Technical Assistance
HYDROLOGY PROJECT

World Bank & Government of The Netherlands funded

Training module # WQ - 14

How to sample groundwater from bore wells for water quality analysis

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with
HALCROW, TAHAL, CES, ORG & JPS

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1. Module context

This module introduces how sampling should be carried out in different types of wells and explains the need for correct sampling of ground water for subsequent water quality analysis. It thereafter explains the procedure for sampling in small diameter monitoring wells in more detail.

This module does not explain the different types of pumps available for sampling nor does it aim at estimating pump capacities for different field situations.

Modules in which prior training is required to complete this module successfully and other available, related modules are listed in the table below.

While designing a training course, the relationship between this module and the others, would be maintained by keeping them close together in the syllabus and place them in a logical sequence. The actual selection of the topics and the depth of training would, of course, depend on the training needs of the participants, i.e. their knowledge level and skills performance upon the start of the course.

No.	Module title	Code	Objectives
1	*Basic water quality concepts*	WQ I-1	• Become familiar with common water quality parameters. • Appreciate important water quality issues.
2	*Basic chemistry concepts*[a]	WQ I-2	• Convert units from one to another • Understand the basic concepts of quantitative chemistry • Report analytical results with the correct number of significant digits
3	*How to prepare standard solutions* [a]	WQ I-4	• Recognise different types of glassware • Use an analytical balance and maintain it. • Prepare standard solutions
4	*How to measure colour, odour and temperature*[a]	WQ 1-5	• Measure natural colours in water samples • Distinguish different types of odours
5	*How to measure the pH of a water sample*[a]	WQ I-7	• Measure the pH of a water sample
6	*How to measure electrical conductivity*[a]	WQ I-9	• Measure electrical conductivity • Appreciate the effect of ion concentration and type on EC value

a – prerequisite

2. Module profile

Title	:	How to sample groundwater from bore wells for water quality analysis
Target group	:	HIS function(s):
Duration	:	1 session of 60 minutes.
Objectives	:	After the training the participants will be able to: • Carry out groundwater sampling with necessary precautions
Key concepts	:	• Representative samples • Purging • Sample preservation
Training methods	:	Lecture, discussion
Training tools required	:	Board, OHS
Handouts	:	As provided in this module
Further reading and references	:	"Practical guide for groundwater sampling", M. R. Scalf, Scientific Publishers Jodhpur, 1988

3. Session plan

No	Activities	Time	Tools
1	***Preparations***		
2	***Introduction***: • Ask participants to enumerate types of groundwater sources. • Differentiate between samples of aquifer water and well water	10 min	OHS, Board
3	***Well purging*** • Discuss need for purging • Define purging efficiency • Discuss factors affecting purging efficiency • Describe recommended pumps and calculation of purging rate and time	20 min	OHS, Board
4	***Field procedures*** Describe steps to be taken in the field while purging and collecting samples	15 min	OHS
5	***Sample handling*** Describe sample containers and preservation	10 min	OHS
6	***Wrap up*** Ask what difficulties may be or are faced in sample collection. Discuss possible solutions.	5 min	

4. Overhead/flipchart master

OHS format guidelines

Type of text	Style	Setting
Headings:	OHS-Title	Arial 30-36, with bottom border line (not: underline)
Text:	OHS-lev1 OHS-lev2	Arial 24-26, maximum two levels
Case:		Sentence case. Avoid full text in UPPERCASE.
Italics:		Use occasionally and in a consistent way
Listings:	OHS-lev1 OHS-lev1-Numbered	Big bullets. Numbers for definite series of steps. Avoid roman numbers and letters.
Colours:		None, as these get lost in photocopying and some colours do not reproduce at all.
Formulas/Equations	OHS-Equation	Use of a table will ease horizontal alignment over more lines (columns) Use equation editor for advanced formatting only

Groundwater sampling

- Sources of GW
- Representative samples
- Purging of wells
- Field procedures
- Sample containers
- Sample handling
- Sample preservation
- Sample identification

Sources of Groundwater

- Spring
- Production well
  - *Open dug well*
  - *Tube well*
- Non-production well, piezometer

Representative samples

- Purging non-production well
  - *removal of stagnant water column*
  - *use portable pump*
  - *indicator parameter*
- Agitation is not purging
- Large dia non-production wells are not suitable for sampling

Purging of wells (1)

- More than standing stagnant water volume should be purged
- Purging efficiency

$$\frac{\textit{aquifer water}}{\textit{stagnant water + aquifer water}}$$

- Purging efficiency is a function of
  - *transmissivity of aquifer*
  - *rate & time of purging*
  - *initial stagnant water volume*
- Purge 4 to 5 times stagnant well water volume for 80 to 90 % efficiency

Purging of wells (2)

- Recommended pumps

Pump, W	*100*	*200*	*600*
Well depth, m	*30*	*60*	*90*
Dynamic lift, m	*10 - 25*	*25 - 45*	*45 - 85*
Q, L/min at lift, m	*15 at 20* *25 at 10*	*10 at 45* *30 at 25*	*10 at 85* *50 at 50*

  – *discharge is adjusted by changing input current frequency*

Purging of wells (3)

- Pump selection & purging time is calculated before going to site
- Pumping test records
    - *borehole diameter*
    - *borehole depth*
    - *depth of SWL*
    - *yield*
    - *depth of WLR*
- Purging time = (4 x Volume) / (flow rate)
- Maximum time < 300 min
- Minimum time > 15 min
- Do not purge before WL reading

Field procedures (1)

- Record SWL, if different change pump setting
- Check borehole for insertion of pump
- Check water level in the motor
- Lower pump 5 m below SWL
- Follow pump installation & start-up instructions

Field procedures (2)

- Set-up instruments for field measurements
- Start pump & stopwatch
- Measure EC, pH, T, every 10 min
- Observe colour, odour & turbidity
- Record time & observations on data sheet

Field procedures (3)

- When parameter values are consistent, measure discharge
- Reduce discharge to 0.1 L/min
- Collect sample
- Check purging time:
  - $\geq$ *calculated time*
  - $\geq$ *15 min*

Sample containers

Analysis	**Material**
General	*Glass, PE*
Hg & P	*Glass*
Pesticide	*Glass, Teflon*
DO	*BOD bottle*
Coliforms	*Glass/ PE sterilised*

- 1 to 3L capacity

Sample handling

- Transfer to containers immediately
- Exclude suspended matter
- Leave minimal air space
- Separate portions for site analyses
- Preservation

Sample preservation

Analysis	**Preservation**
BOD	*4 ^oC, dark*
COD, NH_3, NO^-_2, NO^-_3	*< pH 2, H_2SO_4*
Coliforms	*4 ^oC, dark*
DO	*DO fixing chemicals, dark*
Heavy metals	*< pH 2, HNO_3*
Pesticides	*4^oC*

Sample identification

Sample code											
Observer				Agency				Project			
Date	Time			Station code							
	Container				Preservation				Treatment		
Parameter code	**Glass**	**PVC**	**PE**	**Metal**	**None**	**Cool**	**Acid**	**Other**	**None**	**Decant**	**Filter**
o Gen											
o Bact											
o BOD											
o H Metals											
o T Organics											
Remarks											

5. Evaluation sheets

6. Handout

Groundwater sampling

- Sources of GW
- Representative samples
- Purging of wells
- Field procedures
- Sample containers
- Sample handling
- Sample preservation
- Sample identification

Sources of Groundwater

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  - *use portable pump*
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- Agitation is not purging
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Purging of wells (1)

- More than standing stagnant water volume should be purged
- Purging efficiency

$$\frac{\text{aquifer water}}{\text{stagnant water + aquifer water}}$$

- Purging efficiency is a function of
  - *transmissivity of aquifer*
  - *rate & time of purging*
  - *initial stagnant water volume*
- Purge 4 to 5 times stagnant well water volume for 80 to 90 % efficiency

Purging of wells (2)

- Recommended pumps

Pump, W	*100*	*200*	*600*
Well depth, m	*30*	*60*	*90*
Dynamic lift, m	*10 - 25*	*25 - 45*	*45 - 85*
Q, L/min at lift, m	*15 at 20* *25 at 10*	*10 at 45* *30 at 25*	*10 at 85* *50 at 50*

discharge is adjusted by changing input current frequency

Purging of wells (3)

- Pump selection & purging time is calculated before going to site
- Pumping test records
- borehole diameter
  - *borehole depth*
  - *depth of SWL*
  - *yield*
  - *depth of WLR*
- Purging time = (4 x Volume) / (flow rate)
- Maximum time < 300 min
- Minimum time > 15 min
- Do not purge before WL reading

Field procedures (1)

- Record SWL, if different change pump setting
- Check borehole for insertion of pump
- Check water level in the motor
- Lower pump 5 m below SWL
- Follow pump installation & start-up instructions

Field procedures (2)

- Set-up instruments for field measurements
- Start pump & stopwatch
- Measure EC, pH, T, every 10 min
- Observe colour, odour & turbidity
- Record time & observations on data sheet

Field procedures (3)

- When parameter values are consistent, measure discharge
- Reduce discharge to 0.1 L/min
- Collect sample
- Check purging time:
  - *≥ calculated time*
  - *≥ 15 min*

Sample containers

Analysis	**Material**
General	*Glass, PE*
Hg & P	*Glass*
Pesticide	*Glass, Teflon*
DO	*BOD bottle*
Coliforms	*Glass/ PE sterilised*

1 to 3L capacity

Sample handling

- Transfer to containers immediately
- Exclude suspended matter
- Leave minimal air space
- Separate portions for site analyses
- Preservation

Sample preservation

Analysis	Preservation
BOD	***4 °C, dark***
COD, NH_3, NO^-_2, NO^-_3	***< pH 2, H_2SO_4***
Coliforms	***4 °C, dark***
DO	***DO fixing chemicals, dark***
Heavy metals	***< pH 2, HNO_3***
Pesticides	***4°C***

Add copy of Main text in chapter 8, for all participants.

7. Additional handout

These handouts are distributed during delivery and contain test questions, answers to questions, special worksheets, optional information, and other matters you would not like to be seen in the regular handouts.

It is a good practice to pre-punch these additional handouts, so the participants can easily insert them in the main handout folder.

8. Main text

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2.	Rate of purging and purging time	1
3.	Field procedures	3
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5.	Labelling and preservation	5

How to sample groundwater from borewells for water quality analysis

1. Introduction

The objective of water quality sample collection is to obtain a small portion of material that accurately represents the characteristics of the water body being sampled. This is referred to as taking a 'representative sample' and is vitally important if the analysis that follows sampling and the conclusions that are ultimately drawn from the data are to have any validity.

Groundwater samples may be collected from operating production wells, springs or water level observation wells (purpose built piezometers). If the source of groundwater is a well equipped with a pump or a flowing spring, the sample can simply be obtained at the discharge point.

In case of wells, which are not in continuous use for water supply or purpose built water level piezometers, the quality of water in the well may not be the same as that of water in the aquifer. It is important to pump out the stagnant water in the well or bore to ensure that water from the aquifer, rather than that which has been standing in the well, is sampled. This process is known as purging. It ensures that the standing water does not contaminate the sample. Note that a sample taken after purging is not the same as taking an agitated sample as is often believed.

An effective way to ensure that the water is 'fresh' groundwater is to monitor the temperature, electric conductivity (EC), pH and/or oxidation-reduction potential (ORP) of the emerging water as it is run to waste. Once these readings are constant for some minutes and the amount of water purged approaches the estimated required volume for purging, the sample can be taken.

In case of sampling in purpose-built piezometers not equipped with an installed pump, samples need to be obtained by means of a portable lifting device such as a submersible pump.

When sampling with a submersible pump, the device is lowered into the well and switched on. The purging and sampling can then be carried out as if the well were equipped with a fixed pump, although the rate of discharge may be lower and more time will be required to ensure proper purging.

Special care is required when (open) shallow wells, not equipped with a pump, are sampled manually. In this situation the sample can be collected by lowering a specifically designed bailer sampler or a sampling can into the well. It is important that the can is not allowed to touch the sides or bottom of the well as it is likely that this will contaminate the sample with solid matter.

2. Rate of purging and purging time

As water is purged from a well or a piezometer, drawdown occurs and aquifer water starts flowing into the well. This means that while purging is in progress some of the fresh water is also thrown out. It is therefore not sufficient to purge water only equal to the volume of water in the well under static conditions. In order to obtain 80 to 90 percent purging efficiency (aquifer water volume / {well water volume + aquifer water volume } x 100), 2 to 10 times the well water volume may have to be purged depending on the site and pumping conditions. In most cases 4 to 5 times the well volume is considered sufficient.

Care is also to be taken that the rate of purging is not kept excessively high in order to reduce the purging time. A high purging rate would require larger capacity pumps and also higher head pumps because of a greater drawdown. The increased drawdown may also affect the submergence condition of the pump.

Considering the above factors and site specific conditions of depth of water table, diameter of borehole and transmissivity of aquifers, pumps of the following specifications may be used:

Pump power, W	**100**	**200**	**600**
Well depth, m	30	50	90
Dynamic lift head, m	10 - 25	25 - 45	45 - 85
Discharge at lift head	15L/min at 20m 25L/min at 10m	10L/min at 45 m 30L/min at 25m	10L/min at 85m 50L/min at 50m

In order to select a pump and calculate purging time the data of the piezometer to be sampled must be analysed beforehand. A desk study is needed to establish:

- the anticipated purging duration (can the borehole be purged within a normal working day or less)
- the anticipated draw-down for a specific borehole (what depth below the water level should the pump be installed)

Purging time is calculated using data from well construction and monitoring records (see Table 1 Borehole sampling sheet). Borehole yield is recorded in pumping test records or drilling logs. The following information must collected

- borehole diameter (φ) in centimetres
- borehole depth (D), in meters
- the latest depth to water or standing water level (SWL), in meters
- the bore yield (Y), in L/hour
- standing well water volume (V), in litres,
  $V = 0.025\,\pi \times \phi^2 \times (D - SWL)$
- installation depth of a DWLR or AWLR, if applicable

The above information is assessed by the supervising hydrogeologist/engineer to establish whether the borehole is suitable for sampling using the available submersible pump. The hydrogeologist/engineer will use the following information as guides to evaluate the suitability of the borehole.

- The depth to standing water level should not exceed 50 metres (although in high yielding bores the depth to water could be up to 55 metres.
- A high draw-down, up to 15 metres, can be expected in old and low yielding (< *0.5* L/s) bores whilst a low draw-down, less than 5 metres, can be expected from a higher yielding borehole (> 5 L/s).
- As a working rule the expected pump depth setting is calculated by adding five metres to the water depth.

· The *purging time*, in minutes is calculated by dividing the initial standing well water volume times four by the, anticipated, pump discharge or flow rate (L/min). The pump flow rate is estimated from pump-performance curves or taken from operational experience.

$$PT = \frac{V \times 4}{Q}$$

PT	=	projected time of purging	[min]
V	=	initial volume of standing well water	[L]
Q	=	pump discharge	[l/min]

If a borehole requires more than 300 minutes of pumping before sample collection it may not be included in a monitoring programme. Generally, most bore-holes with diameters of 20cm or greater cannot be used for routine chemical monitoring as the pumping times required to purge bore-hole exceed a normal working day.

The projected time of purging should be 15 minutes at minimum. In case the calculated value is less than 15 minutes the pump discharge should be lowered to such a rate that the purging operation takes at least 15 minutes.

Obviously a borehole is not to be sampled prior to scheduled regular (monthly) water level monitoring. This is particularly important to prevent anomalous water level data being recorded for low yielding boreholes where up to a week of recovery time may be necessary.

3. Field procedures

The steps involved in the collection of a representative groundwater sample, using a submersible pump, are outlined below:

Water Depth

The water depth in the monitoring borehole is measured upon arrival and recorded on the sampling sheet, Table 1. The date, time and the name of the person carrying out the sampling are also recorded. If the depth to water is significantly different from the office-recorded depth, it may be necessary to alter the pump depth setting. Adding 5 meters to the actual water depth is usually sufficient. The water depth is also measured again just before the pump is switched off. This water level is referred to as dynamic water level (DWL) in the sampling sheet.

Pump Installation and Start-up

Before starting purging, the technical condition of the well needs to be checked and its suitability for the insertion of a submersible pump needs to be verified. This is usually performed by inserting a metal body similar in shape to the submersible pump, into the well. Once smooth insertion of the metal body to the required depth and its subsequent removal is performed, the submersible pump can be safely inserted and the purging operation may start

The procedures for Installation and start-up are as follows. Remove the pumping equipment from the vehicle and place near the bore. Be sure to position both the generator and converter in locations that will not be flooded with water during the purging operation. The converter should never come into contact with water and it should always be placed in an upright position to allow cooling. Similarly, electrical cables, although waterproof, should not come into contact with water.

Check the water level in the motor by holding the pump vertically upside down and removing the filling screw. If it is not completely full, fill up with de-mineralised water whilst lifting the shaft in the discharge port to enable all air bubbles to escape. Replace and tighten the screw. Failure to check the motor water level could lead motor damage as the water acts as a lubricant and prevents overheating.

Install the pump to the predetermined depth by releasing the spool lock pin and unwinding the rising main (flexible hose). During this step it is important that the hose and cables are held away from the rough edges of the casing to avoid damage to the cables and hose. If the measuring tape on the hose is damaged or missing, the pump is lowered for an additional five metres after a splash is heard. Once the pump is installed to the required depth the spool is locked by engaging the pin at the side. The actual pump setting is recorded in the sampling sheet.

Position the discharge hose from the hose spool down gradient and as far away from the pumping equipment as possible. Place the hose outlet Into a bucket/container or in which chemical measurements are taken.

Check that the power switches on the converter and the generator are turned to the off position and start the generator following manufacturers procedures. Switch the power on at the generator after the generator is running smoothly.

Once the power is on to the converter the dial display will show zero. If the converter is brand new and has never been used or stored for six months, the converter cannot be switched "on" until 15 minutes after it receives power.

Turn the converter switch to the "on" position. Ensure the frequency dial is in the minimum position, i.e., fully anticlockwise. The display will register 50. Now slowly rotate the dial to the required frequency on the display. The maximum frequency of 400 corresponds to the maximum pump discharge. Lower pump rates are obtained by selecting a frequency between 50 and 400.

Shortly after the converter is turned on water will flow from the discharge hose. If no flow is observed, there is either a blockage in the hoses or a fault in the wiring from the converter to the pump or the pump is not below the water level. Turn converter off and correct problem before restarting.

Start the stopwatch as soon as the converter is switched on and adjusted to its operating frequency.

Field Measurements and Sampling

Field measurements commence at the start of pumping. It is important to be prepared. A sampler with all measuring equipment (pH meter, EC meter, stopwatch and sampling bucket) should be stationed at the hose outlet before the pump is started. All field instruments must be correctly calibrated before pumping commences.

Chemical Measurements

The sampler measures the pH, EC and temperature as soon as the sampling bucket is filled with water. Results and stopwatch time are recorded on the sampling sheet. A sample is also collected to observe the water's physical properties (colour, turbidity and odour). The physical properties are recorded on the same sheet. The sample is discarded after the physical properties have been recorded.

At this point, measure the flow or discharge rate from the pump, see section "flow measurements" below for the procedure.

Chemical parameters (pH, EC and temperature) are measured at 10 minutes intervals until measurements have stabilised or do not change from the previous two readings. It is not necessary to record the physical changes. Consistently stable pH and EC measurements indicate that the water is representative of the aquifer's groundwater and a water sample could be collected. Before taking the sample, reduce the discharge to 0.1 L/min. Also make sure that the following conditions are met:

- ✓ purging should have lasted for the projected time of purging and
- ✓ purging should have lasted for a minimum of 15 minutes

Flow Measurements

Once the initial chemical measurements are recorded, the pump discharge or flow rate is recorded. This involves emptying the bucket and recording the time taken to fill the bucket to a known volume. By dividing the bucket volume (litres) by the time required to fill the volume (seconds) the flow rate in litres/second (L/s) is determined. This procedure is repeated after the water sample has been collected and before the pump is turned off. Both measurements are recorded in the sampling sheet. Complete Table 1.

Pump Shut-off

Shut-off the pump after field chemical measurements and a water sample have been collected. Make sure you have measured and noted the water depth before turning the pump off.

The shut-off procedure is as follows: switch the converter off and subsequently switch the power off at the generator. Pump removal follows the reverse procedure to installation.

4. Sample containers

Collect a water sample by washing the bottle three times before filling the sample bottle to overflowing and screwing down the top. Ensure that the air headspace is minimal

In order to cover the range of parameters which need to be sampled and analysed a variety of sample containers are required as discussed below:

- 1000 millilitre glass (or Teflon) bottles with Teflon lined caps - for pesticides and phenols
- 500 millilitre polyethylene bottles - for metals (except mercury)
- 100 millilitre glass bottles - for mercury and phosphorus
- 1000 millilitre polyethylene bottles for all other chemical parameters
- Strong thick-walled glass bottles of at least 300 millilitre capacity for microbiological analysis.

Bottles, which are to be used for collecting microbiological samples, must be thoroughly washed and sterilised beforehand. This can be carried out by placing them in an oven at 170°C for at least two hours.

5. Labelling and preservation

Immediately after sampling, the sample bottles should be labelled and given a unique code number. Information on the label should include:

- sample code number
- date and time of sampling
- pre-treatment or preservation carried out on the sample
- any special notes for the analyst

- sampler's name

The proforma given in Table 2 includes this information.

Samples for BOD, coliform and pesticides analyses should be stored at a temperature below $4^{o}C$ and in the dark as soon after sampling as possible. In the field this usually means placing them in an insulated cool box together with ice or cold packs. Once in the laboratory, samples should be transferred as soon as possible to a refrigerator.

If samples collected for chemical oxygen demand (COD) analysis cannot be determined on the day of collection they should be preserved below pH 2 by addition of concentrated sulphuric acid. This procedure should also be followed for samples for ammoniac nitrogen, total oxidised nitrogen and phenol analysis.

Samples, which are to be analysed for the presence of metals, should be acidified to below pH 2 with concentrated nitric acid. Such samples can then be kept up to six months before they need to be analysed; mercury determinations should be carried out within five weeks, however.

Following labelling, the samples should be placed in a purpose-built bottle carrier for transportation.

Table 1 Bore well sampling sheet

General Section			
Well Id			
Location			
Name colllector			
Date (ddmmyy)			
Time			
Pump type			
Pump discharge range	Q		L/s
Office Well Data			
Diameter	φ		cm
Depth	D		m
Static water level[a]	SWL		m
Water column	H		m
Initial volume well	V		L
Projected time of purging	PT		min
Field Flow Measurements			
Static water level on arrival	SWL		m
Actual pump setting			m
Time purging start stop			hh:min
Pump Discharge before sampling	Q		L/s
Pump Discharge after sampling	Q		
Volume purged	V		L
Dynamic water level	DWL		m
Field Chemical measurement			
Time sampling	T (°C)	EC(mS/m)	pH
start			
+10 min			
+20 min			
+30 min			
+40 min			
[a] - average SWL, for estimating purging volume and time			

Table 2 Sample identification

Sample code											
Observer				Agency				Project			
Date Time				Station code							
Parameter code	Container				Preservation				Treatment		
	Glass	PVC	PE	Metal	None	Cool	Acid	Other	None	Decant	Filter
o Gen											
o Bact											
o BOD											
o H Metals											
o Tr Organics											
Remarks											