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Extraction of soil solution with ecoTech suction plates

Manual

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Contents

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Extraction of soil solution with ecoTech suction plates

1 Introduction

Suction plates are used for the extraction of soil solution and thus to study solute concentrations and solute fluxes in soils. They allow sampling of soil solution at the same site as often as required. Thus, the suction plate method is basically different from the destructive removal and extraction of soil samples.

One important reason for the application of suction plates is their area-related sampling of soil water. The probability of gathering preferential fluxes and taking them into account therefore is higher than with the use of suction cups. A special version of suction plates is No. 4321V which was especially developed to sample laterally flowing soil water (Interflow; see below).

1.1 Construction of ecoTech suction plates

1.1.1 Construction of plastic suction plates

ecoTech plastic suction plates are available in two different executions. Execution 4321H was developed for horizontal installation and the extraction of mainly vertical flowing soil water. It is applicable as single plate as well as together with other ones since each plate has got a tongue and groove system wherewith the plates can be connected with each other building a suction surface of any size (see Fig. 1, next page).

Execution 4321V is a special issue for vertical installation and the extraction of lateral flowing soil water (Interflow). It was constructed with tongue and groove system as well as 4321H and therefore can be put together to great surfaces. To sample lateral flowing soil water (interflow) in a slope extraction barriers consisting of several suction plates 4321V can be applied (see Fig. 4, P. 10).

[1]) legally registered design

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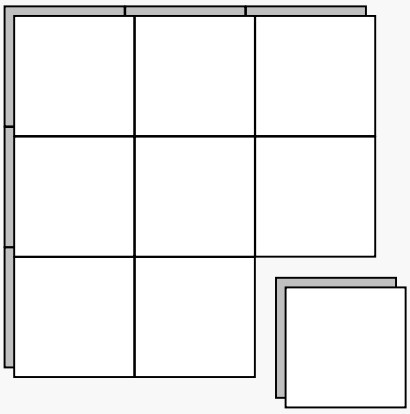
Both types of suction plates (4321H and 4321V) are constructed as a multilayer system. A porous plate is embedded into a solid block with a drainage system for the sampled water. This porous plate is the base which supports the membrane covering the porous plate. The membrane is made of polyamide and is covered against damages by a 3 mm thick protection plate made of coarse PE.

The mean filter element of the suction plate is the already mentioned filter membrane made of polyamide with a pore size of 0,45 µm. Advantages of this membrane are its high bubble point of about 2 bars, an extremely high hydraulical conductivity and very low adsorption capacity. It therefore allows studies of preferential migrating anorganic solutes like heavy metals or phosphate with very little adsorption losses. The high bubble point of the membrane allows to work with free selectable vacuum values

The edges of each suction plate have got boreholes for plug-in connectors which affix the protection plate on their top. They connect several plates to a large coherent sampling system as well. Two of them are sticked together and can be unfixed by turning them against each other with a screwdriver.

Suction plate; single element with tongue and groove system for the arrangement of large extraction areas, e.g. in lysimeters



Soil water extracting area consisting of 9 suction plates which can be driven and sampled separately

Fig. 1: Plastic suction plates (single element and compound system)

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1.1.2 Construction of glass suction plates

This kind of suction plate was designed by Dr. Jan Siemens, Section Soil Science at the Technical University of Berlin and was optimized in cooperation with ecoTech in 2003. It consists of a multilayer borosilicate glass plate that is melted into a glass basin. This construction increases the rigidness as well as the water uptake of the plate, because water can flow through the whole sampling area at the same time.

Fig. 2: Glass suction plate

The sampling tube (teflone or stainless steel) is fixed to the plate without any adhesives, because sealings and glues can release DOC to the sampled soil water (Siemens & Kaupenjohann 2003; literature see at the end of this manual). Thus, exclusively application of glass, stainless steel, and teflone prohibits any adsorption of the observed solute as well as any contamination of the sample by organic compounds of adhesives. Glass suction plates are available with a diameter of 80 and 100 mm and therefore allow soil water sampling over an area of ca. 50 and ca. 75 cm².

1.2 Which plate for what purpose?

A very important point when using suction plates is the choice of the suction plate material. In contact with different suction plate materials many solutes in soils show similar specific sorption properties as with soil substances like humus or clay minerals. Depending on the investigated substance the material for suction plates should therefore be chosen carefully. Table 1 (P. 6) represents an overview and assigns the different solutes to the recommended suction plate material.

These recommendations result of many papers of scientific literature and of a laboratory study conducted by ecoTech and the Institute for Soil Science of the University of Bonn (literature see at the end of this manual). Special conditions (extreme pH-values or high concentrations of other solutes like DOC) may lead to another weighting than listed in table 1, but for a bigger

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part of studies these assessments should be valid.

Table 1: Suitability of suction plate materials for the examination of different solutes in soils

Solutes	Ceramic	Glass	Plastics
Pesticides, DOC	-	++	-
Phosphate	--	++	++
Nitrate, chloride, bromide, sulfate, sodium	++	++	++
Heavy metals	--	-	++

In contrast to suction cups the choice suction plate material does not only depend on its sorption behaviour but also on the realizable geometry. Since plastic suction plates can be manufactured in almost any kind of geometry, they offer a broad range of different executions which cannot be realized with ceramcis or glass.

2 Preparations and installation

2.1 Cleaning

Before installation into the soil new suction plates should be cleaned to remove contaminants due to manufacturing processes. For this procedure you need 2 basins, 0,1 molar HCl (hydrochloric acid), deionised water, a vacuum stable flask (e.g. a sampling bottle) and a vacuum pump. Each suction plate is plunged into the diluted acid, and an amount of about 2 L should be sucked into the bottle. Afterwards the suction plate should be dipped into deionised water and percolated with at least 2 L water to remove the acid. Please note the following two chapters when cleaning suction plates made of plastics and glass.

2.1.1 Cleaning of plastic suction plates

The polyamide membrane of plastic suction plates is not completely acid proof, and therefore the acid solution has to be removed after the cleaning procedure immediately. After leaching the suction plates with hydrochloric acid (as described in 2.1) they have to be washed with several litres of deionised water or plunged into a water bath until the washing procedure can be conducted. Apart from that go on as described above.

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During this procedure please take care for a horizontal placement of each plate to avoid acid/solution remaining inside of the drainage system of the suction plate.

2.1.2 Cleaning of glass suction plates

Glass suction plates are often used for the investigation of organic compounds in the soil solution. We therefore recommend – apart from the leaching procedure with HCl – an additional cleaning with 0,1 molar sodium hydroxide solution. Between these steps of the cleaning procedure we recommend to leach it with deionised water.

2.2 Installation

2.2.1 Preparation of plastic suction plates

The basic filter element of plastic suction plates is a membrane filter made of polyamide which is fixed to a supporting base. The membrane is sensitive to mechanical damage and therefore has to be protected to avoid damages during the installation procedure. Thus, the membrane is covered by a protection shell with extremely great pores.

The pores in the protection shell of plastic suction plates have to be filled with slurry during or before starting the installation procedure (at least if you are going to install the suction plates horizontally). In the following the different steps are described; please take these tools with you into the field:

- 1 stirring tool to make a suspension of water and soil (cordless drill driver with a tool for stirring wall paint)
- 1 basin ca. 50 x 50 cm
- 1 bucket
- 1 can with water
- 1 sampling bottle
- 1 vacuum pump

Please go on as follows:

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1. Make a fluid slurry out of water and your soil material and pour it into the basin.
2. Connect the suction plate with the sampling bottle and the vacuum pump.
3. Dig the suction plate into the slurry.
4. The suspension is sucked into the protection shell and thus the pores in the protection plate are filled with soil material.
5. Go on with this procedure until all pores of the protection plate are filled with soil. This will last about several minutes at least. The performance can be controlled visually by wiping of the soil material on the protection plate.

During this filling procedure the slurry suspension is filtered, the pores of the protection plate are filled with solid soil material and thus a connection between the soil matric and the membrane is build up. If the pores are filled sufficiently, please go on with installation like described below.

Suggestion for soils with high amounts of coarse sand or clay: In soils with a high amount of coarse sand filling of the pores of the protection plate might be difficult and incomplete (pore size of the protection shell is about 0,5 mm, texture of the sand fraction up to 2 mm); in soils with a high amount of clay the hydraulic conductivity may be reduced significantly by blocking the membrane holes through clay particles. In both cases the addition of quartz flour to the original soil/water suspension may improve the hydraulic connection from the suction plate to the soil

2.2.2 Installation from the soil surface

Installation from the soil surface is recommended if great plates or plate systems are going to be installed. This kind of installation is much easier and has got the advantage that the contact between the suction plate and the soil can be recovered more easily than with the installation from a profile pit which requires more effort.

First, a pit has to be digged into the required depth. The bottom has to be levelled, and, if plastic suction cups are used, little trenches have to be made to put the tubes in. The plate can either be installed directly on the levelled ground or bolstered by a viscous slurry which allows an easier handling during the levelling procedure. Levelling has to be done very carefully because the slope inside of plastic suction plates has to be align to the deepest point to govern

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all sucked water directly to the suction tube (use of a spirit level is recommended). When installing glass suction plates with their laterally connected suction tube, the plate should be installed with a slight descent to get the water out and minimize the dead volume inside of the plate.

After levelling the suction plate the soil material is put back again carefully. The best contact between the plate and the re-filled soil will be realized with viscous slurry as the first small layer of about 1 cm thickness. The remaining soil material is put back layer for layer very carefully. It should be compressed slightly to get almost the density the soil had originally. Attention: Avoid a high compaction while this procedure because it will lower the hydraulic conductivity of the soil material and affect your results. **Since glass suction plates are fragile this procedure has to be done very carefully!** After installation the plate is ready for operation.

Fig. 3: Installation of an single plastic suction plate from the soil surface in a forest soil

Gathering interflow

For the installation of plastic suction plates (4321V) to gather interflow a small trench has to be digged out first. The plates are put into the trench, preferably perpendicular to the hill slope, and the tubes layed laterally to the sampling bottles. If possible, several plates can be connected before installation and placed into the trench in the whole. A direct placement of the plates' bottom edge onto the impermeable layer would be ideal (see Fig. 4, next page).

When installing suction plates for gathering interflow please note that their protection plates have to be prepared with soil material like described in 2.2.1. If the plates fit to the soil profile like in Fig. 4, the cavity behind the plates has to be refilled with soil meaterial and compacted intensively to guarantee a good contact and to prevend losses of contact through setting

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processes. If noteworthy, this compaction behind the plates has to be repeated after a few days.

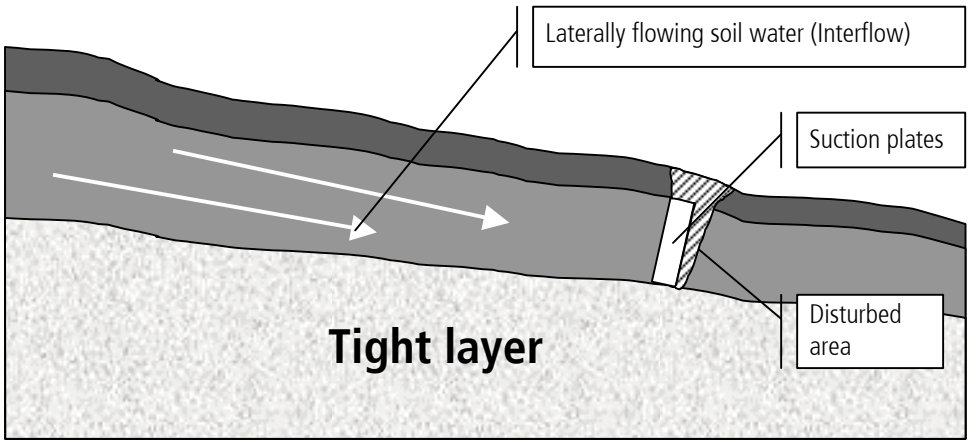
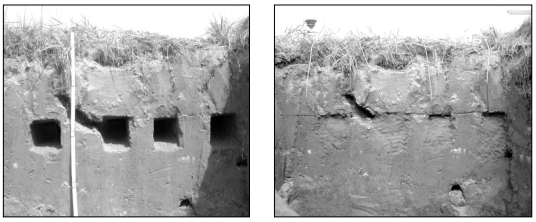


Fig. 4: Installation of plastic suction plates 4321V into a soil layer with lateral water flow (Interflow)

2.2.3 Installation from a profile pit

This kind of installation has got the advantage that the area above the plate has not been disturbed through the installation process (Fig. 5). Since glass suction plates are much smaller than standard plastic suction plates (4321), it is more easy to install them into tunnels digged into a profile wall. Nevertheless, single plastic plates can be installed in this manner, too (see Fig. 6, next page).

For this kind of installation a horizontal installation tunnel has to be digged as far as possible into the undisturbed soil. This tunnel must not be bigger as required and especially the top has to be prepared very carefully. For



Profile wall with open tunnels (left) and after installation of four glass suction plates (right)

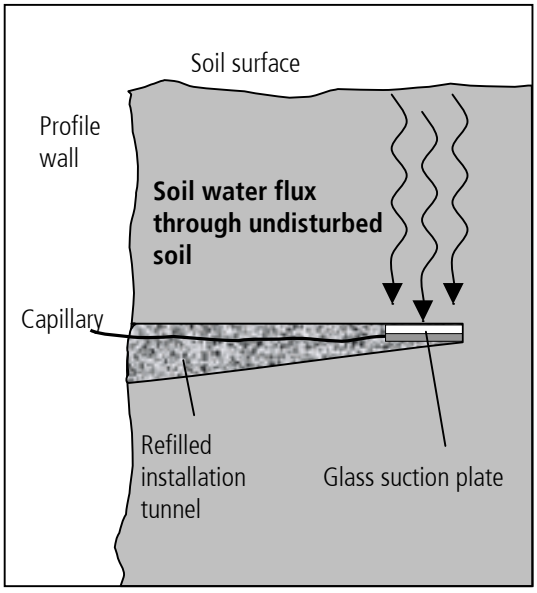


Fig. 5: Installation of a glass suction plate from a profile pit

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glass plates this can be realized best with a normal spatula. In soft soils the last step to get an ideal contact from the plate surface to the ceiling of the tunnel, it can be abraised with the edge of the glass plate **cautiously**. Afterwards a layer of viscous soil slurry is put onto the suction plate direcly before installation. After putting the slurry onto the plate it has to be pressed against the tunnel ceiling immediately. The cavity beneath the plate has to be refilled after installation and compacted intensively to guarantee a good contact and to prevent losses of contact through setting processes. **Attention: Glass plates are fragile!**

Fig. 6: Installation of an single plastic suction plate from a profile pit

After installation

We recommend to take the suction plates into operation immediately after installation. This will take most of the added water out of the system and thus will help to get back to normal soil conditions again. The installation procedure has brought amounts of water and oxygene into the soil, and the structure has been damaged around the suction plate. As a consequence, many chemical and biological processes take place which cannot be avoided but which affect the concentrations of many solutes considerable ("first flush effect"). So one has to wait after installation until the first data can be taken as representative. This period of time depends on the soil, the environmental conditions, the monitored solute etc., and cannot be determined in general. In any case, sampling of soil water should be started immediately after installation. These samples can either be casted away, or (even better) the solute concentrations should be measured to take the data of these first samples into account to get an impression when the concentration values go back to a normal level.

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3 Connection and sampling

3.1 Application of single suction plates

Please go on as follows: Take care that all connections are fixed properly and connect the end of the sampling tube with the sampling bottle (Fig. 3). Then connect the vacuum pump with the sampling bottle, remove the clamp on the soft silicone tube of the evacuation connector and apply the pump until the desired vacuum level is reached. Afterwards the clamp is put back onto the silicone tube, the pump is removed and water will be sucked into the sampling bottle.

3.2 Application of suction plate systems

When using a system of several suction plates on the same site we recommend to operate these suction plates together in one tube system. The connection in principle is the same as described above. The only difference is that the system is evacuated completely and not each sampling bottle with its own evacuation connector (Fig. 7).

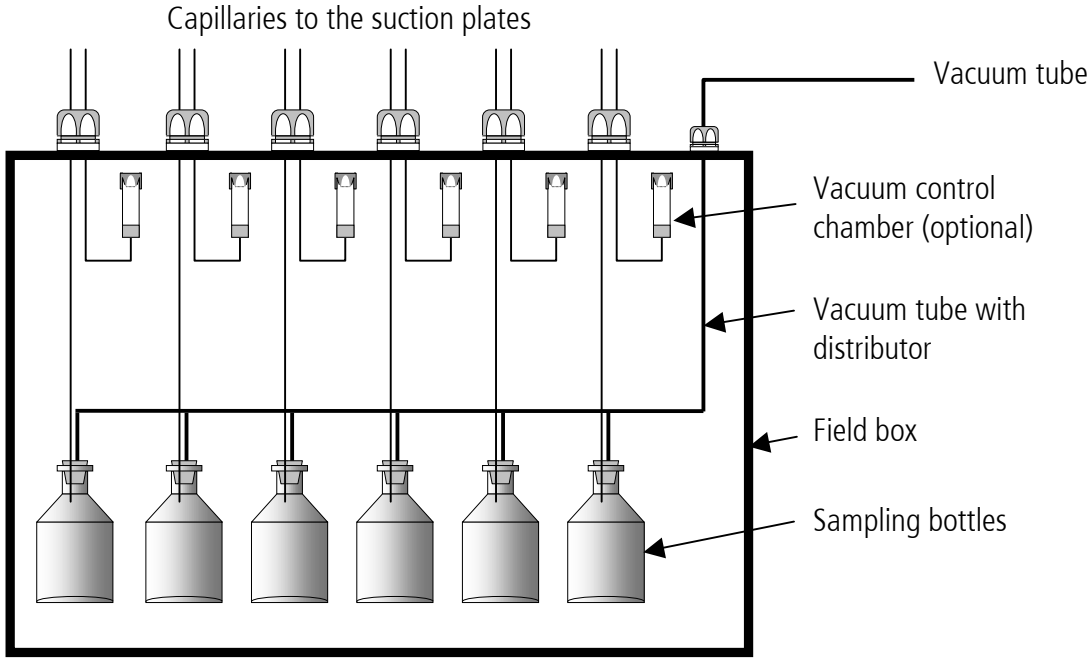

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Fig. 7: Vacuum system with 6 suction plates and 6 sampling bottles in a field box. Vacuum is applied through a common vacuum tube, which can be connected to a mechanical or an electronical vacuum pump

The tube system is evacuated as a whole. A mechanical or electronical vacuum controller can be employed to apply a controlled vacuum with individual settings.

We recommend the following three types of sampling bottles:

- Brown glass bottles for the investigation of organic compounds (protection against photochemical reactions)
- Special plastic (polypropylene) bottles with high wall thickness for the investigation of heavy metals and other solutes which may adsorb to the walls of glass bottles
- White glass bottles for all solutes which are neither expected to adsorb to bottle surfaces nor are subjected to photochemical reactions (NO_3, Cl etc.)

Our glass bottles are closed with a silicone plug which has got an evacuation connector. The plug with connector can be taken off the bottle and put on again very easily. In comparison to bottles with a screw top the sampling procedure (pouring the samples out of the bottles) is much easier and therefore faster. The silicone plug has got a second borehole to insert the sampling tube of the suction plate. When connecting the sampling tube to the plug, both parts should be moistened to push the end of the tube at least 1 cm through the plug hole into the bottle. This prevents any contact of solutes with the silicone plug.

Attention: Do not handle glass bottles under vacuum! Danger of implosion! Ventilate all bottles before removing the water samples! Replace damaged bottles immediately (scratches, cracks etc.)

!

ecoTech sampling bottles made of plastic have got a stable screw cap with two screw connectors. One of these connectors is equipped with a evacuation tube, the other one is to fix the sampling tube of the suction plate and has to be tightened with a jaw spanner.

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4 Possible sources of error and correction

If the suction plate is installed properly and the soil moisture is sufficient to keep the pores of the suction plate filled with water (i.e. air tight), the applied vacuum value will go down very slowly and the suction plate will work for several days or at least several hours, depending on the moisture conditions of the soil. Especially under dry conditions the hydraulic conductivity can be reduced very much, and the flow velocity of soil water is very small. Thus, it may last days or even weeks until an sample volume of e.g. 150 ml has been collected, and the vacuum value has to decrease very slowly. Nevertheless you should note that the applied underpressure has to decrease when water is collected into the sampling system, even without any leaks. The more water is sucked, the more the vacuum value will decrease. This loss of underpressure is proportional to the infiltrating water volume and depends on the water content (or matric potential) and the hydraulic conductivity. After a few days the vacuum value should be appreciable when there hasn't been a high amount of soil solution collected already. Otherwise you have to control your system as described below (all fault descriptions are related to one suction plate with a sampling bottle of 1 L volume):

a) Vacuum level is constant, but no soil water is collected

Possible source of error	Relief
The applied vacuum is lower than the soil matric potential. The capillary forces in soil are stronger as the forces generated by the vacuum in the sampling system.	Raise the vacuum level up to a value above the actual matric potential. For comparison purposes a simple tensiometer can be used.
The capillary between the suction plate and the sampling bottle or the hole in the flask stopper is blocked.	Clean the capillaries.

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b) Vacuum level is falling down immediately or cannot be established at all

Possible source of error	Relief
Capillaries are not connected properly and/or the closing device of the sampling bottle is not tight	Control all tube connectors (shaft, bottle, and pump) Fasten the closing device Check the clamps on the silicone tubes When capillaries were extended subsequent, the junctions have to be controlled
The vacuum gauge is not connected properly; wrong handling of the vacuum gauge may lead to pressure losses	Fasten the syringe on the vacuum gauge Change the syringe
The valve in the vacuum pump has become leaky and air is sucked back into the bottle	Clean the valve (compressed air) or replace it

c) Vacuum decreases over several hours, but no soil water is collected

Possible source of error	Relief
Soil has run dry, suction plate is sucking air	When single suction plates are used, vacuum can be established only when the soil has been wetted again. In systems with suction plates in different soil depths or levels (with different matric potentials) the cutoff of the dry level is recommended. Thus, it is still possible to get water out of the other levels.

If questions remain, please contact us directly:

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5 Literature (choice concerning suction cups/plates and the adsorption of solutes)

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