SafeCREW
ANALYTICAL PROTOCOL #4

PROTOCOLS FOR TESTING MATERIALS IN CONTACT WITH DISINFECTED WATER, INTEGRATING BATCH- AND CONTINUOUS-FLOW CONDITIONS

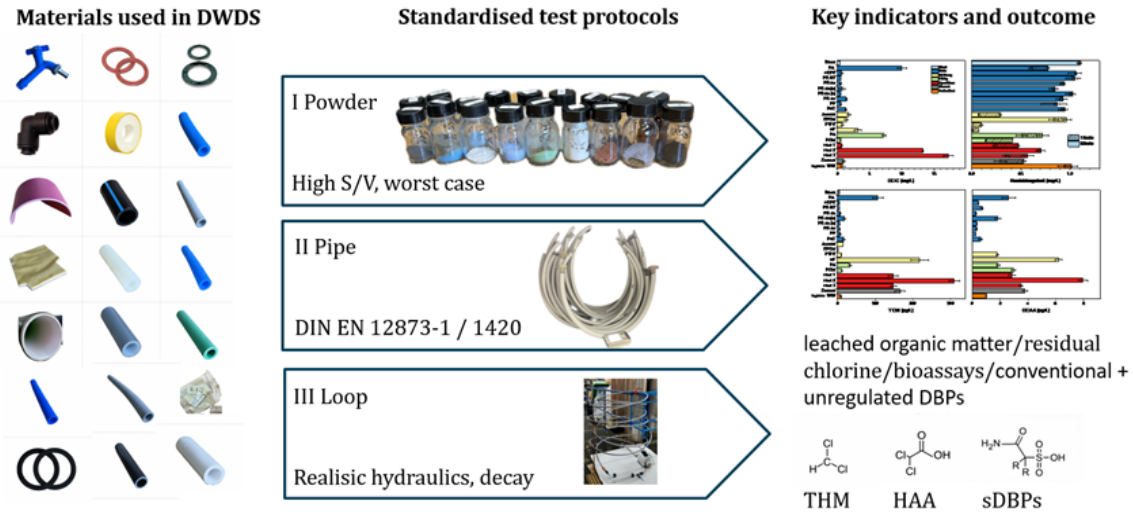

Figure 1 Schematic illustration showing the protocols for testing materials in contact with disinfected drinking water; Powder – Pipe – Loop

Introduction

This guideline provides a practical and comprehensive method to assess the extent to which materials in contact with disinfected drinking water contribute to the formation of disinfection by-products (DBPs). It can be used as an approach to assess the potential for DBP formation through interactions between disinfectants and materials, thereby supporting the implementation of Section 11 of the Drinking Water Directive (DWD). The approach compares batch and flow-through tests to capture a worst-case scenario and enable the selection of materials and disinfection strategies that are safe for human health.

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Target Audience

The guideline is intended for testing laboratories, water utilities, regulators and approval bodies, and manufacturers of plastic pipes, fittings, seals, coatings and cement mortars used in drinking water systems.

Scope and Objectives

The guideline covers protocols to assess disinfectant consumption, organic matter release and DBP formation when typical drinking water materials are exposed to sodium hypochlorite and chlorine dioxide under controlled conditions. Its main objective is to introduce and explain a reproducible method to estimate the DBP formation potential of different materials, enabling comparison between product types and test conditions and supporting risk based material selection. The procedures build on powder and pipe tests, combining batch migration tests with loop experiments to address both maximum release scenarios and more realistic hydraulics.

- Define and standardise test conditions (material preparation, surface to volume ratio, contact time, temperature, disinfectant type and dose).
- Measure key indicators (residual disinfectant, dissolved organic carbon, conventional DBPs and, where applicable, extended DBP groups and bioassays).
- Compare materials and conditions to identify critical combinations and derive recommendations for product design and approval.
- Evaluate the results of the test protocol to inform recommendations and decision-making.

Guideline

The guideline is organised as a step-by-step procedure, from test design to interpretation, to ensure a comparable and health-protective assessment of materials in contact with disinfected drinking water.

1) Define and standardise test conditions (material preparation, surface to volume ratio, contact time, temperature, disinfectant type and dose)

The test protocol applies to materials that are either already approved for contact with drinking water or intended for this purpose. These materials include plastic pipes, epoxy resins, rubber seals and cement mortar linings. They are tested in three forms: as pipe segments, in loop tests and as batches in form of cryomilled powders. When planning the test, the following should be defined: material types; target surface-to-volume (SV) ratios; disinfectants; and exposure scenarios representing both worst-case and realistic conditions.

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1.1 Pre-treatment and test procedures

- Select materials that are intended or approved for contact with drinking water, and document their product identity, intended use, and certification status. If the materials are not purchased new, age and storage should be taken into account.
- Remove adhesive spots, labels or inscriptions and store test pieces sealed with caps in the dark at room temperature.
- Cut and pre wash materials according to DIN EN 12873-1 and DIN EN 1420 (rinsing, stagnation and pre wash) before migration testing.
- Prepare the powder samples using cryogenic milling (described in detail in D. 1.5) to achieve a defined particle size distribution, typically with a dominant range of 2–20 µm. Then, adjust the powder dose to achieve SV ratios comparable to those in the pipe tests.

1.2 Modified procedure for cement mortar

- For cement mortar-lined pipes, follow the staged procedure outlined in DIN EN 14944-3. This includes pre-conditioning, migration, ageing and post-ageing steps.
- During the pre-conditioning stage, apply an elevated disinfection dose and perform multiple flushes to remove loose material. Then, conduct migration, ageing (24 × 72 hours) and post-ageing migration with daily rechlorination using NaOCl and ClO_2.
- Use at least one standard water sample and additional samples of different hardness and alkalinity to assess the influence of the water matrix on TOC leaching and disinfectant decay.

1.3 Disinfection scenarios reflecting common practice

- Apply NaOCl and ClO_2 at concentrations and for contact times that cover typical and elevated operational conditions (e.g. 1–50 mg Cl_2-eq/L and 1–7 days), including non-disinfected blanks.
- For loop tests, maintain typical distribution-system hydraulics (e.g. a 3-day residence time and a continuous flow rate of approximately 1.5 L/min) and perform regular rechlorination to maintain target residuals.

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1.4 Migration tests

- Conduct batch migration tests in temperature-controlled reactors at around 23 °C with a defined tolerance according to DIN EN 12873-1 and DIN EN 1420, recording the disinfectant dose, contact time, re-chlorination steps and water chemistry. Agitate powder suspensions with overhead shakers.
- Conduct pipe loop experiments using pre-washed pipes and a pump that enables a constant flow within a sealed system. Where feasible, align the contact times and S/V ratios with the powder tests.
- Include blanks and filter blanks in all tests. Filter samples (0.45 µm) and quench disinfectants appropriately, depending on subsequent analyses (e.g. sodium thiosulfate or ascorbic acid).

2) Measure and document key indicators

- Quantify the influence of each material on disinfectant behaviour, the release of organic matter and DBP formation using harmonised analytical methods.
- Measure free chlorine and chlorine dioxide, then calculate the disinfectant consumption in terms of chlorine-equivalent demand by comparing with blank tests.
- Determine DOC as an indicator of leached organic matter, and characterise the organic fractions using LC-OCD, UV/Vis, and fluorescence to distinguish changes in composition. Conduct analysis of conventional DBPs (e.g. THMs and HAAs) and unregulated DBP groups in migration waters.
- Complement the chemical analyses with bioassays (e.g. CALUX-based tests) on selected samples, in order to assess the overall toxicological responses, which may not be explained by the targeted DBP measurements alone.
- Report all results together with the test conditions to enable consistent comparison between materials, scenarios and laboratories.

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3) Compare materials and conditions to identify critical combinations and derive recommendations for product design and approval.

- Combine disinfectant consumption, DOC and DBP data with bioassay responses, where available, to evaluate the potential for DBP formation of each material.
- Compare the results of powder and pipe/loop tests in order to distinguish between conservative worst-case behaviour and more realistic performance under typical hydraulic and operating conditions.
- Classify materials and test scenarios into performance categories (e.g. low, medium or high impact) based on combined indicators.
- Highlight critical combinations of material type, disinfectant, dose, water matrix, temperature and ageing that may require reformulation, additional controls or restricted use in disinfected drinking water systems.

4) Evaluation and interpretation of the test protocol for recommendations and decision support

Translate the test outcomes into practical recommendations for material selection and possible product development.

4.1 Material and product design recommendations

- Consider the full range of tested conditions when choosing materials and formulations that demonstrate low DOC release, limited disinfectant consumption and low DBP formation in both powder and loop tests.
- For high-impact materials such as certain rubber seals, epoxy resins and cement mortars, use the results to support decisions regarding reformulation, improved preconditioning or operational controls prior to approval or large-scale use.

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4.2 Support for approval and operational strategies

- Use the combined indicators and material classifications as basis for regulatory decisions, product approvals and material specifications for disinfected drinking water systems.
- Use the results to evaluate and compare disinfection strategies (e.g. NaOCl vs. ClO_2, dosage and contact time).
- Select combinations of materials and disinfectants that minimise the formation of disinfection by-products while ensuring microbiological safety.

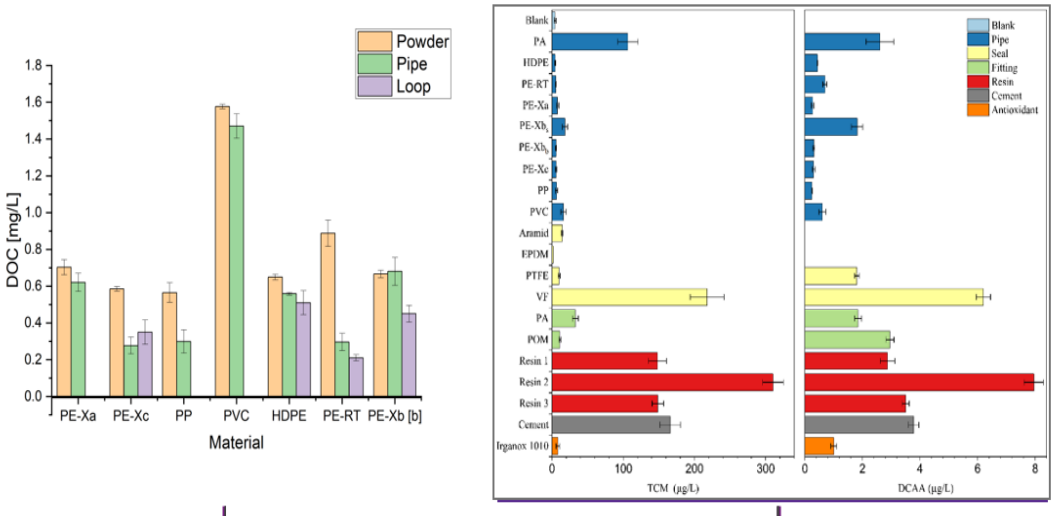

Figure 2 Comparison of DOC levels in migration waters using the three methods tested (left). Formation of DBPs in migration waters of the tested materials in powder form (right)

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Conclusion

The procedures described in this guideline have been developed and evaluated using a wide range of materials, different disinfectants and test conditions, demonstrating their suitability for assessing DBP formation potential from disinfectant–material interactions. They provide a practical basis for supporting DWD §11 compliance, as support for guiding product approval and helping water utilities and regulators manage DBP related risks in both new and existing drinking water systems; detailed protocols, flow charts and full test results are reported in SafeCREW Deliverable D1.5 “Protocols for testing materials in contact with disinfected water, integrating batch and continuous flow conditions”.

References

- Langenbach, D. and Matracchi, M., 2024. SafeCREW Deliverable D1.5 Protocols for testing materials in contact with disinfected water, integrating batch- and continuous-flow conditions, submitted to EC by 30 October 2024

- Dataset « Migration water tests for materials in contact with disinfected drinking water » https://doi.org/10.5281/zenodo.14012190

- SafeCREW- Climate-resilient management for safe disinfected and non-disinfected water supply systems, Grant agreement ID: 101081980, DOI 10.3030/101081980

Disclaimer

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