Opinion on the material compatibility of alcohol-based rapid disinfectants for surface disinfection

1) Introduction
Alcohol-based disinfection of sensitive plastic surfaces, e.g. acrylic glass, Makrolon or polysulphone, is a particular challenge, as alcohols may attack such materials and make them dull or rough.

2) Task
Objective of this investigation was to examine the material compatibility of different alcohol-based rapid disinfectants and demonstrate to what extent the alcohol content determines compatibility with sensitive plastic materials. The current situation is that manufacturers of devices with such sensitive plastic surfaces (e.g. smartphones, touch screens, displays, flat screens, mobile phones and other portable electronic devices) often exclude the use of alcohol-based products. Hence, this investigation aimed at clarifying the following question:

Is it possible to rapidly disinfect very sensitive surfaces in a gentle way?

3) Method
To determine the influence of different alcohol-based formulations for rapid disinfection, the material compatibility of Product C (alcohol content of 74.7 %) and Product B (alcohol content of 30.0 %) was compared with the newly developed Product A (alcohol content of 30.0 %) in a model trial.

In this series of tests, two different methods were combined: first, the material compatibility was assessed optically in immersion testing. Afterwards, a bent strip test was conducted to assess Environmental Stress Cracking (individual and alternating tests; for detailed description, please see point 5).

4) Test products
The three test products are alcohol-based ready-to-use disinfectants for surfaces and medical equipment.

- PRODUCT A contains the following active ingredients in the ready-to-use solution:
  Ethanol 140 mg/g
  Propan-2-ol 100 mg/g
  Propan-1-ol 60 mg/g
  N-alkyl-aminopropyl-glycine 5 mg/g

- PRODUCT B contains the following active ingredients in the ready-to-use solution:
  Ethanol 100 mg/g
  Propan-2-ol 200 mg/g
  Benzalkonium chloride 2 mg/g
  Glucoprotamine 0.1 mg/g

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- PRODUCT C contains the following active ingredients in the ready-to-use solution:
  Ethanol 47 mg/g
  Propan-2-ol 250 mg/g
  Propan-1-ol 450 mg/g

5) Test methods

5.1 Immersion testing for the optical assessment of the material compatibility

Standardised test specimens (6 x 2 cm; layer thickness 1 - 3 mm, depending on the material) were immersed into the test products over a period of four weeks and were visually inspected and assessed at regular intervals. A certain material can be considered compatible with the product when there are no visible signs of damaging on the test specimen.

Tested materials:

Metals:	Stainless steel, aluminium, copper, brass
Plastics:	Rubber, latex, polyacrylate (Plexiglas), polystyrene, polycarbonate (Makrolon), polyethylene, polypropylene, PVC, silicone, Teflon (polytetrafluorethylene), Viton (vinylidene fluoride-hexafluoropropylene copolymers), soft rubber (butadiene rubber).

5.2 Bent strip test for assessing Environmental Stress Cracking

The bent strip test serves for determining Environmental Stress Cracking (ESC) and evaluating material compatibility in detail.
The examination and evaluation is conducted following DIN EN ISO 22088 Parts 1 and 3[1,2] in the climatic exposure test cabinet with fleece cover.
In this test, test specimens are clamped over steel templates that may have different radii (see figure 1) and directly exposed to stress crack-inducing media (in this case the test products) for a specified period.

To prevent quick evaporation of the test products and ensure complete coverage of the test pieces at the same time, the test specimens are covered with an inert fleece (Tecnojet A-650/1, Ahlstrom Milano).

After the exposure times, the fleece patches are removed immediately and the test specimens are rinsed in pure water before drying. After drying, the test specimens are visually checked for cracks in the edges and surface by using a red light laser. The results are used for the assessment. In addition to a simple “yes/no”, the potential for ESC Ω_{ESC} can be applied for assessing the test data.

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[1] DIN EN ISO 22088-1 Plastics – Determination of resistance to Environmental Stress Cracking (ESC) – Part 1: General guidance (ISO 22088-1:2006) and Part 3: Bent strip method (ISO 22088-3:2006)

[2] DIN EN ISO 22088-3:2006 replaces previous DIN 53449 – Part 3 “Evaluation of Environmental Stress Cracking (ESC) – Bent strip method”

Fig. 1: Test specimens are clamped over a steel template

The potential for ESC Ω_{ESC} [3] is a relativised standard parameter, which already includes the weighting of different damage options in the edge and surface areas as well as the test material's mechanical/physical determining factors. The individual weightings are the empirical result of more than 20 years of experience with these tests. The potentials for ESC can be determined in relation to the applied elongation/tension, temperature, exposure time and use concentration of liquid cleaners and disinfectants. The standard threshold value was defined as $\Omega_{ESC} = 1$.

Below this threshold value, stress cracks cannot be observed. Individual, small cracks in the edges are included, but tolerated by the threshold value, as, for example, the resulting elongation of the fibres in the edges (ε_{RF}) is always higher than the elongation of the surface (ε_{Obfl}).

$\Omega_{ESC} \leq 1$: Tolerable impact that may be caused by normal environmental influences and cannot be attributed to the test product.
Considering all test parameters, a liquid may induce stress cracks in plastics (test material) when reaching and being higher than this value.

$\Omega_{ESC} > 1$: When the resulting potential for ESC is > 1, the test specimen tends to induce stress cracking under given test conditions, i.e. influences can be attributed to the test product. The higher this value, the higher the impact.
Hence, the potential for ESC is a value that comprises the sum of all weighted influencing factors: $\Omega_{ESC} = \Sigma(\varphi_{EG}\ f\varphi_{EG})_i$
φ_{EG} = influencing factor
$f\varphi_{EG}$ = weighting factor of the influencing factor

<u>Test specimens used in this study's bent strip tests; individual tests:</u>
Plexiglas XT (PMMA, polymethyl methacrylate, Evonik)
Makrolon 281 (PC, polycarbonate, Bayer)
Tecason S (PSU, polysulphone, Ensinger)

<u>Test specimens used in this study's bent strip tests; alternating tests:</u>
Tecason S (PSU, polysulphone, Ensinger)

Test specimens are produced in accordance with ISO 2818[3]. The dimensions of the test specimens are 120 mm x 35 mm x 3 mm (length x width x thickness).

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[3] DIN EN ISO 2818: Plastics - Preparation of test specimens by machining (ISO 2818:1994); German version EN ISO 2818:1996

6) Compatibility tests as per immersion testing

6.1. Procedure

Material compatibility testing (immersion testing as described in 5.1) was conducted with PRODUCT A and PRODUCT C.

The test specimens were thoroughly cleaned with a neutral cleaner, rinsed with demineralised water and then air-dried. For direct product comparison, they were then put into jars filled with PRODUCT A and PRODUCT C respectively.

The test was conducted at room temperature. The materials were assessed optically after 1 day, 1 week, 2 weeks, 3 weeks and 4 weeks.

6.2 Results

Metals: Over the complete test period of four weeks, PRODUCT A and PRODUCT C did not damage or corrode any of the tested metals.

Plastics: PRODUCT A did not damage any of the tested plastics. PRODUCT C caused damage to polyacrylate (Plexiglas).

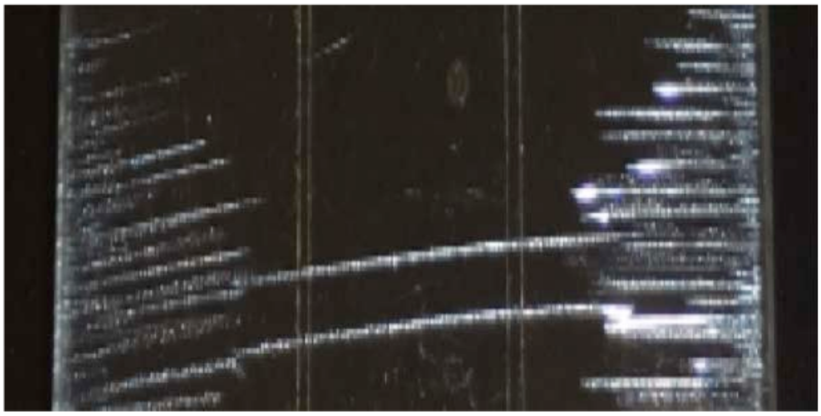

Fig. 2: In sensitive plastics, high alcohol content results in stress cracking. Plexiglas (normal light, actual width: 35 mm).

7) Compatibility tests as per bent strip method

Bent strip testing has confirmed that there are considerable differences with regard to the compatibility with alcohol-based disinfectants, especially in plastics. Products with higher alcohol contents such as PRODUCT C may damage sensitive plastics such as Plexiglas. The bent strip tests were conducted with particularly those plastics that react sensitively to the contact with disinfectants or which are known to be susceptible to damage.

PRODUCT C with its comparatively high alcohol content proved to be not compatible with such test materials (e.g. damages in polyacrylate (Plexiglas)) during immersion testing. Hence, this test product was not used for additional material compatibility tests.

Bent strip testing as described under 5.2. was carried out as comparative test with PRODUCT A having a low alcohol content and PRODUCT B having the same content of alcohol.

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7.1 Individual tests

7.1.1 Procedure

First, test specimens were exposed to the test products PRODUCT A and PRODUCT B for a pre-defined time period and under pre-defined, practical tensions of around 10 N/mm² (MPa). Before testing, the test specimens were pre-conditioned at a temperature of 23 ± 2 °C and relative humidity of 50 ± 5 % over a period of at least 24 hours. Contact times were 5, 10, 15, 20, and 25 minutes. Individual plastic types were also tested with contact times of 60 minutes, and 24 and 48 hours. The steel templates had radii of 400, 450 and 500 mm and the standard test temperature was 25 °C. Additionally, special tests were conducted with the specimen Tecason S (PSU, polysulphone, Ensinger) at temperatures of 35 °C and 45 °C to identify possible temperature dependencies.

7.1.2 Results

Under the defined test conditions at 25 °C and with practical tensions, the test materials Plexiglas XT (PMMA, polymethyl methacrylate, Evonik) and Makrolon 281 (PC, polycarbonate, Bayer) did not demonstrate a significant tendency for stress cracking with both test products, PRODUCT A and PRODUCT B. Tests with Tecason S (PSU, polysulphone, Ensinger) and PRODUCT B could demonstrate tendencies towards promoting stress cracking under the mentioned test conditions: the progression of ESC potential proved that test sample PRODUCT B shows a distinctive increase in tendency towards stress cracking after an exposure time of 15 minutes; PRODUCT A did not reach this increase due to the time delay.
Hence, contact with certain products should not exceed 15 minutes when material tensions of around 10 MPa is expected.

Such a long contact time is unusual in practice and hard to reach due to the products' alcohol-based composition and short-time application. Under described conditions, PRODUCT A does not possess increased tendency towards stress cracking with test material Tecason S (PSU, polysulphone, Ensinger).

In this test, Tecason S (PSU, polysulphone, Ensinger) turned out to be the most sensitive specimen. Determination of the influence of higher temperatures (35 °C and 45 °C) on the test products in combination with Tecason S showed that also here PRODUCT A offers significant advantages over PRODUCT B in terms of material compatibility. PRODUCT B more strongly depends on the temperature and causes interaction, which sets in within a 5-minute contact time at just below 35 °C (see table 1 and figure 3; $\Delta\Omega_{ESC}$ describes the change of the potential for ESC depending on the temperature).

Test temperature	PRODUCT A $\Delta\Omega_{ESC}$	PRODUCT B $\Delta\Omega_{ESC}$
25 °C	0.4	0.4
35 °C	0.8	1.6
45 °C	2.3	5.7

Table 1: Results of the individual test at 25 °C up to 45 °C (Tecason S)

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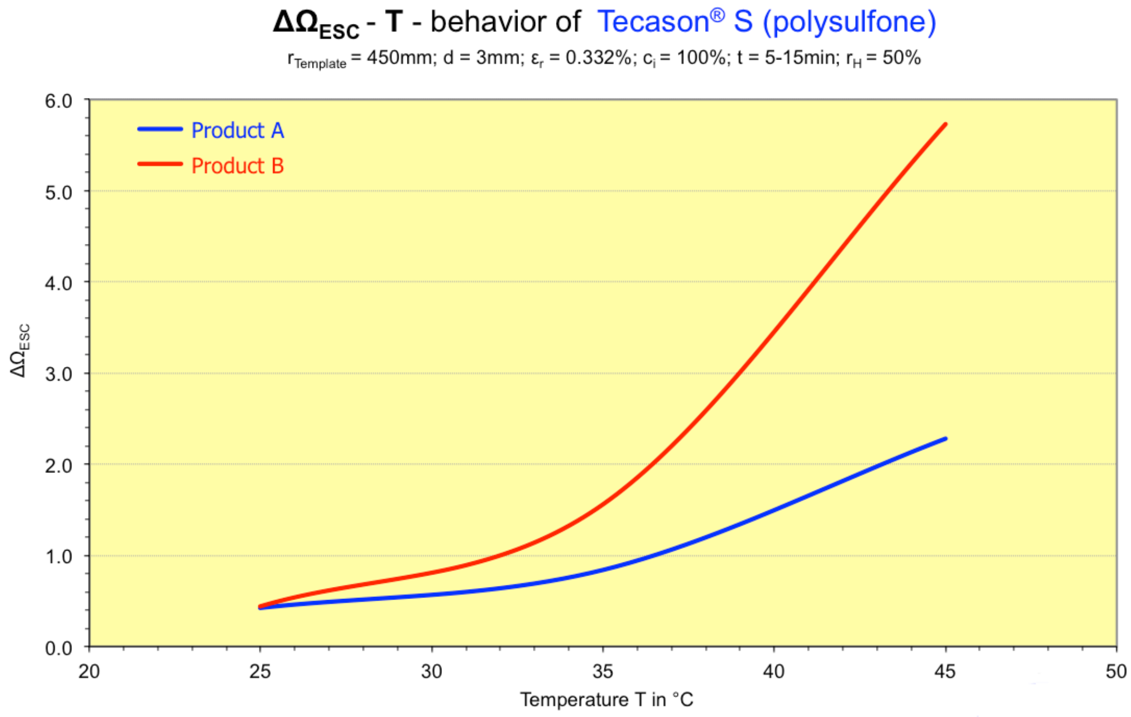

Fig. 3: Results of the individual test at 25 °C up to 45 °C (Tecason S)

7.2 Alternating tests

7.2.1 Procedure

In addition to the individual tests, alternating tests were conducted with Tecason S (PSU, polysulphone, Ensinger), which proved to be the most sensitive material in test. These tests were intended for simulating practical application of the test products as realistically as possible by assessing possible accumulating damage caused by several consecutive applications.

The test sequence consisted of 5 x 5 minutes of exposure to the test product with 5-minute rest and drying periods without contact to the test product between the contact phases – i.e. each test specimen was exposed to the disinfectant (PRODUCT A and PRODUCT B respectively) 5 times for 5 minutes. In between, the contact to the disinfectant (PRODUCT A and PRODUCT B respectively) was interrupted by 5 minutes. Hence, the total exposure time was 25 minutes.

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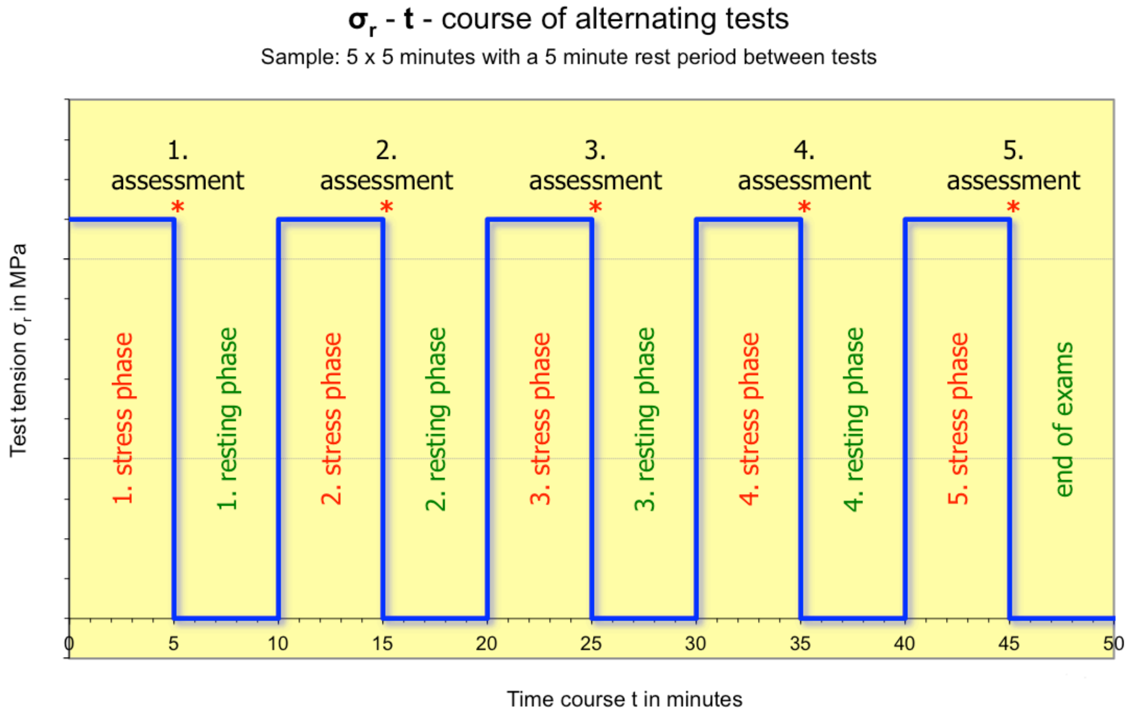

Fig. 4: Diagram illustrating the alternating tests

Tests were conducted with tensions of 9.13 MPa (450 mm steel template) and 10.05 MPa (400 mm steel template). The test temperature was 25 °C.

7.2.2 Results

The alternating tests showed that PRODUCT A has the lowest tendency towards inducing stress cracking. Even with the extended 25-minute tests, the factors of potential for ESC still were significantly beneath the threshold value of 1. Test specimens treated with PRODUCT B, however, showed tendency towards accumulation of damage; the threshold value was exceeded within the test period (see table 2 and figure 5).

Exposure time	PRODUCT A Potential for ESC Ω_{ESC}	PRODUCT B Potential for ESC Ω_{ESC}
5 minutes	0.28	0
10 minutes	0.31	0.31
15 minutes	0.31	0.56
20 minutes	0.47	0.81
25 minutes	0.56	1.13

Table 2: Results of the alternating tests at 25 °C with Tecason S (450 mm steel template in this case)

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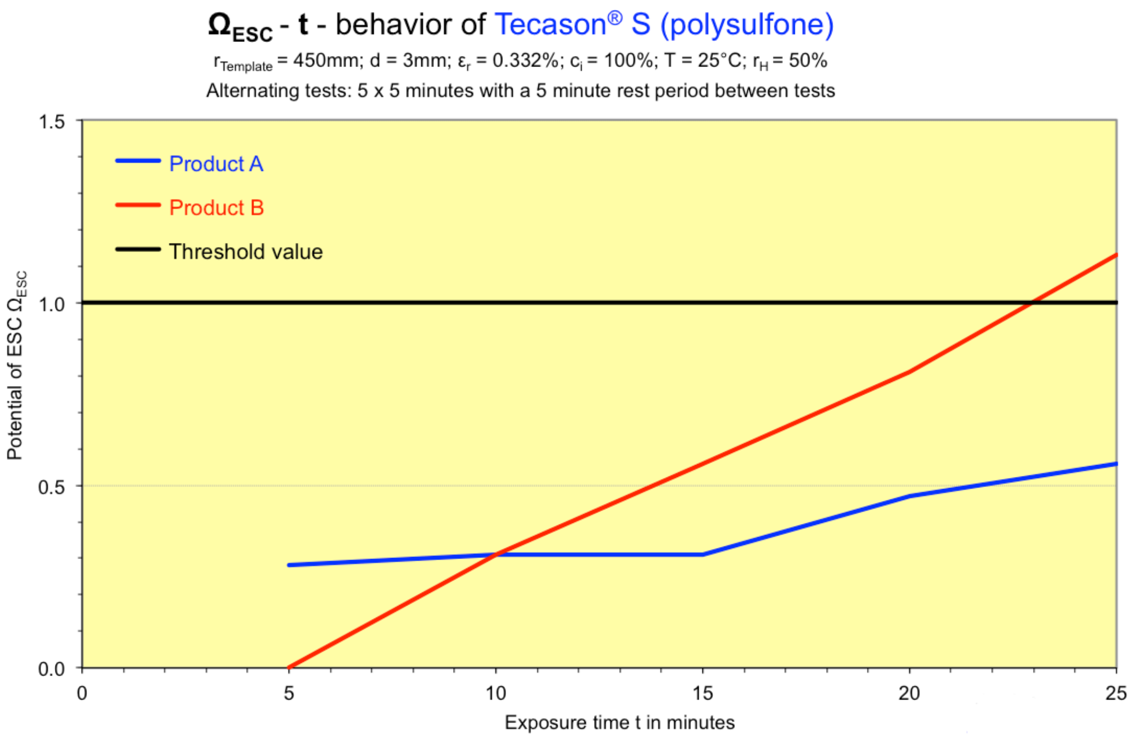

Fig. 5: Results of the alternating tests at 25 °C with Tecason S (450 mm steel template in this case)

8) Conclusions

Up to now, there is no standardised procedure for testing material compatibility of disinfectants within a very short time and, based on the results, assess the material compatibility for long-term use. The procedure used is suitable for quickly and reliably recognise practice-relevant differences in material compatibility of different alcohol-based rapid disinfectants.

The proven significant differences may already be caused by small differences in the products' composition.

The conducted tests show:

Products with different alcohol contents have different material compatibility. Products with comparatively low alcohol content such as PRODUCT A and PRODUCT B possess better material compatibility with sensitive plastics than products with high alcohol content such as PRODUCT C.

Even those products having the same sum of alcohol contents possess different levels of material compatibility with sensitive plastics. The test conducted with the comparable products (A + B) having the same sum of alcohol content showed that PRODUCT A has a lower tendency towards stress cracking or accumulation of damage than PRODUCT B. Also at higher temperatures of 35 °C up to 45 °C, PRODUCT A is significantly superior to PRODUCT B in terms of material compatibility.

It could be demonstrated that it is possible to gently and effectively disinfect sensitive plastic surfaces with a rapid disinfectant based on a balanced low-alcohol composition such as PRODUCT A.

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