

Recommendation no. 9
of the BPC Ad hoc Working Group on Human Exposure

Hand disinfection in hospitals

(revision agreed at the Human Health Working Group I on 19 January 2017)

1. Introduction

Biocidal products of product type 1 (PT 1) are used for disinfection related to human body hygiene, including antiseptics used in topical application on intact human skin surface to prevent infections.

Two types of products can be distinguished:

Hand rub products: the first type are hygienic hand rub products which are applied on dry skin of the hands, then hands are rubbed intensively and the disinfectant is left on the skin. This kind of disinfectant evaporates off. Therefore, these products contain volatile compounds as active substances which in general have a vapour pressure above 0.01 Pa (at room temperature) such as ethanol, propanol or hydrogen peroxide (see table in Annex 1). In order to assess the worker's exposure during application of these products, it is necessary to consider inhalation exposure because of their volatility, as well as dermal exposure. These products stay on the skin and are removed by evaporation. So it is important to consider the evaporation time from the skin.

Hand wash products: the second type are antimicrobial soaps for hygienic hand wash, which are applied on wet skin and are rinsed off with water, after hands are rubbed intensively. These products contain in general non-volatile compounds as active substance with a vapour pressure below 0.01 Pa, such as triclosan. For these products the dermal exposure is the major pathway of exposure.

Hand disinfection may be carried out by private users or by professionals, e.g. at food processing facilities or in hospitals. The following recommendation proposes an assessment of primary exposure for the professional user only. Secondary exposure of general public (e.g. patients) is not part of this document. The professional use in hospitals is regarded as a reasonable worst case assumption, due to the high number of repeated hand disinfections.

2. Exposure assessment

2.1. Hand rub products

2.1.1. Mixing / loading and post-application phase

In general, ready-to-use products are used for hand rub. In most cases a dispenser with the disinfectant is permanently installed in the hospital. These dispensers are suitable for 500 ml up to 1L bottles. For food processing industry 5 - 10L canisters are used as the dispenser. In case of a product change, only the one-way bottle/canister must be replaced and the detachable pumping system must be rinsed. A direct contact with the disinfectant is excluded and inhalation exposure during the exchange is not expected.

A post-application phase is not expected for disinfectants because they are totally used and no residues need to be disposed.

In some cases, the dilution of a concentrate might be necessary. In this case, the exposure during dilution of the concentrate and loading of e.g. a dispenser should be estimated.

2.1.2. Application phase

For hygienic hand rub, a standard rub-in technique in accordance with EN 1500 [1] is followed to ensure an effective disinfection. The disinfectant is applied onto dry palms and rub-in up to the wrists for e.g. 60 seconds in a technique of 6 steps to ensure that the whole surface of both hands is treated.

- Step 1: Apply about 3 ml of disinfectant and rub into palm of hand. Rub palm to palm to spread disinfectant over entire hands and fingers.
- Step 2: Rub the back of your left hand with the palm of the right hand. Reverse and repeat action.
- Step 3: Open fingers and rub the finger webs. Reverse and repeat action.
- Step 4: Rub palm to palm with fingers interlocked (5 times).
- Step 5: Rub thumb of each hand using a rotating movement.
- Step 6: Rub the tips of the fingers against the opposite palm using circular movement. Rub wrist with both hands. Allow hands to dry completely.

The use of a dispenser ensures a simple and exact metering of hand disinfectant. The required quantities are provided by the adjustable stroke from about 1 ml to 3 ml per stroke. The necessary quantity for each hand rub and the rubbing time depends on the product in use. The amount and rubbing time will be provided by the applicant and communicated on the label.

During surgical hand rub, hands and lower arms must be kept moist with the disinfectant for a higher duration, e.g. 90 seconds, depending on the product. However, the general use of hygienic hand rub is the worst case, since this is performed with a higher frequency (4 hand surgical rubs vs. 25 general hand rubs).

The frequency is assumed to be 25 hand rubs per shift based on the HEAdhoc Recommendation no. 1: *Hand disinfection – PT 1 harmonisation of exposure determinants for professional users* [2].

Inhalation exposure

For hand rubs with volatile compounds, an inhalation exposure to vapour is reasonable and calculated as follows.

- Tier 1

It is assumed that a health care worker in a hospital performs 25 hand rubs per shift. In a Tier 1 approach describing the worst case it is considered that all disinfectant is applied in one room successive without break. Calculation of the inhalation exposure is based on the model ConsExpo Web [3] “Exposure to vapour: Instantaneous release”. The room size is assumed to be 80 m³ and the assumed ventilation rate is 1.5/h. The assumption of the room size is for a two bed room. The use of the default values of 80 m³ and 1.5/h was discussed and agreed in the HEAdhoc Group. The room size is based on available information (e.g. from UK [4]). The air exchange rate (natural ventilation) is based on expert judgement taking into account that in a hospital a patient sick room is frequently opened by nurses, doctors, visitors, cleaning personal and patients [5]. Due to these visits a higher ventilation rate is reached as it is considered for e.g. a living room in ConsExpo. Moreover due to a higher infection risk a higher ventilation rate in hospitals is desirable.

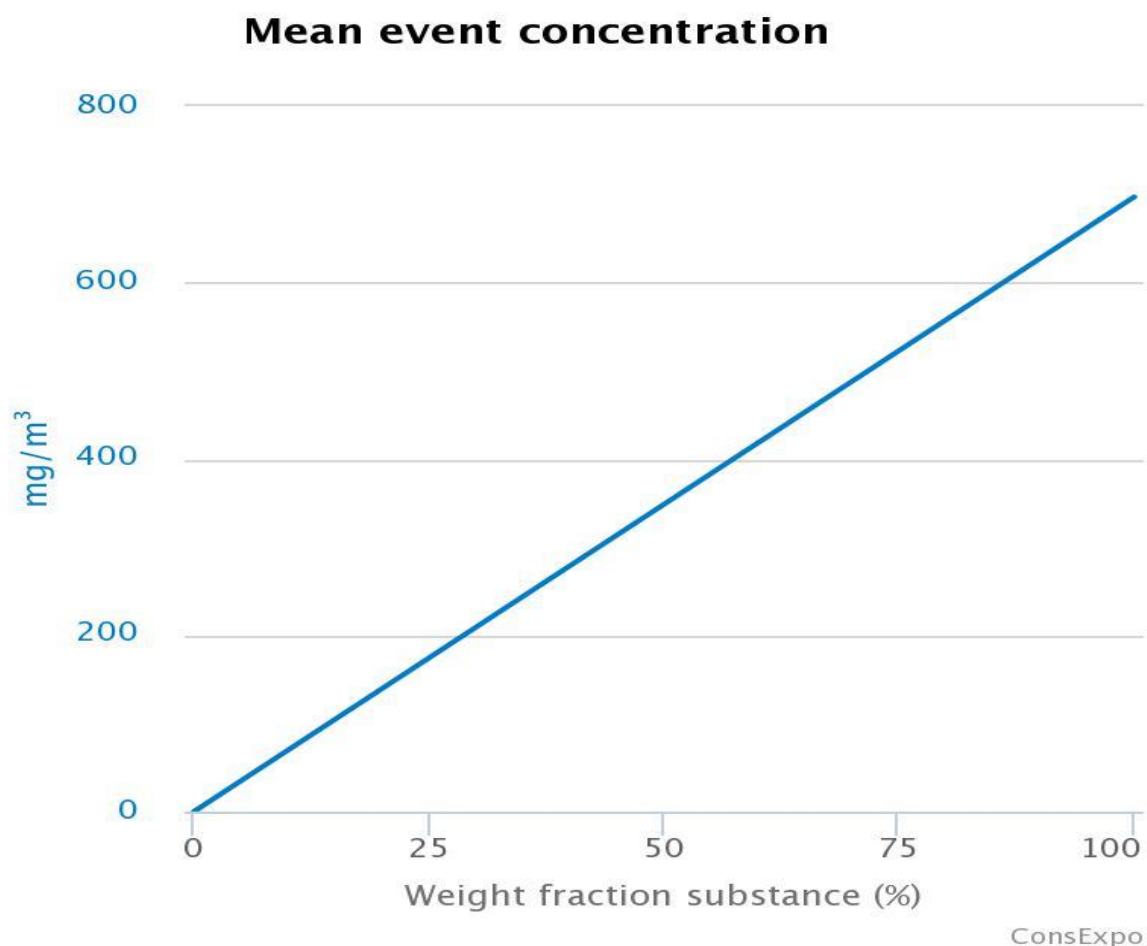
Table 1: Input parameters for ConsExpo (Exposure to vapour: Instantaneous release)

Parameter	Input values
Concentration of a.s.	applicants’ information
Applied amount	25 x 1-3 g (depending on applicants’ information)
Room size	80 m ³

Ventilation rate	1.5/h
Exposure duration	25 x 1 min

The resulting air concentration depends in this case (with fixed room size and ventilation rate) only on the mass (applied amount x weight fraction). The air concentration progress is linear (see Graph 1). The vapour pressure of the substance is not relevant for this assessment.

Graph 1: Example of air concentration [mg/m^3] in relation the weight fraction [%] of the disinfectant (based on applied amount of 75 g, 100 %) in a room of 80 m^3 and ventilation rate of 1.5/h (sensitivity analysis of ConsExpo)











If no risk is identified, the evaluation can stop here. If there is a risk, the following refinement is proposed.


- Tier 2

It is unrealistic that a health care worker carries out all 25 hand rubs at once in one room. For a refinement of the exposure calculation, a more realistic exposure scenario is proposed on the basis of 25 hand disinfections per shift:

One nurse is responsible for 8 patients. This figure is in line with the research done for the HEAdhoc recommendation No. 1 among Europe. Two patients are in one patient room of 80 m³ size with a ventilation rate of 1.5 per hour. During her work in the patient room, 3 hand disinfections are performed. The nurse stays for 20 minutes in every room. After visiting of 4 patient rooms and 12 hand disinfections, she enters the first room again and performs again 3 hand disinfections in each room resulting in additional 12 hand rubs. One hand rub is performed e.g. at start of the shift in an 80 m³ room and staying for 10 minutes. In summary, 25 applications per shift are performed.

Graph 2: Example of distribution of the hand rub tasks over the work shift

Work time [hour]	0-1	1-1,5	1,5-2	2-2,5	2,5-3	3-5	5-5,5	5,5-6	6-6,5	6,5-7	7-8
Room 1											
Room 2											
Room 3											
Room 4											

 3 hand rubs per room (first enter the room – patient (1) care – second – patient (2) care – third – leaving the room) – duration in the room 20 minutes

The refined calculation is done with the model ConsExpo Web “Exposure to vapour: Constant rate release”.

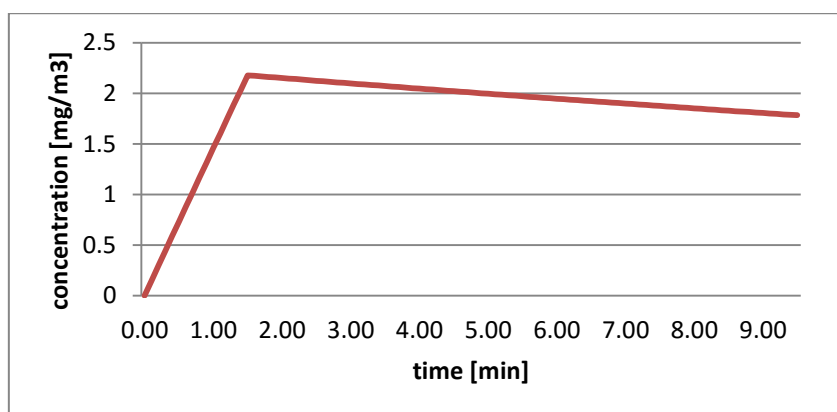
The same input parameters are used as described for Tier 1. In addition, the input parameter “emission duration” is necessary. For the emission duration the evaporation time of the in use amount of the disinfectant on both hands is needed. The evaporation time is calculated according to a generic model (Biocides Human Health Exposure Methodology, section 7.4) [6]). The calculation is based on the formula described in Annex 3. In the calculation the vapour pressure, the amount of active substance and the surface of both hands (820 cm²) are taken into account. For the calculation, the vapour pressure of the active substance at 30 °C is used, since 30° C is in the range of the skin temperature.

The following table summarised the input parameters to calculate one hand rub in the patients’ room.

Table 2: Summary of input parameters for ConsExpo calculation for one hand rub and resulting exposure curve (Exposure to vapour: Constant rate release)

Parameter	Input values
Concentration of a.s.	applicants' information
Applied amount for one hand disinfection	1-3 g (depending on applicants' information)
Room size	80 m ³
Ventilation rate	1.5/h
Exposure duration	10 min
Emission duration	calculated evaporation time at 30°C (see Annex 3)

Graph 3: Example of air concentration in relation to time of exposure (10 min) after one hand rub



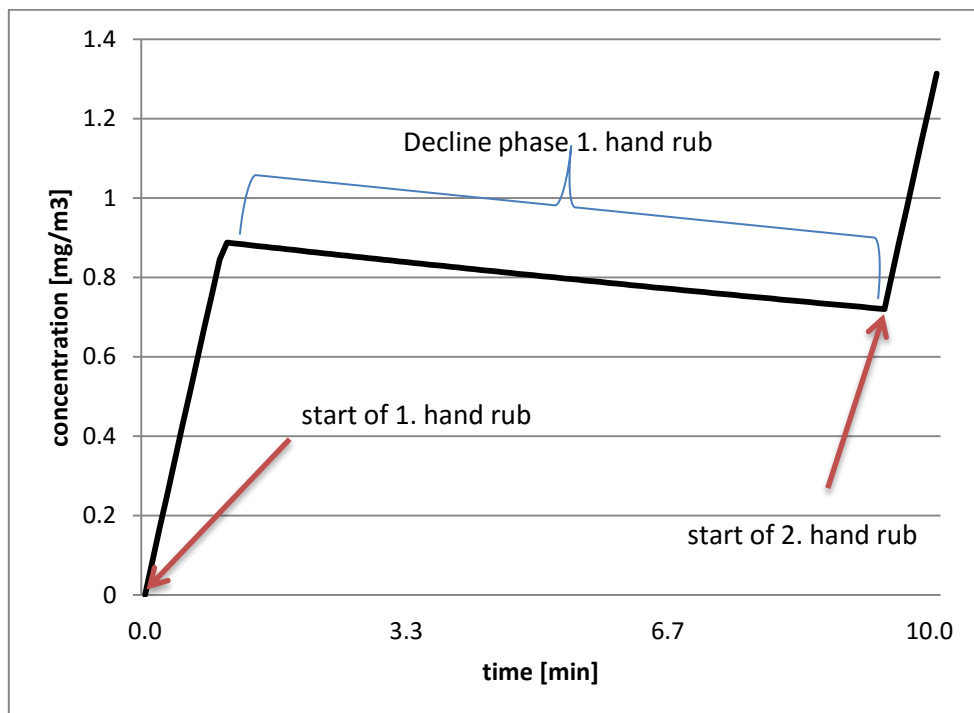
It is not possible to calculate the next 2 hand rubs performed in the same room with ConsExpo. Therefore, the use of Excel is proposed to calculate the further exposure during 3 hand rubs in one room (see Annex 2). In summary the following calculation steps are necessary:

1. Calculation of one hand rub in ConsExpo using the input parameters described in Table 2. The data for one hand disinfection shall be copied into Excel.
2. The second hand rub starts after 10 minutes during the decline phase of air concentration resulting from the first hand disinfection. The air concentration released by the second hand disinfection is therefore increased by the remaining air concentration from the first hand rub. For the calculation in Excel it is necessary to add the remaining air concentration of the first hand rub to the second hand rub values. This is done using the exported data from ConsExpo for one hand rub: To the air concentration value after 10 min for the first hand rub, the value of one hand rub (export file from ConsExpo) is added. This addition is performed in the same way for the next values. The exposure to the substance from multiple hand rubs includes the remaining air concentration and the new arising exposure from the subsequent hand rub. In the calculations the further decline of remaining air concentration is neglected for simplification purposes. The resulting exposure only slightly

overestimates the exposure by a factor of 1.05 (data not shown) and does not change significantly the outcome of the exposure assessment.

The following graph shows the results of the calculation and illustrates the exposure profile.

Graph 4: Example of air concentration in relation to time of exposure after two hand rubs



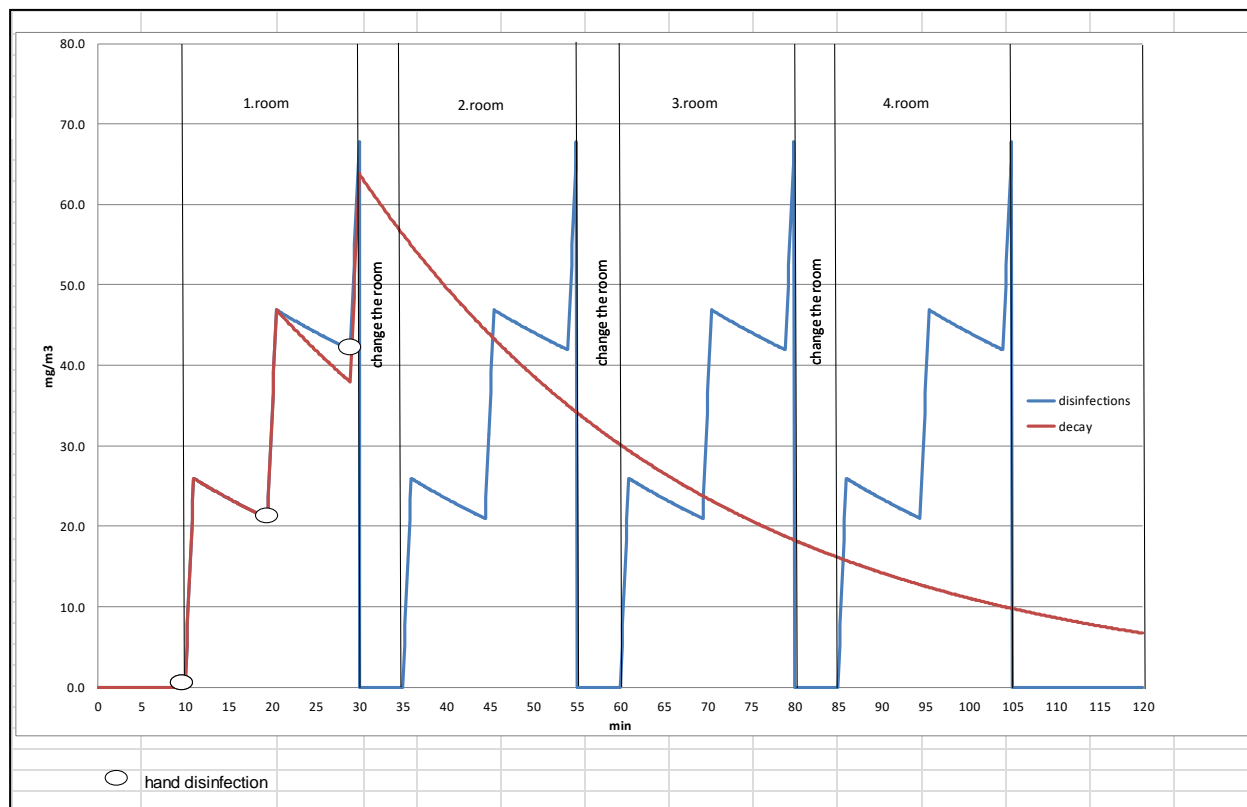
- The third hand rub performed in the same room is calculated in the same manner as described above for the second hand rub.
- Three hand rubs per room are performed in 4 patients' rooms. After 240 minutes, the nurse starts again in the patients' room where the first hand rub was performed. After 240 minutes, the air concentration after 3 hand disinfections is further declined and a remaining air concentration is considered. This remaining air concentration is added to the air concentration delivered by the new 3 hand rubs.

The remaining air concentration after 240 minutes after three hand rubs can be calculated. In the Excel calculation the air concentration after 3 hand rubs is determined.

The physico-chemical properties of the in-use active substance, the room size and the ventilation rate have an influence on how fast the increase and decline of air concentration are under the described conditions.

The following graph illustrates the whole process.

Graph 5: Example of air concentration in relation to time of exposure after visit of 4 patients' rooms. The red decay curve is the decline of air concentration after the third hand rub in one room.



After the second visit of the 4 patients' rooms, 24 hand rubs are performed in summary.

It is assumed that one hand rub is performed e.g. at the beginning of the shift in an 80 m³ room and that the staying lasts for 10 minutes (use of input parameters described in Table 2). The result of the ConsExpo calculation for one hand rub can be used to assess this isolated hand rub. The sum of 25 applications per shift is achieved.

In ConsExpo the external inhalation exposure is calculated as the air concentration during the exposure time (field 'exposure duration'). The output value is the "mean air concentration" during this single task.

The inhalation exposure of the nurse performing 25 hand rubs per shift is summed in the following way:

The following example might help to understand the calculation:

- Mean concentration for 1 disinfection, 10 min (ConsExpo): 22.1 mg/m³
- Mean concentration for 3 disinfections, 20 min (Excel) : 33.9 mg/m³
- Remaining air concentration (240 min) (Excel) : 0.33 mg/m³

The 8-h TWA is the time-weight average concentration by taking one or more events/tasks (mean concentrations) over an eight hour period. The time weighted average should ensure to take into account also times where the worker is not exposed.

$$8\text{-h TWA} = [C1 \times T1] + [C2 \times T2] + [Cn \times Tn] / 480 \text{ min}$$

The 8-h TWA for 3 hand rubs in 4 different rooms (with remaining air concentration) can be calculated as follows:

$$8\text{-h TWA} = [\text{mean event conc. (3 disinfections)} \times 20 \text{ min} \times 4 \text{ rooms}] + [(\text{mean event conc. (3 disinfections)} + \text{remaining conc.}) \times 20 \text{ min} \times 4 \text{ rooms}] + [\text{mean event conc. (1 disinfection)} \times 10 \text{ min}] / 480 \text{ min}$$

– 8-h TWA (Excel): 11.8 mg/m³

The presented complex calculation is presented in an Excel file in chapter 5.2 of this document. The provided Excel sheet can be used to assess the inhalation exposure to volatile substances. It is necessary to calculate the first hand rub in ConsExpo and to export the data to Excel. The exported data can be copied in the provided Excel sheet and the further calculation of 25 hand rubs is performed automatically. It is necessary to use the default value for the exposure duration (10 min) and not to change them otherwise the output of the calculation in this specific Excel sheet is wrong (time steps 0.1 min). However based on the above described procedure it is possible to calculate the exposure with different input parameters (room size, ventilation rate) with ConsExpo and Excel.

To assess the short-term exposure the mean concentration for 1 hand rub for exposure duration of 10 min is taken into account.

Dermal exposure

The ready-to-use solution is poured into the palms of one hand out of an automatic dispenser and the complete surface of both hands is moistened with the disinfectant and let to dry. The dermal exposure is limited to the time the disinfectant remains on the hands. For a worst case assumption, the total amount of the biocidal product (e.g. 3 g biocidal product x 25 hand disinfections resulting in 75000 mg biocidal product), is taken into account. Using the dermal absorption to assess the internal exposure will overestimate the exposure, since parts of the disinfectant will evaporate before entering the body burden.

If information about evaporation time and exposed skin is needed the following approach can be used. The evaporation time of the active substance on the skin can be calculated using the formula considered in Annex 3. This value depends on the physico-chemical properties of the active substance (e.g. for 70% propan-2-ol solution evaporates in 50 seconds). A skin area of 820 cm² is assumed since both hands are exposed.

2.2. Hand wash products

2.2.1. Mixing / loading and post-application phase

In general are ready-to-use hand wash products used for hand disinfection. As described for the hand rub products, normally a dispenser with the disinfectant (liquid soap) is permanently installed in the hospital. These dispensers are sized for 500 ml up to 1L bottles. For food processing industry 5 - 10L canisters are used for dispenser. In case of a product change only the one-way bottle/canister must be replaced and the detachable pumping system must be rinsed. A direct contact to the disinfectant is excluded and inhalation exposure during the exchange is not expected.

A post-application phase is not expected for the disinfectants because they are totally consumed.

2.2.2. Application phase

For hygienic hand wash a standard wash technique in accordance with EN 1499 [7] is followed to ensure an effective disinfection. The disinfectant is applied onto wet hands and washed for e.g. 60 seconds in a technique of 6 steps to ensure that the whole surface of both hands is treated.

- Step 1: Wet hands thoroughly under running water. Apply of soap to cupped hands (by pressing dispenser with heel of hand). Rub palm to palm (5 times).
- Step 2: Rub right palm over the back of the left hand up to wrist level (5 times). Do same with the other hand.
- Step 3: With right hand over back of left hand rub fingers (5 times). Do same with the other hand.
- Step 4: Rub palm to palm with the fingers in interlaces (5 times).
- Step 5: Wash thumbs of each hand separately using a rotating movement (5 times).
- Step 6: Rub the tips of the fingers against the opposite palm using a circular motion (5 times). Rinse hands thoroughly under running water to remove the traces of soap (e.g. 15 seconds).

The applied amount of soap depends on the product in use and is given by the information provided by the applicant and communicated on the label.

The frequency is assumed to be 10 hand washes per shift based on the HEAdhoc Recommendation no. 1: *Hand disinfection – PT 1 harmonisation of exposure determinants for professional users* [2].

For surgical hand wash a number of 4 hand disinfections per day is harmonized, but with a higher amount of product, since hands and forearms have to be washed in this case. For example, if 3 g are necessary for hands, 7 g will be necessary for hands and forearms.

Inhalation exposure

For hand soaps with non-volatile substances, inhalation exposure is not expected. If volatile substance is available in the hand wash soap and have to be assessed than a calculation in ConsExpo is necessary.

Dermal exposure

The ready-to-use solution is poured into the palms out of an automatic dispenser and the complete surface of both hands is moistened with the disinfectant. After disinfection (see 6 steps) the soap is rinsed off with water.

There are no suitable models available in the Biocides Human Health Exposure Methodology (2015) [6] to assess the dermal exposure during hand wash.

For a worst case assumption, the total amount of the biocidal product (e.g. 3 g biocidal product x 10 hand washes resulting in 30000 mg biocidal product) is taken into account. The total amount of product per day is nearly the same for the standard hand wash and the surgical hand wash (e.g. 10 x 3g = 30 g versus 4 x 7 g = 28 g). The contact of hands with the full load of product diluted in water is 1 min. The exposure after rinsing is taken into account.

A guidance of the cosmetic regulation of the Scientific committee on Consumer Safety (SCCS) provides a retention factor of 0.01 or 1 % of the amount of cosmetics on the skin [8]. Based on this, a value of 1% of retention after rinsing is considered for the dermal

exposure assessment in the described case. Therefore, the user is exposed to these residues of the active substance on the skin after rinsing (e.g. 30 mg for one hand disinfection). The quantity of 1% retention is added for each application per day for the whole working day.

3. Discussion and proposal for harmonisation

The use of a simple Tier 1 approach to assess the worker exposure during the application of hand rubs based on volatile active substances implies the tendency to overestimate exposure, especially inhalation exposure.

This paper presents an approach to overcome this risk of overestimation by using a refined Tier 2 scenario to assess the inhalation exposure of a healthcare worker in a hospital environment performing 25 hand rubs per shift. An elaborated Excel sheet is presented in Annex 2, where the output from ConsExpo can be included and the inhalation exposure of the user is calculated for 25 hand rubs.

For hand wash of non-volatile disinfectants, the disinfectant is applied on wet hands and rinsed off afterwards. The dermal exposure is the main source of exposure. The total amount of 10 hand washes are used for normal disinfection and 4 hand washes for surgical disinfection with an increased amount to treat hands and forearms. To assess the dermal exposure, a value of 1 % of the applied soap is used for each application per day.

4. References

1. EN 1500: Chemical disinfectants and antiseptics: Hygiene handrub. Test method and requirements (phase 2/step2); EN 1499:2013
2. Recommendation no. 1 of the BPC Ad hoc Working Group on Human Exposure: Hand disinfection – PT 1 harmonisation of exposure determinants for professional users
3. ConsExpo Web. (2016). <http://www.rivm.nl/en/Topics/C/ConsExpo>.
4. Guidance on building design for UK hospitals; Health Building Note, Adult In Patient Facilities, HBN 04-01, 2009 [<https://www.gov.uk/government/collections/health-building-notes-core-elements>]
5. Publication: Escombe, A., et. al.; Natural Ventilation for the prevention of airborne contagion, PLOS Medicine, Issue 2, Vol. 4, 2007, 309-317
6. Biocides Human Health Exposure Methodology V 1.0 (2015): <http://echa.europa.eu/about-us/who-we-are/biocidal-products-committee/working-groups/human-exposure>
7. EN 1499: Chemical disinfectants and antiseptics: Hygiene handwash. Test method and requirements (phase 2/step2); EN 1499:2013
8. The SCCS notes of guidance for the testing of cosmetic ingredients and their safety evaluation, 9th revision (2015): http://ec.europa.eu/health/scientific_committees/consumer_safety/docs/sccs_o_190.pdf

5. Annexes

Annex 1: Overview of volatile active substances in disinfectants

Substance name	CAS No.	Molecular weight [g/mol]	Vapour Pressure [Pa]	Source
Ethanol	64-17-5	46,07	5700 - 7900 (25° C)	CAR (Ethanol)
Propan-2-ol	67-63-0	60,10	5780 (25° C)	CAR (Propan-2-ol)
Propan-1-ol	71-23-8	60,10	2760 (25° C)	CAR (Propan-1-ol)
Hydrogen peroxide	7722-84-1	34,01	214 (20° C); 299 (25° C)	CAR (Hydrogen peroxide)
Iodine	7553-56-2	253,8	40.7 (25° C)	CAR (Iodine)
Phenoxy ethanol	122-99-6	138,16	4 (20° C)	GESTIS Substance database (IFA, Germany)

Annex 2: Inhalation exposure calculation with ConsExpo

The Annex is available under "Recommendations of the Ad hoc Working Group on Human Exposure": http://echa.europa.eu/web/guest/view-article/-/journal_content/title/recommendations-of-the-ad-hoc-working-group-on-human-exposure

Now available is Version 2 which contains the revised calculation (red curve) for the decline curve after the third hand rub. It is not a new approach; it revises only the not completely precise calculation for the decline curve after the third hand disinfection. Everything else (input parameters and procedure for the calculation), is the same.

Annex 3: Calculation “Evaporation time”

Based on Biocides Human Health Exposure Methodology V 1.0 (2015) [6], page 255

For the purpose of determining the evaporation rate of a substance, an equation can be used which was derived within the framework of a research project. This project was aimed at calculating airborne concentrations of substances when emitted from liquid mixtures taking into account the evaporation and the spreading of the substance at the workplace. To calculate the evaporation times of substances, an equation was derived based on the mass transfer at the interface between the liquid and the vapour (two-film-theory). Mass transfer during evaporation occurs until the equilibrium state is achieved. The main influence on evaporation is the transfer through the interface.

For pure substances, the following equation is used:

$$t_s = \frac{m \times R \times T}{M \times \beta \times p \times A} \times K(\text{sec})$$

Explanation of symbols:

- t: time [s]
- m: mass [mg]
- R: gas constant [J x K⁻¹ x mol⁻¹]: 8.314
- T: skin temperature [K] → 30°C: 303.15
- M: molar mass [g/mol]
- β: coefficient of mass transfer in the vapour phase [m h⁻¹]: 8.7
- p: vapour pressure of the pure substance [Pa]
- A: area [cm²]
- K: conversion factor: 36000

Equation for calculating the evaporation duration of a disinfectant (e.g. for ethanol):

$$t(\text{s}) = (3147 \times 8.314 \times 303.15 \text{ K} / 46 \times 8.7 \times 10400 \times 820) \times 36000 = 83.7 \text{ sec.}$$

Explanation of values used in the example equation for pure ethanol:

- m: mass [mg] → 3 ml (density: 1.049 g/ml^{20°C}) = 3 g = 3147 mg
- M: molar mass [g/mol] → 46 g/mol
- p: vapour pressure of the pure substance [Pa] e.g. for ethanol = 10400 Pa at 30°C (skin temperature)
- A: area [cm²] → skin area both hands of 820 cm²

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