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MODIFICATION AND OPERATION OF CERAMIC CUP SOIL SOLUTION SAMPLER FOR USE IN A GEOCHEMICAL CYCLING STUDY

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PREFACE

The apparatus described in the following note was constructed for use in a project studying geochemical cycling in an upland grassland catchment near Plynlimon, mid-Wales (ITE Project 594). A general introduction to this project is available as Bangor Research Station Occasional Paper No. 4.

SOIL SOLUTION SAMPLER

Introduction

Soil water samples may be collected for chemical analysis using porous ceramic cup suction lysimeters. These devices have advantages over traditional non-tension devices as they are able to collect water from unsaturated soil, and also cause less disturbance during installation.

Descriptions of suction cup lysimeters and various developments are given by Wagner (1962), Reeve and Doering (1965), Parizek and Lane (1970), Wood (1973), Harris and Hansen (1975), De Jong (1976) and Chow (1977). Results obtained from these devices need to be treated with care as the exchange properties of the ceramics can influence the composition of the collected sample, e.g. Grover and Lamborn (1970) found that the cup contributed Na, K and Ca to the sample. Pre-treatment involving leaching with dilute HCl reduced Na and K contamination to acceptable levels, but Ca continued to be released from the ceramics. Adsorption of phosphorus by the cup was found to be low, and rapidly reached equilibrium. Levin and Jackson (1977) also found these devices suitable for extracting phosphate, but were doubtful about nitrate. Hetsch, Beese and Ulrich (1979) found that ceramic cups could not be used for phosphorus determinations however. Ceramic cups from different sources will probably vary in their exchange properties and so no hard and fast rule can be applied to them.

Other problems in practice and of interpretation are

described at length by Hansen and Harris (1975) and Talsma, Hallam and Mansell (1979).

The usefulness of these devices remains, however, and porous ceramic cup samplers having been used in irrigation-salinity studies (Reeve and Doering 1965), wastewater disposal (Wood 1973), catchment management studies (Harris and Hansen 1975) etc.

Porous cup soil solution samplers are available commercially (manufactured by the Soilmoisture Equipment Corporation, P. O. Box 30025, Santa Barbara, California, 93105, U. S. A. and distributed in Britain by D. A. Pitman Limited, Jessamy Road, Weybridge, Surrey, KT13 8LE), in various lengths and consist of a round bottom porous ceramic cup 48 mm in diameter, glued to a length of thin-walled plastic tube 45 mm in diameter (Fig. 1). A neoprene stopper, neoprene tube and clamp complete the assembly. Once installed in soil a vacuum is applied to the sampler, which draws in soil solution through the porous pot.

The following disadvantages have been noted with this sampler, although the simplicity of the design is greatly in its favour:-

1. Cost - the samplers are expensive considering that most of the components are very basic and comparatively cheap. Transport and import costs from the U. S. A. obviously affect the price.
2. Sample extraction is awkward as it involves inserting a small diameter flexible tube through the neoprene tube and stopper until it reaches the sample which is then drawn out by vacuum pump.

The porous pots are available separately from the Soilmoisture Equipment Corporation and the various other items necessary to construct a complete sampler are also readily available. Plastic tubing of 45 mm diameter is not readily available, however, and 40 mm tube with a special coupling have been substituted, thus slightly reducing the capacity of the sampler. However, the opportunity to construct one's own samplers reduces the cost to less than half that of the commercial item and allows the design to be altered slightly to facilitate sample collection. It is this "improved" version which is described below.

Description

Figure 2 shows the components used in the construction of the sampler. A porous, ceramic, round bottom, neck-top cup or pot 48 mm (1 9/10") in diameter and 63 mm (2 7/16") long (excluding neck) is joined to a length of 40 mm (1½") diameter ABS (Acrylonitrile Butadiene Styrene) waste pipe via a coupling designed for joining lengths of this pipe. ABS/PVC adhesive is used to join pot to coupling and coupling to pipe. Two or three coats of adhesive are advisable on the pot, each coat being allowed to dry before the next - this ensures close contact between pot and coupling which might not otherwise be achieved as both items have been found to deviate slightly from a circular section. A piece of 40 mm (1½") diameter ABS waste pipe is glued into the coupling. The length of this pipe can be varied to suit the depth of sampling required but for our purposes

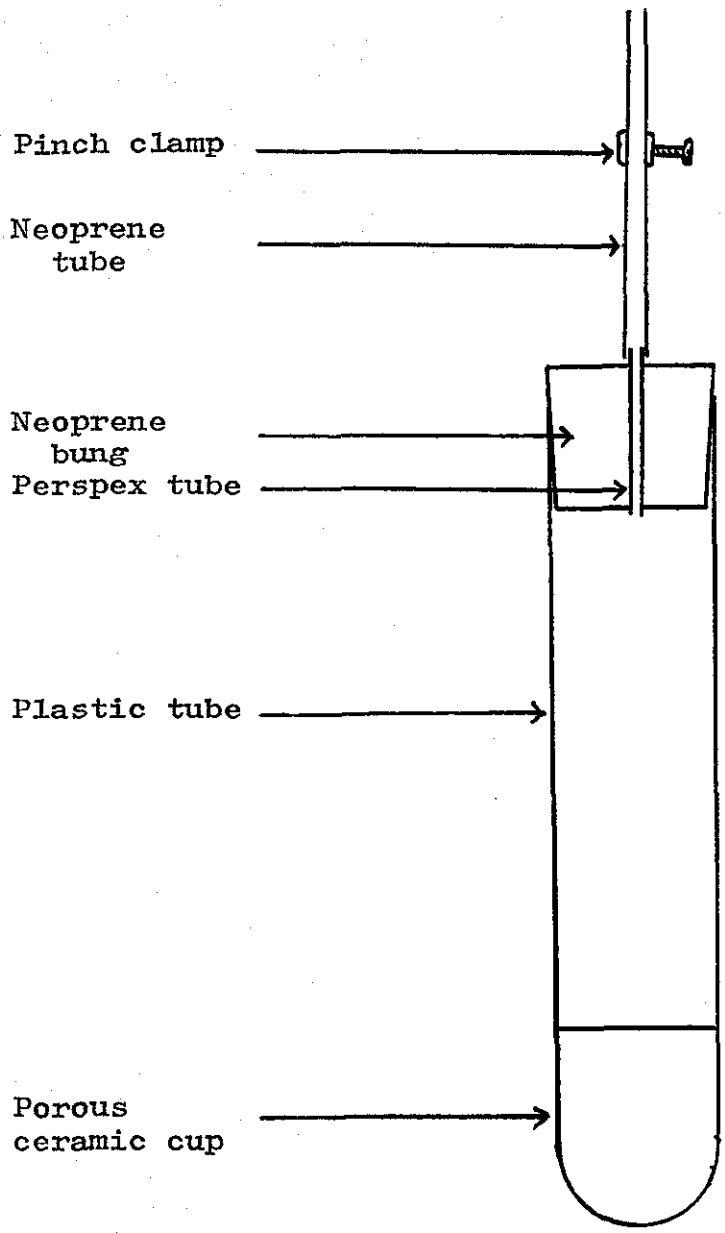

Figure 1. Sketch of commercially - available soil solution sampler

these lengths are such as to produce samplers 68 cm (27"), 38 cm (15") and 22 cm (9") long overall (excluding bung and tube assembly) - equivalent to three of the commercially available versions.

A silicone rubber bung (No. 29) seals the top end of the pipe. Two small diameter (3 mm bore) perspex (acrylic) tubes are inserted through holes in the bung. One tube reaches a short distance beneath the bung, the other reaches to within a millimetre or so of the bottom of the porous pot. This latter tube is used for extracting the sample with a vacuum pump so the small gap between tube and pot is important, ensuring that the sample can be readily drawn out, but also leaving as little sample as possible in the pot before air is withdrawn. Short lengths (150 mm or so) of thick walled neoprene tubing (3 mm bore, 3 mm wall) are attached to the protruding ends of the perspex tubes and polypropylene clips are fitted to allow the system to be sealed. Pieces of PVC tape of different colour are attached to the neoprene tubes to differentiate the 'sample' and 'air' tubes when installed in the field.

Treatment prior to Installation

New porous ceramic cups may release small quantities of certain elements during the first few weeks or months when installed in soil, thus 'contaminating' the samples. It has been reported that treatment of the pots with acid is advisable, but other reports suggest that this increases the pore size of the pot unacceptably.

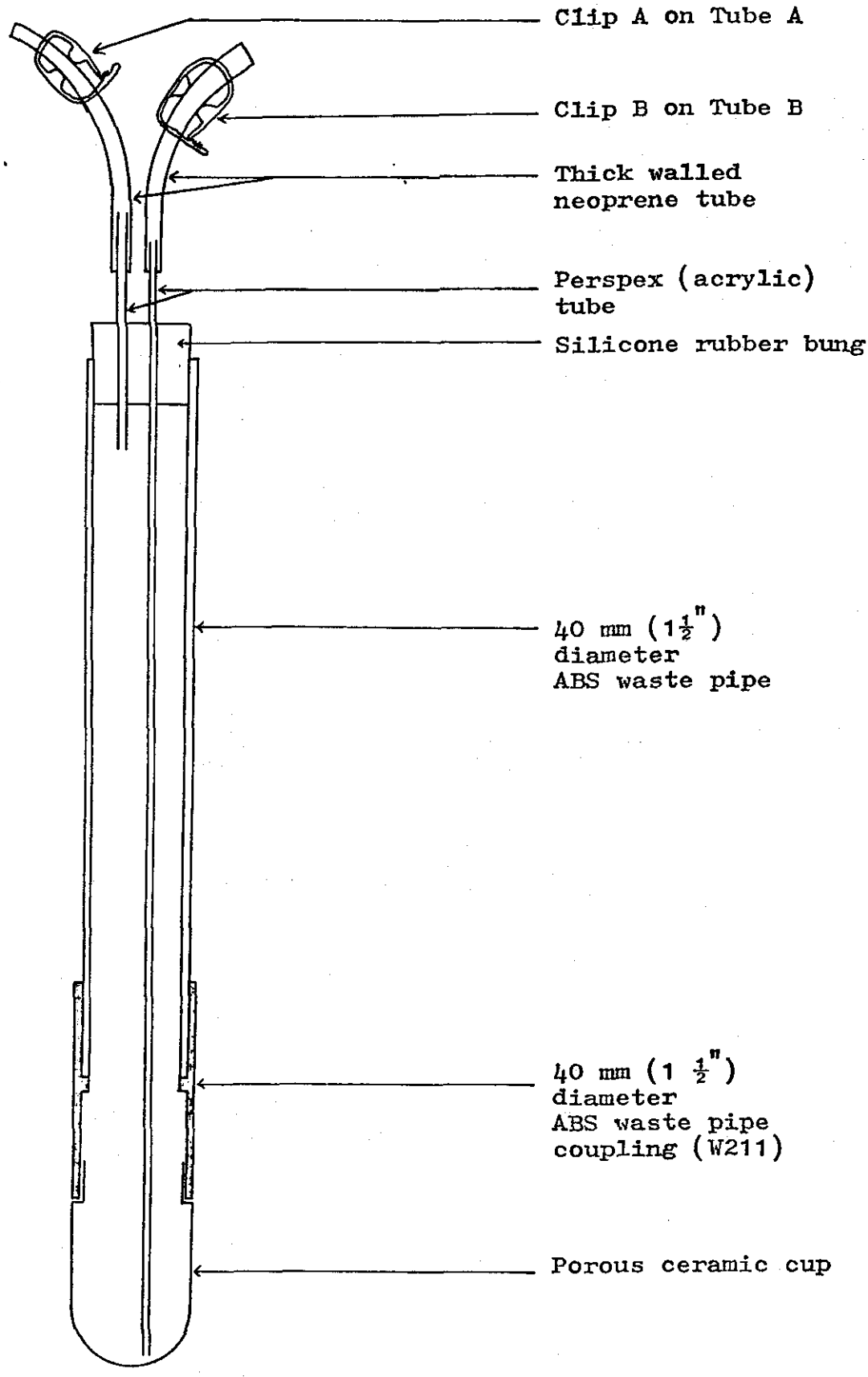

Figure 2 Soil Solution Sampler

A pre-treatment plan involving distilled water is therefore used.

The complete sampler is clamped in a position with the pot immersed in distilled water in a large beaker. The vacuum is established (as is described later in the 'Operation' section) causing water to be drawn into the sampler until it is roughly $\frac{3}{4}$ full. The complete sample is withdrawn, fresh distilled water placed in the beaker and process repeated another 5 times. A polythene bag is wrapped round the pot to prevent contamination during transport to the site for installation.

(This procedure has the additional benefit of revealing any leaks or other malfunctions in the samplers before installation).

Installation

It is important that good contact be made between the porous pot and the soil which is to be investigated. It is also important that the hole around the sampler be sealed after insertion to prevent water from upper horizons trickling down to lower levels and providing an unrepresentative sample.

When the study area and depth at which samplers are to be installed are decided, the points for location of samplers are fixed by investigation with an ordinary small diameter screw auger. A Jarrett auger with 50 cm (2") diameter head is used to excavate a hole to the required depth, the soil from the various horizons being kept separate

for eventual repacking. A slurry is made from distilled or local stream water and soil from the bottom of the hole. This is poured into the hole and the sampler is pushed in; the slurry ensuring good contact between pot and soil. The remaining excavated soil is packed down the sides of the sampler in the correct order and is pressed down with lengths of wooden dowelling (Fig. 3).

Complete protection from grazing animals is difficult to achieve. Unprotected samplers may suffer sheep-chewed neoprene tubes and clips and cattle may pull the entire sampler out of the ground.

At Plynlimon, small square cages constructed simply from four 1" x 1" x 18" wooden pegs and heavy duty plastic $1\frac{1}{2}$" mesh garden netting are used. The samplers protrude only 3 - 4" from the ground surface at most, so the wooden pegs can be driven into the soil for 12" or more, making a firm cage. The top of the cage is held in place with plastic coated cup hooks and is therefore removable, allowing access to the neoprene tube.

Once installed, regular sampling should be initiated immediately. A period of several weeks will probably be needed for equilibration and it may take 3 months for certain elements such as calcium to be removed from the ceramic pot.

Operation

Basically, this involves evacuation of the sampler and allowing it to remain in this state for a few days during

which time water is sucked from the soil through the porous pot into the sampler. The sample is then withdrawn by sucking it out into a collection bottle.

The detailed procedure is:-

1. Attach a portable, hand vacuum pump to Tube A (see Fig. 4) via a length of PVC tubing and a tubing connector. With Clip B closed and Clip A open, establish a vacuum of around 0.65 bar/20" mercury. Close Clip A and leave for the required period (in some cases, a sample will have been collected within a few hours but a longer period is advisable). (Our sampling period is weekly).
2. The sample is collected by drawing it directly into the collecting bottle using the vacuum pump. Figure 4 shows the system used. The bottle needs to be rigid in order to support the vacuum required to extract the sample. Most plastic bottles available are not suitable - the type used here is described as a Mason Jar, has a capacity of 500 ml and is made of rigid polypropylene. This can be fitted with a "Fluid Transfer Closure" with lengths of PVC tubing attached, to form a transfer assembly. Tubing connectors allow this assembly to be joined to Tube B of the sampler and to the vacuum pump. Initially a 'waste' Mason Jar is attached to the transfer assembly and a few mls of sample are drawn through to rinse the tubes. The 'waste' jar is then replaced by the sample jar and the complete sample is drawn through. The volume of sample depends on

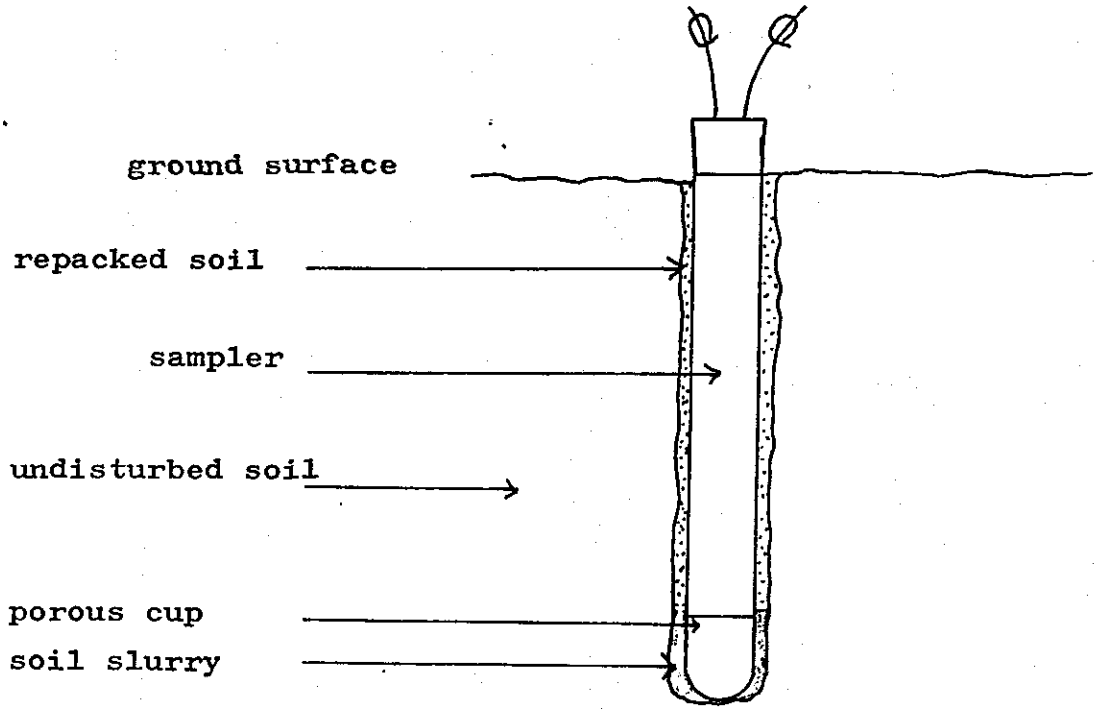

Fig. 3. Installation of soil solution sampler

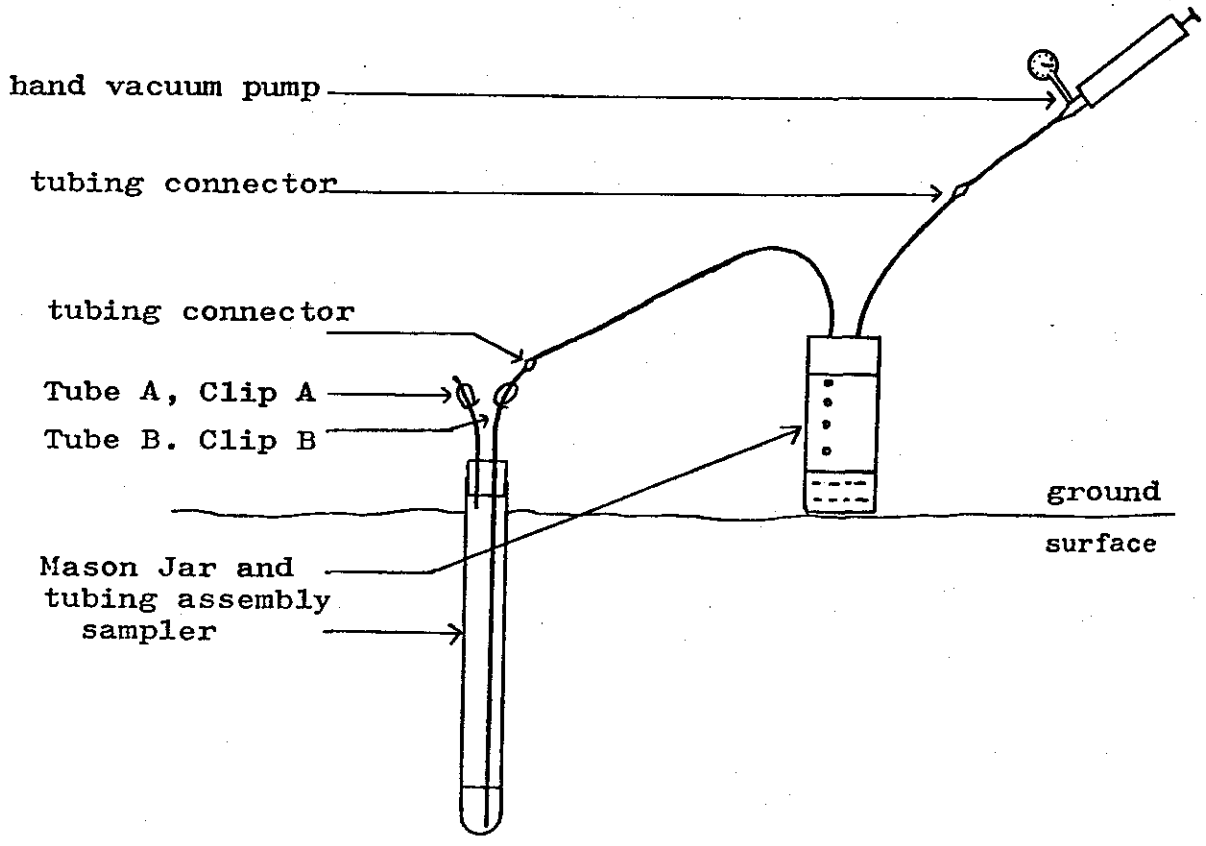

Figure 4 Method of extraction of soil solution sample

soil conditions, rainfall and sampler size. The longest samplers may provide up to 750 ml of sample and the last 250 ml of this will need to be rejected.

3. With all the sample removed, the transfer assembly is disconnected, Clip B closed and the sampler is ready for re-establishment of the vacuum for the next sampling period.

Operational Problems

Pump

The pump supplied by the Soilmoisture Equipment Corporation for use with their soil solution samplers has proved light, quick, robust and simple to dismantle for cleaning and lubricating.

Tubing

Initially it was hoped to use PVC tubing, not neoprene, for the samplers. It was found, however, that the constrictions caused by the clips were very difficult to remove, especially during cold weather and neoprene had to be substituted.

The clips themselves provide a problem. A great variety of designs is available, but for outdoor use a snap type is desirable as the screw type become difficult or painful to operate repeatedly and are subject to corrosion problems. Disadvantages of the snap type are that they may open spontaneously if not carefully closed previously, and they have a limited life (around 9 months outdoors).

Freezing

Difficulties due to freezing weather conditions and when exposed parts of the sampler are buried by snow are obvious. Any drops of water in the neoprene or perspex tube at the surface will freeze, blocking the tube. Even if the tubes are clear, the action of drawing the sample out through these cold tubes may result in blockage when the sample freezes. Only the exposed bung, tubes and extreme top of the sampler are normally subject to freezing - the temperature below the surface soil is very rarely, or never, cold enough to allow freezing of the complete sample.

Drought

At the time of writing (November 1980) samplers have been installed for 12 months and most problems have been overcome. Extended periods of dry weather might be expected to result in little or no sample. However, samplers continued to operate successfully throughout 2 months of dry weather in April/May 1980.

A long term problem is the clogging of the ceramic cup pores with soil particles, leading to poor sample collection and eventual failure. This problem is becoming noticable with a small number of samplers after 12 months of weekly sampling.

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APPENDIX

Materials list

The following items are required to construct one soil solution sampler:-

Number	Description	Comment
1	Soilmoisture Equipment Corporation porous, ceramic, round bottom, neck-top cup. Cat. No. 653X1 - B2M2 (old Cat. No. 1910)	Available from D. A. Pitman Ltd., Jessamy Road, Weybridge, Surrey - British distributors for the Soilmoisture Equipment Corporation Santa Barbara, California.
18,33 or 66 cm	Rymway 40 mm (1½") diameter ABS waste pipe (Cat. No. W202/3)	Available in 3 m length from builders' merchants. Samples can of course be constructed in lengths to suit requirements. The figures given here provide samplers similar in length to three of those available commercially.
1	Rymway 40 mm (1½") diameter ABS coupling (Cat. No.W211)	
1	ESCO No. 29. Silicone rubber bung (stopper), Top diam. 1¼ , Bottom diam. 1½" length 1¼ ".	Available from ESCO (Rubber) Ltd., 43-45, Broad Street, Teddington, Middlesex, TW11 8QZ.
30, 45 or 80 cm	Perspex (extruded acrylic) tube, 3 mm bore x 1 mm wall	Available from Azlon suppliers e.g. Scientific Supplied Co. Ltd., Scientific House, Vine Hill, London. EC1R 5EB.

Description	Comment
PVC tubing, i. d. 3 mm, wall 0.75 mm	Available from Gallenkamp Ltd., (see above).
Tubing connectors	Available from Jencons (see above).
Hand pump	Available from Pitmans (see above) Cat. No. 1900 K1 (Described as "Service Kit" in lists).