

Standardized dirts for testing the efficacy of workplace cleaning products: validation of their workplace relevance

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Summary

Background. In order to assess the cleaning efficacy of occupational skin cleansers, standardized test dirts mimicking the spectrum of skin soiling at dirty workplaces are necessary.

Objectives. To validate newly developed standardized test dirts (compliant with the EU Cosmetics Directive) for their occupational relevance.

Methods. In this single-blinded, monocentric questionnaire-based clinical trial, 87 apprentices of three trades (household management; house painting and varnishing; and metal processing) evaluated the cleanability of six standardized test dirts in relation to their workplace dirts. In addition, they judged the similarity of the test dirts to actual dirts encountered in their working environments.

Results. Most of the household management participants assessed the hydrophilic model dirt ('mascara'), the lipophilic model dirt ('W/O cream') and a film-forming model dirt ('disperse paint') as best resembling the dirts found at their workplaces. Most of the painters and varnishers judged the filmogenic model dirts ('disperse paint' and 'acrylic paint') as best resembling the dirts found at their workplaces. For the metal workers, the lipophilic and paste-like model dirts were most similar to their workplace dirts.

Conclusions. The spectrum of standardized test dirts developed represents well the dirts encountered at various workplaces. The test dirts may be useful in the development and *in vivo* efficacy testing of occupational skin cleansers.

Key words: efficacy testing; occupational dermatitis; occupational skin cleanser; prevention; test dirt; workplace soiling.

Even in highly developed industrial countries, 'dirty workplaces' are still not rare. In a representative survey performed by the Federal Institute of Occupational

Training and the Agency for Occupational Protection and Medicine in 20 000 German workers above the age of 15 years in 2005–2006, 17.6% reported being frequently exposed to oils, fat, soil, and dirt, with men and younger workers being overrepresented (1). Workers exposed to occupational skin soiling are at risk of percutaneous penetration of harmful chemicals (2) and of the development of occupational skin diseases such as irritant and/or allergic contact dermatitis. Repeated cleansing of soiled skin is a well-known risk factor for cumulative irritant contact dermatitis and part of the definition of 'wet work' (3). Skin cleansing products are cosmetic preparations that are

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used during and after work (after the end of the work and before breaks) and are intended to remove soiling from the skin (4). They constitute an important part of the three-step occupational skin protection programme (5–7). Outbreaks of hand dermatitis caused by inappropriate skin cleansers have been described (8), and experimental studies have shown wide differences in the irritant potential of different occupational cleansers (9–12). Removal of occupational soiling with adequate occupational skin cleansers is therefore important for the prevention of occupational irritant dermatitis. Cleansers need to be tested in standardized protocols for cleansing efficacy and irritant potential. For a given soiling compound, the optimal cleanser would be the product removing the dirt sufficiently while causing minimum irritation to the skin.

Few studies have been published on the cleansing efficacy of skin cleansers (11–17). These studies are based on the application of a test dirt followed by a standardized washing procedure with the cleanser to be assessed. The cleansing efficacy is judged by the degree of dirt removal from the skin surface. Dirts used in previous studies included workplace substances such as engine oil, wool wax, petrolatum, iron oxide, carbon black, and graphite (12), or complex artificial mixtures containing azo dyes such as Sudan Red G (CAS 1229-55-6) (17). Validation of these compounds regarding their relevance in mimicking workplace soiling was never performed. Furthermore, from a toxicological standpoint, many of the mentioned compounds are considered to be genotoxic and/or carcinogenic (e.g. Sudan Red G). As test dirt applied on human skin for efficacy testing purposes are subject to the Regulation (EC) No. 1223/2009 of the European Parliament and of the Council of 30 November 2009 on cosmetic products (18), exclusion of genotoxicity and/or carcinogenicity is required, as well as a cosmetic safety assessment. We therefore developed a new panel of model dirt for efficacy testing purposes that were oriented at the typical soiling scenarios from workplaces. These model dirt had to be based on generally available cosmetic compounds without any safety concerns. In order to enable recommendation of their use in experimental protocols, validation of their occupational relevance was performed in the present study.

Materials and Methods

Study design

The study was conducted as a single-blinded, monocentric questionnaire-based clinical trial.

The study was approved by the Ethics Committee of the University Hospital Jena.

Subjects and study procedures

Eighty-seven apprentices of three trades [household management (domestic science); house painting and varnishing, including woodworkers intensively exposed to varnishing; and metal processing] were recruited in two vocational schools.

The volunteers were included after receipt of a written informed consent declaration.

The subjects were asked by the researcher to apply a small amount of every kind of (blinded) model dirt to their hands (two fields on the palmar side and one field on the dorsal side) in a consecutive manner, and spread it evenly to obtain complete coverage of the test field. Immediately after dirt application, the subjects had to clean the test fields with the usual skin cleanser that they used at the workplace, and judge the removability of the specific model dirt in a standard questionnaire in relation to the actual dirt encountered at the workplace. Additionally, the volunteers were asked to complete a questionnaire associating every type of model dirt with the specific dirt that they had experienced at their workplaces.

Model dirt

The formulas of the six model dirt are shown in Table 1, based on their INCI declaration. They contain different quantities of lampblack, ferric oxide, and graphite, causing black staining of the skin and allowing chromametric measurements (Chromameter® CR 300; Minolta, Tokyo, Japan; luminance measuring) before and after a standardized cleaning procedure. The model dirt

Table 1. Model dirt for cleanser efficacy testing: INCI formulations

Hydrophilic model dirt, type 'mascara'
Aqua, CI 77499 (ferric oxide), hydrxyethyl cellulose, sodium hydroxide, PVP, propylene glycol, stearic acid, glyceryl stearate, carnauba acid wax, lanolin alcohol, cera alba, polyquaternium-7
Lipophilic model dirt, type 'w/o cream'
Aqua, CI 77499 (ferric oxide), CI 77266 (lampblack), CI 77266 (graphite), paraffinum liquidum, petrolatum, lanolin, lanolin alcohol, ozokerite, glyceryl oleate
Paste-like model dirt, type 'used oil'
CI 77499 (ferric oxide), CI 77266 (lampblack), CI 77266 (graphite), paraffinum liquidum, petrolatum, lanolin
Paste-like model dirt, type 'ointment'
CI 77499 (ferric oxide), CI 77266 (lampblack), CI 77266 (graphite), paraffinum liquidum, petrolatum, cera alba
Film-forming model dirt, type 'disperse paint'
CI 77499 (ferric oxide), CI 77266 (lampblack), polyacrylate dispersion 30%, polyquaternium-7
Film-forming model dirt, type 'acrylic paint'
CI 77499 (ferric oxide), CI 77266 (lampblack), basic butylated methacrylate copolymer, isopropyl alcohol, alcohol denat

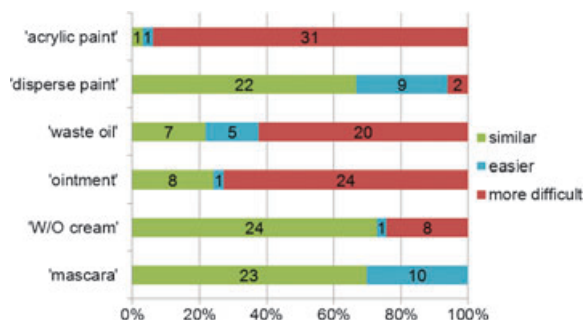


Fig. 1. Assessment of the cleanability of model dirt by household management apprentices ($n = 33$) in relation to their workplace dirt. Volunteers judged the cleanability of model dirt from the skin of their hands with their standard workplace cleanser as easier, similar or more difficult than that of the dirt usually encountered at their workplaces. W/O, water-in-oil.

are characterized by different skin adhesion properties simulating occupational soiling, such as that caused by waste oil and lacquers. The hydrophilic model dirt is based upon the formula of mascara, and the lipophilic model dirt resembles a water-in-oil (W/O) cream. For the development of the paste-like model dirt, the model dirt previously described by Schrader (19) and by the German Statutory Accident Insurance (20) served as models. Because of their characteristics, they are called 'waste oil' (paste-like model dirt I) and 'ointment' (paste-like model dirt II). In addition, a dirt-type 'disperse paint' (film-forming model dirt I) and 'acrylic paint' (film-forming model dirt II) were designed. The model dirt were developed at the University of Applied Sciences in Ostwestfalen-Lippe, Detmold, Germany, Section of Pharmaceutical Technology (Prof. Dr Kutz). Detailed pharmaceutical/galenical information will be published elsewhere (21).

Data analysis and statistics

The data were displayed as tables (absolute numbers) and figures (percentages), with Microsoft™ Excel for Mac 2011.

Results

Thirty-three household management apprentices, 29 future painters and varnishers and 25 trainees in metal processing were included in the study.

Most of the household management participants assessed the hydrophilic ('mascara'), the lipophilic ('W/O cream') and the film-forming model dirt I ('disperse paint') as being cleanable in a similar fashion as the

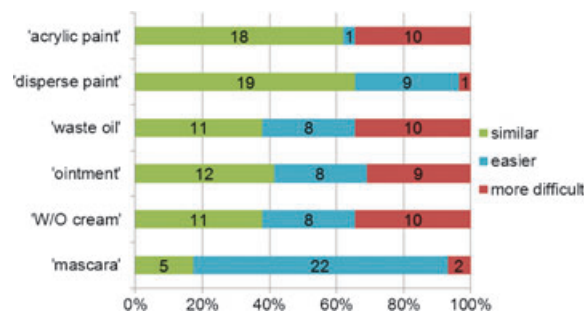


Fig. 2. Assessment of the cleanability of model dirt by painting and varnishing apprentices ($n = 29$) in relation to their workplace dirt. Volunteers judged the cleanability of model dirt from the skin of their hands with their standard workplace cleanser as easier, similar or more difficult than that of the dirt usually encountered at their workplaces. W/O, water-in-oil.

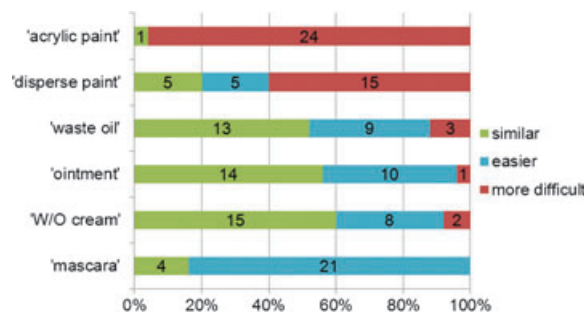


Fig. 3. Assessment of the cleanability of model dirt by metal processing apprentices ($n = 25$) in relation to their workplace dirt. Volunteers judged the cleanability of model dirt from the skin of their hands with their standard workplace cleanser as easier, similar or more difficult than that of the dirt usually encountered at their workplaces. W/O, water-in-oil.

dirt occurring at their workplace (Fig. 1). Most of the painters and varnishers judged the filmogenic model dirt ('disperse paint' and 'acrylic paint') as best resembling the dirt at their workplace (Fig. 2). The hydrophilic model dirt ('mascara') was considered by them to be too easy to clean in comparison with their workplace dirt. For the metal workers, the lipophilic ('W/O cream') and paste-like ('waste oil' and 'ointment') model dirt were closest to their workplace dirt, whereas the hydrophilic dirt ('mascara') was too easy to clean off, and the two film-forming dirt were too difficult to remove (Fig. 3).

In addition, the study participants were asked to compare the standard model dirt with dirt actually encountered in their working environments (Tables 2–4).

The mascara-type hydrophilic model dirt was mostly associated with 'soil/dirt' (household management,

Table 2. Judgement of the association of test dirts with actual workplace dirts by household management apprentices (n = 33)

Categories of workplace dirts	Categories of test dirts					
	Mascara	W/O cream	Ointment	Used oil	Disperse paint	Acrylic paint
Earth/dirt	22	1	2	1	2	–
Shoe polish	1	18	19	4	–	–
Detergent/soap	2	–	–	–	–	–
Oil (polish)	1	2	2	15	–	2
Oil paint	–	–	–	10	–	–
Furniture polish (cream)	–	1	–	1	–	–
Cream	1	13	5	1	–	–
Ointment	–	1	2	–	–	–
Shoe wear on floor	–	–	–	–	2	–
Grease	6	6	5	3	4	–
Window paint	1	–	–	–	3	–
Paint	5	1	–	1	21	2
Lacquer	–	–	–	–	1	11
Glue	–	–	–	–	–	11
Latex paint	–	–	–	–	–	8
Comparable to none of the above	–	–	–	3	3	6
Total of answers	39	43	35	39	36	40

Volunteers were asked to associate test dirts with their usually encountered workplace dirts. Several answers were possible.

n = 22), 'paint' (painters and varnishers, n = 13), and 'metal dust' (metal workers, n = 13).

The lipophilic model dirt ('W/O cream') was mostly associated with 'shoe polish' (household management, n = 18), 'paint' (painters and varnishers, n = 8), and 'grease' (metal workers, n = 9).

The paste-like model dirt I ('ointment') was mostly associated with 'shoe polish' (household management, n = 19), 'paint' (painters and varnishers, n = 6), and 'grease' (metal workers, n = 12).

The paste-like model dirt II ('waste oil') was mostly associated with 'oily polish' (household management,

n = 15), 'oil' (painters and varnishers, n = 8), and 'oil' (metal workers, n = 19).

The filmogenic model dirt I ('disperse paint') was mostly associated with 'paint' (household management, n = 21; metal workers, n = 16), and 'paint' and 'lacquer' (painters and varnishers, each n = 12).

The filmogenic model dirt II (type 'acrylic paint') was mostly associated with 'lacquer' (household management, n = 11; painters and varnishers, n = 25; metal workers, n = 21) and 'glue' (household management, n = 11).

Table 3. Judgement of the association of test dirts with actual workplace dirts by painting and varnishing apprentices (n = 29)

Categories of workplace dirts	Categories of test dirts					
	Mascara	W/O cream	Ointment	Used oil	Disperse paint	Acrylic paint
Earth/dirt	6	1	–	–	–	–
Wax	–	3	3	–	–	–
Oil	1	3	2	8	–	1
Oil paint	–	–	–	6	–	–
Paint	13	8	6	6	12	1
Glue	–	1	2	1	–	3
Grease	4	5	3	4	1	–
Plaster/putty	2	3	2	1	–	–
Cream/paste	2	5	6	–	–	–
Latex paint	–	2	–	–	3	3
Grit	2	–	–	1	1	–
Lacquer	2	3	3	6	12	25
Comparable to none of the above	–	–	–	–	–	–
Total of answers	32	34	27	33	29	33

Volunteers were asked to associate test dirts with their usually encountered workplace dirts. Several answers were possible.

Table 4. Judgement of the association of test dirt with actual workplace dirt by metal processing apprentices (n = 25)

Categories of workplace dirt	Categories of test dirt					
	Mascara	W/O cream	Ointment	Used oil	Disperse paint	Acrylic paint
Metal dust	13	7	3	2	2	–
Grease	4	9	12	9	2	–
Oil	5	4	4	19	3	1
Fats	4	8	3	2	–	–
Metal grits	2	2	3	–	1	–
Cooling agent	–	–	–	1	–	–
Paint	–	–	1	2	16	10
Lacquer	1	–	1	–	6	21
Tar	–	–	–	–	1	1
Comparable to none of the above	–	–	–	–	3	2
Total of answers	29	30	27	35	34	35

Volunteers were asked to associate test dirt with their usually encountered workplace dirt. Several answers were possible.

Discussion

Although several attempts have been made in the past to assess the cleaning efficacy of workplace skin cleansers by using model dirt (12–17), these test dirt were never validated for their occupational relevance. In this study, we validated, for the first time, newly designed test dirt developed according to the EU Cosmetics Directive (18) for their cleanability with actual workplace cleansers and for their similarity to actual workplace dirt.

Our results show that the spectrum of standardized test dirt developed mimick the dirt encountered at various workplaces appropriately. For the household workers, the hydrophilic dirt 'mascara', the lipophilic dirt ('w/o cream') and the less adhesive film-forming dirt ('disperse paint') seem to be the most representative ones. For painting and varnishing apprentices, the film-forming dirt ('disperse paint' and 'acrylic paint') were most similar to their workplace exposures, as could be expected. For the metal workers, the lipophilic dirt ('w/o cream', 'ointment', and 'waste oil') best represented their workplace soiling experience. The mascara-based

hydrophilic dirt was mostly associated with soil and dirt. Interestingly, the metal workers compared it with metal dust, with which they have more contact and which is remarkably adhesive.

Occupational cleansers should be targeted at specific workplaces and specific dirt encountered in them. As it is unrealistic for companies to provide or workers to use a wide variety of cleaning products for each workplace, as few as possible cleansers should be needed to completely remove all dirt encountered in specific jobs. For the future development and *in vivo* efficacy testing of workplace cleansers, the spectrum of test dirt reported and validated in the present study may be useful. Considering the wide spectrum of methods proposed for the testing of cleaners in the past (11–17), standardized testing models with objective non-invasive grading of the cleaning efficacy of different cleansers seem necessary.

Acknowledgements

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References

- 1 BIBB/BAuA. BIBB/BAuA-Erwerbstätigenbefragung 2005/2006. Available at: <http://www.baua.de/de/Informationen-fuer-die-Praxis/Statistiken/Arbeitsbedingungen/Erwerbstätigenbefragung-2005-2006.html> (last accessed 01 February 2013).
- 2 McDougal J N, Boeniger M F. Methods for assessing risks of dermal exposures in the workplace. *Crit Rev Toxicol* 2002; **32**: 291–327.
- 3 Ausschuss für Gefahrstoffe (AGS). Technische Regel für Gefahrstoffe 401, 2008. Available at: <http://www.baua.de/de/Themen-von-A-Z/Gefahrstoffe/TRGS/TRGS-401.html>.
- 4 IKW, FCIO, SKW, and BVH. Group data sheets for skin products (for occupational use), 2012. Available at: <http://gmb.ikw.org>
- 5 Antonov D, Kleesz P, Elsner P, Schliemann S. Impact of glove occlusion on cumulative skin irritation with or without hand cleanser – comparison in an experimental repeated irritation model. *Contact Dermatitis* 2013; **68**: 293–299.
- 6 Berndt U, Gabard B, Schliemann-Willers S, Wigger-Alberti W, Zitterbart D, Elsner P. Integrated skin protection from work place irritants: a new model for efficacy assessment. *Exog Dermatol* 2002; **1**: 145–148.
- 7 Kütting B, Drexler H. The three-step programme of skin protection. A useful instrument of primary prevention or more effective in secondary prevention? *Dtsch Med Wochenschr* 2008; **133**: 201–205.
- 8 Dihoom M, Mahmoud G S, Sudani O H. An outbreak of hand dermatitis among

- workers using sodium lauryl sulfate for skin cleansing. *Contact Dermatitis* 1996; **34**: 366–367.
- 9 Wigger-Alberti W, Fischer T, Greif C, Maddern P, Elsner P. Effects of various grit-containing cleansers on skin barrier function. *Contact Dermatitis* 1999; **41**: 136–140.
 - 10 Spoo J, Wigger-Alberti W, Berndt U, Fischer T, Elsner P. Skin cleansers: three test protocols for the assessment of irritancy ranking. *Acta Derm Venereol* 2002; **82**: 13–17.
 - 11 Mahler V, Erfurt-Berge C, Schiemann S, Michael S, Egloffstein A, Kuss O. Dirt-binding particles consisting of hydrogenated castor oil beads constitute a nonirritating alternative for abrasive cleaning of recalcitrant oily skin contamination in a three-step programme of occupational skin protection. *Br J Dermatol* 2010; **162**: 812–818.
 - 12 Klotz A, Veeger M, Röcher W. Skin cleansers for occupational use: testing the skin compatibility of different formulations. *Int Arch Occup Environ Health* 2003; **76**: 367–373.
 - 13 Schrader K, Rohr M. Methods for measuring the skin-cleansing effect of surfactants in comparison with skin roughness and compatibility. *Clin Dermatol* 1996; **14**: 57–65.
 - 14 Schrader K. Hautreinigung mit Syndets: Chemische, ökologische und klinische Aspekte. In: *Griesbach Konferenz. Hautreinigung mit Syndets*: Berlin, New York, Springer Verlag, 1990: pp. 143–153.
 - 15 Tronnier H. Zur Standardisierung von Waschversuchen an der menschlichen Haut. *Fette, Seifen, Anstrichmittel* 1965; **67**: 512–514.
 - 16 Schmidt P, Straub R. Über die Reinigungskraft neuer, sogenannter hautschonender Waschmittel. *München Med Wochen* 1942; **80**: 1148–1152.
 - 17 Gloor M, Wasik B, Gehring W, Grieshaber R, Kleesz P, Fluhr J W. Cleansing, dehydrating, barrier-damaging and irritating hyperaemising effect of four detergent brands: comparative studies using standardised washing models. *Skin Res Technol* 2004; **10**: 1–9.
 - 18 COUNCIL DIRECTIVE of 27 July 1976 on the approximation of the laws of the Member States relating to cosmetic products (76/768/EEC) (last amendment: Commission Directive 2010/4/EU of 8 February 2010), 2010. Available at: <http://ec.europa.eu/consumers/sectors/cosmetics/documents/directive/#h2-consolidated-version-of-cosmetics-directive-76/768/eec> (last accessed 01 February 2013).
 - 19 Schrader K. On the problems of in vivo cleansing of the human skin. In: *Cosmetics. Controlled Efficacy Studies and Regulation*, Elsner P, Merk H, Maibach H (eds): Berlin, Heidelberg, New York, Springer, 1999: pp. 92–106.
 - 20 Fachausschuss “Persönliche Schutzausrüstungen” der DGUV. Präventionsleitlinie: Systematische Kennzeichnung von Hautschuttmitteln-Verpackungen; Standardexpositionen, Standardsubstanzen, Symbole, 2008. Available at: <http://www.dguv.de/lb-psa/de/regelwerk/leitlinien/index.jsp> (last accessed 01 February 2013).
 - 21 Kutz G. Galenical features of standardized workplace test dirt and generic workplace cleansers. Publication in preparation. 2013.