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Sampling and monitoring of water from building services closed systems – Code of practice

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Contents

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Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under license from The British Standards Institution, and came into effect on 30 November 2012. It was prepared by Technical Committee EH/3, *Water quality*. A list of organizations represented on this committee can be obtained on request to its secretary.

Use of this document

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is "should".

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

0 Introduction

This British Standard addresses the particular issues of sampling water from closed-circuit heating and cooling systems in buildings and related infrastructure, from construction, pressure testing, pre-commission cleaning and commissioning to routine operation. The purpose of sampling a closed-circuit water system is to provide information about the current condition of that system and/or the water within it. That might include, but is not limited to, water treatment status, water quality, bacteriological contamination and corrosion activity. Confidence in the results obtained, which are crucially dependent on consistent sampling and analysis protocols, is extremely important to industry.

Sampling of water used to fill the system is used to assess whether the water is suitable for unrestricted use or requires pre-treatment.

Sampling of system water between filling and pre-commission cleaning is used to monitor the growth of bacteria that could lead to long-term corrosion and water quality problems.

Sampling of system water on completion of pre-commission cleaning is used to verify the success of the pipework flushing and cleaning procedures. Failure to achieve industry guidelines on system cleanliness can result in expensive remedial work and contractual disputes.

Sampling of system water prior to practical completion is used to demonstrate that the system is fit to be handed over.

Sampling of system water during normal operation is used to establish that the water treatment regime is being correctly applied and is effective in minimizing the risk of corrosion and other water quality issues.

Sampling prior to discharge of water from the system is used to apply for, and establish compliance with, discharge permits.

This standard does not set guidelines for water quality; only the sampling and analysis methods that are recommended to assess whether guidelines set by others have been achieved. These are critical in the commissioning and lifecycle maintenance of closed-circuit system heating and cooling systems in new and renovated buildings to prevent the onset of operational problems and premature failure.

1 Scope

This British Standard gives recommendations and guidance for the sampling of water from closed-circuit heating and cooling systems in buildings and related infrastructure to maintain water quality and the integrity of pipework, plant and fittings, including:

a) hydronic space heating and cooling systems;

b) heat pump ground and water loops;

c) thermal storage systems;

d) closed-circuit condenser water systems;

e) low-temperature district heating and cooling mains;

f) generator cooling systems; and

g) similar closed-circuit water systems.

The standard gives recommendations for the design of the sampling programme during each phase of the system lifecycle, including the location and suitability of sampling points, frequency of sampling and record keeping, to facilitate the control of closed system water quality throughout the life of the building.

It also gives guidance on:

1) procedures for the collection, preservation, handling and storage of samples prior to analysis (by reference to BS EN ISO 5667-3); analytical methods (by reference to other British Standards and approved methods) and the statistical treatment of results; and

2) the selection of the analytical parameters appropriate to the sampled system and life stage.

This standard does not provide guidance on the interpretation of results or associated action levels. These matters are discussed in other standards and industry guides, e.g. BSRIA BG29.

This standard is not applicable to sampling water from open circuit systems such as:

i) cold water services (see BS 7592 and BS ISO 5667-5);

ii) open circuit cooling towers and cooling ponds;

iii) steam boiler plant (see BS 6068-6.7 and BS 2486); or

iv) sprinkler systems.

NOTE Annex A gives recommendations for sampling points. Annex B gives guidance and recommendations for appropriate laboratory analytical methods for water quality sampling, while Annex C describes the application of a statistical method for detecting sulfate reducing bacteria (SRBs). Annex D summarizes the minimum performance requirements for on-site analysis of common parameters using test kits and portable instruments. Guidance on the interpretation of sample results for pre-commission cleaning with respect to the guidelines in BSRIA BG29 is given in Annex E.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 1427, *Guide to on-site test methods for the analysis of waters*

BS 6068-2.11, *Water quality – Part 2: Physical, chemical and biochemical methods – Section 2.11: Determination of ammonium: manual spectrometric method*

BS 6068-2.34, *Water quality – Part 2: Physical, chemical and biochemical methods – Section 2.34: Method for the determination of the chemical oxygen demand*

BS EN 872, *Water quality – Determination of suspended solids – Method by filtration through glass fibre filters*

BS EN 15216, *Characterization of waste – Determination of total dissolved solids (TDS) in water and eluates*

BS EN 27888, *Water quality – Method for the determination of electrical conductivity*

BS EN ISO 5667-3, *Water quality – Sampling – Part 3: Guidance on the preservation and handling of water samples*

BS EN ISO 9963-1, *Water quality – Determination of alkalinity – Part 1: Determination of total and composite alkalinity*

BS ISO 10523, *Water quality – Determination of pH*

BS ISO 17381, *Water quality – Selection and application of ready-to-use test kit methods in water analysis*

BSRIA BG29, *Pre-commission cleaning of pipework systems*

3 Terms and definitions

For the purposes of this British Standard, the following terms and definitions apply.

3.1 back-flushing
process of removing debris from a terminal unit by discharging system water from a convenient drain point such that the direction of flow through the terminal unit is opposite to the normal operating flow

3.2 binder point
self-sealing pressure test point from which fluid can be discharged by insertion of a matching needle probe

3.3 cleaning specialist
person or organization appointed to carry out pre-commission cleaning of a heating, cooling or other closed pipework system and related activities

3.4 fixed sample point
preselected sample point used on every occasion when samples are taken, in order to allow comparison between results for different sampling occasions

NOTE Results for insoluble material reflect the concentration of suspended solids in the circulating water, plus the mobile solids that have accumulated in that location only since the last sampling.

3.5 forward-flushing
process of removing debris from a terminal unit by discharging system water from a convenient drain point such that the direction of flow through the terminal unit is the same as the normal operating flow

3.6 method statement
detailed description of the on-site work activity, including preparatory works and access provisions

3.7 practical completion (PC)
point of issuing a certificate of practical completion of construction works for the relevant system by the responsible person appointed by or on behalf of the client, after which responsibility for that system passes to the client

NOTE All installation, commissioning and remedial works are assumed to have been completed.

3.8 pre-commission cleaning (PCC)
process of bringing a new pipework system to a satisfactory state for commissioning and ongoing maintenance of water quality

3.9 pseudomonad
bacteria from the genera pseudomonas and burkholderia

3.10 random sample point
point selected at the time of sampling that is not routinely sampled

3.11 representative sample point (for repetitive sampling)
sample point selected at the time of sampling and used to demonstrate water quality at that location at the time of sampling

NOTE Results for insoluble material reflect the concentration of suspended solids in the circulating water plus the mobile solids that have accumulated in that location since the system was last filled or flushed.

3.12 sampling and analysis plan
detailed description of the objectives of sampling, numbers and locations of samples, and the analyses to be carried out for each sample and applicable guidelines for the result

NOTE A different sampling and analysis plan is required for each life stage of the building or system.

3.13 water quality specialist
person or organization appointed to maintain the water quality and manage the corrosion risk within a heating, cooling or other closed pipework system

4 Design of the sampling programme

4.1 Life stages of the building and system

The objective of sampling a closed-circuit water system in a building or related infrastructure is to provide information about the current condition of that system and/or the water within it.

The objective and requirements for sampling and analysis vary according to the life stage of the system and buildings may contain multiple systems. The applicable sample locations, frequency of sampling and parameters should be selected from Table 1.

A detailed sampling and analysis plan to achieve these objectives for each life stage of the system should be prepared by the cleaning or water quality specialist in accordance with **4.2** to **4.5** and Clause **5**.

Table 1 **Life stages of the closed-circuit water system** *(1 of 2)*

Life stage	Samples	Objective	Timing and frequency	(Sub) Clause
Design	Proposed fill water	Evaluate suitability of water supply and any treatment measures that might be required	As soon as water source is identified (if sufficient information is not already available from water undertaker)	—
Installation of pipework	No sampling required	NA	NA	NA
Filling and pressure testing [A]	Supplied water at point of connection	Assess quality of supplied water and whether treatment is required	Before initial fill and pressure test	
	System water after filling and treatment	Monitor water quality and concentration of water treatment chemicals	On completion of fill and system treatment At suitable intervals, the final samples being taken within 14 days of the start of pre-commission cleaning [B]	**5.1**
Pre-commission cleaning (PCC)	System water during chemical cleaning [C]	Verify concentration and distribution of cleaning chemicals	On completion of addition of chemicals During cleaning On completion of clean	**5.3.1** — **5.3.2**
	System water on completion of flushing	Verify removal of cleaning chemicals and debris	On completion of flushing	**5.3.2**
	System water after PCC and treatment	Verify success of pre-commission cleaning and monitor ongoing condition of system, including chemical and microbiological parameters throughout the system	Seven days after completion of pre-commission cleaning and system treatment	**5.4.1**
Commission-ing	System water	Monitor and maintain water quality	At least every 14 days until practical completion and handover	**5.4.2**
Practical completion (PC) and handover	System water at practical completion	Verify condition of system water and concentration of treatment chemicals	At practical completion	**5.4.3**
Minor modifications to existing system	System water	Monitor and maintain water quality	Before and after modification	—

Table 1 **Life stages of the closed-circuit water system** *(2 of 2)*

Life stage	Samples	Objective	Timing and frequency	(Sub) Clause
Significant additions to existing systems, including shell and core fit out projects	Base build water and new system water before connection	Verify acceptable condition of water quality in additional pipework prior to connection to base build Assess water quality in base build prior to connection and identify any measures required	On completion of pre-commission cleaning and treatment of additional system, before connection to base build	**5.4.1**
Normal operation	System water	Monitor and maintain water quality	Periodically through the life of the system At least every three months [D]	**5.5**
Drain-down at any time	See note	Information required for discharge permit or other disposal method	Before drain-down of system water	—
Demolition	System water	Information required for discharge permit or other disposal method	Before drain-down of system water	**5.6**

[A] Pressure testing of prefabricated pipework modules may be carried out off site.
[B] At this stage the system is filled but not pressurized or circulated. The impact of loss of volume due to system sampling should be considered and kept to a minimum to avoid air ingress.
[C] At this stage the main plant and terminal units is not open to the system.
[D] Some business critical or process critical systems might require more frequent monitoring.

*NOTE See Clause **5** for detailed recommendations on sampling frequency.*

4.2 Sampling

Sampling should be carried out using appropriate methodologies and equipment to ensure that the results obtained from subsequent analyses are accurate and meaningful. Samples should be taken at a sufficient number of locations to provide an overall view of the system condition and, where possible, to allow for statistical assessment of the significance of the results. Guidance on the minimum number of samples required is given in Clause **5**.

4.3 Sampling points

Provisions for sampling should be considered as early as possible at the design stage of the building. Suitable sampling points should be made available at sufficient locations to provide a representative view of the condition of the water within the system.

All sampling points should be capable of being operated safely, with issues such as the following considered:

a) pressure and temperature of the system to be sampled;

b) alternative means of isolation in the event of sampling valve failure;

c) local hazards such as sharp edges, hot pipes and live electrical equipment; and

d) general access including the need for ladders, staging or access to confined spaces.

Flushing and drain points of not less than 15 mm nominal bore with quarter turn valves may be used as general purpose sampling points provided the dead leg is less than 100 mm.

Samples should not be taken from chemical dosing pots as there is a risk that residual chemical in the pots could affect the result.

Drain cocks conforming to BS 2879 should not be used as general purpose sampling points as they are not suitable for this.

Where no suitable sampling points exist in the functional design of the system, dedicated sampling points of not less than 15 mm nominal bore should be installed in accordance with Annex A.

Pressure test points may be used as sampling points for planktonic microorganisms and dissolved components only.

NOTE 1 Dissolved components include total dissolved solids, soluble ions (including hydrogen ion), glycols and soluble biocides.

Pressure test points should not be used as sampling points for settled solids, suspended solids or "total" analysis of inorganic components as they are not suitable for this.

NOTE 2 Pressure test points are not suitable as sample points for suspended material as the samples obtained would under-represent the concentration of solids in system water due to hydrodynamic effects around the sample point.

Sampling locations in individual systems within typical buildings should include pumps (delivery side), risers, distribution circuits and other sampling locations as set out in the sampling and analysis plan. These other sampling locations may include, but are not limited to:

1) air handling units;
2) fan coils;
3) chilled beams;
4) underfloor heating manifold;
5) domestic hot water calorifier primary;
6) heat store;
7) heat exchanger primary and/or secondary;
8) condenser and chilled water at chiller;
9) heating boilers;
10) dry coolers;
11) pressurization sets;
12) standby generator cooling; and
13) district heating and cooling supply.

Proposed sampling points should be documented in the sampling and analysis plan and cross-referenced to system schematics.

NOTE 3 Representative sample points are to be selected at the time of sampling.

4.4 Types of sample

The types of sample to be taken depend on the objectives of sampling and the proposed analyses. These factors define the acceptable sampling points and sampling methodology, the types and volumes of containers and subsequent sample handling. These details should be included in the sampling and analysis plan.

4.5 Analysis

4.5.1 Analysis for water quality

The proposed scope of analysis for water quality should be documented in the sampling and analysis plan.

NOTE Table 2 suggests the scope of analyses (excluding water treatment chemicals) that might be required to assess water quality during the life of the system. Other analyses may be proposed by the cleaning or water quality specialist, e.g. suspicion of excessive corrosion, severe biofouling or investigation of anomalous results. Water source sampling and analysis ought to be repeated prior to any works on the system that involve significant water replacement. Appropriate analytical methods are referenced in Annex B.

Table 2 **Suggested analyses** *(1 of 2)*

Parameter	**Life stage**						
	Before filling (source water)	**Post pressure testing**	**After pre-commission cleaning**	**Between pre-commission cleaning and practical completion**	**Practical completion and handover**	**Routine operation**	**Pre-discharge**
Suspended solids (see **4.5.2**)	W		P	P	P	P	P [A)]
Settled solids (see **4.5.2**)			R	R	R	Z	
Total dissolved solids: gravimetric			R		R	Z	Z
Conductivity	W	R	R	P	R	P	
pH	W	R	P	P	P	P	P
Visual appearance	W	R	R	R	R	P	
Odour	W	R	R	R	R	P	
Dissolved oxygen				Z	Z	Z	
Chemical oxygen demand							P
Total organic carbon							P [B)]
Total alkalinity	W				P	P	
p alkalinity (pH 8.3)	W		Z	Z	Z	Z	
Total hardness	W		P		P	P	
Ammonia			Z		Z	Z	P
Nitrite			R	P	P	P	P
Nitrate				Z	Z	Z	
Sulfate	W		P	P	P	P	P
Chloride	W		P		P	P	P
Total iron			R	R	R	R	
Dissolved iron			R	R	R	R	
Total copper				R	R	R	P
Dissolved copper				Z	Z	Z	Z
Aluminium				Z	Z	Z	Z
Total zinc			Z	Z	P	Z	Z

Table 2 **Suggested analyses** *(2 of 2)*

Parameter	Life stage						
	Before filling (source water)	Post pressure testing	After pre-commission cleaning	Between pre-commission cleaning and practical completion	Practical completion and handover	Routine operation	Pre-discharge
Scale and corrosion inhibitors (see **4.5.3**)		Z [C]	Z	Z	Z	Z	Z
Biocides (see **4.5.4**)		Z	Z	Z	Z	Z	Z
Antifreeze			Z [D]	Z [D]	Z [D]	Z [D]	Z [D]
Total viable count at 22 °C	W	R	R	R	R	R	
Total viable count at 37 °C [E]	Z			Z	Z	Z	
Pseudomonads 30 °C	W	R	R	R	R	R	
Sulfate reducing bacteria	W	R	R	R	R	R	
Nitrite/nitrate reducing bacteria				Z	Z	Z	
Nitrite oxidizing bacteria					Z	Z	
Legionella bacteria	Z [F]	Z [F]					

Key to sample locations

W = Source water supply point

P = Circulating pump (delivery side)

R = Representative points for the relevant life stage of the building (including circulating pump) as detailed in the sampling and analysis plan.

Z = If advised, at the locations advised, by the cleaning or water quality specialist.

[A] Suspended solids are usually acceptable to the sewerage undertaker as an alternative to "settled solids" for the purpose of the discharge application.
[B] If required by sewerage undertaker (see Table 4).
[C] If corrosion inhibitor is used at this stage.
[D] For chilled water circuits, e.g. ethylene glycol or propylene glycol. At circulating pump.
[E] TVC at 37 °C is not required for pre-commission cleaning activity but might be relevant in the routine operation of some plant.
[F] If required by *Legionella* risk assessment. Locations to be advised by the *Legionella* risk assessor.

Where on-site analysis is used, methods should be traceable and the reagents used within manufacturer's declared shelf life. Where instruments are used, these should be calibrated in accordance with manufacturer's recommendations and service interval. Records should be maintained of all time-sensitive field equipment.

Chemical sampling after inhibitor dosing should not be undertaken until full circulation has been assured.

Microbiological samples should not be taken until seven days after biocide dosing.

4.5.2 Analysis for solids

Sampling for solids should be carried out in accordance with **6.3** and the analyses described in **B.2**.

NOTE Both suspended and settled solids are important in the assessment of water quality for closed systems. In this standard they are differentiated by the method of sampling, not by the method of analysis.

4.5.3 Analysis for corrosion and scale inhibitors

The analyses to be used to quantify the levels of active inhibitors in the system and control limits to be maintained should be confirmed with the chemical supplier. The proposed scope of analysis should be clearly documented in the sampling and analysis plan and handover information.

NOTE Proprietary water treatment products often employ a blend of inhibitors, for example nitrite, molybdate and azoles. All major inhibitor components ought to be included in the analyses where they are used in the inhibitor product. Table 3 lists inhibitors that might be found in water treatment products. Appropriate analytical methods are referenced in Annex B.

Table 3 **Examples of corrosion and scale inhibitors**

Component	Function
Nitrite	Corrosion inhibitor
Molybdate	Corrosion inhibitor
Borate	pH buffer, biocide, corrosion inhibitor
Sulfite	Oxygen scavenger
Tannin	Corrosion inhibitor
Phosphonate	Scale inhibitor, corrosion inhibitor
Phosphate	Corrosion inhibitor for steel
Polymers	Scale inhibitor
Silicate	Corrosion inhibitor for steel
Azoles	Corrosion inhibitors for copper

Checks should be made that the product data sheet expresses the control limits for the product using the same units of measurement as the laboratory or converted by the appropriate factor.

Any deviations from control limits should be reported to the relevant person for use in determining appropriate corrective action.

4.5.4 Analysis for biocides

Sampling and analysis for biocides when required, including the use of appropriate sample containers and preservatives, should be carried out in accordance with the biocide supplier's recommendations.

Test kits may be used where these are recommended by the biocide supplier. Copies of the instructions, calibration charts and material safety data sheets should be included with the method statement.

NOTE Biocide analysis is not usually carried out in closed systems unless there are specific queries in relation to biocide persistence and effectiveness.

4.5.5 Analysis during cleaning processes

Additional sampling and analysis may be conducted during pre-commission cleaning or pre-cleaning procedures to verify active concentrations of cleaning chemicals and residues of those chemicals or their reaction products after flushing. The cleaning or water quality specialist should consult with the chemical supplier regarding the appropriate analyses and concentrations of chemical to be achieved.

The required tests should be carried out on site using test kits recommended by the chemical supplier or selected in accordance with BS ISO 17381. Details of the test kits used to carry out the tests (manufacturer, product name/code and use by date) should be documented with the results. Copies of the instructions, calibration charts and material safety data sheets should be included with the method statement.

4.5.6 Analysis for discharge

Additional sampling and analyses might be required to support an application for a permit to discharge system water at any time during the life of the system. The cleaning or water quality specialist should consult with the sewerage undertaker regarding the appropriate analyses and concentrations of chemical to be achieved.

NOTE Table 4 indicates some of the analyses that might be required, but detailed requirements vary between sewerage undertakers and ought to be confirmed with them prior to commissioning the analysis. The samples are normally taken only at the delivery side of the system circulation pump.

Table 4 **Examples of analysis for permit to discharge application**

Parameter
Total arsenic
Total boron
Total zinc
Total copper
Total aluminium
Total cadmium
Total chromium
Total lead
Total nickel
Total phosphorous
Chemical oxygen demand
Total solids
Settleable solids
Rapidly settleable solids
pH

NOTE 1 In the context of this table the word "total" refers to all possible oxidation states of the targeted element as water and acid soluble material.

NOTE 2 For suitable laboratory methods, see Annex B.

The required tests should be carried out by a laboratory using published standard methods acceptable to the sewerage undertaker, e.g. the methods listed in Annex B.

5 Sample locations and frequency

5.1 Water supply

NOTE The purpose of sampling the water supply is to ensure that it is of a satisfactory quality to enter the system. If the raw water is not of satisfactory quality then it might need to be treated. Guidance on the water quality suitable for filling closed systems is given in BSRIA BG29.

Proposed fill water, including raw water that is treated for use in the system, should be sampled at the supply point at the following frequencies.

a) Within 14 days of the first fill and pressure testing.

b) Within 14 days of pre-commission cleaning.

c) Whenever the supply point is modified or relocated.

d) Other times and locations recommended by the cleaning or water quality specialist.

The results of the analyses should be available for consideration prior to use of the water.

5.2 Sampling between pressure filling and pre-commission cleaning

NOTE The purpose of sampling between filling and pre-commission cleaning is to monitor the state of the system for the risk of corrosion and biofouling prior to pre-commission cleaning.

The number of samples should reflect the scale and complexity of the system, nature of the treatment chemicals and anticipated duration of stagnation. The scope of sampling should be in accordance with Table 5.

Sampling should be conducted as defined in Table 1. Sample volume should be minimized to avoid system depressurization.

Table 5 **Number of sample locations between filling/pressure testing and pre-commission cleaning**

System size	Sample points
<3 000 L and <2 terminal units	1 sample location in main plant area
<3 000 L and <25 terminal units	1 sample location in main plant area + 1 remote location
≥3 000 L or ≥25 terminal units	1 sample location in main plant area + 1 remote location plus additional sample locations to be agreed with cleaning or water quality specialist

5.3 Pre-commission cleaning

5.3.1 Sampling and analysis during chemical cleaning

NOTE 1 The purpose of sampling and analysis during chemical cleaning is to ensure that cleaning chemicals are applied at the correct concentration and for sufficient time to be effective. Appropriate site test kits are used to provide an immediate result.

The methods used to monitor the progress of chemical cleaning, including the degreasing and biocide wash stages, should be selected according to the product in use and the recommendations of the chemical manufacturer, and detailed in the chemical cleaning method statement.

The introduction of cleaning chemicals should be monitored at representative positions in the system, or part of the system, being cleaned to ensure complete distribution at the manufacturer's recommended concentration.

NOTE 2 The concentration of cleaning chemicals is often measured/recorded in terms of the increase in conductivity (or the equivalent concentration of total dissolved solids) above mains water (a certain increase in total dissolved solids corresponds to a certain concentration for the particular product), but there are products that use different criteria.

Samples should be taken and analysed throughout the chemical contact time in order to monitor the progress of the clean. The appropriate numbers and locations of samples at each stage of the cleaning process should be determined by the cleaning specialist.

NOTE 3 Very often the required analysis for scale and oxide removers is for soluble iron to ascertain if the cleaning product is saturated with iron (necessitating additional flushing and dosing). Full records of each stage of the clean ought to be kept, and disclosed at practical completion.

5.3.2 Sampling on completion of chemical clean

On completion of the cleaning process, the cleaning chemical is flushed out. Samples should be taken from representative locations in the system and analysed to ensure that that no detrimental residues remain. Water treatment chemicals (passivators, inhibitors and biocides) can then be added and circulated to protect the system. Further samples should be taken and analysed to confirm that the circulating water contains the required concentration of water treatment chemicals.

5.4 Completion of pre-commission cleaning to practical completion and handover

5.4.1 Sampling seven days after completion of pre-commission cleaning

NOTE Sampling of system water after pre-commission cleaning is required to demonstrate that the system has been cleaned effectively and that the specified water treatment regime is in place.

System water should be sampled seven days after completion of pre-commission cleaning for analysis and assessed against guideline values in BSRIA BG29. As a minimum, the number of sampling locations should be selected in accordance with Table 6. Samples should be taken at the following locations.

a) Plant room headers.

b) Main risers.

c) Main branches.

d) Final circuits to terminal units.

e) Outlets of terminal unit coils and major plant, such as boilers, chillers and dry coolers.

f) Other locations as specified by the data user.

5.4.2 Sampling between pre-commission cleaning and practical completion

NOTE Sampling of system water between pre-commission cleaning and practical completion is required to ensure maintenance of inhibitor levels during commissioning (when there might be significant exchange of water), to demonstrate that the system has achieved stable operation and to provide early warning of deterioration of water quality so that early remedial action can be initiated.

System water should be re-sampled every 14 days, using as a minimum the number of sampling locations shown in Table 6. The condition of the sample should be documented and any significant changes in results relative to previous samples reported.

Side-stream filters should be visually inspected during each round of sampling and their condition reported.

The results should be treated in accordance with Annex E for comparison with BSRIA BG29.

Table 6 **Minimum number of sample locations immediately post-clean and up to practical completion**

System size	Sample point [A)]
<3 000 L and <2 terminal units	1 sample location in main plant area
<3 000 L and 2 to 25 terminal units	1 sample location in main plant area + 2 remote locations (1 fixed, 1 random)
3000 L to 8 000 L and 25 to 80 terminal units	1 sample location in main plant area + 3 remote locations (1 fixed, 2 random)
8 000 L to 20 000 L and 80 to 250 terminal units	1 sample location in main plant area + 4 remote locations (1 fixed, 3 random)
20 000 L to 40 000 L and 250 to 500 terminal units	1 sample location in main plant area + 5 remote locations (1 fixed, 4 random)
> 40 000 L and > 500 terminal units	1 sample location in main plant area + (Number of terminal units/500) × 5 (10% fixed, 90% random)

[A)] In the context of this table "random" means locations chosen at random from those that have not previously been sampled since pre-commission cleaning. Additional samples may be taken from locations that have previously been sampled, for example to verify the effectiveness of remedial works.

5.4.3 Sampling at practical completion

NOTE Sampling of system water at practical completion is required to demonstrate that the system is fit for handover.

As a minimum, the minimum number of sampling locations shown in Table 6 should be used to demonstrate the condition of the system at practical completion.

5.5 Sampling during normal operation

NOTE For the purpose of this standard, normal operation of a system is deemed to begin at practical completion and handover, after which the system is assumed to be operating normally with respect to the circulation of system water and routine maintenance activity.

If there is a delay between practical completion and handover then arrangements should be put in place with the cleaning or water quality specialist to cover this period with a sufficient scope of sampling and analysis to protect the system.

The sampling locations should be selected according to the size and complexity of the building or system. The minimum level of sampling is one sample per system in the main plant area, with additional sample locations to be agreed with the water quality specialist.

The number of sampling locations should generally be in accordance with Table 6. Where access to terminal units is difficult, easily segregated areas should be selected (kitchen areas, stairwells, toilets, first aid rooms, etc.). If necessary the samples can be taken out of hours. If results are outside acceptable control limits then the sampling frequency should be increased to support remedial action until the system is again under control.

Sampling in an occupied building needs to be carried out in close liaison with facilities management personnel, who should be made aware of the need for, and consequences of, not collecting the information that these samples would provide.

The provisions for circulation and sampling of a system should continue even if use of the system is temporarily suspended, e.g. because the building becomes unoccupied.

5.6 Prior to demolition

System water should be sampled from the delivery side of the main circulation pump prior to demolition to assess suitability for discharge to drain in compliance with the discharge permit (see **4.5.6**) or other disposal method. If possible the system should be circulated before sampling and the sample point flushed to remove standing water and debris.

NOTE When submitting the results of analysis to the sewerage undertaker, it is recommended that a copy of the last routine monitoring results and product information and/or material safety data sheets for the recently applied water treatment chemicals is also provided for reference.

6 Sampling methodology

6.1 Safety

NOTE 1 Health and safety legislation requires that a suitable and sufficient risk assessment be carried out before any work activity, including sampling.

A copy of the sampling risk assessment should be lodged with the person responsible for safety on site before sampling activity commences.

Possible causes of injury during sampling include:

a) head injuries from accidental contact with overhead building services;

b) hand injuries from contact with sharp edges or hot surfaces;

c) falls from ladders; and

d) electrocution.

The risks from these should be minimized by appropriate design of the sampling point, plant isolation procedures and the use of suitable access equipment.

In addition, there could be hazards from substances in the water such as treatment chemicals and bacteria. Persons carrying out sampling should review the hazard information concerning chemicals known to be in the system and take appropriate measures to minimize the risk of contact with system water, particularly during chemical cleaning activities. Eye protection should be worn for all sampling activities, even where the system water is believed to be non-hazardous.

If sampling is carried out in conjunction with the handling of chemicals then additional measures may include:

1) chemical-resistant gloves or gauntlets;

2) head protection;

3) full face splash protection;

4) chemical-resistant overalls;

5) chemical-resistant boots; and

6) access to eye wash.

The risks associated with on-site use of chemical test kits should also be covered in the risk assessment.

Surplus sample, test residues and other waste should be disposed of in an appropriate manner. Surplus or out-of-date reagents from test kits should be returned to the supplier or otherwise properly disposed of.

When sampling in occupied areas, the area surrounding the sampling point should be quarantined within an area demarcated by hazard notices.

NOTE 2 A "permit to work" might be required for sampling in areas that are deemed to be intrinsically hazardous, such as roof areas and confined spaces or where construction activity is still progressing. When sampling in construction sites, additional safety measures might be imposed by the site safety policy, e.g. site-specific safety briefing, safety hats and boots and high-visibility jackets.

6.2 Preparation for sampling

The following sequence of events should be followed in preparation for sampling.

a) Formulate or update the sampling and analysis plan in accordance with Clause **4** and Clause **5**, including objectives, numbers of fixed sample points, and applicable test parameters, and submit these to the client for agreement. Random sample points should be chosen at the time of sampling.

b) Inform the selected laboratory of the test programme, including number of samples, estimated time of arrival and analyses required.

c) Arrange access to the building and systems, and implement risk reduction measures (method statements, risk assessment, permit to work, provision of access equipment, etc.).

d) Acquire suitable sample containers as required by the analytical method.

e) Deliver all necessary tools and equipment to site.

Sample containers should be clean and compatible with the proposed analyses. High density polyethylene (HDPE) or polyethylene terephthalate (PET) sample containers are suitable for most of the chemical and microbiological analyses within the scope of this standard. Glass sample bottles are not usually required, but may be used for trace organic compounds. Prior confirmation of the suitability of sample containers and volume of sample required should be sought from the analytical laboratory.

Sterile containers are only necessary when sampling for bacteria and should normally contain sodium thiosulfate to neutralize any oxidizing biocide.

NOTE Many laboratories provide sample bottles appropriate to the selected test parameters with pre-numbered and bar-coded self-adhesive labels for sample tracking. This approach is strongly recommended.

6.3 General purpose sampling

6.3.1 General

Where the objective is to determine the general condition of the system water, including suspended solids and bacteria, the sampling methods in **6.3.2** to **6.3.10** should be used, as applicable, for supplied water:

a) after filling and treatment;

b) at intervals during cleaning;

c) on completion of cleaning; and

d) at practical completion and handover, and thereafter.

The sample should normally be taken in "forward flow". If the sampling point is between a terminal unit control valve and the terminal unit itself, then it might be necessary to manually open the control valve or commissioning valve and close the return leg isolation valve to avoid backflow.

Sample containers delivered to the laboratory should always be completely filled.

6.3.2 Duplicate samples

6.3.2.1 Duplicate chemical samples

If the sample is to be split for analysis by two (or more) different laboratories, it should be collected in a clean container that can accommodate more than the required total sample volume. It should be agitated thoroughly, and then decanted into individual sample containers (see **6.2**) for each party to the analysis such that they are completely filled.

6.3.2.2 Duplicate microbiological samples

If the sample is to be split for analysis by different laboratories, it should be collected aseptically (see **6.3.3**) into a single sterile container that can accommodate more than the required total sample volume and filled to the point of overflowing. The sample container should be filled to exclude as much air as possible. The container should then be inverted without introducing air, before being decanted aseptically into individual sterile sample containers (see **6.2**) for each party to the analysis such that they are completely filled. Decanting should be done in such a way as to avoid introducing air.

NOTE Bacteria are not necessarily homogeneously distributed even after agitation so duplicate sampling might not always produce identical results in the individual samples.

6.3.3 Microbiological samples from pump sets and remote locations (terminal units and pipework serving terminal units, etc.)

6.3.3.1 Samples can be taken from a drain cock or binder point. Samples from pumps sets should be taken from the delivery side.

6.3.3.2 Prepare the sampling point for taking the microbiological sample and disinfect by spraying with propan-2-ol (minimum 70% solution). This should be allowed to evaporate before use. If a binder point is used, the binder probe should be sterilized internally and externally before use. Samples should not be taken through a hose or non-sterile conduit.

6.3.3.3 Record the position of any system valves before altering if required.

6.3.3.4 Fully open the sample valve and discharge at least the volume of the dead leg into a waste container.

6.3.3.5 Fully open the sample valve and discharge the water slowly into the sterile sample container (containing sodium thiosulfate to preserve the sample for microbiological analysis) until the bottle is completely full.

6.3.3.6 Seal and label the sample container.

6.3.3.7 Record the date, time and location of the sample on a sampling record sheet, together with any pertinent observations concerning the state of the sample (visual appearance and odour) or the system from which it was drawn.

6.3.3.8 Reset valve positions.

6.3.3.9 Despatch samples to storage and/or transport to laboratory under conditions recommended in BS ISO 5667-3.

6.3.3.10 Properly dispose of the surplus liquid.

6.3.4 Chemical analysis samples from pump sets

6.3.4.1 Samples can be taken from a drain cock or binder point. Samples from pumps sets should be taken from the delivery side.

6.3.4.2 Prepare the sampling point for use.

6.3.4.3 Fully open the sample valve and discharge sufficient volume of water to flush the dead leg into a temporary container (unless previously undertaken with microbiological sample).

6.3.4.4 Open the sample valve and discharge the water into sample bottle.

6.3.4.5 Note the general condition of the sample including the presence of any large particles, visual appearance and odour.

6.3.4.6 Seal and label the sample container.

6.3.4.7 Record the date, time and location of the sample on a sampling record sheet together with any pertinent observations concerning the state of the sample or system from which it was drawn.

6.3.4.8 Despatch samples to storage and/or transport to laboratory under conditions recommended in BS ISO 5667-3.

6.3.4.9 Properly dispose of the surplus liquid.

6.3.5 Chemical analysis samples from terminal units and pipework serving terminal units

6.3.5.1 Samples can be taken from a drain cock or dedicated sampling point as described in Annex A. A binder point is not suitable.

6.3.5.2 Record the position of any system valves before altering if required.

6.3.5.3 Prepare the sampling point for use.

6.3.5.4 Place a clean hose on the sample point.

6.3.5.5 Fully open the sample valve and discharge sufficient volume of water to flush the dead leg into a temporary container (unless previously undertaken with microbiological sample).

6.3.5.6 Fully open the sample valve and discharge the water into sample bottle utilising the hose. Note the general condition of the sample including any large particles, visual appearance and odour.

6.3.5.7 Seal and label the sample container.

6.3.5.8 Record the date, time and location of the sample on a sampling record sheet together with any pertinent observations concerning the state of the sample or system from which it was drawn.

6.3.5.9 Reset valve positions.

6.3.5.10 Despatch samples to storage and/or transport to laboratory under conditions recommended in BS ISO 5667-3.

6.3.5.11 Properly dispose of the surplus liquid.

6.3.5.12 Results are to be interpreted taking the method of sampling, and valve positions, into consideration.

6.3.6 Settled solids from terminal units and pipework serving terminal units

6.3.6.1 Samples may be taken by forward-flushing (in the normal direction of flow) or, if this is not possible, by back-flushing (against the normal direction of flow) as described in Annex A.

NOTE If the amount of debris in the coil is to be assessed it might be necessary to run off the amount of water in the pipework between the drain cock and the terminal coil before filling the bottle. This is to ensure that the water sample is representative of conditions in the coil.

6.3.6.2 Valves should be positioned in such a way as to ensure that the direction of flow is controlled and noted on the sampling records.

6.3.6.3 The sample should be analysed in accordance with BS EN 872, and the result should be reported as milligrams per litre (mg/L). The laboratory should report the presence of heavy solids that might not be represented in the result.

NOTE Settled solids in this context refers to the insoluble material flushed from a terminal unit or defined length of pipe at the maximum available flow rate with the drain point fully open. The purpose of this sampling is to assess the cleanliness of the terminal unit or associated pipework.

6.3.6.4 Samples can be taken from a drain cock or dedicated sampling point as described in Annex A. A binder point is not suitable.

6.3.6.5 Record the position of any system valves before altering as required.

6.3.6.6 Prepare the sampling point for use.

6.3.6.7 Place a clean hose on the sample point.

6.3.6.8 Fully open the sample valve and discharge sufficient volume of water to flush the dead leg into a temporary container (unless previously undertaken with microbiological sample).

6.3.6.9 Select a suitable sample container with a volume that is less than the maximum volume of sample so that the container can be completely filled.

6.3.6.10 Fully open the sample valve and fill the sample container to the brim utilising the hose. Note the general condition of the sample, including any large particles.

6.3.6.11 Seal and label the sample container.

6.3.6.12 Record the date, time and location of the sample on a sampling record sheet together with any pertinent observations concerning the state of the sample and system from which it was drawn.

6.3.6.13 Reset valve positions.

6.3.6.14 Despatch samples to storage and/or transport to laboratory under conditions recommended in BS ISO 5667-3.

6.3.6.15 Properly dispose of the surplus liquid.

6.3.6.16 Results are to be interpreted taking the method of sampling, and valve positions, into consideration.

6.3.7 Water treatment sampling

NOTE The purpose of this sampling is to establish the concentration of water treatment chemicals in the circulating system water.

The sample should normally be taken forward-flow, but it is not essential to avoid back-flow. Therefore, no valve positions need be altered, though they should be recorded. The methods of **6.3.4** or **6.3.5** may be used. A binder point may be used in either case.

6.3.8 Water sampling for chemical analysis on site using test kits

Test kits may be used for intermediate testing during pre-commission cleaning, between pre-commission cleaning and practical completion and ad hoc testing of water treatment status during occupancy. Annex D summarizes the minimum performance of test kits and portable instruments.

All tests kits should be provided with:

a) a comprehensive set of instructions;

b) a material safety data sheet;

c) environmental precautions for disposal of treated samples;

d) details of performance including range, resolution and nominal uncertainty;

e) discussion of possible interferences and limitations to use; and

f) a use-by date for consumables.

Items a) to e) should be included with the method statement. Item f) should be included with test report.

All instruments used in conjunction with test kits should be calibrated using appropriate reference materials or procedures if calibration is not intrinsic to the test method.

The sampling methodology in **6.3.4** or **6.3.5** may be used, except that clean reusable sample containers are permitted and need not be completely filled if the analysis is to be carried out immediately.

Where monitoring of the water system is reliant on results from test kits, a duplicate set of samples should periodically be sent for laboratory analysis to validate the results.

The results for the following sets of samples may be contractually significant, so the samples should be sent for analysis to a recognized laboratory with appropriate quality control.

1) Samples taken seven days after pre-commission cleaning to demonstrate the success of the cleaning process.

2) Samples taken at practical completion to demonstrate satisfactory water quality prior to handover.

3) Samples taken for due diligence prior to the sale or re-leasing of the building.

4) Samples taken at the start of a new maintenance contract.

5) Samples taken prior to application for a discharge license if required by the sewerage undertaker.

6) Samples taken at other times, as agreed with the client.

6.3.9 Water sampling for microbiological analysis on site using dip slides and test kits

Dip slides and microbiological test kits may be used to supplement laboratory microbiological analysis provided there is access to suitable incubation facilities. The results should be treated with caution and interpreted in context by trained personnel. The results cannot be combined with the results of laboratory analysis for the evaluation of trends to demonstrate the condition of the system.

6.3.10 Water sampling for measurements on site using portable instruments

Portable instruments used on site may include:

a) electronic thermometer;

b) hydrogen ion (pH) meter;

c) conductivity meter;

d) turbidity meter;

e) refractometer;

f) luminescence meter [for use with adenosine triphosphate (ATP) testing]; and

g) dissolved oxygen meter (refer to **6.3.11**).

All instruments should be used in accordance with manufacturer's instructions and appropriately calibrated before use or used within the current calibration period as indicated by a calibration label. Instrumentation details, calibration data, sensitivity and tolerances should be included with the method statement.

6.3.11 Water sampling for dissolved oxygen

6.3.11.1 Dissolved oxygen measurements may be carried out on site using a suitable portable instrument or at a laboratory.

For laboratory tests the laboratory should be consulted about the detailed methodology and the supply and use of sample containers and fixing reagents.

6.3.11.2 The sample should normally be taken in the normal direction of flow, but it is not essential to avoid back-flow. Therefore no valve positions need be altered, though they should be recorded.

6.3.11.3 Samples should be taken from a binder point using a binder probe with valve and small diameter flexible tube or from a reduced bore drain valve as described in Annex A. If a sample is to be transported to a laboratory for analysis a glass sample bottle should be used. If the measurement is to be carried out immediately then a plastic sample container may be used.

6.3.11.4 Prepare the sampling point for use.

6.3.11.5 Insert the binder probe and open the sample valve to discharge a small quantity of system water through the sample tube into a temporary container.

6.3.11.6 Open the sample valve and slowly discharge system water through the sample tube into the bottom of the sample bottle avoiding agitation, spraying or splashing. The end of the tube should be submerged in the collected sample.

6.3.11.7 Completely fill the sample bottle. The sample should be collected with the minimum of turbulence and headspace in the bottle.

6.3.11.8 Note the general condition of the sample, particularly any bubbles or frothing.

6.3.11.9 Record the date, time, location and temperature of the sample on a sampling record sheet together with any pertinent observations concerning the state of the sample or system from which it was drawn.

6.3.11.10 Where appropriate, despatch samples to the laboratory under conditions recommended in BS ISO 5667-3.

6.3.11.11 Properly dispose of the surplus liquid.

6.4 Sample storage and transport

Inevitably, the composition of a water sample changes to some extent between sampling and analysis due to gaseous exchange and/or microbiological activity. Samples should therefore be analysed as soon as possible after sampling.

Samples delivered to the analytical laboratory should arrive such that analysis can be commenced within 24 hours (or as advised by the laboratory) of the sample being taken.

The impact of the time between sampling and analysis should be minimized by:

a) filling sample containers to the brim;

b) storing samples in the dark; and

c) refrigerating samples to between 2 °C and 8 °C, if possible, except where otherwise indicated in the analytical method

NOTE General guidance on sample handling and storage is given in BS ISO 5667-3.

7 Documentation and reporting of results

Samples should be traceable from when they are first taken, through transport, storage and analysis, to the final reporting of results. Sample locations should be cross-referenced to system schematics and the sampling and analysis plan.

Information recorded by the sample taker should include the following.

Item	Notes
Sample time/date	—
Building	—
System	For example, heating, chilled water
Nominal water treatment package	Nominal concentrations of inhibitors, biocide, antifreeze
Location	Referenced to physical location or labelled sample locations and system schematics
Sample purpose	For example, validation of PCC, practical completion
Required analysis	Referenced to a predefined set of analysis from the sampling and analysis plan or specific parameters
Sampling method	For example, drain cock and hose, binder point
Sample container	Size, material, preservative
Observations	—
Temperature	Measured temperature
Visual appearance	Clarity, colour, settled solids
Odour	For example, ammoniacal, sulfide
Storage conditions	For example, ambient, refrigerator temperature
Sample despatch time/date	—
Transport conditions	For example, ambient, cool box and ice pack

Information recorded by the laboratory on receipt of samples is defined by its quality system, but should at least include:

a) sample receipt time/date;

b) storage conditions;

c) start of biological analysis time/date; and

d) start of chemical analysis time/date.

Each test report should be referenced to the method used and include:

1) lower limit of method as applied;

2) upper limit of method as applied;

3) resolution; and

4) uncertainty.

The laboratory report should comment on any issues associated with the sample that could influence the uncertainty of the result, including:

i) interferences;

ii) excessive solids;

iii) colouration;

iv) post-sampling changes;

v) presence of specific water treatment components;

vi) delays in analysis; and

vii) deviations from the test method.

8 Interpretation of results

Interpretation of results should be carried out by the water quality specialist taking account of all available information.

NOTE Interpretation of results with respect to the guidelines contained in BSRIA BG29 is explained in Annex E.

Annex A (normative) Sampling points

A.1 Acceptability of sampling points

NOTE Samples may be taken from system drain points, pressure test points or dedicated test points fitted for the purpose. A dedicated test point is normally similar to a reduced bore drain point (from the bottom of the pipe) or a pressure test point (from the top of the pipe).

The sampling point should be selected in accordance with Table A.1.

Table A.1 **Selection of sampling points**

Type of sample	Sampling point		
	Full bore drain point	Reduced bore drain point	Pressure test point
Settled solids	Yes	No	No
Suspended solids and "total" metals	Yes	Yes	No
Dissolved solids	Yes	Yes	Yes
Microbiology	Yes	Yes	Yes
Dissolved oxygen	No	See **A.2**	See **A.2**

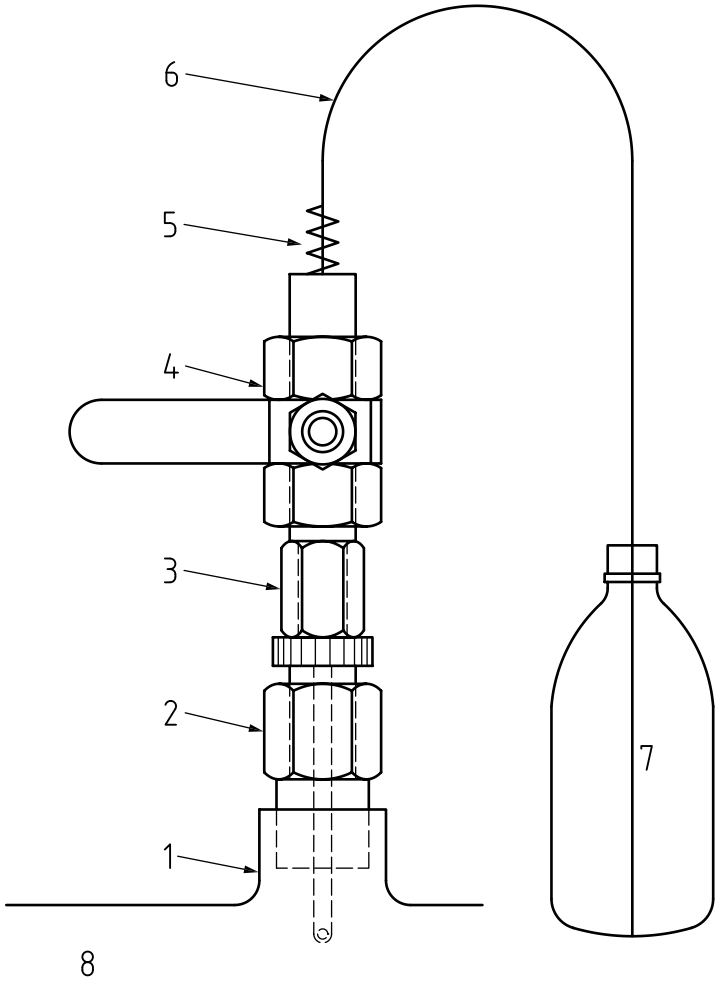
For microbiological samples from binder points, a right-angle binder probe that has been internally disinfected with propan-2-ol should be used, and the sample should be discharged directly into the sample container.

A.2 Sampling for dissolved oxygen

NOTE A suitable arrangement for providing a sample for determination of dissolved oxygen using a binder point is illustrated in Figure A.1.

Each normal drain point should be fitted with a reducing spigot and small bore plastic flexible tube (<8 mm internal diameter), and the sample taken as for a binder point.

Figure A.1 **Binder pressure test point for sampling dissolved oxygen**



Key

1	¼ inch BSP (British Standard Pipe) spigot	5	Anti-kink spring
2	Self-sealing pressure test point	6	Flexible nylon tub
3	Needle probe with locking nut	7	Sample container
4	Quarter turn level ball valve	8	Pipe

NOTE The sample point can be orientated in any direction between horizontal and vertical upwards. This configuration is not exclusive providing the possibility of entrained air can be avoided.

Annex B (normative) Laboratory analytical methods for water quality sampling

B.1 General

The analytical methods referred in this annex are intended to be carried out by trained personnel under laboratory conditions and should be used where definitive results are required for contractual purposes, though they may also be used for routine monitoring. Where there is no relevant British Standard or generally accepted published method, the laboratory should be asked to provide full details of the proposed method and evidence of its suitability for the purpose of assessing water quality in closed systems.

NOTE A summary of the analytical methods is given in Table B.1.

The samples should be transported to the laboratory in completely full, sealed bottles cooled to a temperature of 2 °C to 8 °C as recommended in BS ISO 5667-3. Samples should arrive at the laboratory such that the analysis can be commenced within 24 hours. Where this is not possible advice should be obtained from the laboratory on the possible impact on the results. Certain analyses, such as oxygen and sulfite, should preferably be carried out on site immediately after the sample is taken.

Due attention should be paid to the possibility of interferences and results should be provided with an estimate of uncertainty, together with resolution and detection limits.

In other circumstances sufficiently accurate analysis may be carried out on site by trained personnel, using test kits and methods based on BS 1427 and following the recommendations in **6.3.7**.

B.2 Physical analysis

B.2.1 Conductivity

Conductivity should not be reported as total dissolved solids.

Conductivity should be measured with a conductivity meter at (25 ±1) °C. The conductivity meter should be calibrated and used in accordance with BS EN 27888.

The result should be expressed in micro-siemens per cm ($\mu S/cm^{-1}$).

B.2.2 Filterable solids

A known volume of sample should be filtered through a weighed GF/C filter paper and the collected mass of solids calculated by re-weighing the filter paper after drying at 105 °C in accordance with BS EN 872.

The result should be expressed in milligrams per litre of sample (mg/L)

The method of sampling allows light and heavy solids to enter the sample bottle, but heavy solids (such as large particles of magnetite) rapidly settle and are unlikely to be reflected in suspended solids results reported by the laboratory. For this reason the laboratory should report the presence of heavy solids which are not reflected in the suspended solids results in conjunction with the results. A photographic record of samples taken at the time of sampling assists the interpretation of results. Where a large fraction of heavy solids is present then analysis for total solids, using the entire volume of the sample, might be more appropriate.

B.2.3 Total dissolved solids

For gravimetric testing a known volume of filtered sample should be evaporated to dryness at 105 °C in a weighed vessel and the residual mass of solids calculated by re-weighing the vessel in accordance with BS EN 15216.

The result should be expressed in milligrams per litre of sample (mg/L).

B.2.4 Visual assessment

The appearance of the sample when viewed through the top of a clear plastic sample bottle against a sheet of white paper should be recorded under the following criteria.

a) Clarity: cloudy/clear.

b) Colour: colourless/coloured (describe colour).

c) Settled solids: none/settled solids (describe appearance).

d) Magnetic particles: particles attracted by a magnet against the side of the container.

A digital photograph should be taken for reference in case the visual appearance of the sample changes by the time it reaches the laboratory.

NOTE It is important that changes in colouration after exposure to air are noted and reported to and by the laboratory, due to subsequent precipitation which can influence the interpretation of settled solids results.

B.2.5 Odour

The odour of the sample may be recorded at the time of sampling and on receipt by the laboratory. This is intended to be a subjective descriptive result provided by the analyst and not a formal measurement of odour to relevant standards.

B.3 Metals and cations

B.3.1 General

Most metals can be analysed in a suitably-equipped laboratory using atomic absorption spectrophotometry (AAS) or inductively coupled plasma spectrophotometry (ICP). Classical titration techniques should be used for alkalinity and hardness. Colorimetry should be used for ammonia.

B.3.2 Alkalinity

Alkalinity should be measured using the titration method in BS EN ISO 9963-1.

Total alkalinity should be expressed as milligrams per litre of calcium carbonate (mg/L $CaCO_3$) at pH 4.5.

P alkalinity should be expressed as milligrams per litre of calcium carbonate (mg/L CaCO3) at pH 8.3.

B.3.3 Ammonia

NOTE Ammonia is present at trace levels in some water treatment packages and can also be created by nitrate/nitrite-reducing bacteria.

Ammonia should be measured colorimetrically in accordance with BS 6068-2.11 or by another method with equivalent accuracy.

The result should be expressed as milligrams per litre ammonia (mg/L NH_3).

B.3.4 Boron

NOTE Boron could be present from borate in some water treatment packages.

Methods of analysis that may be used include AAS and ICP. A suitable reference method is BS EN ISO 11885.

The result should be expressed as milligrams per litre boron (mg/L Bo).

B.3.5 Copper

NOTE Copper may be present in the water system from corrosion of copper and brass.

Methods of analysis that may be used include AAS and ICP. A suitable reference method is BS EN ISO 11885.

Dissolved copper should be measured on a filtered portion of the sample. The result should be expressed as milligrams per litre dissolved copper (mg/L dissolved Cu).

Total copper should be measured on an unfiltered sample that has been thoroughly mixed and acidified to dissolve any particulate material. The result should be expressed as milligrams per litre dissolved iron (mg/L total Cu).

B.3.6 Hardness

Total hardness should be measured by the titration method in BS 1427.

The result should be expressed as milligrams per litre calcium carbonate (mg/L CaCO3).

B.3.7 Hydrogen ion

The hydrogen ion concentration should be measured with a pH meter and expressed at (25 ±1) °C. The pH meter should be calibrated and used in accordance with BS ISO 10523.

The result should be expressed in pH units.

B.3.8 Iron

Methods of analysis that may be used include AAS and ICP. A suitable reference method is specified in BS EN ISO 11885.

Dissolved iron should be measured on a filtered portion (0.45 micron filter) of the sample. The result should be expressed as milligrams per litre iron (mg/L Fe).

Total iron should be measured on an unfiltered sample that has been thoroughly mixed and acidified (nitric acid or aqua regia) to completely dissolve particulate material. The result should be expressed as milligrams per litre iron (mg/L total Fe).

NOTE It is important that changes in colouration after exposure to air are noted and reported to and by the laboratory, due to subsequent precipitation, which can influence the differentiation between total and dissolved iron results.

B.3.9 Molybdenum

NOTE Molybdenum could be present from molybdate in the water treatment package.

Methods of analysis that may be used include AAS and ICP. A suitable reference method is specified in BS EN ISO 11885.

The result should be expressed as milligrams per litre molybdate (mg/L MoO_4).

B.3.10 Zinc

NOTE Zinc could be present from corrosion of brass or plated pipework or from zinc phosphonate in a water treatment package.

Methods of analysis that may be used include AAS and ICP. A suitable reference method is specified in BS EN ISO 11885.

The result should be expressed as milligrams per litre zinc (mg/L Zn).

B.3.11 Other metals

For most other metals that could be required (arsenic, cadmium, chromium, lead, nickel potassium, sodium, etc.) analysis by AAS or ICP may be used after suitable preparation of the sample.

B.4 Non-metals and anions

NOTE Most non-metals and anions can be analysed using colorimetric methods and/or ion chromatography. Classical titration and turbidimetry techniques are also used.

B.4.1 Chloride

NOTE Chloride is present in the incoming water supply and could be present in the water treatment package.

Methods of analysis that may be used include ion chromatography and tritrimetry.

A suitable reference method is BS EN ISO 10304-1.

The result should be expressed as milligrams per litre chloride (mg/L Cl).

B.4.2 Molybdate

Molybdate can be measured using colorimetry (no reference standard available) or estimated from soluble molybdenum in a filtered sample determined by ICP.

Colorimetric methods are available as test kits but are subject to interferences.

The result should be expressed as milligrams per litre molybdate (mg/L MoO_4).

B.4.3 Nitrate

NOTE Nitrate could be present as part of the water treatment package.

Methods of analysis that may be used include ion chromatography and colorimetry.

A suitable reference method is BS EN ISO 10304-1.

The result should be expressed as milligrams per litre nitrate (mg/L NO_3).

B.4.4 Nitrite

NOTE Nitrite could be present as part of the water treatment package.

Methods of analysis that may be used include ion chromatography and colorimetry.

A suitable reference method is specified by BS EN ISO 10304-1.

The result should be expressed as milligrams per litre nitrite (mg/L $NaNO_2$).

B.4.5 Phosphate

NOTE Phosphate could be present as part of the water treatment package.

Methods of analysis that may be used include colorimetry (after acid digestion), inductively coupled plasma optical emission spectrometry (ICP-OES) and ion chromatography.

A suitable reference method is specified by BS EN ISO 10304-1, though this is known to suffer from interferences.

The result should be expressed as milligrams per litre phosphate (mg/L PO_4).

B.4.6 Silicate

NOTE Silicate could be present at trace levels in the incoming water supply and as part of the water treatment package.

Silicate can be analysed by colorimetry. An automated method is described in BS EN ISO 16264.

The result should be expressed as milligrams per litre silicate (mg/L SiO_3).

B.4.7 Sulfate

NOTE Sulfate is present in the incoming water supply.

Methods of analysis that may be used include ion chromatography and turbidimetry.

A suitable reference method is specified in BS EN ISO 10304-1.

The result should be expressed as milligrams per litre sulfate (mg/L SO_4).

B.4.8 Sulfite

NOTE Sulfite could be present as part of the water treatment package.

Sulfite can be measured by an iodine/iodate titration. As the dissolved sulfite rapidly disappears on contact with air, the analysis should be carried out on site immediately after sampling using a test kit.

The result should be expressed as milligrams per litre sulfite (mg/L Na_2SO_3).

B.4.9 Azoles

NOTE Azoles could be present in the water treatment package.

Methods that may be used include gas chromatography mass spectrometry (GCMS), high performance liquid chromatography (HPLC) and colorimetry. Test kits are available for on-site determination of specific azoles.

The result should be expressed as indicated in the method employed.

B.4.10 Glycols

NOTE Ethylene or propylene glycol could be present in chilled water systems as an anti-freeze component.

The approximate concentration of ethylene or propylene glycol may be estimated on site with a refractometer provided these have not been mixed. This is sufficient for most water treatment purposes.

Laboratory analysis can be undertaken using gas chromatography. This can differentiate between ethylene and propylene glycol in a mixture.

Glycol content can also be estimated from measurement of specific gravity.

B.4.11 Hydrazine

Methods that may be used include colorimetry (based on reaction with para-dimethyl-amino-benzaldehyde).

The result should be expressed as indicated in the method employed.

B.4.12 Organic biocide

NOTE Organic biocides such as isothiazolone and glutaraldehyde could be present in the water treatment package.

If the concentration of a biocide needs to be quantified, the manufacturer should be consulted for suitable methods.

The result should be expressed as indicated in the method employed.

B.4.13 Tannin

Methods that may be used include colorimetry (based on the reduction of tungstophosphoric and molybdophosphoric acids) or permanganate titration. Test kits are available.

The result should be expressed milligrams per litre tannic acid (mg/L tannic acid) or as indicated in the method.

B.4.14 Phosphonates

Methods that may be used include titration (based on reaction with chromazurol-S or xylenol orange followed by titration with thorium nitrate) or ultraviolet digestion to reactive phosphate. Test kits are available.

The result should be expressed milligrams per litre phosphonate (mg/L phosphonate) or as indicated in the method employed.

B.4.15 Chemical oxygen demand

NOTE Chemical oxygen demand represents the sum total of oxidizable species (organic and inorganic) in the sample.

Chemical oxygen demand should be measured in accordance with BS 6068-2.34 or another method with equivalent accuracy.

The result should be expressed as milligrams per litre oxygen demand (mg/L O_2 demand).

B.4.16 Bacteria

Bacteria are generally analysed by culturing in or on a specified medium, followed by enumeration, though some test results are interpreted only as presence or absence of the bacteria of interest.

B.4.17 Nitrate and nitrite reducing bacteria

Samples are incubated with chromogenic media for seven days at 30 °C or according to manufacturer's instructions, and the result expressed as "presence" or "absence". The media are available as a test kit.

B.4.18 Pseudomonads

A suitable reference method is BS EN ISO 13720, using pseudomonas selective agar base with CFC selective supplement for pseudomonas species. The normal incubation period is 48 hours at a temperature of 30 °C.

The result should be expressed as number per 100 mL.

B.4.19 Sulfate reducing bacteria (SRB)

A suitable reference method is given in NACE TM0194-1994. Samples are incubated in Postgate Medium B[9] (see Appendix D of TM0194-1994) for 21 days at 30 °C, and the result expressed as "presence" or "absence".

NOTE 1 Although some laboratories express the result numerically this is of limited significance since there is no direct relationship between the concentration of SRB in the system water and distribution of SRB in the biofilm.

NOTE 2 Note that that the short-term (five-day) sulfate reducing bacteria test available in kit form is not considered sufficiently reliable for reference samples.

B.4.20 Total viable count (TVC)

A suitable reference method is BS EN ISO 6222 (see also BS EN ISO 19458).

Separate sub-samples should be used to enumerate the total viable count (TVC) after 72 hours incubation at a temperature of 22 °C and, if required, 48 hours at a temperature of 37 °C.

The results should be expressed as number per mL.

TVC dip slides may be used for indicative results during normal system operation, but are not recommended for the assessment of pre-commission cleaning or for evaluation of system condition prior to practical completion.

Bioluminescence instruments that measure adenosine triphosphate (ATP) in system water may be used as an alternative to TVC for rapid assessment of the microbiological cleanliness of the system. ATP is present in the sample from both live and dead bacteria. ATP results should, however, be used with caution and only to establish a trend as they are not directly comparable with TVC results.

Table B.1 **Reference analytical methods** *(1 of 2)*

Parameter	Method	Reference	Measurement condition	Expression of result
Conductivity	Conductivity meter	BS EN 27888	(5 ±1) °C	$\mu S/cm^{-1}$
Suspended solids	Gravimetric	BS EN 872	Filter at 2 °C to 8 °C Dry at 105 °C	mg/L
Total dissolved solids	Gravimetric	BS EN 15216	Evaporate to dry solids at 105 °C	mg/L
Visual assessment	Eye	—		Subjective description
Odour assessment	Nose	—		Subjective description
Total alkalinity	Titration	BS EN ISO 9963-1	Titrate to pH 4.5	mg/L $CaCO_3$
P alkalinity	Titration	BS EN ISO 9963-1	Titrate to pH 8.3	mg/L $CaCO_3$
Ammonia	Colorimetry	BS 6068-2.11		mg/L NH_3
Boron (dis)	AAS, ICP	BS EN ISO 11885	Filtered	mg/L Bo
Copper (tot)	AAS, ICP	BS EN ISO 11885	Acid digested	mg/L Cu
Hardness	Titration	BS 1427	Filtered	mg/L $CaCO_3$
Hydrogen ion	pH meter	BS ISO 10523		pH units
Iron (dis)	AAS, ICP	BS EN ISO 11885	Filtered	mg/L Fe
Iron (tot)	AAS, ICP	BS EN ISO 11885	Acid digested	mg/L Fe
Molybdenum (dis)	AAS, ICP	BS EN ISO 11885	Filtered	mg/L Mo
Zinc (dis)	AAS, ICP	BS EN ISO 11885	Filtered	mg/L Zn
Other metals	AAS, ICP	—	Filtered	mg/L as appropriate
Chloride	Ion	BS EN ISO 10304-1	Filtered	mg/L Cl
Molybdate	From Mo by ICP	—	Filtered	mg/L MoO_4
Nitrate	Ion	BS EN ISO 10304-1	Filtered	mg/L NO_3
Nitrite	Ion	BS EN ISO 10304-1	Filtered	mg/L $NaNO_2$
Phosphate	ICP	—	Filtered	mg/L PO_4
Silicate	Colorimetry	—	Filtered	mg/L SiO_3
Sulfate	Ion		Filtered	mg/L SO_4
Azoles	GCMS, HPLC	—	Filtered	mg/L azole
Glycols	Refractometer	—	Filtered	v/v
Hydrazine	Colorimetry	—	Unfiltered	mg/L hydrazine
Organic biocide	Consult manufacturer	—	Unfiltered	
Tannin	Colorimetry	—	Unfiltered	mg/L tannin
Phosphonate	Titration	—	Unfiltered	mg/L phosphonate
Nitrate and nitrite reducing bacteria	Chromogenic media	—	Incubation time and temperature defined by media supplier	presence/ absence
Chemical oxygen demand	COD test	BS 6068-2.34		mg/L COD
Nitrate/nitrite reducing bacteria	Chromogenic media	—		presence/ absence

Table B.1 **Reference analytical methods** *(2 of 2)*

Parameter	Method	Reference	Measurement condition	Expression of result
Pseudomonads	Pseudomonas sp CFC selective agar	ISO 13720	48 hrs at 30 °C	number/ 100 mL
Sulfate reducing bacteria	SRB selective media	—	21 days at 30 °C	presence/ absence
Total viable count	Plate count	—	72 hrs at 22 °C 48 hrs at 37 °C	number/mL

dis = dissolved

tot = total

Ion = Ion chromatography

Annex C (informative) Method for detecting sulfate reducing bacteria (SRBs)

C.1 Introduction

This annex describes a statistical consideration of a commonly applied method for detecting the presence/absence of sulfate reducing bacteria (SRBs) in a water sample using preparatory test kits. These kits comprise screw-top tubes containing prepared media, which are inoculated with a fixed volume of the test sample and incubated for five days under controlled conditions in accordance with manufacturer's instructions.

It is commonly understood that the presence/absence of SRBs can be inferred after five days of the commencement of the test. However, it is also commonly observed that the test kits vary in their ability to reliably detect the presence of SRBs within the five day reporting window. It is the objective of this annex to set out the limitations of such a test.

The considerations reported in the annex are based on trials carried out on laboratory-proven positive samples taken in accordance with Clause **5**, which were used to inoculate a number of tubes that were observed over varying periods of time.

It is understood that the original intended market for the five-day test was for use in water which was likely to be heavily laden with SRBs, such as sediment liquor, compared to small numbers which might be present in new or well-managed closed systems.

The annex concludes that the presence of sulfate reducing bacteria is best determined using a 21-day test.

C.2 Reporting considerations

The study reported in this annex concludes that the level of confidence in the presence/absence detection of SRBs (i.e. an inoculated tube reacting positive or negative) is improved by increasing the number of tubes inoculated for any one sample to be tested by the five-day method.

One or more inoculated tubes are required to react positively for the presence of SRBs to be confirmed. Table C.1 shows both the probability of detecting the presence and that of the risk of not indicating a presence, in an inoculated sample known to contain SRBs, for varying numbers of tubes used to test the same sample.

Table C.1 **Probabilities of detecting the presence of SRBs using the five-day test**

Number of tubes inoculated from one water sample	Probability of detecting presence of SRBs after five days (%)	Probability of not detecting presence of SRBs after five days (%)	Examples of common analogies to approximate the probability of not detecting the presence of SRBs after five days, even when SRBs are present
1	48	52	The chance of tossing a coin and getting heads
2	73	27	Similar to one tube incubated for 21 days
3	86	14	The chance of rolling a six on a fair die
4	92	8	The chance of rolling a pair of dice that will add up to 4. Die sequence: 3/1, 2/2,1/3
5	96	4	The chance of drawing a red king (hearts or diamonds) from a pack of 52 playing cards
6	98	2	The chance of drawing the ace of spades from a pack of 52 playing cards
7	99	1	Almost equivalent to the full laboratory SRB test

C.3 Conclusion

The use of proprietary test kits in the form of tubes delivering a presence/absence response after five days requires the use of a five or more tubes single test in order to achieve the required level of confidence in the result.

However, the reported probabilities of detection (96% and 99% when five and seven tubes are used, respectively) were measured under laboratory conditions on a sample inoculated with material known to contain SRBs, which might not translate to measurement in the field where different SRB species are present. It is recommended therefore that, in order to achieve the best possible performance from such a technique, the tests are performed in a laboratory using a performance verified application of the technology and run concurrently with the 21-day test given in NACE TM0194-1994.

In practical terms, the use of a five-day test method is not appropriate as the laboratory customer would be required to pay for seven tests on one water sample to obtain a result that is as reliable as one 21-day test.

A 21-day sulfate reducing bacteria test is appropriate under most circumstances, including practical completion after construction of a new building. In very exceptional circumstances where a result is required after five days, the decision may be taken to conduct seven tube tests on one water sample in order to obtain a result more quickly. This is not practical or commercially viable for general use, but the result is comparable with a 21-day test.

Single tests for a five-day sulfate reducing bacteria test on one sample are not valid and ought not to be undertaken.

C.4 Data assessment

A controlled study was undertaken to investigate the likelihood (probability) of a "tube" reacting positively on a water sample known to contain SRBs compared to a control, i.e. no reaction from a blank sample. The study was undertaken under laboratory conditions using the test kit manufacturer's instructions. The study found the following.

a) Probability of a tube reacting (showing the presence of SRBs) in a sample known to contain SRBs after five days incubation was 0.4762 (≈48%).

b) Probability of a tube reacting (showing the presence of SRBs) in a sample known to contain SRBs after 21 days incubation was 0.7500 (≈75%).

c) No blank samples became positive on a sample known not to contain SRBs for five or 21 days of incubation (showing the absence of SRBs).

The probabilities were calculated using the binominal expansion of $(p + q)^k$ to provide the probability of one or more tubes reacting (positively), where:

$(p + q)^k = 1$

p is the probability of positive tube

q is the probability of negative tube $(1 – p)$

k is number of tubes used in the test.

Example

Three tubes are used to test a water sample and the tubes are incubated for five days. If one or more of the tubes become positive after five days then SRBs are present.

With $p = 0.4762$, $q = 0.5238$ and $k = 3$.

All possible results	Potential sequences	Binomial expansion	Probability
3 positive	+ + +	$p^3+3p^2q+3pq^2+q^3=1$	0.1080
2 positive, 1 negative	– + +, + – +, + + –	$p^3+3p^2q+3pq^2+q^3=1$	0.3563
1 positive, 2 negative	+ – –, – + –, – – +	$p^3+3p^2q+3pq^2+q^3=1$	0.3920
3 negative	– – –	$p^3+3p^2q+3pq^2+q^3=1$	0.1437
			1.0000

The probability of detecting 3, 2 or 1 positive tubes after five days is 0.1080 + 0.3653+ 0.3920= 0.8563 (≈ 86%); one or more tube reacting positively confirms the presence of SRBs. **This indicates a ≈14% probability that SRBs are present but were not detected by the tubes.**

This can be expanded to the use of more tubes (see the following example for five and seven tubes and other incubation periods), reducing the probability that SRBs are present but were not detected by the tubes.

Further examples

Probability of detecting SRBs after five days with five tubes (one or more of which has to be positive at five days for SRBs to be present) ≈ 96% [$p = 0.4762$, $q = 0.5238$, $k = 5$]. **This indicates a ≈4% probability that SRBs are present but were not detected by the tubes.**

Probability of detecting SRBs after five days with seven tubes (one or more of which has to be positive at 5 days for SRBs to be present) ≈ 99% [$p = 0.4762$, $q = 0.5238$, $k = 5$]. **This indicates a ≈1% probability that SRBs are present but were not detected by the tubes.**

Probability of detecting SRBs after 21 days with three tubes (one or more of which has to be positive at 21 days for SRBs to be present) ≈ 98% [$p = 0.75$, $q = 0.25$, $k = 3$]. **This indicates a ≈2% probability that SRBs are present but were not detected by the tubes.**

Annex D (informative) Minimum performance requirements for on-site analysis

Table D.1 summarizes the minimum performance requirements for on-site analysis of common parameters using test kits and portable instruments.

*NOTE See **4.5.1** for recommendations on the methods and reagents to be used, the calibration of instruments and the recording of maintenance of time-sensitive field equipment.*

Table D.1 **Minimum performance requirements for on-site analysis of water in building services closed systems**

Parameter	Typical level in system	Lower detection limit of method [A), B)]	Resolution of method [A), B)]	Uncertainty of method [A), B)]
Conductivity (µS/cm)	100 to 3 000	100	10% MV	20% MV
pH (pH units)	5 to 11	n/a	0.1	0.2
Dissolved oxygen (mg/L O_2)	0.1 to 10	0.1	0.1	0.2
Total alkalinity (mg/L $CaCO_3$)	20 to 500	10	10% MV	20% MV
Total hardness (mg/L $CaCO_3$)	20 to 500	10	10% MV	20% MV
Ammoniacal nitrogen [C)] (mg/L N)	1 to 50	0.5	0.5	1.0
Nitrite [C)] (NO_3)	0 to 1 000	10	10% MV	20% MV
Molybdate [C)] (mg/L MoO_4)	0 to 1 000	10	10% MV	20% MV
Sulfate [C)] (as mg/L SO_4)	20 to 200	10	10% MV	20% MV
Total iron mg/L (mg/L Fe)	0 to 10	0.2	0.2	0.5
Soluble iron (mg/L Fe)	0 to 10	0.2	0.2	0.5
Total copper (mg/L Cu)	0 to 5	0.2	0.1	0.2

MV = measured value

[A)] Many test kits and field equipment can achieve better than the values in Table D.1. However, Table D.1 is considered the minimum acceptable performance.

[B)] Columns 3-5 all apply coincidentally for the performance criteria to match.

[C)] Where dilution is used to extend the range of the available test method then deionized water should be used.

Annex E (normative) Interpretation of results for pre-commission cleaning

E.1 Physical and chemical results

In general, the arithmetic mean of results of similar samples from the same system should not exceed the relevant guidelines for physical and chemical parameters and no single result should exceed the relevant guidelines by more than the declared uncertainty of the analysis method.

Since there are different guidelines for different parts of the system, the results for suspended solid at the pumps should not be combined with the results for suspended solids at the terminal units.

E.2 Microbiological results seven days after completion of pre-commission cleaning

In general, the geometric means of TVC and pseudomonad results for all samples from the same system should not exceed the relevant guidelines and no single result should exceed the relevant guidelines by more than the declared uncertainty of the analysis method.

Only samples from the same system can be combined as means.

Microbiological results for samples taken at the pumps can be combined with the results for samples taken at the terminal units.

The geometric mean of n results is obtained by taking the "n^{th}" root of all the results multiplied together, i.e.

$$x = \sqrt[n]{x_1 \times x_2 \times x_3 \ldots \times x_n}$$

This is equivalent to taking the antilog of the arithmetic mean of the "log" results.

Any result that is reported as "less than" should be included in the geometric mean at the detection limit.

Any result that is reported as "more than" invalidates the geometric mean so the system cannot be deemed to conform to the guidelines.

E.3 Microbiological results between pre-commission cleaning and practical completion

NOTE The purpose of sampling prior to practical completion is to demonstrate that water quality is acceptable and stable. For this reason the assessment in relation to practical completion is based on both absolute values of the microbiological parameters and the trend.

In general the assessment in relation to practical completion guidelines should be based on the geometric means of the microbiological results for each set of samples taken in accordance with Table 6.

The geometric mean should only be formed from the results of those samples that were taken on the same date. A minimum of two results is required to create a mean.

Any result that is reported as "less than" should be included in the geometric mean at the detection limit indicated by the laboratory.

Any result that is reported as "more than" invalidates the geometric mean.

All results should be plotted as a graph of log10 concentration against date to provide a visual indication of the distribution of results, and a line drawn between successive geometric means to provide a visual indication of the trend.

Dates with only one result should be excluded from the trend analysis but the result should be plotted on the same graph for information.

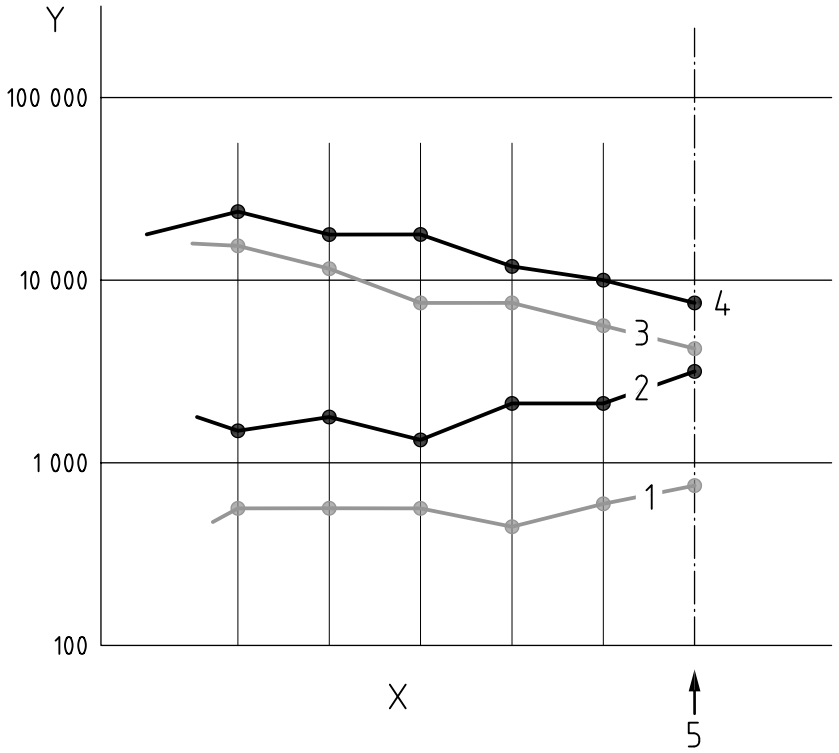
The system is deemed to conform to the guidelines for practical completion if:

a) the last three median results are all within the pre-commission cleaning guideline; or

b) the last three median results are all within the practical completion guideline and there is no increasing trend, i.e. the final geometric mean result should not be greater than the average of the previous two geometric mean results.

Graphical examples for the interpretation of trends are illustrated in Figure E.1.

Figure E.1 **Interpretation of guidelines in relation to BSRIA BG29**



Key

X	Commissioning period	3	Three results below PC guideline of 10 000 cfu/100 mL and falling trend = System conforms
Y	Pseudomonads cfu/100 mL	4	Only two results below PC guideline of 10 000 cfu/100 mL = System does not yet conform
1	Still below PCC guideline of 1 000 cfu/100 mL = System conforms	5	Practical completion
2	Below PCC guidelines of 1 000 cfu/100 mL, but rising trend = System does not conform		

Bibliography

Standards publications

For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 2486, *Recommendations for treatment of water for steam boilers and water heaters*

BS 2879, *Specification for draining taps (screw-down pattern)*

BS 6068-6.7:1994, ISO 5667-7, *Water quality – Sampling – Guidance on sampling of water and steam in boiler plants*

BS 7592, *Sampling for Legionella bacteria in water systems – Code of practice*

BS EN ISO 6222, *Water quality – Enumeration of culturable micro-organisms – Colony count by inoculation in a nutrient agar culture medium*

BS EN ISO 10304-1, *Water quality – Determination of dissolved anions by liquid chromatography of ions – Part 1: Determination of bromide, chloride, fluoride, nitrate, nitrite, phosphate and sulfate*

BS EN ISO 11885, *Water quality – Determination of selected elements by inductively coupled plasma optical emission spectrometry (ICP-OES)*

BS EN ISO 13720, *Meat and meat products – Enumeration of presumptive Pseudomonas spp*

BS EN ISO 16264, *Water quality – Determination of soluble silicates by flow analysis (FIA and CFA) and photometric detection*

BS EN ISO 19458, *Water quality – Enumeration of culturable micro-organisms – Colony count by inoculation in a nutrient agar culture medium*

BS ISO 5667-5, *Water quality – Sampling – Part 5: Guidance on sampling of drinking water from treatment works and piped distribution systems*

NACE TM0194-1994, *Field Monitoring of Bacterial Growth in Oil and Gas Systems*

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