RPE regularly or when needed is a measure that may help solve this issue. However, most unpowered filtering RPE do make breathing more strenuous just by wearing them. During heavy-duty work with an increased demand for oxygen, this effect is especially noticeable. This is an intrinsic property of the concept of RPE and difficult to get around. The workers must be motivated to use RPE through gaining an understanding of the health benefits, so that the pros of RPE use overcomes the cons, in this case, that RPE makes it heavier to breath.

14% of the respondents said that inaccessibility of RPE was a main reason for not wearing RPE (Table III). There are probably various local explanations behind this answer. Nevertheless, this calls for logistic improvements for the companies, given that these results come from the Norwegian metal alloy industry, where access to protective equipment should not be an issue.

A smaller proportion of the respondents (6%, Table III) said that a main reason that they did not use RPE was because their colleagues did not use RPE. Social norms are known to influence behaviour, also in the context of protective behaviour (Fukakusa, Rosenblat et al., 2011, Robertsen Ø, 2017). Measures should be made by the companies to adjust the safety climate so that the necessary changes in the social norms will apply. Additionally, a substantial proportion of the respondents (Table IV) commented that laziness, forgetfulness and bad excuses were reasons not to use RPE. An improved safety climate would probably have an impact also in this regard.

23 of the respondents that made additional comments (Table IV) indicated that mismatch between respirator and protective goggles or condensation on goggles was a problem and a reason not to wear RPE. Many responders mentioned inadequate compatibility between goggles and RPE. In this situation, many workers chose to keep the goggles and loose the RPE to solve this issue. This is an issue when either disposable filtering half face masks or reusable filtering half face masks are used. A recommendation to the manufacturers of protective equipment is therefore to design RPE and goggles that match and can be worn at the same time. Condensation on goggles may be a consequence of bad RPE fit. If the respirator fits the user's face, leakage of air between the respirator and the face over the nose should not occur, and condensation will be reduced. Fit testing of respirators is therefore important not only for adequate protection of the airways (Campbell, Coffey et al., 2001), but also to limit condensation on protective goggles. A well fitted RPE protects the wearer as intended, and previous studies have shown that fit testing is associated with increased RPE use (Fukakusa, Rosenblat et al., 2011, Salazar, Connon et al., 2001) Fit testing should be implemented as a standardized part of the health and safety program in smelters where half face respirators are used, where this is not all ready the case.

Additionally, a substantial share (n=17) of the respondents stated communication issues as reason not to wear RPE (Table IV). Difficulties in talking to each other and deliver messages while wearing RPE is potentially an acute safety issue. Workers tend to solve this by removing the RPE while communicating. This is not a recommended practice concerning respiratory health risk. Unfortunately, innovative technical solutions on how to communicate well while wearing RPE in noise polluted work environments is beyond the competence of this research group and probably best solved by manufacturers of this equipment.

Finally, 19 of the responders with comments (table IV) wrote that they did not use RPE because they did not experience a risk for exposure in the areas where they worked. Hopefully, these workers have a correct perception and adequate knowledge about their working atmosphere, otherwise, education on exposure risks is needed. 2% of the responders (table III) did not trust their RPE to offer sufficient protection, and would therefore not use RPE. Fit testing and education is recommended to avoid the mistrust and to find proper fitting RPE.

CONCLUSIONS

In summary, approximately 80% of the respondents do not comply 100% with RPE regulations and recommendations. Hence, there is a need to address the reasons why RPE use is neglected in order to reduce respiratory health risk. Discomfort, unpracticality, unavailability, motivational issues, incompatibility with other protective equipment and difficulties communicating were the main reasons for not wearing RPE in exposed situations.

Suggested measures to address these issues are:

- RPE manufacturers should, in close contact with the users, continue their effort to improve their products in order to optimize user comfort, practical issues and safety.
- RPE manufacturers and companies are encouraged to improve communication possibilities and solutions for the workers while wearing RPE.

- RPE should be generously and easily available to the workers in exposed situations or locations. Also, workers should be encouraged to change filters or RPE regularly to avoid filter clogging and ease breathing.
- Information on exposure risks and RPE specific education of the workers should be implemented so that the workers truly understand the health benefits of using RPE in such a way that the pros of RPE use overcomes the cons, and motivation to use RPE increases.
- Companies should include strategies to improve the safety climate in their health- and safety plans so that necessary changes in the social norms will happen and protective behaviour among the workers improves.
- Fit testing of RPE is an effective measure with regards to avoiding face seal leakage, both to reduce condensation on protective goggles, but also to increase the protective factor. Fit testing is also positively associated with compliance to RPE regulations (Fukakusa, Rosenblat et al., 2011, Salazar, Connon et al., 2001).

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