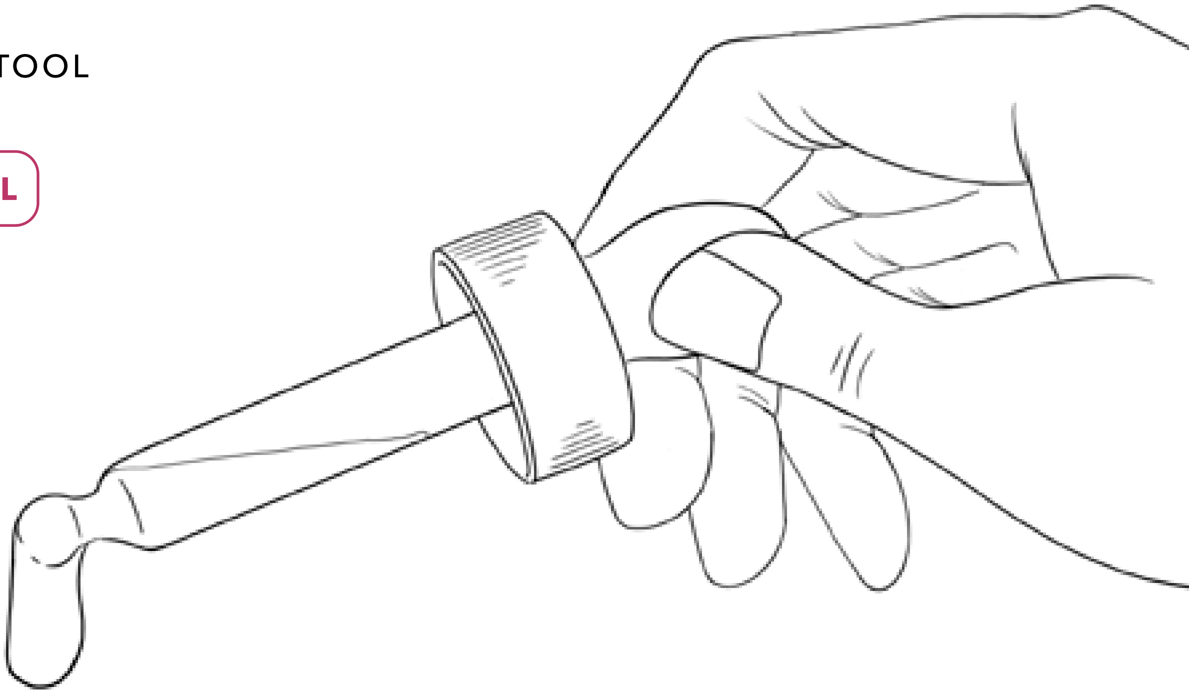
BEWOP

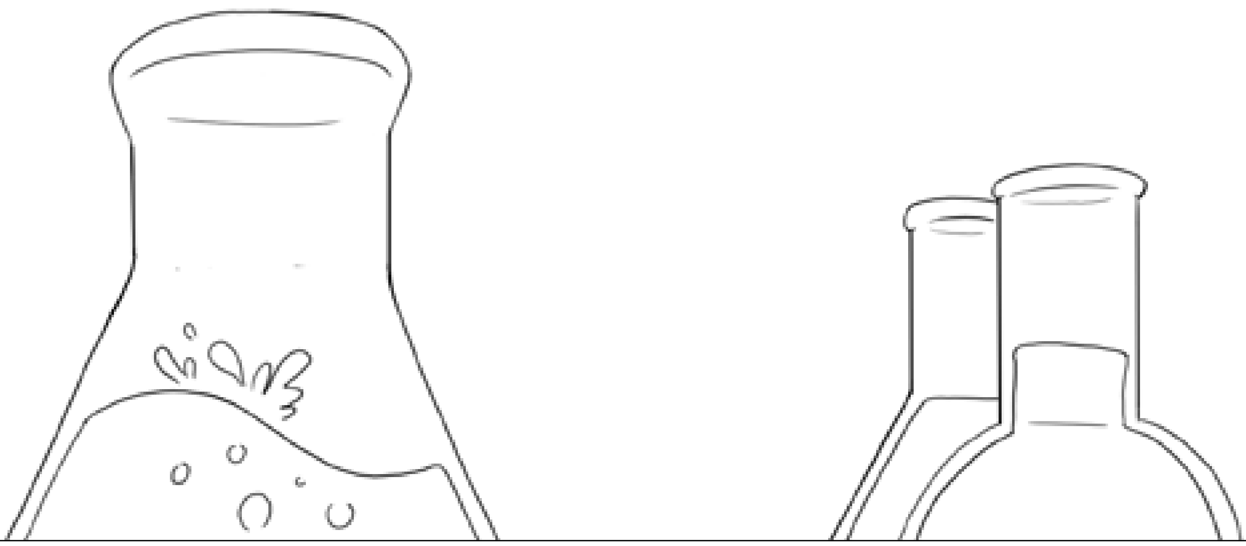
TOOL SERIES

Water Quality Monitoring Tool for Drinking Water Production

OPERATIONAL TOOL

USER'S MANUAL





GWOPA Global Water Operators' Partnerships Alliance

UN-HABITAT FOR A BETTER URBAN FUTURE

UNESCO IHE DELFT

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BEWOP

Water Operators' Partnerships are peer support arrangements between two or more water and sanitation operators, carried out on a not-for-profit basis with the objective of strengthening operator capacity.

The Boosting Effectiveness of Water Operators' Partnerships (BEWOP) initiative is producing a series of guidance materials, tools and games to help WOP partners expertly plan and implement WOP partnerships and effectively learn and share knowledge with one another.

Two types of products feature in the second phase of this BEWOP initiative. Process Tools support WOP participants prepare for, design, implement and follow through with their WOPs. Operational Tools support in the transfer of knowledge on specific operational topics relevant for water utilities.

Find out more

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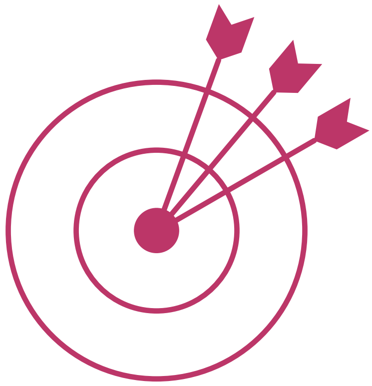

Objective

The objective of this tool is to help water operators decide which parameters to monitor in each step of the water treatment and distribution process, from catchment to consumers. This tool can also support local, national, and international organizations in charge of designing plans for monitoring drinking water quality.

How this tool works

Establishing a comprehensive water quality monitoring plan is a complex process, in which a number of variables need to be taken into account (e.g. treatment train, sampling points, water quality parameters, sampling frequencies and priorities). This toolkit consists of this user manual and a step-by-step decision support tool that runs in Excel. To make the most of this toolkit follow the steps below:

1. Download the tool from the BEWOP website.
2. Define your water source: either surface or groundwater.
3. With the guidance given in the tool, establish and select the set of parameters to be monitored in each step of the treatment train.
4. Print out the PDF report with the summary of the chosen (X) or optional parameters (O).

Access the full Water Quality Monitoring Tool for Drinking Water here.

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Disclaimer

This tool is a support mechanism, designed to assist users in establishing a set of parameters for water quality monitoring schemes. It does not replace any national guidelines or regulations. The guidance on treatment trains, priorities, and frequencies given by the tool should be used only as an aid in the decision-making process. It is essential that users consider local, national, and international regulations that may apply to their specific context.

Introduction

Safe drinking water

Drinking water systems supplied by surface water and groundwater are subject to contamination that may affect raw and treated water quality. Contamination by pathogenic micro-organisms or toxic chemicals may have severe impacts on public health. To address this, the production of safe drinking water must comply with public health standards for drinking water quality, i.e. the maximum concentrations of chemical, radiological, and microbiological contaminants that can be present in drinking water without presenting a public health risk (Ministry of Health, 2017).

The World Health Organization (WHO) defines safe drinking water as water that does not represent any significant risk to health over the lifetime of its consumption, including different sensitivities that may occur between stages in its life. To ensure the supply of safe drinking water, WHO has developed a framework for safe drinking water, based on three key components: health-based targets, water safety plans, and independent surveillance (WHO, 2017). WHO recommends the implementation of this preventive management approach not only through the implementation of water safety plans[1], but also through the use of sanitary inspections[2], and Quantitative Microbial Risk Assessment (QMRA)[3].

Water quality expresses the suitability of water to sustain various uses or processes, such as drinking water, irrigation water and nature conservation. Natural water quality is determined by the geology, hydrology, and hydrogeological conditions of each basin, and is also subject to changes caused by a wide range of water pollutants. The natural conditions of raw water and its changes pose complex challenges to water treatment and water quality surveillance, e.g. the difficulty in addressing widespread practices of wastewater discharge, due to point and non-point sources of contamination. Therefore, specific quality requirements need to be considered depending on the contexts and uses of water (Balzergue et al., 2019).

Water quality monitoring is an integral part of drinking water supply, involving multiple variables that encompass a very complicated process. Establishing a monitoring programme is a highly complex task due to the work needed to establish the monitoring objectives as well as the human, technical, and financial capabilities, and to select the sampling points, water quality parameters, sampling frequencies and priorities, and legal compliance. It is also fundamental to consider the logistics and implementation of the programme, as well as the concise and accurate representation of the results (Behmel et al., 2016). Thus, water quality is not merely the sum of a particular set of parameters, it is also an indicator of the interplay between naturally occurring water components and anthropogenic pollutants (Balzergue et al., 2019).

Parameters

Following the risk management strategy outlined above (WHO, 2017), assessing the suitability of drinking water relates to the measurement and reporting of water quality parameters. The list of parameters to be monitored

1 Water safety planning is a comprehensive risk assessment and risk management approach that encompasses all the steps in the water supply from catchment to consumer.

2 Sanitary inspections are periodical evaluations to identify existing and potential microbiological hazards that could affect the safe use of a particular source of water.

3 Quantitative Microbial Risk Assessment (QMRA) is a mathematical framework for evaluating infectious risks from human pathogens, which can assist in understanding and managing waterborne microbial hazards, especially those associated with sporadic disease. QMRA is used as the basis for setting microbial health-based targets.

should reflect the conditions of the water at the source, the intended water use, as well as the local laboratory and financial capabilities. To assess water quality and ensure water is safe for human consumption, the measured parameters are usually compared against quality criteria that are local (Schriks, 2017; Zorzano, Donocik, & van Huijkelom, 2018), national (Dutch Ministry of Housing, 2011; Ministry of Health, 2017), regional (European Commission, 2018; UNECE, 1999), or international (WHO, 2017).

Based on the guidelines from WHO (2017) and Balzergue et al. (2019), water quality parameters can be classified as follows:

- Physico-chemical parameters: these reflect the intrinsic characteristics of water (e.g. temperature, electrical conductivity, suspended solids, acidity, organic compounds, inorganic compounds, COD) and the environmental conditions surrounding the water source (e.g. agrochemical substances, pesticides, leachates, industrial and pharmaceutical discharges).
- Biological parameters: these reflect the biological characteristics (dissolved oxygen, BOD) as well as the biological and microbiological composition of water at the source (bacteria, viruses, nematodes, and biological traces of insects).
- Calculated operational parameters: these refer to the calculation of relevant water quality indices such as saturation, corrosion, Langelier, and QMRA.

Table 1 lists some examples of different parameters and their categories.

Table 1. Parameter classification (adapted from Balzergue et al. (2019) and own work).

Category	Type	Example
Physico-chemical	General	Temperature, turbidity, conductivity, alkalinity, colour, odour, taste, suspended solids, COD
	Inorganic (compound)	Nitrate, nitrite, calcium dioxide, arsenic, boron, bromide, chromium, copper, lead, fluoride, manganese, mercury, calcium, chloride, potassium, magnesium
	Organic (compound)	Benzene, toluene, xylene, ethylbenzene, PAHs, aromatic hydrocarbons, trace organic compounds, persistent organic pollutants
	Agrochemical	1,2-dichlorobenzene, dmst, guanylureum, N,N-dimethyl-N'-p-tolylsulfamide (DMST), N,N-dimethylsulfamide (DMS), N′,N′-dimethyl-N-fenylsulfamide (DMSA)
	Pesticide	DDT, 2,4-D, MCPB, lindane, aldicarb, chlorthion, fenthion, malathion, terbufos-sulfone
	Industrial discharge	Tetraglyme, tertiair-amyl-methylether (TAME), perfluorodecanoic acid (PFDA), n-nitrosodiethylamine (NDEA), fluorene, diheptyl phthalate, 1,3-dichlorobenzene, chemical dyes, surfactants, exhaust fumes, precursors, food additives, petrol additives
	Pharmaceutical	Azithromycin, chloramphenicol, cortisone, paracetamol, progesterone, diclofenac, veterinary medicines
	Disinfectant	Chlorine
	Disinfectant by-product	Dichloroacetic acid, dichloromethane, monobromoacetic acid, bromate, NDMA
Biological	Biological	Dissolved oxygen, BOD
	Microbiological	Bacteria (*E. coli*, *C. perfringens*, *Enterococci*), virus (*Vibrio cholerae*), nematodes (wire worms), *Giardia*, *Cryptosporidium*, *Campilobacter*, cyanobacteria toxins
Calculated operational parameters	Index	Saturation index, corrosion index

The Decision Support Tool

Objective

The objective of this tool is to help water operators in deciding which parameters to monitor in each step of the water treatment and distribution process, from catchment to consumers. This tool could also support local, national, and international organizations in charge of designing plans for monitoring drinking water quality.

Methodology

Data sources

The tool is based on the WHO drinking-water quality guidelines (WHO, 2017), the list of parameters monitored by two major Dutch water utilities (Schriks, 2017; Zorzano et al., 2018), guidance on monitoring frequency and prioritization of parameters from the European framework directive (European Commission, 2018), and the Dutch Drinking Water Decree (Dutch Ministry of Housing, 2011). In addition, the tool incorporates elements from the Guidelines for Drinking-water Quality Management for New Zealand to establish the water treatment trains, parameter prioritization based on source evaluation, and monitoring frequency (Ministry of Health, 2017). The tool also reflects the hands-on experience of water quality and water safety planning experts who provided their input in the overall development, parameter classification and testing the tool in different settings.

Parameter classification

Data from different sources was gathered in a single database holding 1518 entries. This database was built using widely accepted guidelines: 240 parameters from the WHO guidelines (WHO, 2017), 115 parameters from the New Zealand guidelines (Ministry of Health, 2017), and 30 from the Dutch Drinking Water Decree (Dutch Ministry of Housing, 2011). It also includes parameters from the water quality monitoring programmes of Dutch water companies: 132 parameters from the Vitens-waterbedrijf monitoring program for rain water and groundwater (Schriks, 2017), 30 risk-based parameters from Brabant-water (Zorzano K et al., 2018), and 971 parameters from the online monitoring scheme of Waternet (personal communication).

The initial database was corrected to delete duplicated entries (either by name or chemical synonymic) and classified into generalizable categories, referred to as ‘Type’ of parameter. These categories align with the classification presented in Table 1. This categorization follows pre-established criteria from distinct data sources.

Establishment of simplified treatment trains

Simplified water treatment trains were established based on the bibliography and on expert knowledge.
For surface water, conventional water treatment was adopted, consisting of the following unit processes: coagulation, flocculation, sedimentation, filtration, and disinfection. For groundwater treatment, the following unit processes were considered: aeration, softening, filtration, GAC filtering, lime, and disinfection. Groundwater treatment trains were established, paying special attention to the condition and origin of the raw abstraction (i.e. aerobic, anaerobic, or river bank), that determine the standardized versions of the treatment trains.

It should be noted that, depending on the characteristics of the source water and the technological choices, the treatment train may include additional steps (e.g. ozonation, aeration).

Priority and frequency

This tool suggests priority categories and frequencies for the water quality parameters to be monitored in each step of the water treatment chain, based on the experience of the Dutch water sector.

Priority

Priority 1: tthe parameter provides essential information about the current state of the resource and is pivotal for the development of the following step in the treatment train (for example, temperature, pH, *E.coli*, copper, and lead). Some of the priority 1 parameters have a priority icon ⟨!⟩, indicating even higher priority.

Priority 2: the parameter provides useful information about the current state of the resource and is important for the development of the following step in the treatment train (for example, colour, ammonium, iron, dissolved oxygen, pesticides, and chemical solvents).

Priority 3: the parameter provides non-essential information about the current state of the resource, and it does not impede the operation of the following step in the treatment train (for example pharmaceuticals, food additives).

Frequency

Monitoring programs require adequate sampling frequencies to provide representative information about water quality. Frequency of sampling at the tap is generally established based on the population served or the volume of water supplied. It may also be a reflection of the quality of water at the source and the type of treatment. There is no one-size-fits-all approach to define how often a parameter should be measured. Therefore, the tool is structured with three tiers of monitoring frequencies:

- **Online or daily:** the parameter needs to be monitored with high frequency due to its public health implications and normative compliances (e.g. pH, free residual chlorine). It also considers those parameters whose concentration is needed to adjust the treatment process (e.g. temperature, turbidity, pH, and dissolved oxygen); for example, free residual chlorine is needed to adjust chlorine dosage. This category also includes parameters that should have a frequent measurement at the beginning of the monitoring program, and whose frequency can be decreased after one year of measurements.
- **Weekly to monthly:** the parameter needs to be monitored with medium frequency to adjust for the following steps of the treatment process (for example, bromate, bromide, chromium, copper, fluoride). This category also includes parameters whose frequency of monitoring will depend on water quality and pollution assessment at the source.
- **Monthly to yearly:** the parameter needs to be monitored with low frequency due to legal compliance requirements, sources of pollution in the catchment, and overall evaluation of the treatment process (for example, pesticides, chemical solvents, persistent organic pollutants, food additives).

Practical guidance for using this tool

Downloading and saving

This tool is available for downloading from the BEWOP webpage. It is advisable not to modify the name of the file in order to avoid losing its properties.

Customizing the tool

If needed, the tool can be adapted to add/delete steps in the treatment trains. Contact us if you wish to personalize the tool for your own water treatment facility.

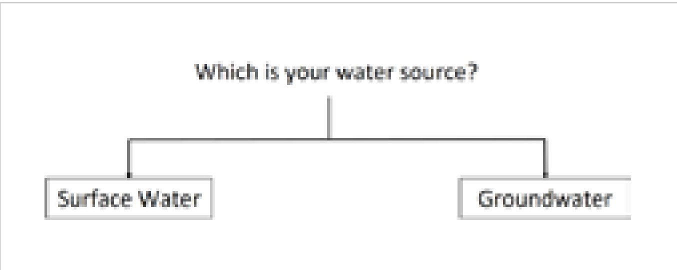
Step-by-step guide

Download and save the tool in an accessible file, and make sure that when you save the file you retain exactly the same name in order to avoid loss of information or the format.

Which is your water source?

The first question the tool requires you to answer refers to the origin of the water (Figure 1).

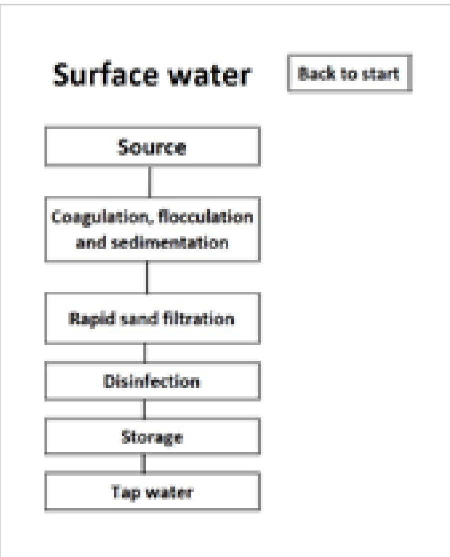
Figure 1. Initial page.



Surface water

If you select 'Surface water', you will see the treatment train for this type of water source. It consists of six steps (see Figure 2), and each step entails the monitoring of distinct water quality parameters.

Figure 2. Surface water treatment train.

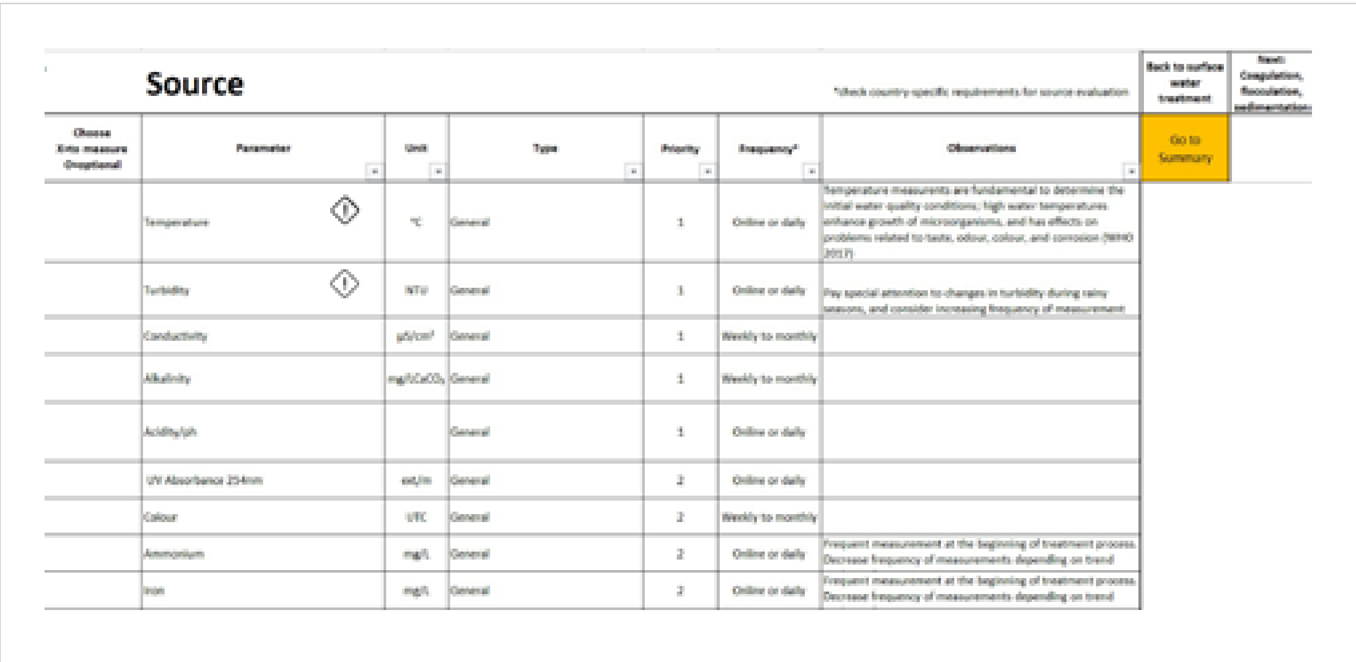


Treatment steps

When clicking on any button of the treatment train, you will be directed to a page showing the list of parameters considered for each step. For example, if you click the **Source** button, you will see a display of a set of 723 different parameters to be considered for water quality assessment at the source. Bear in mind that it is not necessary to measure the entirety of the list, instead try to use this information as a way to understand the water source. Identify possible water contaminants up-stream, the history of pollution events, and the general composition of the raw water to be treated. You can also filter the list depending on the priority or frequency of monitoring to reduce the number of parameters being displayed (see Figure 3).

Each list can be filtered by each category (i.e. type of parameter, priority, frequency). Also, after revising and assessing which parameters will be part of your monitoring scheme, you can use the **Choose** button to indicate if the parameter will be measured (by using the X) or if it is an optional parameter (by using the O). After choosing the preferred parameters, you can click on the **Go to summary** button to go to a page where all the chosen parameters will be displayed. To go to the next step in the treatment train, click on the top right-hand button.

Figure 3. List of water quality parameters for source assessment.



Source

*check country specific requirements for source evaluation

Back to surface water treatment | Next: Coagulation, flocculation, sedimentation | Go to Summary

Choose X=to measure O=optional	Parameter	Unit	Type	Priority	Frequency*	Observations
	Temperature	°C	General	1	Online or daily	Temperature measurents are fundamental to determine the initial water quality conditions; high water temperatures enhance growth of microorganisms, and has effects on problems related to taste, odour, colour, and corrosion (WHO 2017)
	Turbidity	NTU	General	1	Online or daily	Pay special attention to changes in turbidity during rainy seasons, and consider increasing frequency of measurement
	Conductivity	µS/cm²	General	1	Weekly to monthly	
	Alkalinity	mg/l CaCO₃	General	1	Weekly to monthly	
	Acidity/pH		General	1	Online or daily	
	UV Absorbance 254nm	ext/m	General	2	Online or daily	
	Colour	UTC	General	2	Weekly to monthly	
	Ammonium	mg/L	General	2	Online or daily	Frequent measurement at the beginning of treatment process. Decrease frequency of measurements depending on trend
	Iron	mg/L	General	2	Online or daily	Frequent measurement at the beginning of treatment process. Decrease frequency of measurements depending on trend

The final treatment step will show a page with a comprehensive list of parameters that are of importance to consider for the final drinking water, consisting of 134 parameters. This list contains values for the WHO guidelines (2017) and the Dutch decree (2011) (see Figure 4).

Figure 4. List of water quality parameters for clear water storage and tap water.

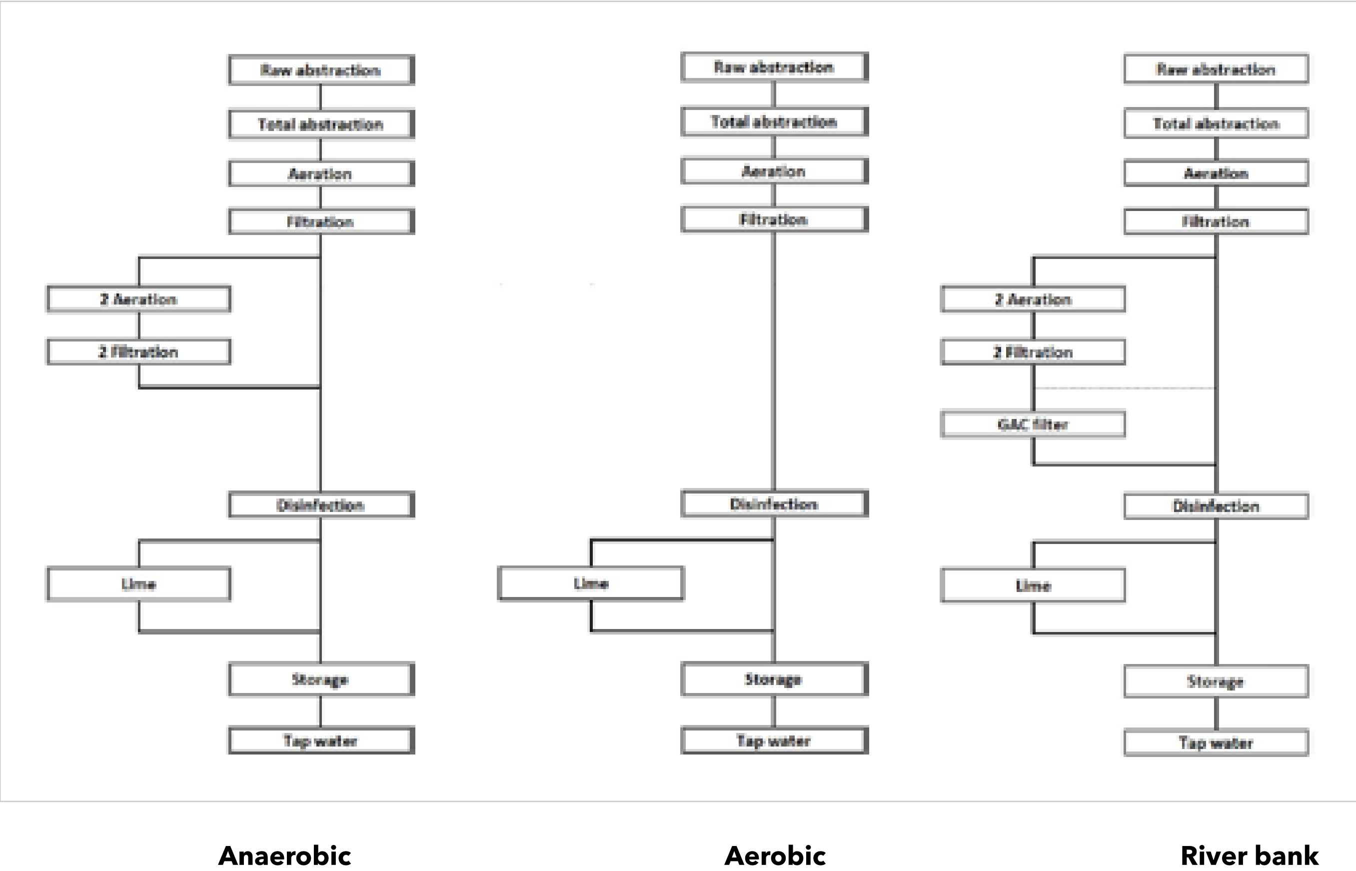
Groundwater

If the source to treat is groundwater (Figure 1), click on this option. First, the tool helps users to establish whether the groundwater to be treated is **aerobic**, **anaerobic**, or abstracted from a **river bank** (Figure 5). The first two can be determined by assessing the dissolved oxygen concentrations at the source. The 'River bank' option refers to groundwater abstracted at river-bank level, where superficial aquifers are more exposed to surface water contamination. Choose one of these options depending on the initial characteristics of the groundwater source.

Figure 5. Groundwater source.

Three different treatment trains will be displayed depending on the type of source (see Figure 6). If your source is anaerobic, the treatment will entail additional steps of aeration and filtration; if the source is aerobic, the treatment train entails disinfection after the first round of aeration-filtration. If the source comes from river bank abstraction, the treatment train guides you to develop additional rounds of aeration-filtration followed by an optional round of GAC filtering (which will depend on the concentration of persistent pollutants in your treated water).

Figure 6. Aerobic, anaerobic, and river bank groundwater treatment trains.

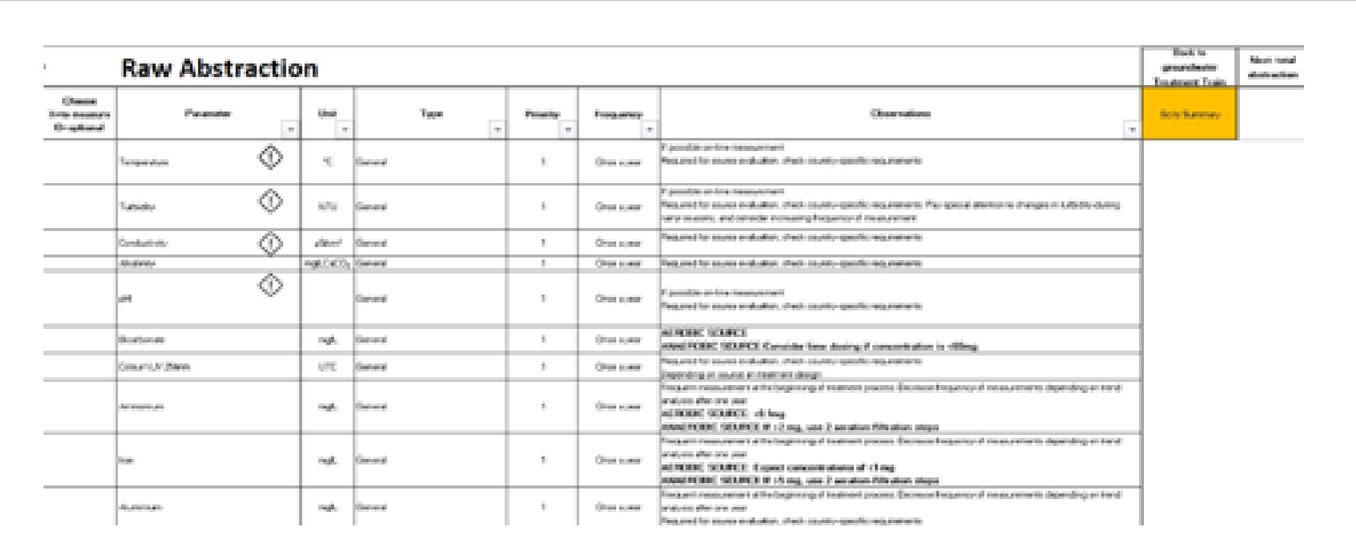


The first four steps are the same in the three groundwater treatment trains. The **Raw abstraction** and **Total abstraction** steps indicate the possibility that you might be abstracting water from more than one well, meaning you may have one step of monitoring at the actual source and then another at the point where water is gathered before entering the treatment facility.

Treatment steps

The parameters included in the first four steps of the treatment train guide you to analyse the water source in terms of oxygen concentration (<1mg), methane, colour, H_2S, pH, HCO_3, VOCs, nitrates, and other sources of contamination. Iron concentrations will indicate whether additional aeration-filtration steps are needed – in general, it is common to include 2 aeration-filtration steps if concentrations of iron are >5 mg/L. Similarly, if the concentration of ammonium (NH_4) is >2 mg/L it is recommended to include 2 aeration-filtration steps. Make sure to check the **Observations** column, since specific conditions for either aerobic or anaerobic sources apply (Figure 7).

Figure 7. List of water quality parameters for abstraction wells.

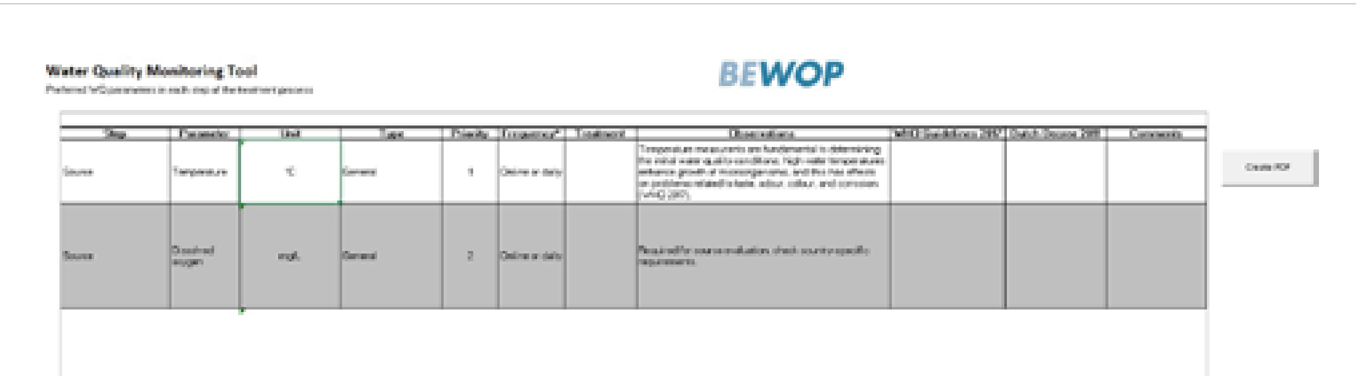


The lists, parameters, and requirements of the following steps will depend on the type of source, the treatment train followed, and the design of the monitoring scheme.

Additional features

When you click on the **'Go to measurements'** button, you will be directed to a page that will show the parameters you have chosen. You will see an overview of the parameters and their characteristics, and an additional column where you can add your own comments. The parameters chosen as optional will appear shaded in grey. Once you have decided on a full list, you can click on the **'Create PDF'** button, which will create a PDF report of the preferred parameters to monitor in each step of the water treatment process (Figure 8).

Figure 8. Summary page showing preferred parameters.



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Notes

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