



METER

SOIL WATER EXTRACTION METHODS

TABLE OF CONTENTS

Forward	iii
1. Introduction to Water Extraction Methods.....	1
1.1 Simple Extraction Method	1
1.2 Constant Vacuum Extraction Method	2
1.3 Tension Controlled Extraction Method.....	3
1.4 Recommendations for Sandy Soils	3
1.5 Recommendations for Vacuum Ranges.....	3
1.6 Recommendations for Pore Clogging	4
1.7 Achievable Sample Amounts	4
1.8 Additional Notes	4
2. Vacuum Systems	5
2.1 Sampling Bottle Cap	5
2.2 Suitable Material	5
2.3 Volumes	6
2.4 Overflow Protector	7
2.5 Solution Storage	8
2.6 Vacuum Buffer Bottle.....	8
2.7 Suction Tube Material	9
2.8 Suction Tube Dimension	9
2.9 Vacuum Tube Proper Use.....	9
3. Setup Options.....	10
3.1 Discontinuous Sampling.....	10
3.2 Contant Vacuum Method	10
3.3 Tensiometer controlled Vacuum.....	11

3.4 Level Differences	11
3.5 Collection Interval	12
3.6 Power Management	13
3.7 Discontinuous method collecting sampled solution	13
3.8 Continuous Method Collecting Sampled Solution.....	14
4. Scientific Background	15
5. METER Sampler Types.....	17
5.1 Customer Support.....	18
5.2 Terms and Conditions	18
Glossary	19
References	21
Index	23

FORWARD

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. INTRODUCTION TO WATER EXTRACTION METHODS

To extract soil water in the unsaturated zone, the soil water tension (retention force) must be surpassed by the sample's potential. To surpass potential a vacuum must 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 a high vacuum.

Variations in the pressure difference between the sample's inside and outside will lead to different filtration results. This means, memory effects occur. Memory effects are prevented by a tension controlled vacuum unit.

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, sandy soils up to pF 2, and clay soils up to pF 2.7. Suction cups always act as chemical and physical filter. High vacuum applied at soils close to saturation causes the transport of small particles into the sample's pores. There is little chance to reverse this process even by applying pressure, as an area of small particles will accumulate around the cup.

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

METER offers three different vacuum methods: Simple, Constant Vacuum, and Tensions Controlled. These options are described in the next sections. The most suitable will depend on the specific task.

Please read all instructions before operating the soil water extraction equipment to ensure it performs to its full potential.

PRECAUTION

METER sensors are built to the highest standards, but misuse, improper protection, or improper installation may damage the sensor and possibly void the manufacturer's warranty. Before integrating sensors and equipment into a system, make sure to follow the recommended installation instructions and have the proper protections in place to safeguard sensors from damage.

1.1 SIMPLE EXTRACTION METHOD

Discontinuous evacuation is the simplest method. Evacuate the 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

1.2 CONSTANT VACUUM EXTRACTION 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

1.3 TENSION CONTROLLED EXTRACTION METHOD

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

1.4 RECOMMENDATIONS FOR 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 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].

1.5 RECOMMENDATIONS FOR 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.

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.

1.6 RECOMMENDATIONS FOR 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].

1.7 ACHIEVABLE SAMPLE AMOUNTS

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.

1.8 ADDITIONAL NOTES

- Interfering sorption effects get smaller over a longer period.
- Sampled solution should be stored with protective gas.
- 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.
- Samples can only be extracted from moist soil so 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 a 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.

2. VACUUM SYSTEMS

The following sections detailed vacuum system materials for setup.

2.1 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 (Figure 1).



Figure 1 Sample bottle cap with 3tube nozzles

The left (blue) tube as seen in the photo (Figure 1) 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.

2.2 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. METER 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.

2.3 VOLUMES

METER bottles are available with a volume of half litre (SF-500, [Figure 2](#)), 1 litre (SF-1000) or 2 litres (SF-2000).

Which size is the best depends on the application. Consider the following questions:

1. What sample amounts are expected during which interval?
2. Are several samplers connected to the bottle for getting a mixed sample?

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 the volume of the desired sample size with the discontinuous sampling method.

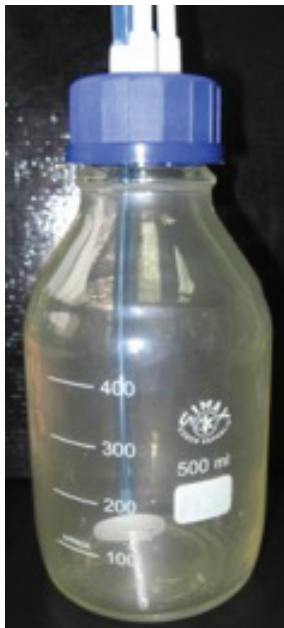


Figure 2 Sampling bottle half litre

With the overflow protector SF-protect the volume to be sampled can be adjusted or limited. For example, if a sample amount of 100 ml is used, push the vacuum tube deeper into the sampling bottle so the protector is positioned at the appropriate level.

2.4 OVERFLOW PROTECTOR

An optional overflow protector which is inserted into the sampling bottle is available for usage in automatic vacuum systems (Figure 3).

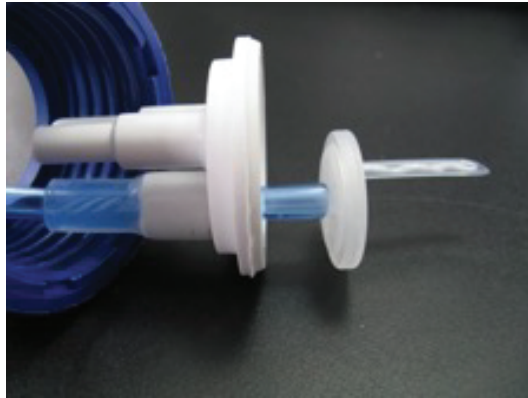


Figure 3 Overflow protector

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, the bottle is cut off from the vacuum system while the other bottles still continue to work.

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 (Figure 4).



Figure 4 Overflow protector

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 recommended.

2.5 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.

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

2.6 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.

METER 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.

2.7 SUCTION TUBE MATERIAL

Suitable material for the suction tube (also check the suitability list in [Table 2](#)):

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

METER 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.

2.8 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.

2.9 VACUUM TUBE PROPER USE

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.

IMPORTANT

You must ensure that the complete system is tight.

3. SETUP OPTIONS

As described in [Introduction to Water Extraction Methods](#) above there are three possible sampling methods. This sections covers suggestions for assembling and setting up a system depending on the sampling method.

3.1 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.

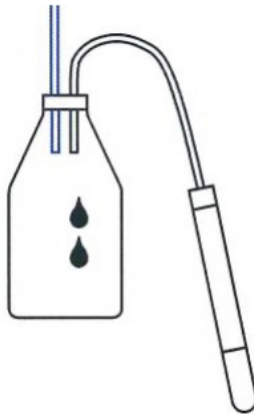


Figure 5 Soil water ampler connected to sampling bottle

3.2 CONTANT 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 ([Figure 6](#)), or by using T-fittings ([Figure 7](#)). If a sampling bottle is equipped with an overflow protection valve (see [Section 2.4](#)), a T-fitting must be used 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.

SOIL WATER EXTRACTION METHODS

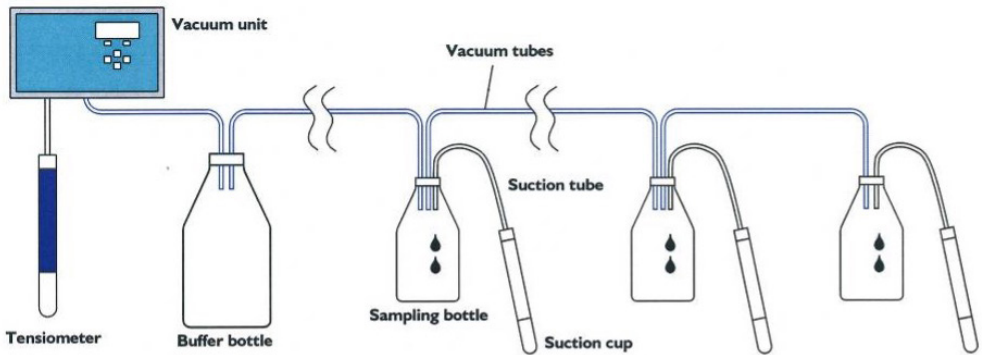


Figure 6 Sampling bottles connected in a row using third nozzle on the cap

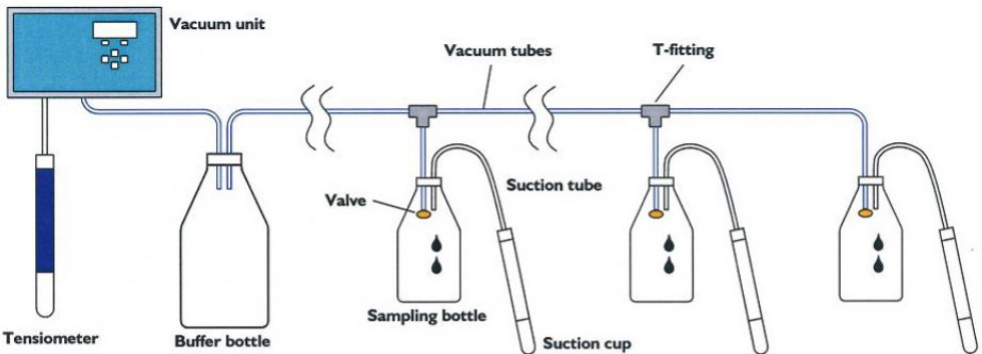


Figure 7 Sampling bottles connected to main vacuum line with T-fittings

3.3 TENSIO METER 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.

3.4 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.

SETUP OPTIONS

If a sampling bottle is placed in a higher level than the suction cup (Figure 8) 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.

NOTE: 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).

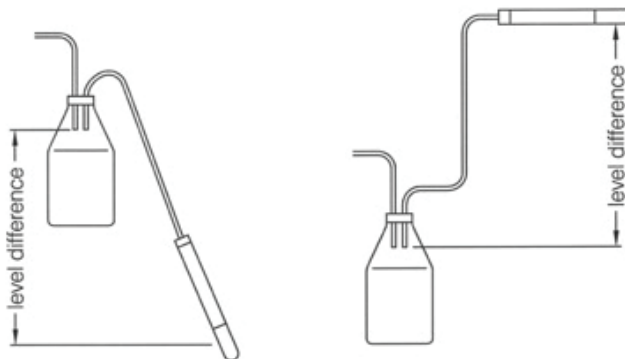


Figure 8 Level differences

Accordingly, if the sampling bottle is lower than the suction cup, for example in a manhole (Figure 8), 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, do not reduce the vacuum so solution is extracted even with bubbles inside the tube.

⚠ CAUTION

Do not compensate the level difference if the sampling bottle is lower than the suction cup!

3.5 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. To specifically gain the peaks from intense rain incidents the collection time should be shorter.

For the chronological change of the sample amount, 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.

3.6 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.

3.7 DISCONTINUOUS METHOD COLLECTING SAMPLED SOLUTION

METER sampling bottles are either plugged with a clamp or with a fitting as seen in the photo (Figure 9).

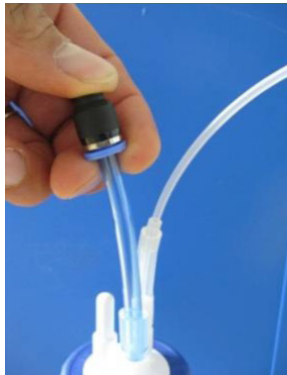


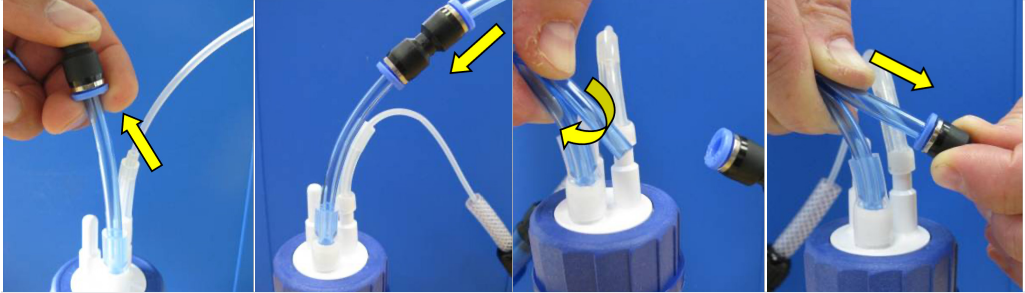
Figure 9 sample bottle with fitting

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 the pump. Now bend the vacuum tube to seal it and remove the pump. Reattach the fitting or the clamp.

Table 1 Procedure of the discontinuous method

Step 1	Step 2	Step 3	Step 4
Take off the plug from the sampling bottle	Connect the vacuum tube from the pump with the connector piece. Evacuate the bottle to the needed vacuum.	Bend the blue tube on the sampling bottle to retain the vacuum while taking off the connector piece.	Immediately put back the plug on the tube of the bottle. The short tube can now be released.



3.8 CONTINUOUS METHOD COLLECTING SAMPLED SOLUTION

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.

Be sure to check the Tensiometer readings and the sampled amounts and adjust the settings of the vacuum unit.

4. SCIENTIFIC BACKGROUND

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 METER 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 through [Customer Support](#). We would be grateful to learn about your experiences and recommendations.

Table 2 Table of Suitability

Material types:	Al2O3 ceramic sintered material	Polyethylene/Nylon	Silicon carbide	Borosili-cate glass
METER type:	SK20 SKPE25	SPE20	SIC20, SIC40 SIC300	SG25 SPG120
Suitable for determination of...				
Anions:				
NO3-	Nitrate	+++	+++	+++
SO42-	Sulphate	+++	+++	+++
PO43-	Phosphate	+++	+++	+++
Cl-	Choride	+++	+++	+++
Cations:				
Ca2+	Calcium	+ [1]	+++	+ [1]
K+	Potassium	+ [1]	+++	++
Na+	Sodium	++[1]	+++	

SCIENTIFIC BACKGROUND

NH ₄ ⁺ Ammonium	+++	+++	+++	+++
Table of Suitability (continued)				
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:				
n/a				
Heavy metals:				
Cd Cadmium	--- [6]	+ [6]	-	-
Pb Lead	--- [5] [6]	+ [6]	-	-
Herbicides	+ (Atrazin) [3] [7][8]	+ (Atrazin) [7]		/
Pesticides	/	/		/
Fungicides	/	/		/
PAK				
Trace elements	-	/		/

Table 2 Literature source

Table 2 Suitability symbol Legend

[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	/	no experiences
[6] Haberhauer 1997	+	limited suitability
[7] Schroll 1996	++	suitable after conditioning and sufficient forerun for flushing
[8] Klotz, 1997	+++	suitable after sufficient forerun for flushing

5. METER SAMPLER TYPES

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. METER 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

SUCTION PLATES

A suction plate can be installed in disturbed soil columns or filled Lysimeters.

If a horizontal trench is dug into the wall of a manhole or profile pit the plate is pressed against the soil from underneath using for example an air cushion or stainless steel springs. As the plate has no raised edge it is important that the applied vacuum is exactly corresponding to the soil water tension of the soil horizon. Otherwise the plate will either create a hydraulic drain or a flow resistance. The advantage of a plate is the larger extent compared to suction cups.

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.

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.

5.1 CUSTOMER SUPPORT

NORTH AMERICA

Customer service representatives are available for questions, problems, or feedback Monday through Friday, 7:00 am to 5:00 pm Pacific time.

Email: support.environment@metergroup.com
sales.environment@metergroup.com

Phone: +1.509.332.5600

Fax: +1.509.332.5158

Website: metergroup.com

EUROPE

Customer service representatives are available for questions, problems, or feedback Monday through Friday, 8:00 to 17:00 Central European time.

Email: support.europe@metergroup.com
sales.europe@metergroup.com

Phone: +49 89 12 66 52 0

Fax: +49 89 12 66 52 20

Website: metergroup.com

If contacting METER by email, please include the following information:

Name	Email address
Address	Instrument serial number
Phone	Description of the problem

NOTE: For products purchased through a distributor, please contact the distributor directly for assistance.

5.2 TERMS AND CONDITIONS

By using METER instruments and documentation, you agree to abide by the METER Group, Inc. Terms and Conditions. Please refer to metergroup.com/terms-conditions for details.

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.

APPENDIX A

Table A.1 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

REFERENCES

- Czeratzki, W.; 1971: Saugvorrichtung für kapillar gebundenes Bodenwasser. Landforschung Völkerode 21, 13-14.
- DVWK; 1990: Gewinnung von Bodenwasserproben mit Hilfe der Saugkerzenmethode. DVWK Merkblätter, Heft 217.
- DVWK; 1980: Empfehlungen zum Bau und Betrieb von Lysimetern.
- Grossmann, J.; Quentin, K.-E.; Udluft, P.; 1987: Sickerwassergewinnung mittels Saugkerzen-eine Literaturstudie. Z. Pflanzenernährung u. Bodenkunde 150, 281-261.
- G.HENZE, 1999: Umweltdiagnostik mit Mikrosystemen, Verlag Wiley-VCH, ISBN 3-527-29846-0.
- RAMSPACHER, P., 1993: Erste Erfahrungen mit tensiometergesteuerten Unterdrucklysimetern zur Erstellung von Sickerwasserbilanzen (Lysimeterstation Wagna), Bericht über die 3. Gumpensteiner Lysimetertagung, "Lysimeter und ihre Hilfe zur umweltschonenden Bewirtschaftung landwirtschaftlicher Nutzflächen", BAL Gumpenstein, 20.-21.4.1993, S. 67-72.
- HARTGE, HORN, 1992: Die physikalische Untersuchung von Böden, Verlag Enke, ISBN 3 432 82123 9.
- FEICHTINGER, F., 1992: Erste Erfahrungen beim Einsatz eines modifizierten Feldlysimeters, Bericht über die 2. Gumpensteiner Lysimetertagung "Praktische Ergebnisse aus der Arbeit mit Lysimetern", BAL Gumpenstein, 28.-29.4.1992, S. 59-62.
- KLAGHOFER, E., 1994: Antworten auf die 7 Fragen an uns Lysimeterbetreiber, Bericht über die 4. Gumpensteiner Lysimetertagung "Übertragung von Lysimeterergebnissen auf landwirtschaftlich genutzten Flächen und Regionen", BAL Gumpenstein, 19.-20.4.1994, S. 5-7.
- ROTH, D., R. GÜNTHER und S. KNOBLAUCH, 1994: Technische Anforderungen an Lysimeteranlagen als Voraussetzung für die Übertragbarkeit von Lysimeterergebnissen auf landwirtschaftliche Nutzflächen, Bericht über die 4. Gumpensteiner Lysimetertagung "Übertragung von Lysimeterergebnissen auf landwirtschaftlich genutzten Flächen und Regionen", BAL Gumpenstein, 19.-20.4.1994, S. 9-21.
- SCHWABACH, H. und H. ROSENKRANZ, 1996: Lysimeteranlage Hirschstetten - Instrumentierung und Datenerfassung, Bericht über die 6. Gumpensteiner Lysimetertagung "Lysimeter im Dienste des Grundwasserschutzes", BAL Gumpenstein, 16.-17.4.1996, S. 41-45.
- KRENN, A., 1997: Die universelle Lysimeteranlage Seibersdorf - Konzeption, Bericht über die 7. Gumpensteiner Lysimetertagung "Lysimeter und nachhaltige Landnutzung", BAL Gumpenstein, 7.-9.4.1997, S. 33-36.

REFERENCES

- EDER, G., 1999: Stickstoffausträge unter Acker-und Grünland, gemessen mit Schwerkraftlysimetern und Sickerwassersammlern, Bericht über die 8. Gumpensteiner Lysimetertagung, "Stoffflüsse und ihre regionale Bedeutung für die Landwirtschaft", BAL Gumpenstein, 13.-14.4.1999, S. 93-99.
- KUNTZE, ROESCHMANN, SCHWERDTFEGER, 1988: Bodenkunde, Verlag UTB Ulmer, ISBN 3-8001-2563-3.
- Starr, J.L.; Meisinger, J.J. ; Parkin, T.B.; 1991: Experience and knowledge gained from vadose zone sampling. In: NASH, R.G.; Leslie A.R. (Eds.): Groundwater Residue Sampling Design. Am. Chem. Soc. Symp. Series 465, 279-289.
- Udluft, P.; Quentin, K.-E.; Grossmann, J.; 1988: Gewinnung von Sickerwasser mittels Saugkerzen-Verbesserung der Probenahmetechnik und Minimierung der Veränderung der chemischen und physikalischen Eigenschaften des Sickerwassers. Abschlußbericht zum Forschungsvorhaben DU 3/10-1. Institut für Wasserchemie der TU München.

INDEX

A

Air bubbles 9

B

buffer bottle 7

C

clay soils 1, 2

cleaning 14

constant vacuum 2

customer support 18

D

discontinuous sampling 6, 10

drainage water 3

E

email address 18

F

fax number 18

I

implosion proof 5

in-situ soil water tension 1

L

leakage 9, 13

level differences 11

M

maintenance iii

memory effects 1

O

overflow valve 7

P

phone number 18

pore clogging 4

S

sample amounts 4

sampling bottle 5, 6

sand fraction 3

sandy soils 1, 3

simple method 1

sorption effects 4

stony soil 1

suction tubes 9

T

tensiometer controlled vacuum 11

tension controlled extraction 3

terms and conditions 18

U

unsaturated zone 1, 19

V

vacuum tubes 9

W

water intrusion detector 9

workshop

METER 15

METER Group, Inc.

2365 NE Hopkins Court Pullman, WA 99163

T: +1.509.332.2756 F: +1.509.332.5158

E: info@metergroup.com W: metergroup.com

METER Group GmbH

Mettlacher Straße 8, 81379 München

T: +49 89 1266520 F: +49 89 12665220

E: info.europe@metergroup.com W: metergroup.de

