PROTOCOL FOR TESTING THE PERFORMANCE OF IN SITU
REGENERATED ION-EXCHANGE BASED NITRATE REMOVAL
UNITS FOR TREATMENT OF PRIVATE WATER SUPPLIES
(DWQ 9028)

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PROTOCOL FOR TESTING THE PERFORMANCE OF IN SITU REGENERATED ION-EXCHANGE
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1. **SCOPE**

This protocol is one of a series which has been published by the British Effluent and Water Association under licence from Her Majesty's Stationery Office. The protocols complement the Manual on Treatment of Private Water Supplies which has been published by HMSO.

This test protocol specifies the test parameters and methods for determining the performance of ion exchange based nitrate removal units for connection to a private drinking water supply at the point of use or entry.

The purpose of this protocol is to ensure consistent, relevant testing and presentation of performance data. Any change in device specification would necessitate re-testing to demonstrate acceptance under this protocol.

Tests shall be carried out by a laboratory possessing the appropriate equipment, staff, experience and procedures for chemical analysis of drinking water. The laboratory shall be independent of the manufacturer and preferably NAMAS approved for testing or calibration relevant to this protocol.

This document represents a standard of good practice. Compliance with it does not confer immunity from relevant legal requirements, including regulations, byelaws and health and safety at work acts.

2. **REFERENCES**


2.4 British Standard 6920:1990 - Suitability of non-metallic products for use in contact with water intended for human consumption with regard to their effect on the quality of the water.

2.5 United Kingdom Water Fittings Byelaws Scheme (UKWFBS). Information and Guidance Note No 5-01-03 Issue 1- Requirements for the testing of metallic materials for use in contact with potable water. ISBN 0267-0313.

2.6 British Effluent and Water Association COP.01.85 (as revised) - Code of Practice for salt regenerated ion exchange water softeners for direct connection to the mains water supply. ISBN 0 9509979 0 0.


2.8 British Standard 5728:Parts 1 to 3 (ISO 4064/1 to 3) - Specification for water meters.

2.9 British Standard 6282: Parts 1 to 4 : 1982 - Devices with moving parts for the prevention of contamination of water by backflow (see also UKWFBS Information and Guidance Notes Nos. 5-11-01 to 04).

2.10 British Standard 1042: Parts 1 to 3 (ISO 5167) Methods of measurement of fluid flow in closed conduits.

2.11 British Standard 3955 1986 - Specification for electrical controls for household and similar general purposes.

2.12 British Standard 2690: Parts 6 & 7 - Methods of testing water used in industry: Chloride and sulphate, Nitrite, Nitrate and Ammonium.


2.15  British Standard 6068: (ISO 6107/1 to 2 & ISO 6059) - Water quality.


2.20  Treatment of Private Water Supplies 1992, HMSO.


3.  DEFINITIONS

For the purposes of this protocol the following definitions apply:

3.1  AMBIENT. Of, or relating to, the immediate surroundings.

3.2  ANION EXCHANGE. In relation to nitrate removal, the exchange of negatively charged ions, typically nitrate (NO₃) , sulfate (SO₄) , bicarbonate (HCO₃) and carbonate (CO₃) ions in water for chloride (Cl) ions by an anion ion exchange material - (see RESIN )
3.3 BACK PRESSURE. Resistance to flow exerted on the nitrate removal unit, by the pipework installation and other fittings. This may adversely affect the performance of the equipment and is particularly relevant to the drain pipework.

3.4 BACKWASH. One of the possible conditioning stages. A flow of water is passed upwards through the resin bed, loosening it, removing sediment and dirt particles.

3.5 BAR. A metric unit of pressure (equivalent to approximately 14.5 pounds per square inch).

3.6 BED VOLUME (BV). A volumetric unit, used to measure ion exchange material volume after backwashing, settling and draining the bed to surface level of the bed. This also provides a convenient means of presenting process flows and volumes.

3.7 BRINE. A solution of sodium chloride (NaCl) in water.

3.8 BRINE (SALT) TANK. A housing, normally formed from plastics or other corrosion resistant materials, providing storage for salt and/or brine.

3.9 CABINET. A housing, normally formed from plastics or other corrosion resistant materials, containing the components for the nitrate removal unit and providing storage for salt and brine.

3.10 CHANNELLING. Preferential flow through areas of an ion exchange resin bed which can occur at flow rates too low to generate a backpressure required for satisfactory distribution. Usually results in reduced nitrate capacity and/or increased nitrate leakage.

3.11 COLLECTOR. A term used to describe a system designed to collect treated water or brine from an ion exchange bed while at the same time preventing the loss of resin from the vessel.
3.12 COLOUR THROW. The release of colour by the ion exchange resin into water during any stage of the operating cycles. This sometimes occurs during start-up and regeneration of this type of equipment. It may also occur following extended non-use of the equipment.

3.13 CONTROL HEAD. A term used to refer to the control mechanism by which means water is diverted through the ion exchange bed during its various operating cycles. Typically it will include initiating and cycle timing devices required for service and regeneration operations.

3.14 DISTRIBUTOR. A term used to identify a system designed to distribute water or brine above or onto an ion exchange resin bed.

3.15 DOWNFLOW. A term applied to designate the direction (downward) in which water or brine flows through an ion exchange resin bed during any part of the operating cycles of the nitrate removal unit.

3.16 DRAIN. A pipework assembly used to carry backwash water, spent brine and rinse water to the waste system.

3.17 DUPLEX. A nitrate removal unit type comprising two pressure vessels and ion exchange resin beds operating in either in parallel or alternating mode.

3.18 EJECTOR (also EDUCTOR OR INJECTOR). A hydraulically operated device using water to withdraw brine from a salt tank or cabinet, diluting it and introducing the solution into the pressure vessel and through the ion exchange resin bed.

3.19 END POINT. Defined as the position in the treated water run where the nitrate level in the treated water has increased to 50 milligrams per litre (mg/l as NO₃⁻).

3.20 FLOW. A measure of the quantity of water or a solution flowing, measured in litres per hour (l/h), litres per minute (l/min), cubic metres per hour (m³/h) or bed volumes per hour (BV/h).
3.21 ION EXCHANGE. A process in which ions of like charge are exchanged between the water phase and the solid resin phase.

3.22 MINIMUM DRAW (point of minimum draw). For the purpose of this protocol, the minimum level of brine within the brine tank at which brine can be drawn off.

3.23 NITRATE LEAKAGE. A small nitrate residual present in the service water during the normal operating cycle of the unit.

3.24 POINT OF ENTRY TREATMENT (Point of Entry Device). Treatment of the entire supply of water delivered to or entering buildings or properties.

3.25 POINT OF USE TREATMENT (Point of Use Device). Treatment of water for drinking at the point of use or immediately prior to the point of delivery, i.e. typically at the dietetic or kitchen tap, using for example a plumbed-in unit or system.

3.26 PRESCRIBED CONCENTRATION OR VALUE (PCV). The maximum or minimum permissible concentration or value of a parameter as established in the Water Quality Regulations (2.16 and 2.17).

3.27 PRESSURE DROP. A decrease in water pressure measured between two points in a hydraulic system. Commonly related to the pressure difference under flow conditions between the inlet and outlet connections of a nitrate removal unit. Expressed in bar.

3.28 PRESSURE REDUCING/LIMITING VALVE. A valve which reduces the pressure of water in a pipe, whether flowing or not, to a set value over a predetermined range of inlet pressures.

3.29 PRESSURE VESSEL. A component of a nitrate removal unit containing the ion exchange material distribution and collection systems and which is capable of withstanding the hydraulic pressure imposed upon it by the water supply system.
3.30 RATED SERVICE FLOW. The maximum flow specified by the manufacturer at which a nitrate removal unit will deliver its Rated Nitrate Removal Capacity during the normal service cycle. Measured in litres per minute (l/min) or cubic meters per hour (m³/h). See also 3.39.

3.31 RATED NITRATE REMOVAL CAPACITY. The quantity of nitrate expressed as NO₃ removed by the nitrate removal unit during the production of treated water between successive regenerations. Capacity is normally expressed as grams (g) of nitrate (as NO₃). Expression of nitrate removal capacity shall be related to the quantity of salt used per regeneration.

3.32 REGENERATION. The process of reversing the ion exchange activity carried out during the normal service cycle. Typically it involves backwashing, brine wash and rinse stages.

3.33 REGENERATION LEVEL. The quantity of salt per unit volume of ion exchange material used to regenerate the ion exchange bed. Expressed as grams of 100 percent NaCl/litre of resin.

3.34 REGENERATION WATER. The water, brine or spent regenerant which emerges from a nitrate removal unit during any stage of the regeneration cycle and flows to drain.

3.35 RESERVE. A proportion of the total operating capacity, equivalent to at least ONE day’s maximum use allocated for meter initiated systems that regenerate at a fixed specific time of day.

3.36 RESIN. The term used to designate a synthetic organic ion exchange material such as the high capacity selective anion exchange resin widely used in nitrate removal units. Typical ion exchange resins are small beads ranging from 0.3 to 1.3 mm diameter.

3.37 RINSE. That part of the regeneration cycle when water is introduced into the ion exchange bed to remove the spent brine prior to returning the nitrate removal unit to the normal service cycle.
3.38 SALT (Sodium chloride). A crystalline compound which is at least 98 percent pure NaCl. It is used for regenerating ion exchange nitrate removal units. Typically available in fine powder, granular or pelletised form.

3.39 SERVICE WATER FLOW. The normal flow of water through a water treatment device to points of use (see also 3.30).

Maximum Service Water Flows:

Point of Use Devices - the volume of water per unit time for a pressure drop of ONE bar across the complete nitrate removal unit.

All other installations - the volume of water per unit time that allows the nitrate removal unit to produce treated water for a minimum period of 10 minutes.

Individual manufacturers may impose other constraints that determine the maximum service flow.

3.40 TOTAL DISSOLVED SOLIDS (TDS). The total amount of dissolved solids in a solution. The ionic components of the TDS may also be measured as conductivity or resistivity.

3.41 TREATED WATER (For the purpose of this protocol). Water containing less than 50 mg/l nitrate (expressed as NO₃ - the Prescribed Concentration or Value (PCV), see 2.17). However specific applications may require lower values. Treated water is that which emerges from the unit during normal operation and flows to points of use.

3.42 TREATED WATER RUN. That part of the operating cycle usually regarded as a service operation when water is passed through a regenerated and rinsed ion exchange bed, thereby producing treated water.

3.43 UNTREATED WATER. (For the purpose of this protocol). Water containing nitrate in excess of 50 mg/l (as NO₃ - the PCV) (see TREATED WATER).
3.44 UPFLOW. A term applied to designate the direction (upwards) in which water or brine flows through an ion exchange bed during any part of the operating cycle of a nitrate removal unit.

3.45 WATER SUPPLY (for the purpose of this protocol). Either the incoming mains water supply or alternatively a bulk supply of water the chemical characteristics of which have been artificially created. The details are contained in Section 10 of this protocol.

4. LEGAL REQUIREMENTS (Water Byelaws)

4.1 Certain requirements must be observed before a water fitting is connected to a public water supply in the United Kingdom. These requirements are contained in the water byelaws which are made by water undertakers and based on the Model Water Byelaws, issued by the Department of the Environment and the Welsh Office. The purpose of the water byelaws is to prevent the waste, undue consumption, misuse or contamination of water.

4.2 The water byelaws do not apply to private water supplies but it is recommended that, where practicable, only products and materials which have been tested for compliance with the requirements of the water byelaws are used in private water supplies. The Water Byelaws Scheme is operated by the WRc Evaluation and Testing Centre and approvals are published in the Water Fittings and Materials Directory.

4.3 The nitrate removal unit assembly should comprise components and materials that comply with the requirements of the water byelaws enforced in the area of installation. Such compliance may be assumed if the components appear in the "Water Fittings and Materials Directory" of the United Kingdom Water Fittings Byelaws Scheme, and have been properly connected and installed (see also Section 7.1). The inclusion of components or assemblies in the Directory certifies that they have been found not to contravene the water byelaws if properly installed. This does not imply or certify fitness for purpose, or overrule specific local requirements (see Section 4.1).

5. **NITRATE REMOVAL UNIT CONSTRUCTION**

5.1 In general, salt regenerated ion exchange nitrate removal units comprise the following basic components (individual products or designs may incorporate any or all of these features).

   a) Pressure vessel(s) containing anion ion exchange material (RESIN), distribution and collection systems.

   b) Control head device(s) designed to regulate and control the service and regeneration times and flows.

   c) Tank(s), cabinet(s) and accessories for the storage of salt and the production of brine.

5.2 The initiation of the regeneration of a nitrate removal unit may be controlled by any of the following methods:

   a) Volume water meter (preferred) - either immediate or reserve regeneration types

   b) Timeclock

   c) Manual initiation

5.3 The control and sequence of regeneration can be carried out either manually, by operation of the control head or valves by an operator, or alternatively, by semi or, to be preferred, fully automatic operation based on e.g. the volume of water treated.

5.4 As the design and performance of nitrate removal units vary from manufacturer to manufacturer the details of the specific nitrate removal unit type should be obtained from the supplier.
Note: This protocol has been written on the assumption that brine (sodium chloride solution) will be the regenerant. If a unit is designed to use another regenerant (e.g. sodium bicarbonate solution) then that regenerant shall be used in the tests and the procedure modified accordingly. Modifications to other aspects of the test protocol may be required to accommodate particular designs and methods of operation; any deviation from the procedure shall be given with the test results.

6. DESIGN

6.1 All nitrate removal units shall be designed in such a way as to reduce to the lowest practical level the quantity of salt and total regeneration water volume required to produce treated water between successive regenerations. Resins must be listed in the List of Substances, Products and Processes Approved Under Regulations 25 and 26 For Use In Connection With The Supply Of Water For Drinking, Washing, Cooking Or Food Production Purposes. This list is issued annually by the Drinking Water Inspectorate and an equivalent publication is issued in Scotland.

6.2 Frequency of regeneration:

The preferred method of initiation is by volume water meter, with manual override.

For water meter initiated delayed regeneration reserve nitrate removal units, the reserve capacity is to be calculated on the worst likely operating conditions for a 24 hour period.

For water meter initiated nitrate removal units with immediate regeneration sufficient treated water storage and mains water by-pass isolation to prevent untreated water entering the storage tank shall be provided for single vessel nitrate removal units. Alternatively a duplex system may be installed.
For timeclock initiated units the sizing and frequency of regeneration should take into account the possibility of excessive unpredictable and unmeasured flows prematurely exhausting the unit.

*Nitrate removal units, irrespective of the method of initiation of regeneration, shall under normal operating conditions have a regeneration interval not greater than 5 days.*

7. COMPONENTS, ASSEMBLIES AND MANUFACTURE OF NITRATE REMOVAL UNITS

7.1 Compliance with the requirements of Water Byelaws may be assumed if the components and assemblies are listed in the Water Fittings and Materials Directory of the United Kingdom Water Fittings Byelaws Scheme, having regard to any Installation Requirements and Notes (IRNs) which are included in the Directory. Manufacturers should ensure that equipment is assembled under hygienic conditions to prevent negation of the aims of the United Kingdom Water Fittings Byelaws Scheme tests on materials and their effect on water quality (see also Section 6.1).

7.2 Prior to dispatch each nitrate removal unit should be disinfected.

7.3 Storage of components, assembly and final storage should be carried out under hygienic conditions. Prior to dispatch each unit is to be fully tested. Before use, the unit should be cleaned by carrying out the regeneration procedure manually, with omission of the salt regenerant. A disinfection stage may be incorporated into this cleaning stage. These actions are required to minimise colour throw and bacterial contamination during storage, delivery, installation and commissioning. Alternatively and preferably, the nitrate removal unit should be disinfected following commissioning and prior to use.
8. INFORMATION

8.1 INSTALLATION INSTRUCTIONS. The nitrate removal unit manufacturer or supplier shall provide adequate installation and operating instructions, including the arrangement of plumbing connections, electrical wiring where applicable, disinfection procedures and other information. The information should be specific to the model of nitrate removal unit supplied.

8.2 WORKING PRESSURE. The nitrate removal unit manufacturer or supplier should specify the maximum and the minimum pressure requirements under flow and no-flow conditions that will ensure satisfactory operation of the unit. Reference should be made to a requirement for the installation of a pressure reducing/limiting valve in the event that the maximum pressure rating of the nitrate removal unit is likely to be exceeded. In this case, the unit manufacturer or supplier should draw attention to the possible flow reducing effects of such devices.

8.3 PERFORMANCE DATA. The nitrate removal unit manufacturer or supplier shall provide basic performance information relating to the equipment.

8.4 WATER TESTING. At the time of a sale a water test is to be carried out for nitrate. Testing shall conform to the details given in 2.12 and 2.15. Test apparatus shall conform to the specifications given in Appendix A.

A simple nitrate test kit is to be provided with each nitrate removal unit, together with operating instructions. The end user of the nitrate removal unit is to be trained at the time of installation by the installer on the use, safety and interpretation of the test kit. Test kits incorporating liquid reagents are not recommended.

8.5 HYGIENE. If disinfection, other than that afforded by brine regeneration, is recommended by the manufacturer then a simple method, together with comprehensive instructions and customer training, are to
be provided on the means of disinfecting nitrate removal units on a regular basis. Disinfection chemicals should be non-hazardous and readily available.

9. PERFORMANCE REQUIREMENTS

NOTE. Where a complete nitrate removal unit assembly is referred to it should include accessories such as hose assemblies if these are supplied as standard equipment. All tests relate to a single pressure vessel and its ion exchange resin bed. No attempt has been made in this series of tests to prove or select the best means of operating meter initiated units, including those with statistically averaging electronic circuitry. The results obtained relate only to the test conditions specified in Section 10.

These test methods may also be used for sizes above and below those specified in the absence of any other suitable protocol.

9.1 SIZE DEFINITION. Ion exchange nitrate removal units covered by this protocol are those containing between 5 and 250 litres of resin.

9.2 ACCURACY/REPEATABILITY OF THE BRINE SYSTEM. The brine refill and draw system shall be accurate to within ±5 percent of the manufacturer’s stated figures.

9.3 RATED NITRATE CAPACITY. The claimed capacity is to be based on the average volume of treated water per pressure vessel produced in three runs between successive regenerations when operated under the specified test conditions (see Section 10). The capacity figures shall be related to the regeneration levels used.

The treated water nitrite concentration shall be no more than 0.1 mg/l.

It is at the manufacturer’s discretion whether to take into account ageing of the resin during any warranty period and the effect of channelling and meter accuracy due to very low flow rates.
a) Point of Use nitrate removal units - these should deliver treated water at a continuous flow of between 20 and 30 bed volumes (BV) per hour.

b) All other nitrate removal units - these should deliver treated water at the claimed maximum Rated Service Flow for a period of not less than 10 minutes. Further, they should deliver the claimed Rated Nitrate Removal Capacity at the claimed Rated Service Flow.

9.4 ACCURACY OF THE METERED SYSTEM. For all nitrate removal units, the system should be suitable for a minimum flow of 1.5 litres per minute. In all assemblies the meter shall have a minimum accuracy of ±5 percent.

9.5 REGENERATION WATER VOLUME. For all nitrate removal unit assemblies the total regeneration water for each pressure vessel shall not exceed eighteen bed volumes (18BV).

9.6 RINSE EFFECTIVENESS. On completion of a normal regeneration cycle the conductivity of the treated water shall not be more than 20 percent higher than the conductivity of the mains/test water.

9.7 OVERRUN. On completion of the Rated Nitrate Capacity Test (Section 11.4) the unit is to be overrun by a factor of TWICE the rated capacity volume or for a maximum of 5 days (whichever is the shorter) to ensure that the treated water nitrate level does not exceed 110 percent of the influent test water and that the nitrite concentration does not exceed 0.1 mg/l. The overrun test simulates faulty operation due to low or no salt, ineffective regeneration due to electrical, mechanical or hydraulic failure, power or other failures during service, incorrect setting of meter/time clock or excessive consumption.

9.8 MICROBIOLOGICAL CONTAMINATION. Samples taken immediately after start-up (Section 11.2 (n)) shall have total and faecal coliform counts not exceeding 0 per 100 ml. The Total Viable Count\(^1\) shall be taken into

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1. Total Viable Count (TVC) refers to the colony count (22 °C, 72 hr) by the pour-plate method described in reference 2.18.
account when assessing and interpreting the results of the test for microbiological colonisation.

9.9 MICROBIOLOGICAL COLONISATION. Samples of treated water taken one day before and one day after regeneration shall have Total Viable Counts (22°C, 72 hour) no greater than one hundred (100) times the corresponding influent water counts, when tested in accordance with Section 11.6.

9.10 WORKING PRESSURE. The manufacturer should state the maximum and minimum pressures between which the nitrate removal unit will provide the Rated Nitrate Removal Capacity.

9.11 PRESSURE DROP. Complete nitrate removal unit assemblies should have the following maximum pressure drops at the specified test conditions.

- Point of Use devices: 1.0 bar at the claimed Rated Service Flow.
- All other assemblies: the pressure drop shall be stated at the claimed Rated Service Flow.

9.12 HYDROSTATIC PRESSURE. The complete assembly shall satisfy the UKWFBS test criteria (TCS 11121-Porosity & TCS 11131-Joint effectiveness).

9.13 ELECTRICAL SAFETY. All electrically powered nitrate removal units shall comply with the requirements of BS 3955: 1986 including all amendments.

9.14 RESIN BED VOLUME (BV). The volume of resin in litres used in the tests shall be determined to enable the performance to be expressed in terms of Bed Volumes (BV).

10. TEST CONDITIONS

During the tests the following test conditions shall apply
10.1 WATER TEMPERATURE. The mains or test water temperature shall be between 5 and 25 degrees Celsius.

10.2 AMBIENT TEMPERATURE. The ambient temperature shall be between 15 and 25 degrees Celsius.

10.3 WATER PRESSURE. For tests involving flow conditions the mains or test water pressure shall be between 2.5 and 3.5 bar.

10.4 WATER FLOWRATE. For tests involving flow conditions, the unit shall be operated at the manufacturer’s maximum recommended flowrate.

10.5 WATER QUALITY. Water used for the Conditioning/Stabilising, Rated Nitrate Removal Capacity and Overrun tests shall have a nitrate concentration of 150 ±10 mg/l as NO₃, a sulfate concentration of 250 ±10 mg/l as SO₄, and a nitrite concentration <0.01 mg/l as NO₂.

To prepare a test water, use a mains public supply water treated as follows. To increase the nitrate concentration by 20 mg/l as NO₃ add 27.4 grams of sodium nitrate (NaNO₃) or 32.6 grams potassium nitrate (KNO₃) per 1000 litres of water. To increase the sulfate concentration by 20 mg/l (as SO₄) add 29.6 grams of anhydrous sodium sulfate (Na₂SO₄) or 51.4 grams of magnesium sulfate heptahydrate (MgSO₄.7H₂O) per 1000 litres of water. Carry out tests to verify the composition of the test water. Alternatively, test water may be spiked continuously using a suitable dosing pump provided that this procedure consistently achieves the required concentrations of nitrate and sulfate.

Safety Note: Use and store all chemicals and reagents safely.

NOTE: The relatively high concentration of sulfate is intended to provide a stringent test of the nitrate capacity. The treated water may contain sulfate at a concentration above the PCV as a result of this spiking procedure.
For safety the electrical installation shall conform to the Institution of Electrical Engineers: Regulations for Electrical Installations, 15th Edition, including all amendments.

11. TESTING

11.1 TEST APPARATUS. The test apparatus shown diagrammatically in Figures 1 and 2 enables the tests to be carried out. Accurate and reproducible results can only be obtained by conformity to the test apparatus design and the use of reliable and accurate test equipment. All instruments shall be calibrated prior to commencing testing. Water sampling shall be carried out using clean and well-rinsed containers.

The test rig should be situated away from areas where airborne contamination or bacteria-containing aerosols could compromise aseptic sampling.

Sampling ports should be constructed in such a way that they have as little tendency as possible to become contaminated from the air or by touching. Ideally the discharging nozzle should point vertically downwards and be shielded by a filling bell arrangement. It would also be an advantage if the sampling port could be covered completely when not in use. Surfaces which are in contact with the air, but which will also come into contact with the test water during sampling, should be easy to clean. The sampling ports should be designed such that minimal ‘dead legs’ are created when the valve is closed.

The rig should be designed taking account of the requirements for the test used to demonstrate the suitability of the rig for microbiological testing (below). In particular, suitable means will be required for filling the rig with test seed culture, and subsequently draining the apparatus.

Samples for microbiological assay shall be obtained taking suitable precautions to avoid sample contamination.
In general sampling ports or valves should be cleaned before a sample is taken (flaming of metal fittings is undesirable, as the temperature in that part of the rig will be affected, and heat-sensitive materials could be damaged). The tap or valve, particularly the inside of the discharging nozzle, should be swabbed using a suitable material (e.g. cotton wool, paper tissue) moistened with alcohol. The alcohol should be allowed to evaporate, and then the valve should be opened and sufficient water run to waste to flush out the valve, and ensure that a representative sample is obtained. In practice several times the volume of any stagnant region on the discharge side of the valve should be run to waste in a steady stream; the sample should be taken without altering the flow through the sampling valve to avoid disturbing sediments or deposits.

The suitability of the test apparatus for bacteriological testing shall be demonstrated as follows, prior to the test run. Inoculate a volume of Test Water (Section 10.5), sufficient to fill completely the empty (devoid of any nitrate removal unit) test apparatus and the reference glass sample container (see below), with a culture prepared as follows:

Using the Test Water as a source isolate a representative sample of the naturally occurring bacteria by passing 100 ml through a sterile membrane filter having a mean pore size of 0.45 μm. Place the membrane grid uppermost on to a plate of yeast extract agar and incubate for 72 hours at 22 °C. Following incubation, flood the surface of the membrane using an appropriate volume of ¼ strength Ringers solution and emulsify the bacterial growth present on the membrane. Concentrate the resultant bacterial suspension by centrifugation at 6000g for 10 minutes or 3000g for 30 minutes. Wash the bacterial cells by re-suspending the pellet in ¼ strength Ringers solution after first discarding the supernatant. Centrifuge again and finally re-suspend in a further volume of ¼ strength Ringers solution; this constitutes the seed culture. Store at 4 ± 1 °C. After storage for 24 hours, estimate the number of viable cells by the standard method (2.18).
Using the seed culture, prepare a volume of inoculated water, sufficient to completely fill the test apparatus and the reference sample container, and having a TVC of 500 to 50 000 per ml. Fill the test apparatus with this inoculated test water after isolating the test nitrate removal unit. At the same time, fill a clean sterile borosilicate glass container (the reference container) with the inoculated test water and seal as a reference sample. Store the reference sample in the dark at the same temperature as the test apparatus.

After a 72 hour holding period collect the whole contents of the test apparatus via the drain valve into a clean sterile container and mix thoroughly. Take a representative sample of the same volume as the stored reference sample. Perform triplicate Total Viable Counts (22 °C, 72 h) on both samples.

If the geometric mean of the triplicate samples from the test apparatus is within 50 percent of the geometric mean of the reference samples the apparatus will be deemed to be acceptable. A difference greater than 50 percent will invalidate the test apparatus.

11.2 CONDITIONING/STABILISING RUNS

a) The test flowrate shall be the manufacturer’s maximum recommended flow, or

in the absence of a recommended flow, the flow shall be between 20 and 30 BV per hour.

b) Connect the unit to the apparatus shown in Figure 1. Do not connect the electrical supply at this stage.

c) Ensure that all valves are closed.

d) Set the regeneration initiation controls as follows:
i) on meter initiated units (immediate or delay/reserve type), set the meter to its maximum volume or set it assuming a low (typically 20 mg/l) inlet nitrate concentration.

ii) on timeclock initiated nitrate removal units, set the time interval of regeneration to the maximum possible or alternatively, set the control to manual initiation.

e) Set the timeclock to the correct time of day (electrically powered units).

f) Set the time of regeneration (if adjustable) to approximately 02:00 am.

g) Set the regeneration cycles (if adjustable) to the manufacturer’s recommended values in the operating instructions, suitable for a test water pressure range of 2.5 to 3.5 bar.

h) Ensure that the control head is in the SERVICE position.

i) Connect and switch on the electrical supply (if required).

j) Note the test meter reading and time of day.

k) Fully open the inlet isolating valve. Carry out any commissioning procedures recommended by the supplier.

l) Slowly open the outlet isolating valve/regulating valve until the test flow rate (from a)) is established and stabilised.

m) Monitor the flow and maintain it at the required value.

n) Take samples immediately after start-up and perform microbiological assay for total coliforms, faecal coliforms and Total Viable Count (22°C, 72 hour) using the methods in 2.18.
o) Check the treated water nitrate concentration at regular intervals.

p) Record the results.

q) Fill the salt tank/cabinet to the maximum level with the recommended grade or type of salt. Keep it filled to the maximum during all Conditioning/Stabilising runs.

r) Stop the flow to service when the treated water nitrate concentration reaches an End Point of 50 mg/l as NO₃.

Note: If new resin has been used for the first time the initial treated water output may be abnormally high.

s) Note the meter reading and time of day.

t) Manually initiate a regeneration.

Note: A colour throw may be experienced during the brine injection/slow rinse stages. This is due to the elution of any organics removed by the resin from the test water.

u) Note the times and volumes.

Repeat the above procedure from stage h) (stage (n) may be omitted) at least a further FOUR times to stabilise the resin bed. During these preliminary runs the following tests shall be conducted to gain experience for the detailed tests to be carried out later in the test series:

11.3 - Accuracy/Repeatability of the brine system;

11.4.2 - Rinse Effectiveness.

11.3 ACCURACY/REPEATABILITY OF THE BRINE SYSTEM

For salt and brine data see Appendix B.
Test apparatus required:
a) Salinometer (Brineometer)/Hydrometer
b) Thermometer
c) Ejector connected to the mains water supply
d) Closed vessel to collect the brine under vacuum. A 20 litre protected glass or plastic bottle may be used for this purpose.
e) Graduated cylinder of 2000 or 4000 ml volume, calibrated in millilitres.

11.3.1 FLOAT TYPE BRINE VALVES

a) Install the brine valve as recommended in the manufacturer’s instructions.
b) Fill the salt tank/cabinet to its MAXIMUM level with the recommended grade or type of salt.
c) Connect the brine line of the float type brine valve to the test set-up as shown in Figure 2.
d) Open the mains water isolating valve until the float valve stops the flow. Close the isolating valve.
e) Leave for one of the following periods appropriate to the design of unit under test:

i) Meter initiated models with 24 hour reserve 20 hours
ii) Meter (single and duplex vessels) with immediate initiation Minimum service period likely to be encountered
iii) Timeclock initiated models 20 hours

23
Note: For some duplex units with short service periods between regenerations it may be necessary to increase the refill volume to compensate for the brine not being fully saturated. This depends on the brine system and salt type being used.

f) Disconnect the brine line from the water supply and connect it to the inlet of the brine collection vessel. Open the ejector isolating valve, applying a vacuum to the vessel. Continue to apply the vacuum until the brine float valve stops the flow.

g) Disconnect the vacuum and brine lines. Measure the total volume, temperature and salinometer/hydrometer reading of the collected brine solution. Use the Tables in Appendix B to calculate the amount of salt dissolved.

h) Repeat b) to g) at least a further FOUR times until stability is reached. The variation of the last three tests shall not exceed 10 percent of the mean.

The mean of the last three tests is used as the amount of salt per regeneration for the Rated Nitrate Capacity test.

11.3.2 TIMED BRINE REFILL

a) Disconnect the brine line from the salt tank/cabinet, downstream of the refill flow controller.

b) Connect the nitrate removal unit as shown in Figure 1. Close the outlet isolating valve. Initiate a manual regeneration.

c) Measure the refill volume. Repeat at least a further FOUR times to obtain an average volume. The variation shall not exceed 10 percent of the average.

d) Use the tables in Appendix B to calculate the weight of salt to be dissolved. Adjust the refill time and/or flow controller to obtain the refill volume required.
The mean of these tests is used as the amount of salt per regeneration for the Rated Nitrate Capacity test.

11.4 RATED NITRATE CAPACITY

Repeat the procedures given in 11.2, except that the brine is produced as follows:

a) For brine tanks/cabinets with FLOAT type brine valves:

i) Install the brine valve in a suitable open container. Connect the brine line to the control head as in a normal installation. Add saturated brine (prepared separately) to the open container until the point of minimum draw is reached. For each regeneration, measure the required volume of saturated brine into the container.

ii) During regeneration, the saturated brine will be injected into the unit. The float should be lifted manually when the brine suction cycle is complete to prevent refill of water into the container. An elastic band may be used to hold the float and/or rod temporarily in the raised position.

or for brine tanks/cabinets with TIMED brine refill:

i) Install the brine valve in a suitable open container. Connect the brine line to the control head as in a normal installation. Add saturated brine (prepared separately) to the open container until the point of minimum draw is reached. For each regeneration, measure the required volume of saturated brine into the container.

ii) If the timed refill system is without a safety overflow float, it is necessary to mark carefully the position of minimum draw on the brine tube. Add saturated brine (prepared separately)
to the open container until the point of minimum draw is reached. For each regeneration, measure the required volume of saturated brine into the container.

iii) During regeneration, the saturated brine will be injected into the unit. Remove the brine tube assembly from the container to prevent the refill of water into the container.

b) During the service run, take samples of equal volume of untreated test water at the beginning, middle and end (i.e. at the start of the test, halfway through the test and when the treated water nitrate concentration reaches 50 mg/l as NO₃). Mix these together to obtain a representative sample. Determine the concentrations of nitrate, sulfate and nitrite. Record the details.

c) Take samples of treated water at regular intervals, and analyse for nitrate and nitrite. No sample of treated water shall have a nitrite concentration greater than 0.1 mg/l (as NO₂). Continue the run until the run until the treated water has reached an end point of 50 mg/l as NO₃.

d) Calculate the nitrate capacity:

\[
\text{Rated Capacity} \ (g\ NO₃) = \frac{\text{REMOVAL} \ (mg/l\ NO₃) \times \text{VOLUME} \ (l)}{1000}
\]

where

\[
\text{REMOVAL} = \text{Mean concentration of nitrate removed, i.e. Test Water concentration minus average treated water concentration.}
\]

\[
\text{VOLUME} = \text{volume of water treated before 50 mg/l NO₃ end point reached.}
\]
e) Repeat a) to d) to obtain three successive values for Rated Nitrate Capacity which do not vary by more than +10 percent from the mean.

f) As far as possible, service runs and regenerations should occur with the minimum delay between the two operations.

 g) Reconnect brine tube assembly.

11.4.1 REGENERATION WATER VOLUME

a) During the three Rated Nitrate Capacity runs, measure the volume of water used for regeneration for the test pressure range of 2.5 to 3.5 bar. (See also Section 11.4.2.)

b) Record the volume.

11.4.2 RINSE EFFECTIVENESS

This determines the effectiveness of the rinse and is an indicator of the efficiency of the distribution and collection systems.

a) Take a sample of test water.

b) During the Conditioning/Stabilising runs, on completion of a regeneration cycle, take a sample of treated water.

c) Measure the conductivity of both the test water and treated water.

If the conductivity of the treated water sample is within ±20 percent of the test water then the unit is adequately rinsed. If the conductivity of the treated water sample is higher than this then additional rinsing is required. This can be achieved by increasing the Slow Rinse and/or Fast Rinse volumes by changing the flows or cycle times, or a combination of both.
If conductivity reduction is achieved too quickly then consideration should be given to reducing the total rinse volume.

d) Repeat the test to check that the changes have been effective.

e) Record the details.

11.5 OVERRUN TEST

a) From 11.4 determine the average volume of water treated before the 50 mg/l NO₃ end point was reached. Multiply this figure by TWO to obtain the overrun volume.

b) Carry out an identical regeneration to those in 11.4. Again note the volumes and times.

c) Using the same flow as in the Rated Capacity test, allow the unit to flow to service either up to the total volume calculated in a) above or for a maximum run time of 5 days, whichever is the shorter.

d) During the service run, take samples of equal volume of untreated test water at the beginning, middle and end of the run. Mix these together to obtain a representative sample. Determine the concentrations of nitrate, sulfate and nitrite. Record the details.

d) Take test water samples at the beginning, middle and end of the run and determine nitrate and nitrite.

e) Take treated water samples at frequent intervals. Beyond the normal treated water volume limit take samples at least every 5 BV.

f) Record the details.
11.6 TEST FOR MICROBIOLOGICAL COLONISATION

This test establishes whether the resin bed becomes colonised by micro-organisms to an unacceptable extent. Follow the basic procedure given in 11.4 for operation of the unit. Carry out a regeneration, then continue the run until 24 hours before the next regeneration is due (based on the rated nitrate capacity previously determined in 11.4). Take samples of influent and treated water and determine Total Viable Count (22 °C, 72 hours) by the method given in 2.18. Continue the treated water run up to exhaustion (rated nitrate removal capacity), conduct a regeneration and start a further treated water run. After 24 hours take samples of influent and effluent and determine TVCs as before.

11.7 RESIN BED VOLUME (BV) DETERMINATION

This test enables the actual resin volume to be determined for use in calculations.

a) Remove the control head from the pressure vessel and extract the resin contents.

b) Place the resin in a calibrated container fitted with a backwash water supply.

c) Measure the resin volume in litres after it has been backwashed, settled and the water drained to the level of the surface of the bed.

12. RESULTS

The results from the tests should be recorded and used to calculate the performance data.
12.1 RATED NITRATE CAPACITY

From the last THREE consecutive test results, calculated according to 11.4(d), within 10 percent of the average, calculate the mean rated capacity expressed as grams NO₃ to 50 mg/l NO₃ end point. See 11.4(d).

12.2 RESIN BED VOLUME (BV)

Record the BV in litres.

12.3 REGENERATION WATER VOLUME - IN BV

\[
\text{BV of Regeneration water} = \frac{\text{Mean Regeneration Water Volume (l)}}{\text{Resin BV (l)}}
\]

13. CONVERSION FACTORS

13.1 MASS

1 kilogram = 2.205 pounds (lb)

1 lb = 0.4536kg

or 453.6 grams

13.2 VOLUME

1 litre = 0.220 Imperial gallons

or 0.2642 US gallons

1 Imperial gallon = 4.546 l

1 US gallon = 3.785 l

1 ft³ = 28.317 l

1 m³ = 220 Imperial gallons

or 264 US gallons
### 13.3 Pressure

<table>
<thead>
<tr>
<th>Unit</th>
<th>Conversion</th>
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<tbody>
<tr>
<td>1 bar (gage)</td>
<td>= 14.5 lbf/\text{in}^2 (psi)</td>
</tr>
<tr>
<td>1 atmosphere</td>
<td>= 14.7 lbf/\text{in}^2 (psi)</td>
</tr>
<tr>
<td>1 bar</td>
<td>= 10 metres H$_2$O (water head)</td>
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<tr>
<td>1 bar</td>
<td>= 100 kPa</td>
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### 13.4 Nitrate

<table>
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<tr>
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<th>Conversion</th>
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</thead>
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<tr>
<td>1 mg/l N</td>
<td>= 4.43 mg/l NO$_3$</td>
</tr>
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Figure 1: Nitrate removal unit test installation

<table>
<thead>
<tr>
<th>Pipe size</th>
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<tr>
<td>&lt;14mm</td>
<td>20mm</td>
</tr>
<tr>
<td>14 - 21mm</td>
<td>25mm</td>
</tr>
<tr>
<td>21 - 41mm</td>
<td>70mm</td>
</tr>
<tr>
<td>&gt;41mm</td>
<td>2x bore</td>
</tr>
</tbody>
</table>

Not shown: Test kits, TDS meter, pressure tester, stop watch, thermometer, salinometer.

Note: Pressure gauge tapping points to be as close as possible to the inlet & outlet connections of the nitrate removal unit.

---

Figure 2: Float brine valve test rig

Note: The elevation of the drain points is to prevent siphonage & obtain consistent ejector performance.
APPENDIX A - TEST EQUIPMENT

i) Pressure gauges to BS 1780. A minimum diameter of 65 mm is recommended.

ii) Water meters to BS 5728:Part 1 Class D, calibrated in litres or cubic metres.

iii) Flow indicators to BS 1042, calibrated in litres per minute or cubic metres per hour.

iv) Flow controllers with an accuracy of ±5 percent calibrated in litres per minute or cubic metres per hour.

v) Nitrate test kit with an accuracy of ±5 percent over the range 5 to 200 mg/l as NO₃.

vi) Sulfate test kit with an accuracy of ±5 percent over the range 20 to 500 mg/l.

vii) Conductivity meter with an accuracy of ±5 percent over the range 100 to 1000 µS/cm.

viii) Stopwatch and clock

ix) Thermometer calibrated in degrees Celsius.

x) Balance accurate to ±10 grams over the range 0 to 5 kg.

xi) Salinometers or hydrometers covering the specific gravity range 1.0 to 1.25 (sodium chloride concentration equivalent to 0 to 100 percent saturation).

xii) Double check valve to BS 6282: Part 1.

xiii) Valves and fittings shown in Figures 1 and 2.
### APPENDIX B - SALT AND BRINE DATA

<table>
<thead>
<tr>
<th>% Satn.(1)</th>
<th>10 °C NaCl S.G.</th>
<th>15 °C NaCl S.G.</th>
<th>20 °C NaCl S.G.</th>
<th>25 °C NaCl S.G.</th>
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<tr>
<td></td>
<td>g/l</td>
<td>g/l</td>
<td>g/l</td>
<td>g/l</td>
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<td>1.010</td>
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<td>10</td>
<td>1.021</td>
<td>31.6</td>
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<td>95</td>
<td>1.199</td>
<td>300.6</td>
<td>1.197</td>
<td>300.9</td>
</tr>
</tbody>
</table>

| g NaCl to saturate 1 litre of water | 358.0(3) | 359.0 | 360.0 | 361.0 |

#### Notes:

1. Saturation as percent by mass
2. NaCl is g/litre of NaCl in 1000 ml of brine solution
3. At 10 °C, 1 litre of water will dissolve 358 grams of NaCl, to produce 1.132 litres of brine.
4. Crystalline NaCl has a specific gravity (S.G.) of 2.165
5. Bulk density of granular and pelletised salt is approximately 1.2 g/cm³
6. Void volumes range from approx. 10 percent for granular salt to 50 percent for pelletised salt.
APPENDIX C - EXAMPLE TEST SHEET

Results of tests to determine compliance of <name of unit> with protocol for testing the performance of in situ regenerated ion-exchange based nitrate removal units for treatment of private water supplies.

Description and identification of unit under test:

Flowrate (l/min): ___ Pressure (bar): ___ Bed Volume (litre) ___

<table>
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<tr>
<th>Sample Number</th>
<th>Date/Time</th>
<th>Volume</th>
<th>Outlet Treated</th>
<th>Outlet Nitrate</th>
<th>Outlet Nitrite</th>
<th>Other Information</th>
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</tbody>
</table>

Total Volume to 50 mg/l end point (litres) = ___ = ___ BV

Note: the above is an example which may require modification in particular circumstances.
Attach:
(a) Analytical performance characteristics (data)
(b) Results of analysis of Test Water
(c) Results of test of suitability of test rig for microbiological testing
(d) Results of test of regeneration water volume
(e) Results of test of rinse effectiveness
(f) Results of overrun test
(g) Results of test for microbiological colonization

This unit does/does not* meet the requirements of the test protocol

Signed: ___________  Position: ___________  Company: ___________

* delete as appropriate
APPENDIX D - ACKNOWLEDGEMENT

This test protocol was produced by the Nitrate Removal Unit Working Group of the DoE Committee on Point of Use Device Test Protocols. The composition of these groups was as follows:

DoE Committee on Point of Use Device Test Protocols

<table>
<thead>
<tr>
<th>Name</th>
<th>Organization</th>
<th>Position</th>
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</thead>
<tbody>
<tr>
<td>Mr A Lloyd</td>
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<td>Convention of Scottish Local Authorities</td>
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<td>Mr D A Burt</td>
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<td>Mr T Carter</td>
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<td>Mr P Davis</td>
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<tr>
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<td>Dr A Evans</td>
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<td>Mr P Evans</td>
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<tr>
<td>Mr M Hind</td>
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<tr>
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<tr>
<td>Mr J Millar</td>
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<tr>
<td>Mr R Tanner</td>
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<td>Mr J Tate</td>
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<tr>
<td>Ms H Walter</td>
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<tr>
<td>Mr D M Wilson</td>
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<tr>
<td>Mr P J Jackson</td>
<td>WRC</td>
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</table>

Working Group on Nitrate Removal Units

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<thead>
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<th>Name</th>
<th>Organization</th>
<th>Position</th>
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<td>Convenor</td>
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<tr>
<td>Mr J Barraclough</td>
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</table>
This protocol was developed on the basis of existing standards produced by the British Effluent and Water Association\(^1\) (BEWA, Standard P.07.90) and the National Sanitation Foundation\(^2\) (NSF, Standards 42 and 58). Both of these organisations played an active role in developing this protocol, and their contributions and permission to make use of copyright material are gratefully acknowledged.

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