

User Manual



SK20

Pore water sampler (suction cup)

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1 SK20

1.1 Safety instructions and warnings

Please pay attention to the following possible causes of risk:

- ⚠ Caution! Use only implosion-proof sampling bottles. Danger of injury!
- ⚠ The ceramic cup is fragile. Excessive load, bending or force can lead to the break.
- ⚠ Never touch the ceramic cup. Grease, oil or sweat will disturb the quality.

1.2 Content of delivery

The delivery of a SK20 includes:

- SK20 pore water sampler with suction tube (standard tube length 5 m) inside reinforced protection tube

1.3 Foreword

Measuring systems must be reliable and durable and should require a minimum of maintenance to achieve target-oriented results and keep the servicing low. Moreover, the success of any technical system is directly depending on a correct operation.

At the beginning of a measuring task or research project the target, all effective values and the surrounding conditions must be defined. This leads to the demands for the scientific and technical project management which describes all quality related processes and decides on the used methods, the technical and measurement tools, the verification of the results and the modelling.

The continuously optimized correlation of all segments and it's quality assurance are finally decisive for the success of a project.

So please do not hesitate to contact us for further support and information. We wish you good success with your projects.

Yours,

Georg von Unold

1.4 Intended Use

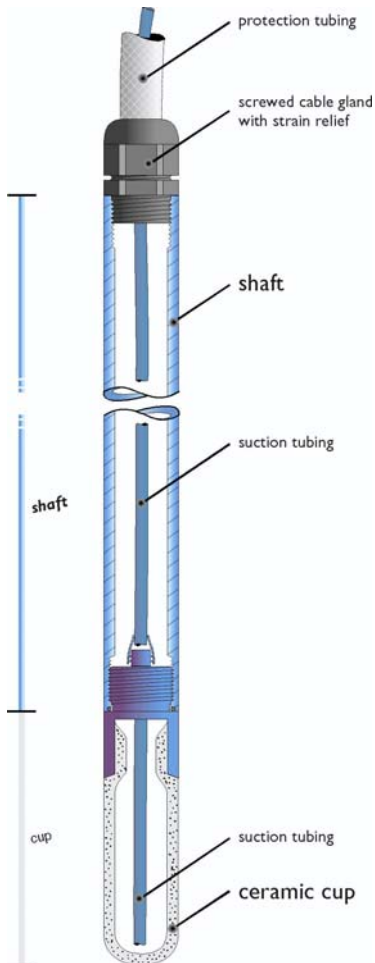
Pore water samplers are designed to extract soil water from saturated and non saturated soils. To extract a soil water solution, a negative pressure has to be applied. The cups are made of a special ceramic with constant and defined pore distribution with small chemical activity and adsorption.

1.5 Guarantee

UMS gives a guarantee of 12 months against defects in manufacture or materials used. The guarantee does not cover damage through misuse or inexpert servicing or circumstances beyond our control. The guarantee includes substitution or repair and package but excludes shipping expenses. Please contact UMS or our representative before returning equipment. Place of fulfilment is Munich, Gmunder Str. 37!

2 Description of the sampler

2.1 Construction



2.2 The ceramic cup

The cup consists of 70% porous Al_2O_3 and about 30% SiO_2 sinter material. The special manufacturing process guarantees homogeneous porosity with good water conductivity and very high firmness. Compared to conventional porous ceramic the cup is much more durable.

The bubble point is higher than 2 bar.

The cup has been tested by the Technical University Munich, Center of Life and Food Sciences Weihenstephan, department forest nutrition and water balance. The applied test procedure has been proposed to the DIN-NORM committee NAW12/UA5/AK4 for implementation as a DIN standard.

Suitability as been approved for:

✓ Nitrate ✓ Chloride ✓ Sulphate ✓ Calcium
✓ Sodium ✓ Magnesium ✓ DOC

It is not suitable for:

✗ Heavy metals and Aluminium
(see chapter “Scientific background”)

♥ Before first use treat the cup as described in chapter “Rinsing”.

2.3 Acrylic glass shaft

With the shaft it is possible to install the sampler in the required depth. The shaft consists of an extremely resistant Acrylic material with highest durability against bending, scratches, breakage.

2.4 Suction tube

The suction tube is made of polyethylene, outer diameter is 2.8 mm and the inner diameter 1.6 mm. Normally the suction tube is connected to a sampling bottle with vacuum.

2.5 Protection tube

The reinforced protection tube prevents that the suction tube is bended or damaged by rodent bite.

3 Soil water extraction

3.1 Extraction methods

To extract soil water in the unsaturated zone the soil water tension (retention force) has to be surpassed by the sampler's potential - a vacuum needs to be applied.

The vacuum should be as close as possible to the in-situ soil water tension, as i.e. carbon will fall out in high vacuum.

Variations of the pressure difference between the sampler's inside and outside will lead to different filtration results - thus, memory effects occur. This is prevented by a tension controlled vacuum unit.

Please note that water can only be extracted if water is available.

The bigger the soil pores are, the less water is available at rising tensions!

Sampling is possible in stony soils up to pF 1, in sandy soils up to pF 2, and in clay soils up to pF 2.7.

Suction cups always act as chemical and physical filter. High vacuum applied at soils close to saturation cause transport of small particles into the sampler's pores. There is nearly no chance to reverse this process even by applying pressure, as around the cup an area of small particles will get accumulated.

The effective active suction force is the difference of soil water tension and applied vacuum.

UMS offers three different vacuum methods - the most suitable will depend on your task.

3.1.1 The simple method

Discontinuous evacuation is the simplest method. Evacuate your sampling bottle down to approx. 50 kPa. If the soil water tension is lower than 50 kPa, soil water solution will be extracted until vacuum and soil water tension are equalized. When the samples are collected, the bottle is evacuated again.

Applications

- For qualitative analysis of soil water

Benefits

- Low cost
- Easy handling

Limits

- Discontinuous sampling
- Undefined sampling

Tools

- Pore water samplers
- Hand-operated vacuum floor pump VPS-1 or portable vacuum case VacuPorter

3.1.2 The constant vacuum method

A constant vacuum is continuously maintained by a regulated vacuum pump. The vacuum can be set between atmospheric pressure and 85 kPa.

Leachate samplers for example are supplied with approx. 6 kPa, while pore water samplers in silt and loam are supplied with 10 to 30 kPa. As clay soils retain water even at higher tensions a vacuum from 30 to 85 kPa could be applicable.

Applications

- Long term monitoring projects
- Studies on leachate
- Soil water extraction from a certain pore size with a vacuum which is exactly suitable to the pore size.

Benefits

- Defined sampling

Limits

- Constant vacuum ignores changing soil water tensions

Tools

- Pore water or leachate samplers
- Vacuum station VS without controlling Tensiometer

3.1.3 Tension controlled extraction

A Tensiometer measures the soil water tension. The programmable vacuum station VS automatically supplies a vacuum in correspondence to the measured tension. Due to the numerous

functions of the unit an optimal adaptation to the sampling task is possible.

Benefits

- Constant sorption and constant filter effects
- Prevents memory effects

Limits

- Takes samples from various pore sizes depending on the current vacuum

Tools

- Pore water or leachate samplers
- Vacuum station VS with controlling Tensiometer

3.2 Experiences and recommendations

3.2.1 Sandy soils

When sampling in coarsely to medium grained sandy soils it can be a problem that, in the unsaturated range, the water content often is too low to extract a sufficient amount of solution.

In sandy soils the method with constant vacuum should be applied as drainage water occurrences are only short. Drainage water will rush through quickly and either no solution is won, or only some solution is extracted by chance.

In contrary, if there are only sand fractions up to 50% the sampled amount can be quite high [Riess 1993].

3.2.2 Vacuum ranges

If the applied vacuum is too high the soil around the cup is drained, and with unfilled soil pores the conductivity drops considerably. The effect depends on the soil type and is the most significant in sandy soils.

Therefore, the vacuum should only be as low as necessary. In general it is sufficient to apply a vacuum which is 20 kPa lower than the soil water tension (see chapter "Extraction methods").

With the discontinuous method (consecutive vacuum - no vacuum - cycles) the natural water movement is disturbed. Especially in sandy

soils it can happen that the capillary contact ruptures with a decreasing vacuum.

3.2.3 Pore clogging

Over an extended period of time the ceramic pores might get clogged by fine particles. To flush the ceramic while installed normally is just a temporarily solution as the fine material is only flushed into the area right around the ceramic.

Therefore, clogging should be prevented right from the beginning by keeping the flow-through low and constant, for example with Tensiometer controlled vacuum and with a vacuum just a low as necessary [Riess 1993].

3.2.4 Achievable sample amounts

You can expect the following sample amounts:

- Maximum: in free water and with a vacuum of 50 kPa approximately 5 ml per 10 minutes.
- Minimum: in sandy loam soil with 50 kPa approximately 5 ml per hour.

In high-flow ceramics the flow rate is max. three times as high.

3.3 Further notes

Interfering sorption effects get smaller over a longer period.

In case sampled solution should be stored with protective gas.

As suction cups have a small catchment area heterogeneous soils cause some difficulties. Depending on the hydraulic contact to primary or secondary pores (cracks, macro pores) diverse water is sampled.

As samples can only be extracted from moist soil no sampling is possible in hot and dry seasons.

Mouse holes can cause some troubles as soil water quickly flows into deeper layers where it might accumulate [Riess 1993].

Please observe the following:

- ❗ Long tubes and bubbles in tubes cause a certain resistance. This has to be considered when planning your suction tube system.
- ❗ To avoid incorrect regulation the vacuum should be measured close to the pump and not next to the suction cup.
- ❗ Pump and vacuum units have to be protected from water intrusion by sufficient measures (overflow protection, adequate volume, water sensors on vacuum ports).
- ❗ All parts of a vacuum system have to be implosion proof.
- ❗ Suction cups should not be installed too close to Tensiometers. Provide sufficient space between samplers, Tensiometers and soil moisture probes.
- ❗ If suction cups and sampling bottle are installed at different levels you must consider the potential difference when selecting your vacuum. Please read chapter "Level difference".

4 Vacuum systems

4.1 Sampling bottles

4.1.1 Sampling bottle cap

The sampling bottle normally picks up the suction tube of a sampler and a vacuum tube to evacuate the bottle.

The cap of the sampling bottle has 3 tube nozzles.

The left (blue) tube as seen on the photo is the vacuum tube.

The right tube is the suction tube of the sampler. Insert this tube far enough into the bottle so the silicone tube section will not get in contact with the sampled solution.



The third nozzle is not open but optionally can be used for connecting another suction tube or to conduct the vacuum to another sampling bottle. To do so, cut off the tip of the nozzle. Cut off the upmost section for a thin suction tube or the lower section for a thicker vacuum tube.

4.1.2 Suitable material

Glass is the best material for sampling, storage and transportation. If a vacuum is applied to a glass bottle it must be implosion proof. Glass bottles must have a plastic coating as an implosion protection. UMS supplied sampling bottles type SF are implosion proof.

Bottles made of polyethylene, polypropylene or polyamide normally are not suitable for applying a vacuum, but, depending on the substances, can be used for transportation or storage of the solution.

4.1.3 Volumes

UMS bottles are available with a volume of half litre (SF-500), 1 litre (SF-1000) or 2 litres (SF-2000).

Which size is the best depends on the application:

1. What sample amounts are expected during which interval?
2. Are several samplers connected to the bottle for getting a mixed sample?
3. With discontinuous sampling the sampling bottle is also the vacuum buffer. Note that the vacuum is already used up when the bottle is only partially filled with solution. Therefore, the sampling bottle should have 3 times of the volume you want to sample at least with the discontinuous sampling method.

With the overflow protector SF-protect you can also adjust or limit the volume to be sampled. For example, if you want to sample an amount of 100 ml push the vacuum tube deeper into the sampling bottle so the protector is positioned at the appropriate level.



4.1.4 Overflow protector

An optional overflow protector which is inserted into the sampling bottle is available for usage in automatic vacuum systems (see left photo).

The valve consists of a capillary membrane which is permeable to air when dry, but tight if it gets wet. The overflow protector prevents that soil water solution is drawn out of the sampling bottle and into the vacuum unit. As soon as the sampling bottle is full the protector closes. Thus, this bottle is cut off from the vacuum system while the other bottles still continue to work.

Simply attach the SF-protect to the end of the vacuum tube. The protector opens up again as soon as the sampling bottle is emptied. If the overflow protection valve SF-protect is used the flow resistance is higher. Therefore, an additional buffer bottle (2 liter) should be inserted before the vacuum unit.

Note that then the vacuum system has to have a main line, and each sampling bottle is connected to the main line with T-fittings (see right photo).



The purpose of the overflow protection is to prevent damages to the vacuum unit and to avoid that solution from one bottle contaminates other bottles in case of unexpected incidents. It is not intended as an automatic stop switch, mainly because the membrane has to completely dry off before it again is permeable to vacuum.

Therefore, the size of the sampling bottles and the collection interval should ensure that no overflow occurs at all.

A further buffer bottle still is recommendable.

4.2 Solution storage

The soil water samples should be stored dark and at soil temperature. Therefore, the sampling bottles can be placed in a buried box, so the storage temperature is identical to the soil temperature, and the samples are protected against sunlight.

- ♥ The sampled solution should be stored dark and at soil temperature to prevent algae growth, for example inside a buried box.

4.3 Vacuum buffer bottle

It is recommendable to insert an additional vacuum bottle between the sampling bottles and the vacuum port of the pump. Insert it as

close to the vacuum port as possible. This will work as an additional overflow protection (if no SF-protect valve is used - see above) as well as a compensating reservoir to stabilize the vacuum.

UMS vacuum units VS to VS-pro (not the VacuPorter) have a water intrusion detector which will shut off the pump when water enters the vacuum port. Note that the unit remains shut down until the detector has completely dried out again.

4.4 Suction tubes

4.4.1 Tube material

Suitable material for the suction tube (also check the suitability list in the appendix):

- Polyethylene, polypropylene or polyamide: for anions and cations.
- Stainless-steel capillary tubes: for all substances but not for metals and heavy metals.

UMS samplers are designed that the sampled solution will not have contact to any material other than the cup material and the suction tube material if connected properly.

4.4.2 Suction tube dimension

In general suction tubes should be as short as possible for the following reasons:

- Little dead volume and real-time sampling.
- Low reflow with rising water tension as the solution left inside the tube is always drawn back into the soil.
- Least possible flow resistance.

Air bubbles inside the tube create a high flow resistance which will be highest in thin and long tubes. In a 20 meter long tube with an inner diameter of 1.6 mm the flow resistance in worst case can be up to 50 kPa.

Please refer to chapter „Installation“ for instructions how to install the suction tubes.

4.5 Vacuum tubes

Observe the following points about the vacuum tube:

- Keep vacuum tubes as short as possible. With longer tubes the risk of leakage, damage or rodent bite rises.
- The distance between the pump/vacuum unit can be up to 200 meters. In a tight system the pumped volume will be low and pressure drop is neglectable.
- Recommendable inner diameter for a vacuum tube is 4 to 10 mm. Select the inner diameter depending on the tube lengths, number of samplers and the sampling method.

⚠ You must ensure that the complete system is tight.

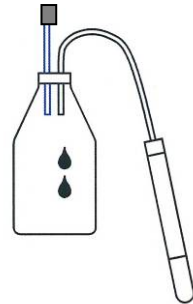
4.6 Possible setups

As described in chapter „Extraction methods“ there are three possible sampling methods. Following some suggestions how to assemble a system depending on the sampling method.

4.6.1 Setup for discontinuous sampling

A soil water sampler is connected to a sampling bottle. The sampling bottle is evacuated, for example with the vacuum floor pump VPS-2 or the VacuPorter. Solution is extracted from the soil until the decreasing vacuum drops below the soil water tension.

Note: the sample amount can be max. 2/3 of the bottle volume.



4.6.2 Setup for constant vacuum method

Each soil water sampler is connected to a sampling bottle. With a vacuum tube network several sampling bottles are connected to a vacuum controlling unit like the VS units. The vacuum units are set to the desired vacuum and keep up a constant vacuum by controlling and re-establishing the vacuum.

Note the following when connecting sampling bottles:

Several sampling bottles can be connected in a row by using the third tube connection on the sampling bottle cap (upper scheme on the next page), or by using T-fittings (lower scheme).

If a sampling bottle is equipped with an overflow protection valve (see chapter above) you must use T-fittings as a blocked valve would block the whole system.

In systems with automatic vacuum units sufficient measures should be applied to avoid that the pump draws up water or the system gets blocked by overflowing bottles.

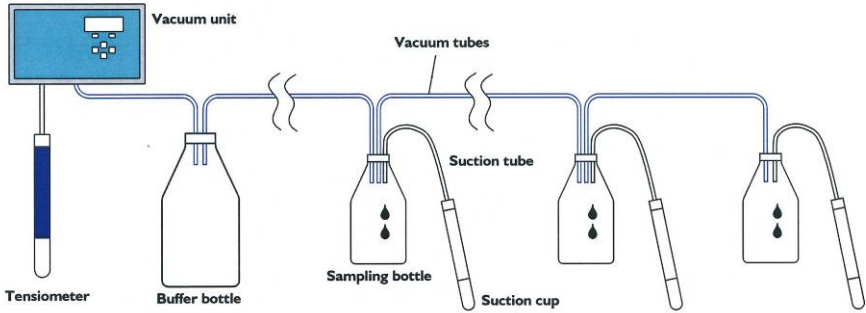


Fig: Sampling bottles connected in row using 3rd nozzle on the cap

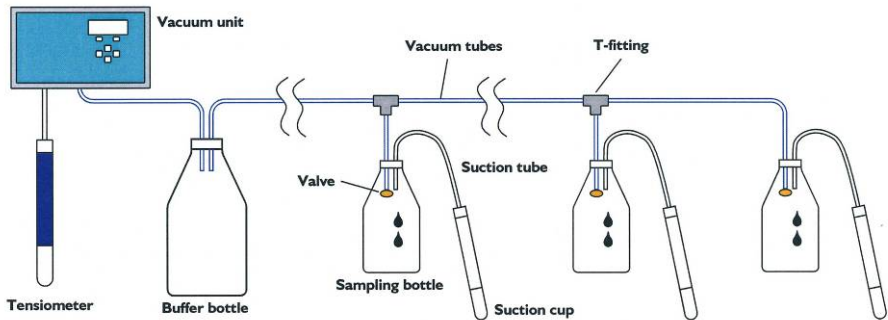


Fig: Sampling bottles connected to main vacuum line with T-fittings, Tensiometer and overflow valves are optional

4.6.3 Setup for Tensiometer controlled vacuum

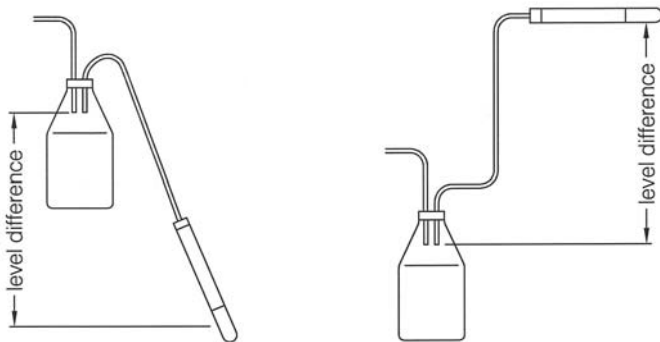
Samplers, sampling bottles and vacuum tubes are connected the same way as with the constant vacuum method (see figures above). A controlling Tensiometer is connected to the VS unit and the vacuum is regulated in dependence of the current soil water tension.

4.7 Level differences

It is recommendable to place the sampling bottle at the same height as the suction cup. Consider the following if this is not the case.

If a sampling bottle is placed in a higher level than the suction cup (left figure) the level difference causes a pulling water column which reduces the effective vacuum on the sampler. If for example the suction cup is 1 meter beneath the level of the bottle the vacuum at the sampler is approximately 10 kPa lower than the vacuum inside the bottle.

- ⚠ To compensate the level difference when the sampling bottle is higher than the suction cup add 1 kPa to the vacuum for each 10 cm of level difference (or exactly 0.98 kPa per 10 cm water column).



Accordingly, if the sampling bottle is lower than the suction cup, for example in a manhole (right figure), the effective vacuum on the sampler is higher than inside the bottle - if the tube is completely filled with water. In a normal situation there will be vapor and bubbles inside the tube. Therefore, you do not reduce the vacuum so solution is extracted even with bubbles inside the tube.

- ⚠ Do not compensate the level difference if the sampling bottle is lower than the suction cup.

4.8 Collection interval

It depends on the research task how often the extracted solution should be collected from the sampling bottles.

For long term monitoring studies an interval of 1 to 2 weeks might be applicable. If you want to specifically gain the peaks from intense rain incidents the collection time should be shorter.

If you want to know the chronological change of the sample amount you can place the sampling bottle on a scale and log the weight with a data logger, or insert a vacuum-tight tipping counter with logger before the sampling bottle.

4.9 Power management

A soil water extraction system which cannot be supplied by mains power requires either battery, solar or wind energy. It is necessary to establish a power management plan in consideration of amount and intervals of extraction, possible leakage and shut-down.

5 Installation and operation

5.1 Rinsing

Always rinse each ceramic cup or plate with 500 to 2000 ml de-ionised water, and then condition them with the adequate soil water solution.

If there is enough time before the first samples should be analyzed you can do without rinsing and then discard the samples from the first week, or at least 1000 ml.

It might be considerable to discard an amount of 500 to 2000 ml of your first won samples.

When charged with high amounts of acidity sintered ceramic materials corrode and release Aluminium. Therefore, we strictly oppose to rinse the ceramics with acid solution, although this is recommended in some literature.

- ⚠ We do not recommend to rinse the cup with hydrochloric acid as this might destruct the cup. This will breach the warranty!
- ⚠ Before installation it is recommendable to immerse ceramic cups in de-ionised water for some time, preferably over night, so the pores will be water saturated.

5.2 Installation

5.2.1 Auger

The ceramic cup has to have a good capillary contact to the soil matrix. Therefore, the ceramic cup should fit into the drilling as tight as possible. To achieve this, the auger tip should exactly have the same diameter as the cup.

The shaft itself should have a space of 1 to 2 mm for easy insertion, low disturbance and possibility to control the fitting of the cup.

UMS offers the special gouge auger **TB-20** with a tapered tip as an accessory. This auger has a diameter of 20 mm on the first 5 cm of the tip, and 22 mm on the further section.

5.2.2 Slurrying the cup

It is only recommendable to slurry the ceramic cup in a highly sandy or stony soil. Slurry the cup with a paste made of the soil taken from the bottom of the augered hole. Optionally you may use washed quartz sand (mesh size 1200).

Mix a viscous paste with water and fill it into the hole with a properly sized pipe. In horizontal installations blow the paste into the pipe.

Note that fine material might be washed out by heavy drainage water. Then, the cup might lose its capillary contact to the soil. In this case repeat the slurrying.

Also note that sandy soils drain quickly (see pF/wc curve for sandy soils). Therefore, soil solution can only be extracted with a suction cup at low soil water tension ($pF < 2$ or unbound water). Sandy soils drier than -10 kPa only have small volumetric content of water as large pores are already vented.

5.2.3 Jacket tubes

Specially in coarse sand or pebbly soils it might be necessary to install jacket tubes as a drilled hole collapses before the suction cup is inserted.

If the samplers are installed in jacket tubes ensure that condensed water or leachate is conducted away from the suction cup. In horizontal installation a decline of 3% towards the manhole is suitable.

Note that the jacket tubes should not be installed closer than 50 cm away from the suction cup.

If the jacket tubes are installed with percussion drilling machine the final 100 cm should not be rammed but manually drilled to prevent compaction of the soil.

Beside in compact sand also drilling rockets can be used.

5.2.4 Installation angle

The sampler should be installed in a way that the major flow path is not disturbed by the sampler's shaft.

If for example the flow path is vertical the shaft should be installed with an angle of at least 20° away from the vertical line.

5.2.5 Drilling

- Put a mark on the auger to drill to the proper depth.
- Take away the organic layer with a shovel to avoid that the auger pushes organic material into lower layers.
- Drill the hole.

- If required insert the slurry paste into the hole with a pipe. Immediately insert the sampler. In pebbly soils you only have 10 seconds until the slurry paste might drain away.

- ⚠ Do not use force when inserting the shaft. Do not use tools or a hammer.
- ⚠ The SK20 sampler has a black mark on the top end of the shaft. If the shaft is not installed vertically this mark should point upwards - then the opening of the suction tube inside the cup is at the lowest position of the cup.

- In case put pack the organic layer and tighten the soil to close the gap between the shaft and the augered hole.
- Push the supplied rubber surface water retaining disk over the shaft to prevent that surface water runs along the shaft. Optionally the top part of the hole can be sealed with swellable Bentonite pellets.

5.2.6 Lay the tubes

Tubes should be buried in a depth of at least 10 cm. If the system should work year round the suction tubes have to be installed in a frost free depth.

UMS supplied samplers have a reinforced protective tube which protects the suction tube. It is recommendable to insert tubes without a protective tube in proper plastic protection tubes.

5.3 Assembly and start-up

Insert each suction tube into a sampling bottle. In a discontinuous system attach your vacuum pump to each sampling bottle, create the required vacuum and then lock the bottle.

In an extended vacuum system connect all sampling bottles with vacuum tubes and with your vacuum unit. Start to evacuate the

system. Please refer to the manual of your vacuum unit for instructions.

A vacuum should assemble. If no vacuum is established, check your system for leaks.

- ⚠ With the first won solution the system is flushed. Discard the first samples.

5.4 Collecting sampled solution

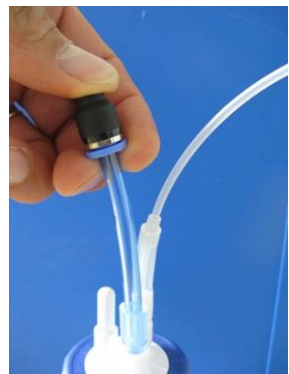
5.5 Collecting sampled solution

5.5.1 Discontinuous method

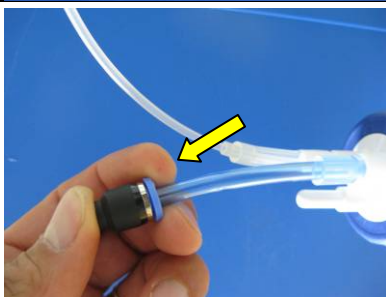
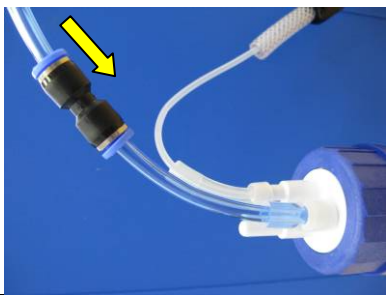


UMS sampling bottles are either plugged with a clamp or with a fitting as seen the photo.

Open the vacuum tube to vent the bottle. Screw off the cap and collect the sample, or replace the bottle with a clean one.

Put back the bottle cap and evacuate the bottle with your pump. Now bend the vacuum tube to seal it and remove your pump. Reattach the fitting or the clamp.



Procedure of the discontinuous method

<p>1. Take off the plug from the sampling bottle</p>		
<p>2. Connect the vacuum tube from the pump with the connector piece. Evacuate the bottle to the needed vacuum.</p>		
<p>3. Bend the blue tube on the sampling bottle to retain the vacuum when you take off the connector piece.</p>		
<p>4. Immediately put back the plug on the tube of the bottle. Now you can release the short tube.</p>		

5.5.2 Continuous method

In a system with continuous vacuum, switch off the vacuum unit. Then vent the system. Now collect all samples from the sampling bottles and reassemble the system.

In case check the Tensiometer readings and the sampled amounts and adjust the settings of your vacuum unit.

6 Service and maintenance

6.1 Empty suction cups before frost

If suction cups should remain installed during periods with temperatures below freezing point, they must be emptied to prevent frost damage. Please note, that in times free of snow but with air temperatures below 0°C, the area of frost declines from the soil surface into deeper soil horizons.

Required tools for emptying: One retaining tube clamp for each suction cup, a syringe (50 ml) and a vacuum pump.

How to proceed:

- With the vacuum pump, completely extract the water left in the suction cup.
- Attach the syringe to the extraction tube. Press 20 ml of air into the cup to achieve a positive pressure of approx. 100 hPa.
- Lock the extraction tube with a tube clamp to keep up the overpressure.

⚠ As soon as water inside the extraction tube is frozen, the suction cup cannot be emptied anymore. The ceramic cup might be damaged by the frozen water.

6.2 Cleaning and storage

For cleaning, wipe of the shaft with a moist cloth. The suction cups should be stored in a position where a deformation of the shaft is avoided.

⚠ Do not touch the ceramic with your fingers.

7 Protecting the measuring site

7.1 Theft and vandalism

The site should be protected against theft and vandalism as well as against any farming or field work. Therefore, the site should be fenced and signposts could give information about the purpose of the site.

7.2 Cable and tube protection

Cables and tubes should be protected against rodents with plastic protection tubes. UMS offers dividable protection tubes as accessory. For long term studies we recommend to dig cables and tubes a few centimetres below soil surface inside protection tubes.

7.3 Frost

For all-season operation install suction tubes in a frost-free depth and the sampling bottles in an insulated and buried box.

8 Troubleshooting

If no or only a little amount of water is extracted over a longer period of time please check the following:

- If you have an automatic regulation, for example with the VS vacuum station, and the pump repeatedly switches on the reason could be a leak in the system. Check all tubes and connections for tightness.
- Sampling cups have a very small sphere of influence. Depending on their hydraulic contact the sampler either extracts water from the primary pores or, specially in heterogeneous soils, the secondary pores (cracks, macro pores). Therefore, results can turn out variously in extremely heterogeneous soils.
- As water can only be extracted from a moist soil results can be poor during summer or in dry soils.
- Pathways caused by mouse holes or roots quickly conduct water into lower horizons where the water accumulates [Riess 1993].
- Fine particles can clog the ceramic pores over the time. To flush the ceramic while installed will only have a short-lived success as the particles are only moved into the surrounding soil. Clogging should be diminished from the beginning by keeping the flow rate as low and as constant as possible, for example by a tension controlled vacuum. The vacuum should only be as high as required. Test have shown that these measures reduce clogging [Riess 1993].

9 Scientific background

9.1 Supporting institutes

The recommendations in this manual were written in cooperation with the following institutes:

- Österreichischen Bundesamt für Wasserwirtschaft
Petzenkirchen, Österreichischen Arbeitsgruppe Lysimeter,
<http://www.lysimeter.at/>
- University of Hohenheim and Technical University Munich,
- Helmholtz Zentrum München, Deutsches Forschungszentrum für
Umwelt und Gesundheit,
- Bayerischen Landesanstalt für Wald und Forstwirtschaft
- Bayerischen Landesamt für Wasserwirtschaft.

These recommendations compile some basic information and experiences for the extraction of soil water. This cannot be exhaustive and cannot replace detailed consulting as the complete process, sampling conditions, soil type, extraction method and intervals, sample storage and last but not least the analysis have to be designed in accordance with the individual task.

Note:

The information for suitability of materials on the following page base on experienced data, laboratory analysis or (unevaluated) citation in literature. It was initially created in a UMS workshop about soil water sampling in the year 2000 and is elaborated since. The list is published in all conscience but makes no claim to be complete, and therefore cannot replace specific consulting. Please do not hesitate to contact us.

Furthermore, we would be grateful to learn about your experiences and recommendations.

9.2 Table of suitability

	Al ₂ O ₃ ceramic sintered material	Polyethylene/ Nylon	Silicon carbide	Borosilicate glass
UMS type:	SK20 SKPE25	SPE20	SIC20, SIC40 SIC300	SG25 SPG120
Suitable for determination of ...				
Anions:				
NO ₃ - Nitrate	+++	+++	+++	+++
SO ₄ ²⁻ Sulphate	+++	+++	+++	+++
PO ₄ ³⁻ Phosphate	+++	+++	+++	+++
Cl ⁻ Chloride	+++	+++	+++	+++
Cations:				
Ca ²⁺ Calcium	+ [1]	++ [1]	+++	+ [1]
K ⁺ Potassium	+ [1]	++ [1]	+++	++
Na ⁺ Sodium	++[1]	+ [1]	+++	
NH ₄ ⁺ Ammonium	+++	+++	+++	+++
Al ³⁺ Aluminium	---(critical [2])	++(critical with pH<2[1])		+++
Cu ²⁺ Copper	---[3] [5][8]	+++	+++	+++
Cr ²⁺ Chromium	--	+++	+++	+++
Fe ²⁺ Iron	- [2]	+++	+++	+++
Mg ²⁺ Magnesia	--	+++	+++	+++
Ni ²⁺ Nickel	--	+++	+++	+++
Elements				
S Sulphur	+ [1]	+ [1]	+++	+++
P Phosphorus	++ [2]	+++	+++	+++
Si Silicon	---	+++	-	+++
DOC	++ [8]	++[3]	++	+
TOC	++ [1]	+ [1]	++	+
Humins:				
Heavy metals:				
Cd Cadmium	--- [6]	+ [6]	-	-
Pb Lead	--- [5] [6]	+ [6]	-	-
Herbicides	+ (Atrazin) [3] [7][8]	+(Atrazin) [7]		/
Pesticides	/	/		/
Fungicides	/	/		/
PAK				
Trace elements	-	/		/

Literature source	Caption
[1] Göttlein, 1996	--- completely unsuitable
[2] Grossmann et al., 1987	-- unsuitable
[3] Klotz, Unold, 2000	- only for experts, requires good knowledge and suitable conditioning of the suction cups
[4] Riess, 1993	/ no experiences
[5] Guggenberger und Zech 1992	+ limited suitability
[6] Haberhauer 1997	++ suitable after conditioning and sufficient forerun for flushing
[7] Schroll 1996	+++ suitable after sufficient forerun for flushing
[8] Klotz, 1997	

9.3 UMS sampler types

9.3.1 Suction cups

SK20

SK20 simple ceramic cup with removable shaft. For continuous and discontinuous extraction. Suitable for determination of nitrate and common organic and inorganic substances.

SIC20

Pore water sampler SIC20 with removable shaft like the SK20, but with a SiC silicon carbide cup instead of the ceramic cup. SiC is sintered at 2500°C and is less absorbent/desorbent than ceramic or borosilicate. The bubble point 90 kPa. UMS SiC cups are patented.

SPE20

Instead of a ceramic cup the SPE20 pore water sampler has a porous PE-nylon-membrane which is specially suitable for heavy metals and whenever ceramics are inappropriate.

SKPE25

The sampled solution is stored inside the shaft and is collected by applying a pressure to the additional tube. With ceramic cup.

SG25

Pore water sampler with porous borosilicate glass cup. Borosilicate is suitable for phosphate and DOC. Available with a diameter of 20 mm or 25 mm

9.3.2 Suction plates

SIC300

Suction plate made of porous silicon carbide for laboratory use or field leachate sampling. The plate is backed with a butyl rubber foil and a bottom tube connector to apply a 6 kPa vacuum. Bubble point is 10 kPa.

SPG120

Leachate sampling plate made of porous borosilicate glass. Suitable for phosphate and DOC. With tube connector ending inside the plate's center. Utility patented.

9.3.3 Lysimeter KL2

The leachate bucket can be buried in situ to collect leachate - or can be used as a laboratory soil column and lysimeter. On the bottom of the polyethylene bucket a 0.5 bar high flow ceramic plate is fixed.

10 Appendix

10.1 Technical specifications

Technical Specifications SK20

Shaft	Acrylic, \varnothing 20 mm	
Extraction tube	Polyethylene, \varnothing inside 1.6 mm	
Protective tube	PVC, with reinforced fabric, \varnothing 11 x 5 mm	
Cup type	K100	
Cup size	Length 54 mm \pm 0,8, diameter 20 mm - 0.5	
Active surface	34 cm ² \pm 1	
Filling volume	8 ml \pm 1	
Cup porosity	45% \pm 2 %	
Pore size	1 μ m \pm 0.1 μ m	
Hardness (Mohs)	7 MH	
Flexural strength	60 N/mm ² \pm 0,5	
Compressive strength	240 N/mm ² \pm 10	
Coefficient of elongation	5.8 x 10 ⁻⁶ \pm 3	
Chemical Compound	Al ₂ O ₃	70 \pm 0,5 % by volume
	SiO ₂	29 \pm 0,5 % by volume
	R ₂ O	0,8 \pm 0,1 % by volume

10.2 Accessories

Description	Art. no.
Portable vacuum case without regulation, internal pump for max. vacuum -85 kPa (-0.85 bar) or pressure max. 3.5 bar, rechargeable battery 7 Ah, particle filter, gauges for vacuum and pressure, in watertight storm case 30x25x13 cm, 4.8 kg; supplied incl. recharger 230 VAC	VacuPorter
<u>Please order additionally:</u> Mains recharger 110 VAC ... 230 VAC, for VacuPorter, incl. set of international plug adapters	vp.110VAC
Hand-operated vacuum floor pump, volume 410 ml per stroke, achievable vacuum 0 -80 kPa, aluminum body, steel foot, height 57 cm, weight 2 kg, for evacuation of larger volumes	VPS-2



VacuPorter



VPS-2



Sampling bottle



SF-box

Sampling bottle 500 ml, implosion protected, with screw cap for up to 3 tubes	SF-500
Sampling bottle 1000 ml, implosion protected, with screw cap for up to 3 tubes	SF-1000
Sampling bottle 2000 ml, implosion protected, with screw cap for up to 3 tubes	SF-2000
Spare cap for sampling bottle GL45, blue	SFK
Clip for wall mounting of sampling bottles	SF-CLIP
PVC-box for 6 sampling bottles, L 400 x B 300 x H 350 mm, incl. 6 lead-throughs PG9	SF-BOX
Insulated box, dimension outside 600 x 400 x 365 mm, inside 510 x 310 x 300 mm, incl. 14 lead-throughs PG9 for protective tubes	SF-ISOBX
Automatic overflow valve for sampling bottles	SF-Protect



SF-protect



VS-pro



VS-single

Vacuum systems	
2-channel vacuum unit for two adjustable vacuum circuits 0...-85 kPa, one controllable with optional Tensiometer T4 or T8, display keypad, Aluminium enclosure 26x16x22cm, IP66, incl. tensioLink connector tL-8/USB-Mini and software tensioVIEW	VS-pro
2-channel vacuum system, without display/keypad, adjustable vacuum pump 0 -85 kPa, for two constant vacuum circuits, one controllable with optional Tensiometer T4 or T8, Aluminium enclosure 26x16x22cm, IP66, incl. tensioLINK connector tL-8/USB-Mini and software tensioVIEW	VS-twin
1-channel vacuum system, incl. adjustable vacuum pump 0 -85 kPa, for one constant vacuum circuit, controllable with optional Tensiometer T4 or T8, Aluminium enclosure 26x16x22cm, IP66, tensioLINK interface RS485 for external data logger connection	VS-single



b.TB-20 TBE-100

Special gouge auger, shaped tip for UMS-Tensiometers and UMS-suction cups, diameter 20 mm, length 1250 mm, with hammering head (without elongation)	b.TB-20
Gouge auger elongation 100 cm for Tensiometer and suction cup augers	b.TBE-100
Cable protection tube, inner diam. 8,7 mm, max. cable diam. 4 mm, dividable	ks.DN-10
Cable protection tube, inner diam. 12,5 mm, max. cable diam. 7 mm, dividable	ks.DN-14
Cable protection tube, inner diam. 24,2 mm, max. cable diam. 14 mm, dividable	ks.DN-23
Cable protection tube, inner diam. 30,0 mm, max. cable diam. 18 mm, dividable	ks.DN-37

10.3 Glossary

Suction cup, pore water sampler or lysimeter

Different terms are common. In this context it is an instrument consisting of a hydrophilic membrane, shaft and suction tube which is used to extract soil water solution from unsaturated zones.

We do not use the term lysimeter for pore water samplers as we define a lysimeter as a monolithic soil column.

Lysimeter

Container with defined surface, filled with soil and with at least one outlet. Used for quantification of water and substance flows, decay/reaction processes and simulation.

Tensiometer

Instrument for measuring soil water tension.

Vacuum

Pressure below atmospheric pressure.

10.4 Units

	pF	hPa	kPa=J/kg	MPa	bar	psi	%rH
Wet	1	-10	-1	-0,001	-0,01	-0,1450	99,9993
	2,01	-100	-10	-0,01	-0,1	-1,4504	99,9926
Field capacity	2.53	-330	-33	-0,033	-0,33	-4,9145	99,9756
Tensiometer ranges*	2.93	-851	-85,1	-0,085	-0,85	-12,345	
	3	-1.000	-100	-0,1	-1	-14,504	99,9261
	4	-10.000	-1.000	-1	-10	-145,04	99,2638
Permanent wilting point	4.18	-15.136	-1.513	-1.5	-15	-219,52	98,8977
	5	-100.000	-10.000	-10	-1 00	-1.450,4	92,8772
Air-dry**	6	-1.000.000	-100.000	-100	-1 000	-14.504	47,7632
Oven-dry	7	-10.000.000	-1.000.000	-1.000	-10 000	-145.038	0,0618

* standard measuring range of Tensiometers

** depends on air humidity

Note: 1 kPa corresponds to 9,81 cm water column

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