Presentation of an approach for risk characterization of exposure to chemicals in cleaning work

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1 Introduction

The association between use of chemicals in cleaning sector and increasing asthma cases among cleaners is becoming more apparent (Folletti et al 2014; Siracusa et al 2013; Vizkaya 2011; Medina-Ramon et al 2005) This is also the case with prevalence of occupational contact dermatitis (Bauer 2013; Carøe et al 2014). In a literature review by Charles et al (2009), of 35 epidemiological studies, 26 were for respiratory diseases (17) and dermatitis (9) and these were associated with cleaning agents, wet work and latex. In yet another review, Jaakkola and Jaakkola (2006) concluded that studies strengthen the evidence of an increased asthma risk among cleaners or workers in other jobs in which they are involved in cleaning. Assessing the risk of exposure to chemicals in the sector in order to establish good work practices is important to both the employers and their employees. Different methods and strategies have been developed over time to assess the risk of the chemicals used at various workplaces (Brooke 1998; Bullock & Ignacio 2006; Hawkins et al 1991; Kromhout 2002; Maidment 1998; Russell et al 1998). With advent of EU regulation 1907/2006 on registration, evaluation, authorisation of chemicals, REACH, (European Council 2007) use of exposure estimation models such as ECETOC TRA (Ecetoc 2012), Stoffenmanager (TNO 2003), RiskofDerm (Van Hemmen et al 2003) among other have been steadily gaining ground. The approaches of these methods usually involves modelling and/or measurements of occupational exposure. Others, employ hazard phrases and occupational limit (OEL) values in assessing levels of exposure (Balsat et al 2003; Topping 1998). All these methods and strategies require considerable industrial hygiene expertise, something the many small cleaning companies lack. Assessment using hazard data mapping using direct-reading instruments can provide information necessary for strategic control and interventions design, but may lack data completeness and representativeness resulting in measured data mischaracterisation (Koehler &

Volckens 2011). Great challenges are seen in this respect. Qualitative assessment methods can thus be used as alternative for screening exposure risks, and in setting workplace intervention priorities (Mulhausen & Damiano 1998).

Workplace risk assessment, which is a regulatory requirement (European Council 1998), is in most cases, if not always, conveniently left in the hands of the occupational health services (OHS) the companies may be affiliated to. However, safety advisors do not use structured assessment approach, but rather use personal judgement and information from suppliers of chemicals (Balsat et al 2003). Moreover, although cleaning companies are according to the Norwegian legislation, required to be affiliated to OHS and have to document risk assessment done (Direktoratet av arbeidstilsynet 2011), experiences from workplace inspections (as reported by inspectors from the Labour Inspection Authority) show that the contracts between cleaning companies and OHS for provision of services are minimal, and are only meant to fulfil the OHS affiliation requirement. It can be confidently deduced thus, that little is done in terms of risk assessment in the cleaning sector. Furthermore, it is evidently apparent that in cleaning work, factors external to the cleaning company may determine the type of chemicals used for the tasks contracted. Such include among others, price of the products, existing agreement with suppliers of the cleaning products, types of surfaces to be cleaned, type of dirtiness, what to attain by the cleaning task e.g. disinfection in hospitals, degreasing of kitchen walls. This gives the cleaning companies little leeway in choosing which chemicals to use at the different cleaning stations. Moreover, suppliers of the chemicals continuously recommend new products. Hence risk due to chemicals needs to be constantly assessed. This can be time consuming, and very few companies make risk re-assessments (Suleiman & Svendsen 2015).

A cleaner may perform several tasks which determine the risk of exposure to chemicals; the level of exposure is task-based (Bello et al 2009; Marquart et al 2003). Employers and eventually safety representatives need a method for quick determination of potential risk of exposure to chemicals at a given workplace that they and the workers themselves can easily use.

The aim of this study was thus to propose a straight-forward methodological approach for determination of potential risk of exposure to chemicals based on determinants of exposure in cleaning work. The approach was applied at a few workplaces to elaborate on it usability.

2 Materials and Method

2.1 Gathering of information on cleaning work

Information on daily cleaning patterns and use of chemicals was gathered through interviews with cleaners and their supervisors. Participants interviewed included 12 hospital cleaning workers, 11 domestic and offices cleaners, and 8 hotel cleaners. Others were 13 supervisors/shift leaders from different cleaning enterprises with a spectrum of cleaning assignments. The participants, selected by the supervisors, were cleaners with minimum two years' work experience and were proficient in Norwegian/English. In one meeting, representative from Occupational Health Service (OHS) also participated. Tasks in which chemicals are used were selected, including cleaning of toilets/bathroom, kitchen, windows/glass surfaces, and cleaning of floors. These tasks were common among those who participated in the interview and were thus used for the assessment purpose. Each of these tasks is an exposure scenario on its own and same determinants apply. Frequency of use of chemicals, dilution of the chemicals before use, use of spray bottles (SB) in work performance, use of personal protective equipment (PPE) and workplace ambiance are some of the underlying determinants of exposure which influence the different scenarios. These were the determinants chosen for this study. Workplace ambiance is here defined by and restricted to task being performed in "open" or "closed/confined" locality.

2.2 Construction of scenario risk factors

Each of the selected determinant were labelled with symbols, and the symbols assigned numerical values that differentiate one scenario from another, as is shown in table 1 and 2. Since the number of the task performed may vary from one work station to another, the symbol φ is included in table 1 in order to allow adjustability for situations where all or only some of the scenarios would apply. Thus, $\varphi=1$ when the task is performed, and $\varphi=0$ when not performed. For dilution of the chemical, use of spray bottle (SB) and workplace ambiance, only one or another scenario may apply, whereas frequency of use of chemicals and use of PPE can each manifest variedly in work situations hence resulting into varied exposure scenarios. No differentiation is considered for use of different PPE such as gloves or masks, but only whether required PPEs are used or not. Accordingly, for frequency of use of chemicals and use of PPE, 4 bands that differentiate the various scenarios one can encounter are set up as given in table 2.

Counting the number of times a task is performed was such that every spell of the task performance within the same work shift per day is counted as one. A shopping centre cleaner who cleans floors on different planes of the centre, will have each plane counted as one spell. When cleaning a number of corridors e.g. in hospitals, each corridor cleaned in a shift in a day is considered as one spell. The same count was applied where same place was cleaned repeatedly within the same shift as was the case with e.g. cleaning at travel terminals. For toilets, each toilet cleaned, or repeat cleaning of the same within same shift of the same day, is counted as one spell. For windows, eventually other tasks not performed on daily basis, the number of counts is the number of times/week the windows are cleaned and not the number of windows in a spell.

The product of the determinants' specific scenario factors is conceptualised here as the assessment factor, and given the symbol ω. For each task, or more appropriately exposure scenario, the assessment factor is thus represented by the equation $\omega = \nu*\theta*\delta*\sigma*\xi$. Using occupational hygiene expert assessment, weighting coefficients considered from the risk involved in the task are suggested. Combining φ, ω for the task and the weighting coefficient gives conceptual scenario risk factor (RF), thus:

$RF_T = 2\varphi*\omega_T$ (for toilets/bathrooms);

$RF_K = 2\varphi*\omega_K$ (for kitchen);

$RF_W = \varphi * \omega_W$ (for windows/glass surfaces);

$RF_F = 0.5\varphi * \omega_F$ (for floors).

The total actual risk of the work that the cleaning workers perform is obtained by summing up risk factors of all the task, i.e. $\sum RF$. This total actual risk is workplace and cleaner specific and is designed for one full work shift.

2.3 Calculation of risk factors for ideal situation and work risk characterisation ratios

A comparison between the $\sum RF$ and $\sum RF_I$ for a construed ideal situation where the risk of exposure is considered minimal, would give work risk characterisation ratio (RCR), a comparative indication of risk level for the work done, and how the risk involved in actual work deviates from the ideal situation. Since occupational exposure to chemicals is completely undesirable, the ideal situation would be when the risk of exposure to chemicals is the least possible. Supposing one performs all the type of tasks in one shift, the ideal lowest risk situation based on the determinants and factors in table 1 and 2 for that shift, would be that the frequency of use is 1-3 times/shift; personal protective equipment is used all the times; chemicals are diluted before use for all tasks; spray bottle is never used; and that the tasks are performed in open, not confined, work stations. The $\sum RF_I$ of this ideal situation is 0.17. The complete opposite would be the worst case scenario which gives $\sum RF = 88.00$. This means the worker performs all the four tasks; that the cleaning is repeated several times (≥10 times per day), and windows are cleaned every day of the week; no PPE used at all; chemicals are used undiluted in all cases and spray bottles are used in all operations, yet all the work is done in confined localities. The worst case although may seem a bit far-fetched, it represents the furthest end of the determinants application spectrum and in a cleaning work situation, and such would depict a completely undesirable workplace and irresponsible employer and cleaning workers.

RCR is hereby defined and presented as: RCR $= Actual \sum(RF))/(Ideal \sum(RF)$.

RCR=1 is ideal situation, RCR < 1 and RCR >1 represent risk lower and higher than the ideal respectively.

2.4 Practical application of the method

A total of 71 cleaning workers, others than those mentioned earlier, tasked in cleaning a bus and a train (travel) terminal (N=9), a Shopping Centre (6), Municipal offices (24), kindergartens (6) and a hospital (26) took part in the evaluation of the method. For the groups with few participants i.e. 6/9, each individual was interviewed and the responses recorded in a prepared sheet. For the larger groups, the cleaners, under instructions to ensure common understanding, filled in a scheme indicating their work patterns. For each group, the general trend of working pattern was established. The working pattern of the individuals in the small groups were in agreement with each other on the number of times the tasks were performed and similarly agreed upon how the other factors applied, and responses are used as were reported. For the larger groups (24 and 26 participants), varied responses were expected. In order to get a unified view for the purpose of applying this approach, and to enable establishing a general trend for the group that allows for calculating RF, responses agreement level was set at ≥ 60%, meaning in this case at least 14 of 24, and 15 of 26 had to agree in their responses on the interval on the number of times and how the tasks are performed, whether PPE are used or not, and all the other factors.

3 Results

As mentioned earlier, information on cleaning tasks where chemicals are generally used was collected from 12 (27.2%) hospital cleaning workers, 11(25.0%) domestic and offices cleaners, 8 (18.2%) hotel cleaners and 13 (29.5%) supervisors/shift leaders. The different groups were rather evenly distributed and thus give a good overall view of the important tasks.

The RF values for each task under the different work situation, the ∑RF, and the RCR for all the different situations obtained on applying the approach, are given in table 3.

The risk level is relative for the higher or lower RF values. The higher the RF attained for a specific task, the higher the risk of exposure when performing that task e.g. as is shown in table 3, for travel terminals, there is a higher risk level when cleaning toilets (RF_T=1.00) than when cleaning floors (RF_F=0.13). The same applies for the ∑RF for the different work places, i.e. workplaces with higher ∑RF have higher risk level.

All the work stations assessed gave RCR >1, i.e. ∑RF higher than that obtained for the designed ideal. Cleaners of travel terminals had the highest ∑RF (1.26) and so the highest RCR (7.41). Kindergarten cleaners reported performing all the task, and had the second highest ∑RF (0.82) and RCR (4.82). On the other hand, cleaners of the Shopping centre who participated, performed only two of the four tasks, giving the lowest ∑RF (0.28) and lowest RCR (1.65).

Comparing the RCRs, reading vertically in table 4 below, shows that workers cleaning terminals risk exposure to chemicals 4.5 times more than those in the shopping Centre; 1.9 times more than those cleaning offices; 1.5 times more than kindergarten cleaners; 1.7 times more than hospital cleaners. More results of such comparisons are given in table 4.

The largest disparity in RCR is seen in ratios between cleaners of the travel terminals: shopping centre (4.49), while the least is that for office: hospital (0.91) and hospital: kindergarten (0.93), and their respective reverses with ratios 1.10 and 1.08 respectively.

4 Discussions

The approach proposed in this paper is not meant for assessing the level of exposure to cleaning chemicals, but to characterise the risk of exposure at workplaces. Characterisation of exposure is vital in evaluating the suitability of the safety paradigm of workers' practices irrespective of the hazardous/non-hazardous nature of the chemical used. Chemicals classified as non-hazardous may well pose hazardous effects not associated with any specific hazard class. This assessment on non-classified chemicals therefore renders the hazard nature of the chemical to be a constant parameter, hence is left out from the assessment factor equation ($\omega = \nu*\theta*\delta*\sigma*\xi$). This omission does not affect the outcome of the assessment.

Application of this approach will be mostly appreciated in work situations where the cleaners have multiple tasks in each work shift such as cleaning floors, toilets, kitchen windows etc. Where the cleaner has only one task such as those specialised in cleaning windows/glass surfaces on the exterior of buildings, or cleaners of staircase in residential apartment buildings, applying this approach by comparing to an all-tasks-done ideal as presented here, will result in underestimation of the RCR. However the ω for that single task can be compared to a designed ideal ω_I in order to get a general view on closeness to the lowest risk level ideal.

The RCRs calculated for the different workplaces are not absolute for the workplaces assessed, but will vary according to the working patterns of the cleaners, procedures of the cleaning companies, and the agreements each company enters with the task givers. The approach thus provides workplace safety staff with a method for systematic assessment of the work situation, and the outcome gives an indication on how cleaning work patterns might deviate from what is construed as minimal exposure ideal situation. This method of screening cleaning work to be done, provides an initial step in deciding the work procedures and risk management methods to apply. Supervisors can set up their own ideal work situation and use this as company's internal standard for assessment of cleaners safe performance of tasks assigned. The RCR values give a reasonably good tool for comparing the different work places and therefore dependent on the unity of the working trend of the cleaners. For this reason, a minimum 60% agreement between responses in larger groups was set as the unity acceptance criteria in calculating RF. Those lying outside the 60% agreement may be performing the work differently from the general trend, e.g. one may use spray bottle and do not dilute chemicals used for some tasks in contrast to the general trend where the majority do not use spray bottles and do dilute chemicals. With the 60% acceptance criteria as the starting point, workplace work performance instructions, safety routines can thus be formulated and risk management measures designed such that $RCR<1$ is ensured and maintained. Such instructions and measures would also be applicable to those lying outside the 60% trend agreement, and would contribute to a more unified work performance paradigms.

In some cases, some task RF=0 (when $\varphi=0$), i.e. where the task is not performed, the RCR is calculated by dividing the actual $\sum$RF with that of the ideal situation in all cases irrespective of whether all the tasks are performed or not. This is made so in order to keep a similar rationalization for making comparison between different workplaces. By keeping the basis of comparison constant, it becomes sensible to explain how a specific work place deviates from the designed ideal. When RCR>1, i.e. risk is above construed lowest level, the workers need to adjust the working procedures to bring the RCR as closer to ideal as practically possible.

The high RCR for terminals cleaner is due to the fact that they clean toilets more than 10 times/work shift. Moreover, they use spray bottles in all the situations. Kindergarten cleaners performed all the tasks, and also use spray bottle in all situation, and because of this they had the second highest RCR. Hospital cleaners who took part in this study do not use spray bottles at all and do not clean kitchens, hence the lower RCR than the former. The strength of this method is elaborated here by showing that it functions well with practical workplace determinants that affect the risk of exposure and not the risk of the chemical i.e. the hazardous nature of the chemical including physical and chemical properties. Hospital cleaning normally involves use of very hazardous chemicals (Nilsen 2012). One would have obtained a higher RCR for hospital if the hazard classification and other properties of the chemicals were considered as a factor, as would have been the case in the methods mentioned in the introduction. The essence of the approach in this study is practice-based.

In a review of determinants of expsoure to chemicals in different sectors, operations performed, duration of task, ventilation, work practices, use of PPE, and location were listed as among the most widely used determinants of exposure (Burstyn & Teschke 1999). Determinants chosen for building of the method in this study agree well with what the reported findings. It is important to note here that, in this study, no differentiation is made in use of PPEs, i.e. no different θs are envisaged for different types of PPEs, or room size other than “open” and “confined” as would be the case when the purpose is to assess exposure level.

In assessing exposure to chemicals, for mixtures as is mostly the case with cleaning products, concentration of components, and duration of use are important parameters. These parameters are however not included here as these are difficult to translate into easily answerable questions. It is earlier reported that better study outcome can be obtained when such assessment is based on elements related to exposure which the cleaners can easily recall (Teschke et al 2002) e.g. number of times a task is performed. Mixtures components' concentration and duration of use are indirectly made up for in the approach; dilution reduces the concentration, whereas frequency of use covers partly for the duration. Ambience (ξ) implicitly covers ventilation, environmental conditions and nearness to the source of exposure. Use of spray bottle is a general work practice.

Assignment of the coefficients was such that the task considered higher risk were assigned higher coefficients. Cleaning of toilets and kitchens involves several small tasks (Bello et al 2009), e.g. cleaning of sink, toilet bowl cleaning as part of cleaning toilet, whereas in the kitchen, one may clean different surfaces, cookers etc. In addition one uses stronger chemicals in cleaning toilets and kitchen than those used for other areas. These tasks are hence given a coefficient of 2, while cleaning of windows/glass surfaces and floors are assigned coefficients 1 and 0.5 respectively due to the decreasing level of risk of exposure. Moreover, windows/glass surfaces are, in most cases, not cleaned on daily basis. The frequency factor assigned for the window/glass surfaces when the task is performed a limited number of times/week is similar to that of daily basis, with exception of ≥10 times/shift which does not apply. This was made so since cleaning a fewer number of times/week gives a lesser exposure paradigm than daily cleaning. Although floors cleaning may be done on daily basis, the extent of dilution of the ready-to-use solution is greater for floor cleaning than that for window/glasses surfaces (Bello et al 2009). With this in mind, the cleaning of floors is assigned a lower coefficient than the windows/glass surfaces.

In assigning the values for the different scenarios (ν; θ; δ; σ; ξ) the contributing effect of the determinant, to, is assumed doubled on moving from one situation scenario to another in order to give consistency, e.g. when one goes from a frequency of 1-3 per work shift to 4-6, or not using spray bottle to using it. Frequency is assigned 0.25 as the lowest factor to indicate that risk level is considered the least as when task is performed 1-3 times. Similarly, same factor is used where PPE are used all the time during work performance. On the high side, is a factor 2 for situation where the risk level is considered the highest, i.e. when work is done ten or more times, and for PPE, when not used at all. Using spray bottle may increases the risk of exposure manifold, but for the purpose of consistency in this approach, the risk was also assumed doubled. In addition to spreading the chemicals, spray bottles also spray bacteria in the room (Remote Health Atlas 2007), further supporting the doubling of risk suggestion.

5 Conclusion

The method suggested, although mostly subjective as it depends on information provided by the cleaners, and/or supervisors' perceptions, gives a practical approach that allows for evaluation of cleaning work situations and puts forward a systematic procedure for establishment of the potential risk of exposure to chemicals. It is apparent that use of determinants of exposure instead of risk of chemicals makes the approach a versatile tool for determination of potential risk of exposure. The outcome is dependent on the tasks performed, how the tasks are performed and the measures taken, and not the chemical risk.

The determinants of exposure used in the approach are independent of the type and hazardous nature of chemicals used in any given work situation and this allows use of the method across different work situations with similar assessment basis.

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Table 1: The numerical values assigned different scenarios that can be actual in relation to cleaning work at different work stations

Task		Dilution		SB[1]		WE[2]	
Performed	φ	*Done*	δ	*Used*	σ	*Ambiance*	ξ
No	0	No	1	No	1	Open	1
Yes	1	Yes	0.5	Yes	2	Closed	2

[1] Spray Bottle; [2] Work Environment

Table 2: Scenario bands and the factors assigned for frequency of task performance (on daily /weekly basis) and the extent of use of PPE.

Frequency			Use of PPE	
No. of times	ν_D[3]	ν_W[4]	*Extent of use*	θ
1-3	0.25	0.25	All the time	0.25
4-6	0.5	0.5	≥50%	0.50
7-9	1	1	<50%	1
≥10	2	n/a	None	2

[3] For Cleaning tasks performed on daily basis.

[4] For task which are not performed on daily basis, but only a number of times per working week such as cleaning windows (max seven times a week).

n/a: Not applicable; 7-days maximum

Table 3: Presentation of tasks' RFs, ∑RF and RCR of the different work situation assessed using the proposed approach

	NP[5]	RF_T	RF_K	RF_W	RF_F	**∑RF**	**RCR**
Travel terminals[6]	9 (12.7%)	1.00	0	0.13	0.13	1.26	**7.41**
Shopping Centre	6 (8.5%)	0	0	0.25	0.03	0.28	**1.65**
Offices	24 (33.8%)	0.50	0.13	0	0.06	0.69	**4.05**
Kindergarten	6 (8.5%)	0.50	0.13	0.06	0.13	0.82	**4.82**
Hospital	26 (33.8%)	0.50	0	0.13	0.13	0.76	**4.47**

[5] Number of participants

[6] Covers a train station and a regional bus terminal

NB: RF = 0 when φ=0, which means that the task is not performed in that particular work station, or the tasks are performed by other cleaners (different company) than those interviewed.

Table 4: Comparion of the RCRs of the different cleaning work situations. The values in the table show the disparity between the different workplaces as by the ratio: a/b

		Travel Terminals (a_1)	Shopping Centre (a_2)	Offices (a_3)	Kindergartens (a_4)	Hospital (a_5)
	RCR	7.41	1.65	4.05	4.82	4.47
Travel Terminals (a_1)	7.41	--	0.22	0.55	0.55	0.60
Shopping Centre (a_2)	1.65	4.49	--	2.45	2.92	2.71
Offices (a_3)	4.05	1.89	0.41	--	1.19	1.10
Kindergartens (a_4)	4.82	1.53	0.34	0.84	--	0.93
Hospital (a_5)	4.47	1.66	0.37	0.91	1.08	--

Note that the labels $a_1 \ldots a_5$, are only used to give an indication on how the values are calculated, i.e. comparison ratio. So, a_2/a_1= 0.22, whereas a_1/a_2=4.49.

Since the values given in the table are ratios, there are no units.

Highlights

- Methodological approach for risk characterization of cleaning work that gives foundation for workplace intervention.
- Determinants of exposure such as frequency of use of chemicals, use of PPEs, use of spray bottles, not physical properties of chemicals are employed.
- Different work situations can be compared to a minimal exposure construed ideal to give workplace risk characterization ratio.

Table of acronyms

OHS	Occupational Health Service
PPE	Personal Protective Equipment
RCR	Risk Characterisation Ratio
RF	Risk Factor
SB	Spray bottle
WE	Work Environment

Table of symbols used

ω	Assessment factor ($\omega = \nu * \theta * \delta * \sigma * \xi$)
ν	Frequency of use chemicals
θ	Use of PPE
δ	Dilution
σ	Use of SB
ξ	Work Environment