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'Natural' recharge of groundwater: bank infiltration in the Netherlands

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ABSTRACT

In the Netherlands 5% of the drinking water is produced from bank infiltrated surface water. The catchment with this recharge method amounted in 1999 to 62.4 million m^3. This is performed by 17 catchment areas.

The median travel time during the aquifer passage varies between 3.8 and 250 years. The contribution of surface water in the abstracted bank infiltrated water varies between 20 and 100%, and the quality of the abstracted water is strongly influenced by this aquifer passage.

Nowadays, three important challenges for the production of drinking water from bank infiltrated surface water are (polar) organic micropollutants, hardness and chloride. In the Netherlands 13 treatment plants have been installed. Since 1985 several additional treatment steps have been implemented to cope with this challenges. Treatment with anaerobic nanofiltration is very promising to cover all three challenges.

Key words | bank infiltration, bentazone, treatment philosophy, nanofiltration

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INTRODUCTION

In the Netherlands 65% of the drinking water is produced from groundwater and 21% from surface water (by storage reservoirs or direct intake). The remaining 13% is produced from infiltration of surface water. There are two methods of infiltration, or artificial recharge, in use:

- Dune infiltration, artificial recharge of groundwater
- Bank infiltration, 'natural' recharge of groundwater

In this paper the state of the art of bank infiltration in the Netherlands is presented. Attention will be paid to a SWOT-analysis (Strength, Weaknesses, Opportunities and Threats) of this method of catchment and treatment.

The catchment of bank infiltrated surface water has a long history. The oldest, still existing, catchment area was founded in the 19th century (at Nijmegen, in 1879). In 1999 the production of drinking water in the Netherlands from bank infiltrated surface water amounted to 62.4 million m^3 $year^{-1}$. This is 5% of the total Dutch drinking water supply, covered by 13 treatment plants.

Bank infiltrated surface water is a mix of groundwater and surface water. Raw water is called bank infiltrated surface water if at least 10% of the raw water originates from a river (Van der Kooij 1985). In practice, the amount of surface water in the abstracted water varies between 20 and 100% (Annex 1). The mean value is 62%. This raw water source has the advantages of both groundwater and surface water. Quality and quantity of the abstracted water depend on the distance to the river (130–1300 m, mean value 655 m) and the soil properties (sand, clay and peat).

QUANTITY

Due to the addition of surface water, the capacity of the well field is bigger than a comparable groundwater area. The availability of water is high, also in dry seasons. Because the reduction of groundwater abstraction (by 25%) is currently an objective of the Netherlands water supply companies, bank infiltration is an important alternative for groundwater abstraction. The capacity of a bank infiltration system is lower than a direct intake of surface water. The advantage compared with direct intake of surface water is that no raw water reservoir is needed, which reduces space requirements.

To develop a new catchment area for bank infiltration, the important design parameters are:

- the desired capacity of the well field;
- the (minimum) residence time of the water in the riverbank;
- the orientation of the wells to the river (distribution of residence times).

For the minimum residence time water supply companies make use of a rule of thumb of two months to obtain raw water free of pathogens. A study to prove this empirical value (based on the protection of groundwater) shows that a residence time of two months is a safe approach (Van Olphen *et al*. 1993).

To prepare safe drinking water from surface water a DEC (decimal elimination capacity) of 10 for viruses is needed (Smeets 1995). Modelling of the removal of viruses with a DEC-value of 0.6 day^{-1} showed that with a residence time of 25 days the minimum distance of the wells to the river should be 25 m.

Raw water quantity: existing catchment areas

The catchment areas in the Netherlands with bank infiltration receive all surface water from the river Rhine or one of its side rivers. Some characteristics of the existing catchment areas for bank infiltration are:

- The raw water abstraction in 1999 of the 17 existing well fields varied between 0.37 and 12.9 million m^3 $year^{-1}$, mean value 3.67 million m^3 $year^{-1}$. This raw water is transported to 13 treatment plants (see below).
- The mean distance of the well fields to the river varies between 130 and 1,300 m. The median travel time of the water (T_{50}) varies between 3.8 and 250 years.
- The minimum distance of one well field (De Elzengors, WZHO) is 21 m. The minimum residence time is in this case 8 weeks. The minimum distance for the other well fields varies between 150 and 1,020 m.
- The orientation of the well fields: three are parallel with the river, four have a right angle to the river and ten have no orientation (cluster of wells).
- Not all the catchments started with the objective of bank infiltration. For instance the catchment area Engelse Werk (WMO) started in 1952 as a groundwater abstraction. By improving the abstraction the catchment turned to bank infiltration.

The data of the 17 existing catchment areas (and 1 new catchment area) are summarised in Annex 1. The catchment areas for bank infiltration are ordered by increasing median travel times (T_{50}, in years).

SWOT-analysis: quantity

In contrast to the situation in Germany, the Dutch well fields have no problems with clogging of the river bottom (Van Dijk 1993). Probably this is caused by lower abstraction rates in the Netherlands.

A weak point is that the well fields are not configured to perform optimal peak reduction. This is compensated in practice with long median travel times (T_{50}>3.8 years). The disadvantage of long median travel times is that if sanitation measures are performed it takes a very long time for the pollution to disappear from the riverbank.

An opportunity is that there is an abundance of riverbanks in the Netherlands. A threat can be the clogging of wells by small particles (experience of WZHO).

QUALITY

The travel time of the surface water to the wells is at least two months. Through the soil passage the bank-filtered

 Journal of Water Supply: Research and Technology—AQUA | 52.1 | 2003

Table 1 | Processes during bank infiltration (Van der Kooij 1985)

Parameter		Removal
Pathogenic micro-organisms	T > 2 months	100%
Colloidal/suspended matter		100%
Precipitation/adsorption trace-elements		75–100%
Organic matter and nutrients	DOC	50–75%
	UV-extinction	50–75%
	NO_3	50–100%
	PO_4	75–90%
Organic micropollutants (decomposition and adsorption)	AOX	25–50%
	VOCl	25–50%
	EOCl	50–75%
	Taste	0–25%
	Pesticides	0–100%
Specific groundwater components	Fe, Mn, NH_4, CH_4, hardness	Increase
Mix with groundwater	Cl^-	Decrease

water is free of pathogens and algae. The bank-filtered water has a constant temperature and a stable groundwater composition, containing iron, manganese, ammonia and methane.

The disadvantage of this type of catchment is that there is no barrier for organic micropollutants originating from the surface water. Lower concentrations of organic micropollutants are obtained by dispersion, mixing with groundwater and (in some cases) by anaerobic decay. The processes that take place in the riverbank are summarised in Table 1.

For the production of drinking water from bank infiltrated surface water, three (groups of) parameters have proved to be very important (Stuyfzand and Lüers 1996; Stuyfzand and Kooiman 1996):

Organic micropollutants

In 1987 and 1989, due to improved analytical methods, two 'new' organic micropollutants were detected in the river Rhine as well as after riverbank filtration. Both micropollutants are polar compounds (log $K_{ow}<3$).

The pesticide bentazone was discovered in the drinking water of Amsterdam (1987) above the guideline of 0.1 μg l^{-1} (Netherlands Drinking Water Decree). The source was a long-existing discharge of wastewater from BASF in Ludwigshafen, Germany (Smeenk *et al*. 1988).

Dikegulac was discovered in the river Rhine in Germany in 1989 (Hopman *et al*. 1990). Its origin in the river was due to two chemical factories, as a side-compound of the production of vitamin C. Because dikegulac-sodium is also used as a growth regulator in market gardening the guideline of 0.1 μg l^{-1} applies. Dikegulac is a more polar compound than bentazone.

Hardness

During bank infiltration hardness increases (Table 1). Low hardness of drinking water offers comfort to consumers. Higher values for hardness are connected to higher values for the solubility capacity of copper (Cu_s). With the revision of the European guidelines for drinking water the guideline for Cu_s was lowered from 3 to 2 mg l^{-1}. The practical consequence of this modification is that the hardness of the drinking water may not exceed 2 mmol l^{-1}.

Chloride

Since 1880 the chloride content of the river Rhine increased from about 20 mg l^{-1} to the highest values in 1971 (238 mg l^{-1}) and 1976 (227 mg l^{-1}), this increase was due to French salt mines (Vreedenburgh and van Zanten 1991). After 1976 the quality of the river Rhine improved.

Higher values for chloride (>100 mg l^{-1}) and sulphate are causing corrosion of cast iron followed complaints by consumers about brown water.

Raw water quality: existing catchment areas

The data of the 17 existing catchment areas are summarised in Annex 2. The catchment areas are placed in the same order as the table in Annex 1 (increasing median travel times, T_{50}). The following conclusions can be derived from these data:

- The concentrations for bentazone and dikegulac in the raw water are exceeding the guide level for drinking water (0.1 μg l^{-1}) in 11 and 10 catchment areas, respectively.
- Sanitation measures for bentazone (in the middle of 1988) and dikegulac (1 October 1989) have had a positive effect, which can be demonstrated in catchments with T_{50}<10 years. The mean value of bentazone in the bank infiltrated surface water (first six catchments in Annexes 1 and 2) decreased from 0.84 μg l^{-1} in 1988 (Hopman *et al*. 1990) to 0.17 μg l^{-1} in 1999. In the catchment area with the shortest T_{50} (3.8 years, Lekkerkerk/Schuwacht) the levels of both pollutants 10 years after the sanitation measures are below the guideline level of 0.1 μg l^{-1}.
- In the three catchment areas with longest T_{50} (>150 years) the influence of the river is absent or very small (low values for chloride, sulphate, AOX and bentazone).
- The catchment areas with a T_{50}<50 years and a percentage bank infiltrated surface water>30% have chloride levels>100 mg l^{-1}.
- The hardness of the abstracted water is in all catchment areas higher then 2 mmol l^{-1}. The mean value is 2.6 mmol l^{-1} (min 2.0–max 3.5).

To demonstrate how long bentazone will be present in the riverbank after sanitation measures, a prediction for the raw water of catchment area 'De Put' (WZHO) was made (Van der Linden and Dijkhuis 1998) (see Figure 1). The bentazone in 'De Put' comes from two directions, the river Rhine contributing 75% in the abstracted water, and polder water contributing 25%. The bentazone content in the polder water is supposedly 10 times lower than that in the River Rhine. Because for the period 1970–1988 there are no data for bentazone available, the input of bentazone has been reconstructed based on well known travel times

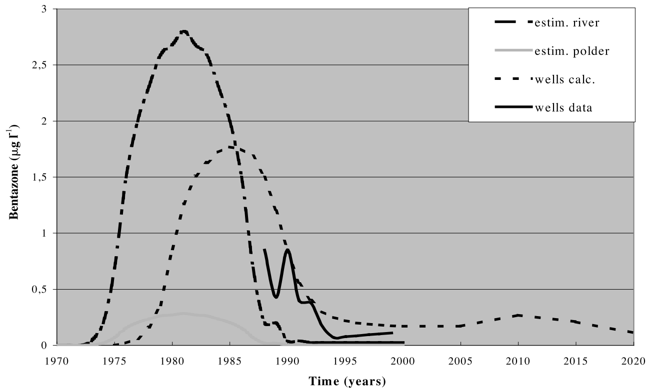

Figure 1 | Prediction of bentazone of raw water at 'De Put' (WZHO).

of wells that contain bentazone. Chloride is used for verification of the model.

The response of the wells is influenced by the two different input signals (river and polder), and it can be concluded that until 2020 the concentration of bentazone will stay above 0.1 μg l^{-1}. In Figure 1 the calculated response of the wells and the measured values are plotted.

SWOT-analysis: quality

The strong points of bank infiltration are the smoothing of peaks and the removal of substances, e.g. radionuclides (Sybrandi 1990), heavy metals (Stuyfzand and Lüers 1996; Stuyfzand and Kooiman 1996) and suspended matter. Further strong points are the absence of faecal contamination and the constant composition and temperature.

Weak points of bank infiltration are the reaction on continuous loads, especially when sanitation measures took place (e.g. chloride and bentazone), the impossibility of stopping the infiltration and the increase in hardness.

An alternative for the pre-treatment of surface water (coagulation, sedimentation and filtration) is the use of riverbank filtration (opportunity). Table 1 gives an overview of the processes that take place in the riverbank.

A threat is the uncertainty about the presence of polar compounds, which are (possibly) not removed through the installed treatment processes.

 Journal of Water Supply: Research and Technology—AQUA | 52.1 | 2003

Table 2 | Overview of the installed treatment processes in 1999

No.	WSC	Water treatment plant (*scheme 1999*)	Standard groundwater treatment (softening included)						Additional treatment		
1	WZHO	Lekkerkerk	AER	DRSF	AER	RSF				GAC	UV
2	WZHO	't Kromme Gat	AER	DRSF	AER	RSF				GAC	UV
3	WZHO	C. Rodenhuis	AER	RSF	AER	RSF				GAC	UV
4	WZHO	De Put	AER	DRSF	AER	RSF				GAC	UV
5	WZHO	Hendrik Ido Ambacht	AER	DRSF	PS	AER	RSF			GAC	UV
6	WMO	Engelse Werk	AER	RSF	AER	RSF				GAC	AER
7	WZHO	De Elzengors	AER	DRSF	AER	DRSF			OZON	GAC	UV
8	WZHO	De Hooge Boom	iAER	DRSF	PS	RSF				GAC	UV
9	WZHO	Reijerwaard	iAER	DRSF	AER	DRSF	PS	RSF		GAC	UV
10	WGe	Lent	AER	RSF						GAC	
11	NUON	Nieuwe Marktstraat	iAER	PS	RSF					GAC	UV
12	WZHO	De Steeg (groundwater)	iAER	RSF							
13	WZHO	De Laak	iAER	RSF							

→
Order treatment processes

Legend
OZON, ozone dosage; GAC, granular activated carbon filtration; UV, UV-disinfection; AER, aeration; iAER, intensive aeration; RSF, rapid sand filtration; DRSF, dry rapid sand filtration; PS, pellet softening.

TREATMENT

Until 1985 the treatment of bank infiltrated surface water was executed with standard groundwater treatment, like aeration and filtration. At two plants there was an additional step in the water treatment, to remove taste and odour from the water. This taste and odour gave rise to consumer complaints because of the presence of taste-affecting compounds originating from the river water. The additional treatment step was performed with ozone (De Elzengors) and granular activated carbon filtration (De Put). Softening of the water was applied at five plants, but these plants are all now out of production.

Disinfection is not applied for bank infiltrated surface water (Van der Kooij 1985).

Existing treatment schemes

The water abstracted by the 17 catchment areas (Annex 1/2) is transported to 13 treatment plants. In Table 2 (ordered by increasing T_{50}) an overview is presented of the installed treatment processes in 1999. A difference is made between standard groundwater treatment (softening included) and additional treatment. The following conclusions can be derived from these data:

- Standard groundwater treatment processes:

- The first nine treatment plants have double rapid sand filtration
- At five plants the first step is intensive aeration to remove methane and in the case of Nieuwe Marktstraat volatile organic micropollutants (influence of the city)
- At seven of ten plants, WZHO uses dry rapid sand filters (DRSF), owing to high ammonia contents. The mean value for ammonia for these plants is 4.2 mg l^{-1} (min 2.18 mg l^{-1}, max 10.5 mg l^{-1}). For the other six plants the mean ammonia content amounts to 0.89 mg l^{-1}
- At only 4 of 13 hardness removal (with pellet softening) is installed.

• Additional treatment processes:

- At 11 of 13 plants granular activated carbon (GAC) filtration is installed. At nine plants the installation of GAC-filtration was performed after the discovery of bentazone in the abstracted raw water (Versteegh 1989; Van der Toorn 1993)
- To reduce the HPC values of the GAC filtrates, especially after reactivation, WZHO uses ultraviolet disinfection (Van der Toorn 1993)
- The high values for chloride are not solved by treatment techniques. Most water supply companies try to use mixing with (low chloride) groundwater.

SWOT-analysis: treatment

The strong points of the applied treatment schemes are that the treatment is less complicated than the treatment of surface water, that bentazone is well removed with GAC-filtration and that with this scheme biostable drinking water is produced (Van der Kooij *et al*. 1999). Also a strong point is that the quality of the drinking water meets all requirements of the Dutch Guidelines, except for dikegulac. The responsible authorities tolerate this situation, because of the properties of this component.

Compared with direct treatment of surface water no coagulation/sedimentation is needed. That causes the generation of fewer residuals and lowers production costs.

A weak point is the absence of barriers for (harmful) polar organic micropollutants.

An opportunity is to find an economical solution for the remaining challenges, a barrier for polar organic micropollutants and the higher values of hardness and chloride. At this moment just four plants have installed hardness removal and two are under construction. This is a great opportunity to develop a strategy for dealing with the remaining challenges.

A threat is that components in the bank filtrate have been discovered for which the present treatment scheme forms no barrier.

Treatment philosophy

The strategy for dealing with the remaining challenges (see above) has to be based on a treatment philosophy. The outlines of the treatment philosophy of the water supply companies involved are:

- Physical processes are preferred to chemical processes (to avoid the formation of harmful oxidation by-products)
- To produce biostable drinking water without disinfectant residual (Van der Kooij *et al*. 1999)
- To produce chemically stable drinking water (prevention of corrosion in the distribution system).

In general the water supply companies prefer source-oriented measures instead of end-of-pipe solutions, like water treatment.

As a first indication of which unit operations are able to deal with the treatment challenges mentioned above, Table 3 gives an overview of (selected) possibilities. Based on Table 3 it can be concluded that:

- Nanofiltration and reverse osmosis are the only unit operations that can solve all three challenges.
- The classic unit operations of pellet softening in combination with activated carbon or advanced oxidation cannot solve the chloride problem.
- Activated carbon and ozone ($\pm H_2O_2$) cannot remove/oxidise sufficiently the more polar organic micropollutants (like dikegulac).
- The UV/H_2O_2-process is very promising (Kruithof *et al*. 2000) because bromate formation is absent.

Table 3 | Overview of possible removal efficiencies (based on Hopman 1990, 1998; Kruithof 2000)

Unit operation removal percentages Parameters	Classic unit operation		Membrane filtration		(Advanced) Oxidation		
	Pellet Softening	GAC-filtration	Nano-filtration	Reverse osmosis	Ozone	Ozone/ H_2O_2	UV/ H_2O_2
Org. micropollutants							
Dikegulac		± 10%	± 90%	± 90%	10–15%	± 30%	
Bentazon		± 90%	> 90%	> 90%	± 80%	± 90%	± 80%
MCPP		± 90%	> 90%	> 90%	± 75%	± 90%	
Diuron		± 90%	> 90%	> 90%	± 75%	± 90%	± 90%
Hardness							
Ca + Mg	Adjustable		60–85%	± 99%			
Chloride							
Cl			40–65%	> 95%			

The disadvantage of this process is that the hardness and chloride removal is not covered.

From an economic point of view membrane filtration is a very interesting treatment technique, especially when all three challenges have to be solved at the same time.

New concepts and research

Based on the above-mentioned treatment philosophy new concepts are developed and research has been executed to test some of these concepts in practice. Five different approaches can be distinguished (combinations are possible):

1. Double aquifer passage
2. Enlargement of scale
3. Optimisation of unit operations
4. Application of membrane filtration
5. Project WNF 'living rivers'

Double aquifer passage

Between 1993 and 1998 WMN developed the OEDI-concept as a solution for the necessary reduction of groundwater abstraction (Jutte and Roelofs 1995; Adamse and Kruithof 1998). The concept includes surface water abstraction by way of (anaerobic) bank filtration within a short distance of the river Rhine (travel time 2 weeks). After pre-treatment the water will be transported (≈15 km) to an infiltration area, where a second (aerobic) aquifer-passage (travel time 1 year) will take place, followed by post-treatment. The concept, with 10 treatment scenarios, was developed for 15 million m^3 $year^{-1}$. The advantage of this specific concept is that the existing infrastructure can be maintained.

Enlargement of scale

WZHO has executed a strategy to enlarge the scale of treatment by closing smaller treatment plants and transporting the raw water to a central treatment facility (e.g. WTP C. Rodenhuis). This makes investments in additional treatment, like GAC-filtration, more cost-effective. Also some catchment areas were closed permanently and a new and enlarged catchment area developed (De Steeg).

Optimisation of unit operations

At 11 of 13 treatment plants GAC-filtration is applied. To save costs of GAC-reactivation, WMN, WGe and WZHO

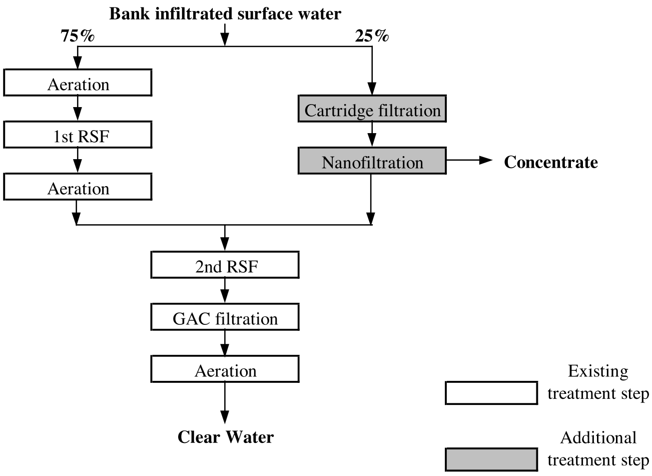

Figure 2 | Design of treatment plant Engelse Werk (WMO).

performed research with advanced oxidation (AOP) to extend the time between two reactivations. The application of a soft oxidation regime (ozone/H_2O_2), prior to GAC, resulted in a twofold lengthening of the running time of GAC, while bromate formation stayed just below 0.5 μg l^{-1} (Meijers *et al*. 1999). The results with UV/H2O2 (Kruithof *et al*. 2000) are also very promising for application in the treatment of bank infiltrated surface water.

Successful research is going on in WZHO to understand and improve on phenomena like additional artificial recharge, clogging of wells by small particles and underground aeration for improving nitrification in the rapid sand filters.

Application of membrane filtration

WMO has planned to reduce hardness at the treatment plant Engelse Werk by the application of nanofiltration. To avoid membrane fouling, split treatment of anaerobic feed water will be applied (Hiemstra *et al*. 1999) (see Figure 2). To improve the quality of the drinking water further, the wells with the highest percentage of surface water will be selected for the nanofiltration extension.

Table 3 shows the results of the WMO research with nanofiltration at Vechterweerd (a new site for bank infiltration) (Van Paassen *et al*. 1998; Hopman 1998). With a MWCO (molecular weight cut off) of about 200, nanofiltration is able to remove the 10 tested pesticides by between 83 and 99% (Hopman 1998). Also WZHO have performed research with anaerobic nanofiltration on bank infiltrated surface water (De Hooge Boom).

Project WNF 'living rivers'

To stimulate the development of nature in forelands (the areas close to a river between the summer and winter dykes that are dry in summer and flooded in winter) WNF published in 1992 the plan 'living rivers' (Wereld Natuur Fonds 1992). By removing clay layers and creating side-channels the formation of a new landscape is stimulated (higher acceptance by society) and infiltration is improved. This was applied in the catchment area Engelse Werk (WMO).

CONCLUSIONS

Bank infiltration has proved to be a reliable system for the 'natural' recharge of groundwater in the Netherlands. It combines the advantages of groundwater (free of pathogens) and surface water (availability). To solve the challenge of the (polar) organic micropollutants, mainstream treatment with anaerobic nanofiltration and the newly developed UV/H_2O_2-process are very promising. Application of nanofiltration is more cost-effective if the removal of hardness and/or chloride are also objectives.

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Annex 1 | Data quantity: catchment areas bank infiltration in the Netherlands

No.	WSC	Name well field/WTP	City	Remark	Water abstraction '99 10^6 m^3/yr	Percentage bank infiltration surface water	Orientation wells	Distance wells—river Min (m)	Distance wells—river Mean (m)	Distance wells—river Max (m)	Travel time Min (year)	Travel time T_{50}* (year)
1b	WZHO	Lekkerkerk (Schuwacht)	Lekkerkerk	Well field 1b (35%)	1.07	85%	N	160	205	260	0.4	3.8
2	WZHO	't Kromme Gat	Hardinxveld-Giessendam		1.06	98%	R	230	350	475	1	4
3c	WZHO	Schoonhoven (Rodenhuis)	Schoonhoven	Well field 3c (3%)	0.37	100%	N	290	310	325		6
4	WZHO	De Put	Nieuw-Lekkerland		3.40	78%	P	580	630	720	1.5	7.6
5	WZHO	Hendrik Ido Ambacht	Hendrik Ido Ambacht		0.86	52%	P	200	300	490		8
3b	WZHO	Dijklaan (Rodenhuis)	Bergambacht	Well field 3b (5%)	0.72	84%	N	550	580	600		8
3a	WZHO	Rodenhuis (WTP)	Bergambacht	Well field 3a (92%)	12.94	59%	P	570	810	1060	2	10
6	WMO	Engelse Werk	Zwolle		10	67%	N	600	815	1000	3	12
7	WZHO	De Elzengors	Zwijndrecht	2 clusters of wells	3.03	40%	N	21	130	280	0.15	20
8	WZHO	De Hooge Boom	Kamerik		2.88	20%	N		± 1000			25
1a	WZHO	Lekkerkerk (Tiendweg)	Lekkerkerk	Well field 1a (65%)	1.95	67%	R	1020	1250	1460	6	25
9	WZHO	Reijerwaard	Ridderkerk		2.96	61%	R	500	940	1500	1.8	35
10	WGe	Lent	Lent		0.92	26%	N	295	350	425	6	50
11	NUON	Nieuwe Marktstraat	Nijmegen		4.03	43%	N	260	470	670	12	55
12b	WZHO	De Steeg (BI, extension)	Langerak	Extension BI water (12b)	(+ 5)	76%	R	150	450	750		83
13b	WZHO	De Laak (Vianen)	Vianen	Well field 13b (7%)	0.75	33%	N		500			181
12a	WZHO	De Steeg (groundwater)	Langerak	Well field 12a (100%)	6.11	75%			± 1200			210
13a	WZHO	De Laak/WTP	Lexmond	2 well fields 13a (93%)	9.36	67%	N	1000	1300	1700		250

T_{50}*, Median travel time; Total abstraction 1999, 62.4$*10^6$ m^3. P=Parallel with river; R=right angle to river; N=no orientation (cluster of wells).

Journal of Water Supply: Research and Technology—AQUA | 52.1 | 2003

Annex 2 | Data quality: raw water bank infiltrated surface water in the Netherlands

No.	WSC	Name well field *Raw water 1999*	Fe mg l^{-1}	Mn mg l^{-1}	NH4 mg l^{-1}	CH4 mg l^{-1}	Cl mg l^{-1}	SO4 mg l^{-1}	tot. hh mmol l^{-1}	DOC mg l^{-1}	AOX µg l^{-1}	MCPP µg l^{-1}	Bentazone µg l^{-1}	Dikegulac µg l^{-1}
1b	WZHO	Lekkerkerk (Schuwacht)	2.72	0.96	2.07	0.43	138	56	2.5	2.6	9	< 0.05	0.04	0.08
2	WZHO	't Kromme Gat	2.12	0.85	2.82	0.26	140	54	2.6	2.4	9	0.06	0.35	0.32
3c	WZHO	Schoonhoven (Rodenhuis)	1.70	0.70	1.41	0.03	144	80	2.4	2.0	14	< 0.05	0.25	1.65
4	WZHO	De Put	2.00	0.53	3.34	1.05	111	57	2.4	2.5	11	< 0.05	0.11	0.44
5	WZHO	Hendrik Ido Ambacht	5.32	0.76	2.18	0.36	135	62	2.5	2.7	11	< 0.05	0.13	0.25
3b	WZHO	Dijklaan (Rodenhuis)	2.08	0.65	1.05	0.04	140	75	2.5	2.2	11	< 0.05	0.15	0.56
3a	WZHO	Rodenhuis (WTP)	1.72	0.68	1.00	0.17	118	65	2.5	2.1	10	< 0.05	0.18	0.48
6	WMO	Engelse Werk	4.75	0.53	0.74	0.11	110	58	2.4	2.6	8	< 0.05	0.18	0.3
7	WZHO	De Elzengors	2.45	0.52	3.15	1.84	125	30	2.6	4.2	14	< 0.05	0.05	0.09
8	WZHO	De Hooge Boom	8.44	0.54	3.52	1.62	76	53	3.5	8.1	10	< 0.05	0.06	0.19
1a	WZHO	Lekkerkerk (Tiendweg)	4.78	0.61	4.97	0.85	140	51	2.4	2.9	13	0.09	0.39	0.82
9	WZHO	Reijerwaard	5.21	0.39	10.49	7.14	138	5	3.4	4.7	< 5	< 0.05	0.16	0.07
10	WGe	Lent	1.56	0.75	1.94	nd	98	54	3.4	1.3	< 5	< 0.05	0.32	nd
11	NUON	Nieuwe Marktstraat	0.5	0.3	0.1	nd	66	55	2.3	0.8	11	< 0.05	0.14	nd
12b	WZHO	De Steeg (BI, extension)	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
13b	WZHO	De Laak (Vianen)	0.91	0.18	0.26	2.93	10	3	2.4	2.4	< 5	< 0.05	< 0.01	0.02
12a	WZHO	De Steeg (groundwater)	1.26	0.08	0.96	2.71	11	7	2.0	3.4	< 5	< 0.05	< 0.01	< 0.02
13a	WZHO	De Laak/WTP	0.83	0.11	0.61	1.09	25	16	2.3	2.2	< 5	< 0.05	0.03	0.26

nd, No data available.