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Sampling Strategy for Karst Waters

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Introduction

Karst waters are highly dynamic systems in terms of water flow and water quality changes (1, 2). These changes should be considered when defining sampling strategies for drinking water controls. When assessing results from drinking water controls, it is crucial to know if base flow or peak flow was monitored. This however, requires the knowledge of the local system behaviour. Routine drinking water controls in Switzerland based on the legal foundation can not give this information needed because sampling frequencies are mainly based on the number of consumers (3). Especially small water supplies, using karst spring waters have their water therefore only tested two to four times a year. Regarding long time periods of several years or decades to describe system behaviour does not help much further. The data only allow giving a general statement on the behaviour of karst springs i.e. a raise of fecal contamination after precipitation events but no evidence regarding the maximum concentration or the exact time of occurrence of the contamination. However, the aim of a drinking water control should be to get a water quality description specific to the water supply tested over some period as accurate as possible. Instead a static description is given that only allows a general statement on the water at the sampling location.

To account for the dynamic behaviour of karst systems continuous measurement instruments have to be installed. Suitable parameters for such kind of measurement are e.g. discharge, turbidity, electrical conductivity and UV-extinction and as a supplement microbiological parameters sampled several times a day during precipitation events (4). These measurements can show the reaction time of the karst spring after precipitation events, this means how long it takes e.g. for the turbidity to begin to rise, to reach the peak maximum and to come back to the base level again. This information allows a conclusion on the quality changes over time of the karst water. In addition, it is a basis for the dimension of drinking water treatment plant and for the optimization of the control loop in drinking water treatment. Furthermore, it helps to plan the dimension of water supply reservoirs and the combination of water supplies in order to bridge periods with bad water quality. The recorded breakthrough curves of the continuously measured parameters can also be used to determine transport velocities like for tracer tests and are so used to optimize the time of sampling for the specific location (5). A continuous measurement of appropriate parameters in karst waters can therefore contribute to an optimization of several parts of the water quality system.

The study presents two sampling strategies, routine sampling and event-based sampling. The data for the formulation of these strategies were gathered in a small water supply that uses two karst springs. The aim was to optimize the sampling strategy and significance of the drinking water analysis by keeping the time, cost and effort as low as possible. Therefore the study is based mainly on available data (e.g. previous tracer tests and discharge measurements from local authority). New data acquisition, data analysis and data interpretation was reduced to a minimum in order to present a practicable approach especially for small water supplies. It is shown, that with routine sampling general statements on karst springs can be made whereas with event-based sampling, site specific information is gained.

Catchment area

The study was carried out at a small water supply in Tabular Jura of Northwestern Switzerland. The water supply uses three very closely located karst springs. Since January 2004, only two springs are used as the third spring caused high turbidity in the water supply. Our findings are therefore based on the two springs (spring 1 and 3) which are currently in use. The catchment area of the springs, which was delineated in (6) according to general geological criteria and dye tracer tests is part of the syncline of "Rossboden/Bürten" and has an dimension of about 1.8 km^2. The aquifer is built on top of this syncline by tertiary marls with low to middle permeability depending on the thickness of the formation. The main aquifer consists of highly porous detritic limestone so called Sequanian Formation (Malm) which is embedded in a low permeable marly clay formation. This latter formation (Effinger-Formation) builds the aquitard. The underlying formations, built by formations of Dogger and Jura are not part of the cachment area. The three springs occur at the stratigrafic contact of the Sequanian Formation and Effinger Formation in the spark-eroded depression of Bürtengraben (6,7).

Previous Tracer tests

Two tracer tests were performed at Bürtengraben springs (6). In the first tracer test in 1969, Uranine was injected into Bürtengraben creek 250 m above the springs (Fig. 1). The tracer could be detected in all three springs 1¾ hours after injection, peak maximum was after about 3 to 5 hours. Unfortunately, only a semi quantitative analysis of tracer concentration was made. Therefore, the time of peak concentration is unclear and the tracer recovery can not be calculated. In the second tracer test in 1998, three input locations with three different tracers (Uranine, Eosin and

Naphthionate) were chosen (Fig. 1). During the tracer test it was raining. The following days unsettled weather conditions prevailed. The Uranine (amount 200 g) was flushed with 3 m^3 of water on a sloping stony pasture (area 14×3 m^2). The input site showed good infiltration capacity. Also Eosin (amount 200 g) showed good infiltration. The tracer was flushed with 2 m^2 of water into a dredger slit, which reached the intensively karstified rock. Naphthionate (amount 2 kg) was flushed with 3.3 m^3 of water into a natural depression in the terrain. Fastest transport was detected for Uranine which was transported over a distance of 570 m within 14 hours (Fig. 2). For Eosin first arrival was after 7 days (flow distance 850 m). Naphthionate could not be detected within a sampling period of 20 days in the two springs but in the Bürtengraben creek. It is assumed, that the Naphthionate like the other tracers exfiltrated at the stratigraphic contact of the Sequanian and Effinger Formation, but according to the topographic circumstances, did not reach the catchment area of the springs. Unfortunately, in this tracer test spring discharge was not measured, the three springs were not analysed separately and sampling period was too short to give the whole breakthrough curve of Eosin. A rough estimation of the tracer recovery, assuming a discharge between 200 and 400 L/min as a sum for the three springs, gives a range of 2 % to 6 % for Uranine and 2 % to 8 % for Eosin.

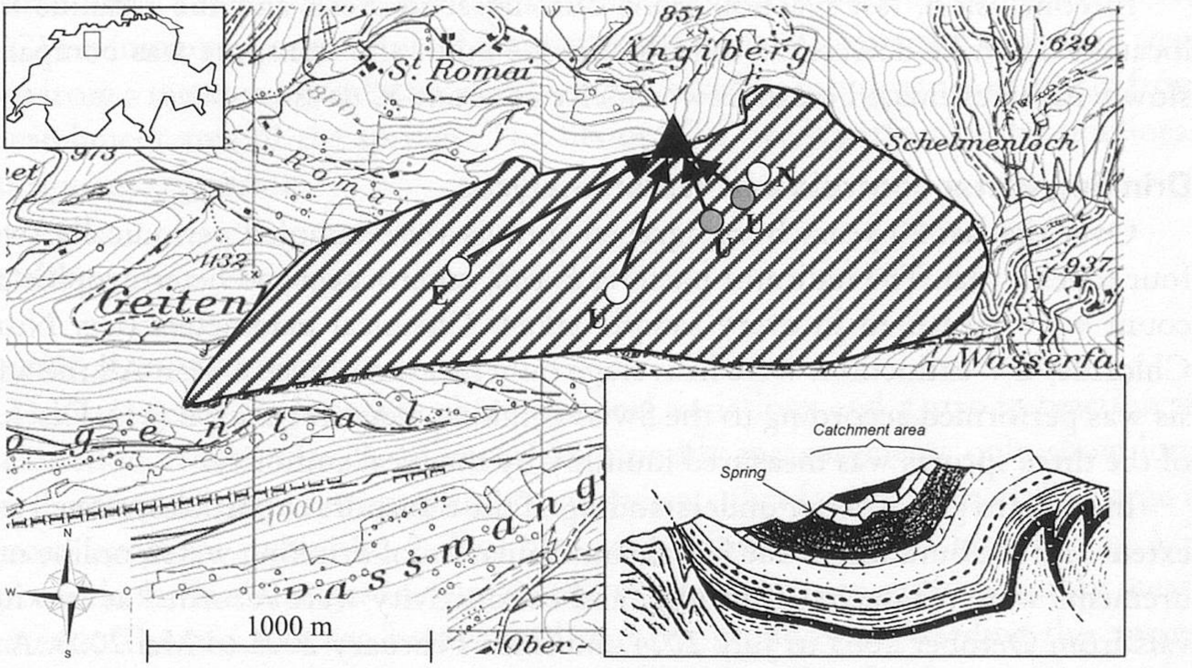


Figure 1 **Map of study area in Northwestern Switzerland with springs, input locations of tracers and a geological cross profile. The two top formation of the syncline, the tertiary marls and the Sequanian Formation (Malm) build the aquifer. The underlying Effinger-Formation builds the aquitard. Black triangle: location of the three springs; grey points: input locations in the tracer test of 1969; white points: input locations in the tracer test of 1998; E: Eosin input; U: Uranine input; N: Naphthionate input**

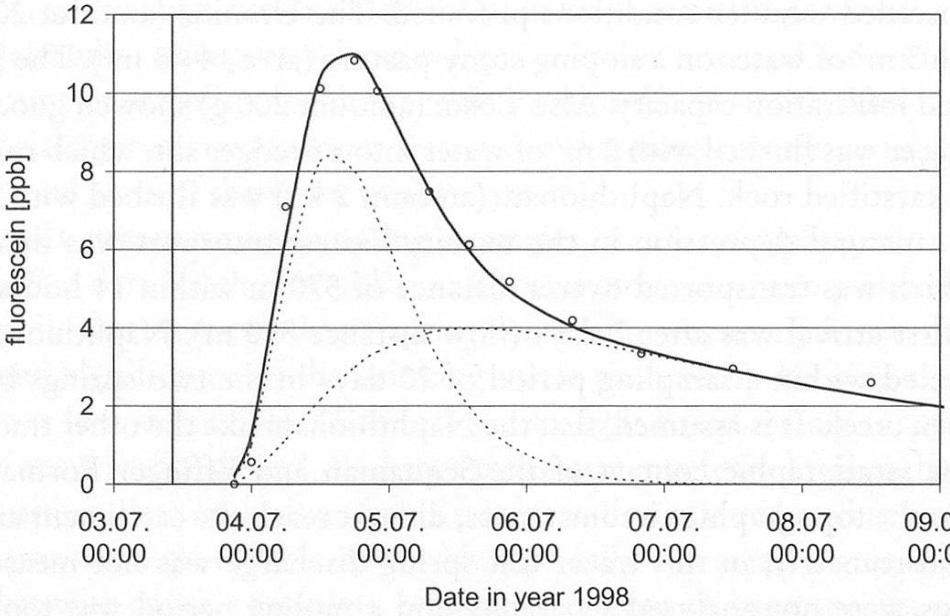


Figure 2 **Measured data from the tracer test in 1998 (circles) (6) and fitted tracer breakthrough using eq. 1. The initial time is indicated by the vertical line, dotted lines are the two fitted curves, the black line is the whole fitted BTC**

In conclusion, fast reaction from Bürtengraben creek and the Uranine input location could be detected. From the Eosine input site transport was comparably slow with an estimated mean flow velocity of about 30 days.

Drinking water controls and water analyses

Over the last 20 years Bürtengraben springs were sampled periodically two to four times a year. The indicator bacteria *E. coli,* enterococci and heterotrophic plate count were measured in every sample taken. Chemical parameters (e.g. Nitrate, Chloride, UV-extinction) were in average only measured once a year. All the analysis was performed according to the Swiss drinking water regulation (11). Discharge of the three springs was measured monthly by the local authority.

In order to gain a better understanding of the transport of particles, as well as the extent and the duration of the faecal contamination of drinking water, online measurements were conducted. Turbidity and conductivity were recorded at two intervals from October 2003 to July 2004 and from February 2005 to Mai 2005. A discharge of up to a value of 260 L/min was recorded online in the reservoir inlet of the water supply. The spring overflow at the water catchment was additionally measured between January 2004 and Mai 2005. For a period of one year beginning in March 2004, the overflow of the spring was recorded using a V-notch wire with an angle of 30° according to (12). Over a period of two weeks from 14th to 28th April 2005, samples of *E. coli* and enterococci were taken every four hours with a sampling device. The samples were collected daily and analysed in the laboratory according to the Swiss drinking water regulation (11).

Transport model

In order to analyse the breakthrough curves of the tracer Uranine, turbidity and microorganisms and to also calculate transport parameters, a 1D-advective-dispersive transport model according to (13) and (14) was used:

$$c\,(x,\,t) = \frac{M}{Q}\,\frac{x}{\sqrt{(4\pi D_L t^3)}}\exp\left(-\frac{(x-vt)^2}{4D_L t}\right) \qquad \text{(eq. 1)}$$

where c is the tracer concentration, M is the tracer mass at input, Q is spring discharge, x is distance from input site to spring, D_L is longitudinal dispersion coefficient, t is time and v is average tracer transport velocity.

This model is designed to analyse tracer tests in different kinds of geological settings. We suggest, that the model can also be applied in modelling transport of particles in fast flow conduits in karst systems. During fast flow the main transport components are advection and dispersion, whereas adsorption, desorption and decay have a measurable influence on transport only during slow flow.

Over the observation period, 6 main precipitation events were recorded. An event was defined as a time period in which turbidity begins to rise, reaches the peak maximum and comes back to the base level again. To generate a breakthrough curve (BTC) a minimum precipitation of 5 mm was necessary. The precipitation data were taken from a meteorological station at Gempen which is in a distance of 10 km from the catchment area of the springs. The fits of BTC were performed by nonlinear least squares regression.

Results

Discharge measurements

Measurements of discharge show seasonal variations and a strong reaction to precipitation events (Fig. 3). Whereas the monthly measurements only show long term variations, continuous measurements indicate that fast increase of discharge is induced approximately 1 to 2 days after a precipitation of 15 mm. Spring 3 is responsible for fast changes in total discharge as can be seen in the monthly measurements. Therefore, it can be assumed that the groundwater feeding this spring only has a small residence time with marginal filter capacity. On the contrary, spring 1 only shows little variation in discharge with a mean value of about 100 L/min. This spring must be fed by a long term reservoir with good filtration capacity. The values of the monthly measurements correspond very well with the continuously recorded values. However, it is impossible to gain information on the specific behaviour of spring discharge to precipitation by monthly measurements.

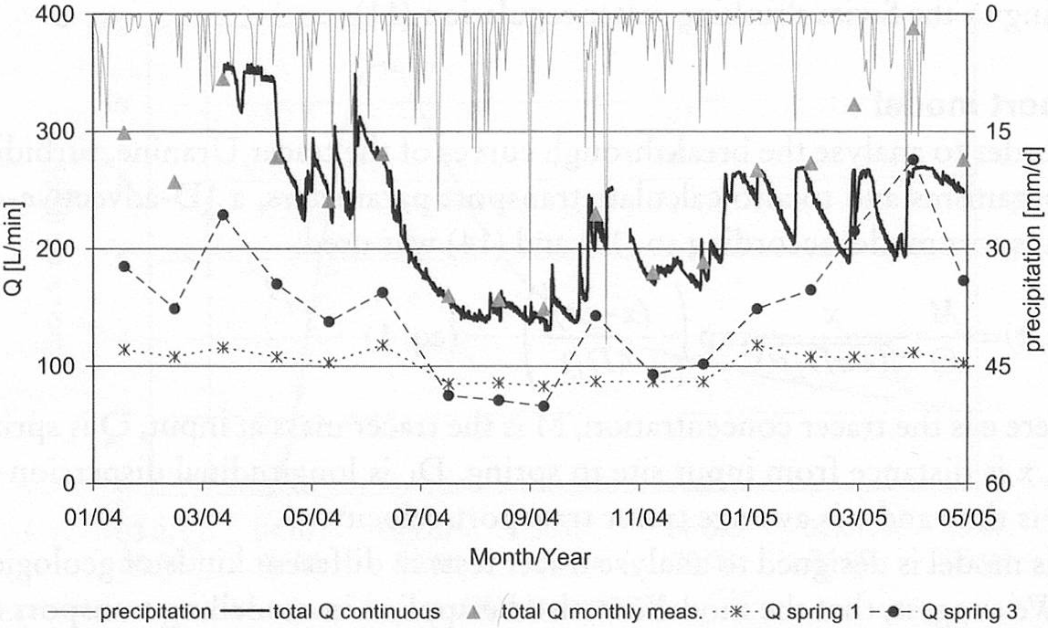


Figure 3 **Measurement of discharge of spring 1, spring 3 and total discharge. The sum of monthly measurements of spring 1 (Q spring 1) and spring 3 (Q spring 3) results in total discharge (total Q monthly meas.) which corresponds well with the continuous measurements of discharge (total Q continuous)**

The two springs together have a mean annual discharge of about 220 L/min. The effective precipitation (precipitation minus evapotranspiration) that feeds the groundwater is about 550 mm/a. This results in a catchment area of 0.22 km^2. The calculated area is much smaller than the one determined on geological information by (6). In (6) the catchment area was delineated by the dimension of the water leading formation building the aquifer. This however, leads to a too big area because also other springs and little creeks are fed by this groundwater.

The microbial water quality of karst springs is mainly influenced by the fast flow component of the system, which is in most cases fed by a small part of the catchment area. To determine this area a peak separation according to (21) was performed. The derived area is very small with a dimension of about 0.02 to 0.03 km^2 what corresponds to about 10 % of the whole catchment area.

Routine drinking water controls

Over a period of 20 years, 59 microbial samples and 17 to 35 chemical samples (number depending on the parameter) of total spring water were performed. During sampling, the atmospheric conditions at the moment of sampling and 1 to 4 days before sampling were noted.

Microbiological data show a low to middle fecal load of raw water of the spring. Concentrations of *E. coli* and enterococci are in a range of 0 to 50 and 0 to 111 CFU/100 mL, respectively. Due to the fact that sampling was not based on specific atmospheric conditions, it is not known if fecal contamination could be much higher e.g. during storm events. However, a separation of the samples according to the noted atmospheric conditions 1 to 4 days before sampling shows significant higher microbial load after precipitation than during dry periods (Tab. 1). This effect can also be seen for some chemical parameters. However, for turbidity and electrical conductivity which are expected to clearly show a dependence on precipitation, no significant difference can be measured.

Table 1
Comparison of samples taken during dry periods and 1 to 4 days after precipitation. The t-test on a significance level of 0.05 shows that there is a significant difference for microorganisms and some chemical parameters. HPC: heterotrophic plate count, n: Number of samples

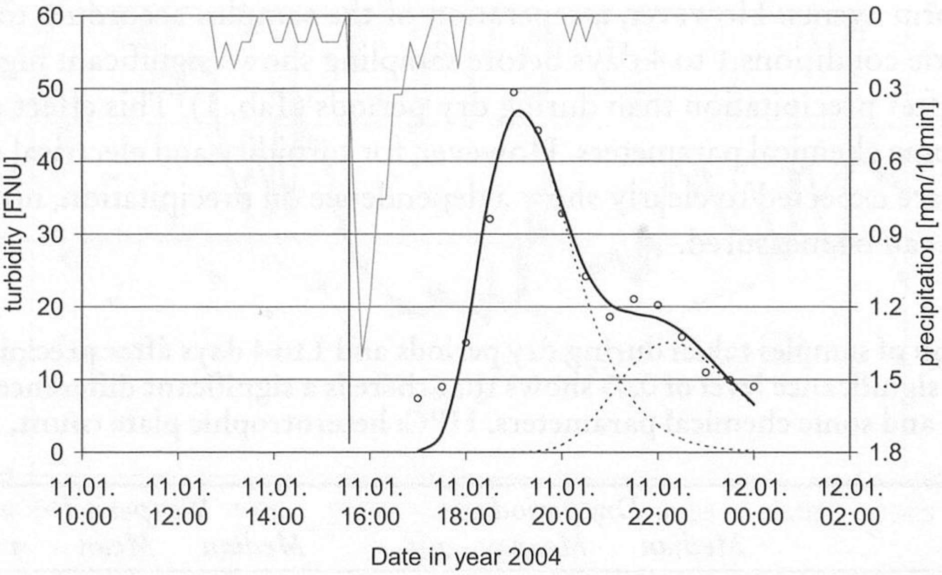
	Dry period			*Wet period*			
	Median	*Mean*	*n*	*Median*	*Mean*	*n*	*t-test*
El. conductivity	379	375	15	372	371	17	0.61
$KMnO_4$ consumption	2.3	2.5	16	2.95	3.1	16	0.02
UV-extinction	1.640	1.665	9	2.465	2.495	8	0.03
Turbidity	0.520	0.530	7	0.67	0.79	10	0.18
Chloride	1.5	1.7	13	1.9	2.2	15	0.02
Nitrate	6.5	6.9	17	7.5	7.5	18	0.04
HPC	89	186	23	320	549	24	0.01
Enterococci	2	3	23	9	18	26	0.01
E. coli	1	2	23	9	13	26	0.00

The information gained from routine sampling is very general. It shows what one would expect when analyzing karst spring water and gives no indication on the flow system and reaction times of the spring.

Event-specific sampling and derivation of transport parameters

During the observation period, six precipitation events occurred resulting in a raise in turbidity. Fig. 4a shows a single input pulse by precipitation in January 2004 leading to two overlapping breakthrough curves of turbidity. During the event in June 2004 (Fig. 4b), two rainfall events followed each other closely. Only one turbidity breakthrough curve per precipitation input could be detected instead of the suggested two curves from the event in January 2004. Most probably, the second curves are hidden in the main breakthrough curves of the event.

The breakthrough curves of *E. coli* and enterococci are shown in Fig. 4c and 4d. The whole precipitation event of 6 hours led to one main peak and one minor peak. With the sampling interval of 4 hours, it was not possible to receive the beginning and the maximum concentration of the BTC. The maximum concentration measured of *E. coli* was 103 CFU/100mL and of enterococci 312 CFU/100mL. The real maximum concentrations are expected to be much higher and to occur 2 to 3 hours after the beginning of the precipitation. In addition, the microorganism peak preceded the turbidity peak in the event in April 2005.



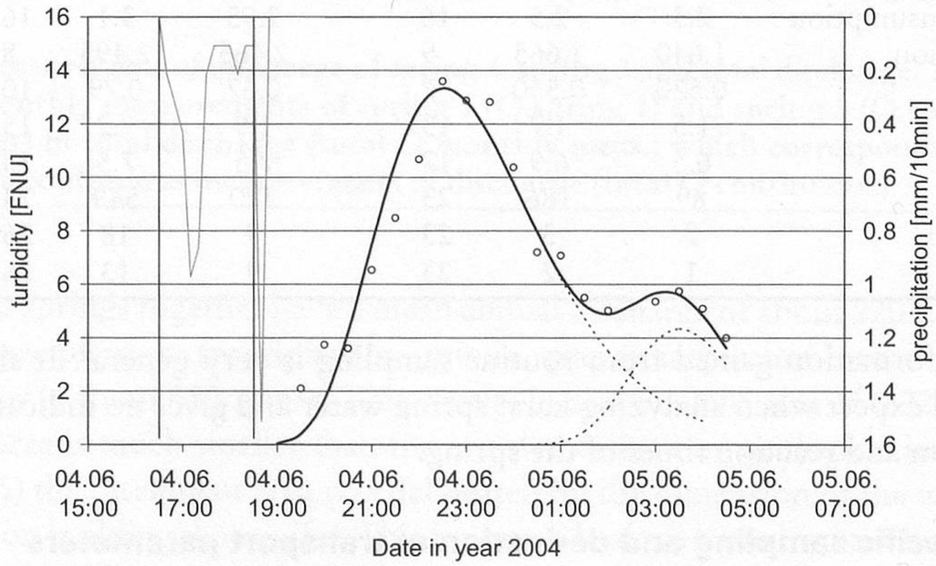


Figure 4a and 4b **A single input pulse by precipitation in January 2004 leads to two overlapping break through curves (BTC) of turbidity. The precipitation event in June 2004 has two broad input pulses. This results in a BTC of turbidity with two overlapping peaks. The two second peaks of the first and second sub-precipitation event are completely hidden in the two main peaks. The initial times for fitting the data are indicated by the vertical lines, dotted lines are the single BTC, the black line is the whole fitted BTC, the circles are the measured turbidity, and the grey line is precipitation**

The times for peak maximum after the beginning of the precipitation can be calculated for all the turbidity and microorganisms breakthrough curves to be in a range of 3 to 8 hours for the first peak and 7 to 14 hours for the second peak. This fast peak occurrence and the results from the previous tracer tests suggest that the raise in turbidity and microbial contamination is most probably caused by infiltrating water of the Bürtengraben creek and to a lesser extent also from the Uranine input site in the tracer test of 1998. The duration of the contamination was in a range of a half to one day depending on the duration of the precipitation event.

To test the applicability of the model (eq. 1) in our karst system, the tracer test derived in 1998 was fitted (Fig. 2). The tracer curve has a long tailing which could be caused by a second flowpath, pool like structure in the underground or matrix diffusion (15, 16, 17). Because of very few data from only one tracer test and in order to keep the model as simple as possible, the tailing was fitted to a second breakthrough curve. The calculated curve fits well with the data. The peak maximum of the tracer was measured about 24 hours after injection. This is much longer compared with the recorded BTC of turbidity and microorganisms which had a peak maximum after 3 to 8 hours. Therefore, it seems more appropriate to fit particle BTC using the information of the tracer test in 1969 which showed transport velocity of about 3 to 5 hours for a flow distance of 250 m from the input in the Bürtengraben creek to the spring. To account for the fast transport velocity of the particles, precipitation events with interruptions in precipitation were divided into two or three sub-precipitations and two or three input pulses were fitted accordingly.

As Fig. 4a to 4d show, the model fits well with the data. Table 2 gives the derived transport parameters. The transport velocities of turbidity are in a range of 16.2 to 65.0 m/h with a mean value of 31.4±11.9 m/h. These values are comparable to other karst systems (2, 8, 9). Whereas the transport velocities for *E. coli* and enterococci are in the same range as for turbidity, the Uranine in the tracer test of 1998 was transported slower than the particles. This may have two reasons: first the input of Uranine was at an other location as the input of microorganisms during precipitation is and second, as a dye tracer Uranine can undergo matrix diffusion, what results in a retardation of the tracer.

The derived values of the transport velocities are only rough estimations of the real transport velocities because the input conditions with rainfall events over several hours and changing intensities are fairly different from a Dirac impulse (eq. 1). Although, the calculated transport parameters give some insight into transport behaviour of particles in our karst system.

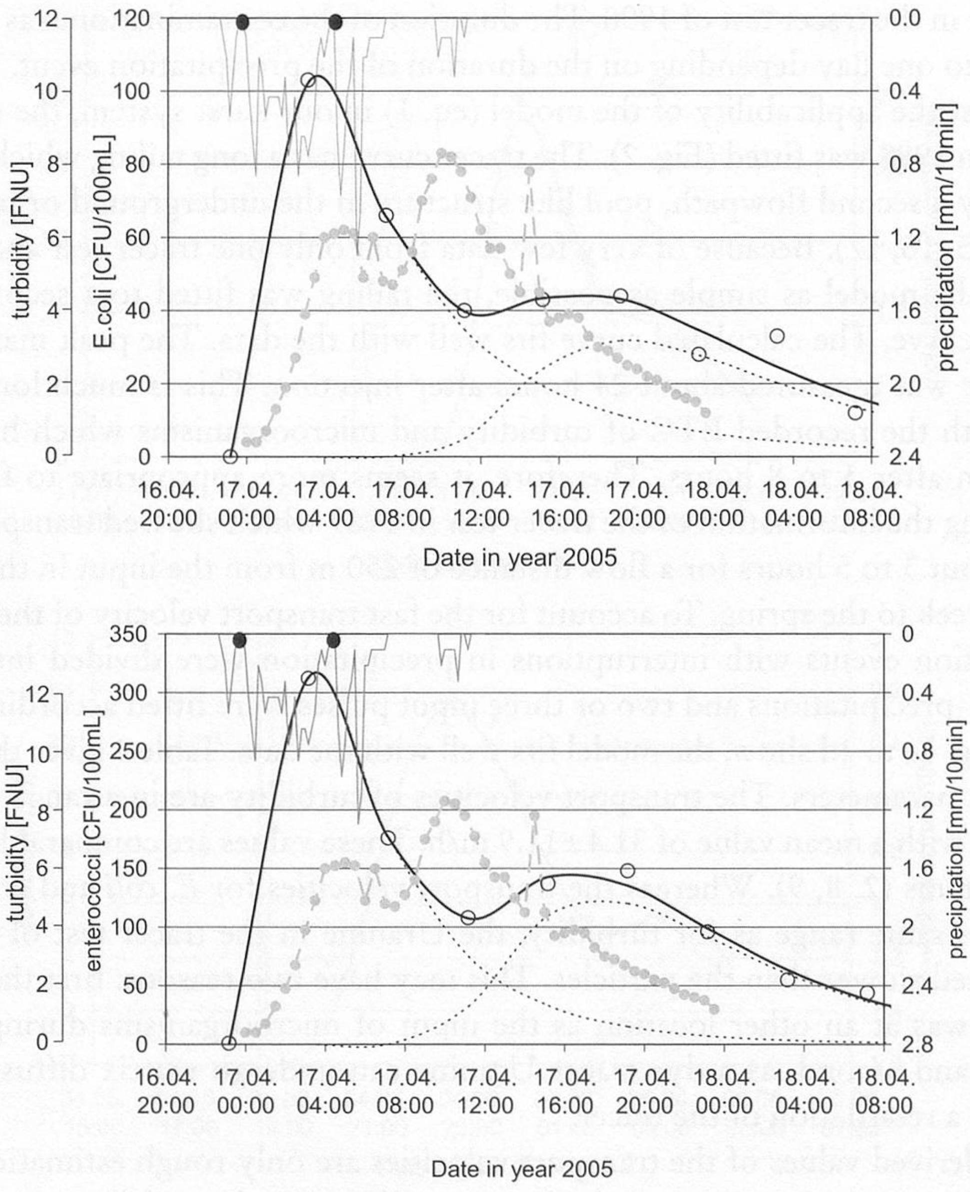


Figure 4c and 4d **Break through curve (BTC) of *E. coli*, enterococci and turbidity in the event of April 2005. For each microorganism two BTC were fitted. The initial times are indicated by black points, dotted lines are the single BTC, the black line is the whole fitted BTC, the circles are the measured data, grey dotted lines with points is turbidity and the grey line is precipitation**

Table 2
Transport parameters of BTCs of tracer fluorescein and particles causing turbidity and microorganisms. The input site of fluorescein is at a distance of 570 m and of the particles 250 m from the spring. No. pulse: number of input pulses caused by precipitation in one event; No. peak: number of fitted peaks for the particular pulse (e.g. for the date 11th January 2004 precipitation caused one pulse which resulted in a first and second peak of the break through curve; for the event of 17th April 2005 there were two pulses induced by precipitation what resulted in one peak for the first pulse and a first and second peak for the second pulse); M: ppb for fluorescein, FNU for turbidity, CFU/100 mL for microorganisms; Sd. standard deviation

Date	*Parameter*	*No. pulse*	*No. peak*	*M/Q [M/m³]*	*Sd. M/Q [M/m³]*	*v [m/h]*	*Sd. v [m/h]*	D_L *[m²/h]*	*Sd.* D_L *[m²/h]*
03.07.1998	fluorescein	1.	1.	9432	4030	16.6	0.9	609	122
	fluorescein	1.	2.	23852	5335	3.9	0.5	887	460
11.01.2004	turbidity	1.	1.	4.7	0.7	65.0	3.6	595	136
	turbidity	1.	2.	1.9	0.8	36.2	1.9	149	110
12.01.2004	turbidity	1.	1.	5.1	0.2	18.0	0.2	149	13
	turbidity	2.	1.	1.5	0.4	16.2	0.3	9	2
	turbidity	3.	1.	1.9	0.7	34.1	5.5	2126	1667
13.01.2004	turbidity	1.	1.	4.2	1.3	33.8	0.4	78	16
	turbidity	1.	2.	7.3	1.3	23.6	1.0	196	54
03.06.2004	turbidity	1.	1.	1.8	0.4	33.5	0.8	38	13
	turbidity	2.	1.	9.4	0.5	30.3	0.3	155	21
04.06.2004	turbidity	1.	1.	2.4	0.1	37.8	0.4	384	17
	turbidity	2.	1.	0.5	0.1	27.1	0.4	50	13
17.04.2005	turbidity	1.	1.	2.6	0.3	25.2	3.8	1631	116
	turbidity	2.	1.	0.7	0.2	40.9	1.9	327	57
	turbidity	2.	2.	1.2	0.3	18.5	0.9	337	119
	enterococci	1.	1.	97	32	34.9	14.5	2349	1650
	enterococci	2.	1.	83	29	14.1	0.6	368	133
	E. coli	1.	1.	40	27	26.5	29.4	2625	2234
	E. coli	2.	1.	24	25	12.5	2.3	330	286

Discussion

The studied karst system shows a fast and violent reaction in spring discharge, turbidity and microorganisms during precipitation events. However, only a marginal part of the catchment area is responsible for the observed contamination which is displayed mainly in spring 3. The recovery rates of the previously conducted tracer tests and the resident times calculated for the tracers, particles causing turbidity and microorganisms emphasize, that this small area of 0.02 km² must be located very close to the spring and therefore most probably is the area of Bürtengraben creek. To get further information on exact flowpath of particles and microorganisms tracer tests with particles (2) and microbial source tracking could be performed (22).

The whole catchment area of the two observed springs is about 0.22 km². This calculated area is much smaller than the one of 1.8 km² derived from the general geological considerations. Therefore, the main part of the agricultural land in the hydrogeological catchment area derived from existing geological maps probably does not contribute to microbial contamination.

Furthermore, the transport velocity of microorganisms is faster than for particles causing turbidity. Such findings were also made for other karst systems (2, 10, 18) indicating that turbidity is not always an appropriate parameter to control a rise in concentrations of microorganisms.

The model used to calculate transport velocity is applicable not only for fluorescent tracers but also for particles. However, there are some restrictions regarding eq. 1, that must be accounted for, when interpreting results. First, the input function is meant to be a Dirac impulse what is not always true for some precipitation events. To get better model fits, only heavy short time storm events should be used for fitting or the input function should be adaptable to the input by precipitation. In general, the shorter the input pulse compared to the flow time, the closer the input conditions come to a Dirac impulse. Second, the changes in spring discharge during the precipitation should be included into the model. But this latter effect probably has a minor influence on the derived values as was already stated by (15). Third, during particle transport also sorption and desorption may play a role. However, regarding the BTCs these effects do not have a major influence on transport velocity and dispersion in our system because transport is very fast. Finally, a further restriction is the exact location of the contaminant input which is not absolutely clear from the previously performed tracer tests. Anyhow, the model fits well with the data, the derived transport parameters are clearly defined and the obtained parameter values of flow velocity and dispersion are comparable to other studies in karst systems.

Before performing tracer tests, continuous measurements of discharge, turbidity, el. conductivity, or other online measurable parameters should be performed during several precipitation events. These results give an indication of the expected output signal in tracer tests and numbers of input locations for fast particle transport (19). The temporal decomposition must be rather high to be able to differentiate changes e.g. in discharge, turbidity and electrical conductivity in order to distinguish different processes as e.g. remobilization of particles (23, 24) or direct transport from input to output (2). Further it is recommended to integrate as well the precipitation – discharge relations based on monitoring of at least one hydrological cycle. During tracer tests discharge should be measured to be able to calculate the recovery rates of the tracer mass. Furthermore, it is recommended to perform tracer tests during precipitation events because the input conditions of this tracer test correspond with the input conditions of microorganisms. Moreover, turbidity can be measured and this BTC can be compared with the BTC of the tracer.

As a conclusion and recommendation for the water supply from the above statements, the following aspects are important: 1) only spring 1 should be used for the water supply. This spring provides about 470 l/d*person compared to the needs of 332 l/d*person (20); 2) the area of Bürtengraben creek should be exclusively considered as a protection zone with tight restriction, however, for other parts of the current protection zone restrictions can be loosened; 3) a turbidimeter must be installed and the turbid water must be rejected; 4) if the capacity of the reservoir is not able to bridge the time of rejection, a filter system as a further measure for water treatment, beside the existent UV-disinfection, has to be installed.

Defining sampling strategies in the studied water supply to control raw water quality and water treatment process in a classical manner is difficult, because maximum concentrations of microorganisms and turbidity, building high risk phases, occur 2 to 5 hours after the begin of a precipitation event. Manual sampling of single samples to evaluate the water quality is therefore almost impossible. For that reason, a water management and treatment system that is able to handle high contaminations has to be installed. In order to control such a system, an automated sampling device should be arranged. The raw and treated water samples are then automatically taken when previously defined tolerance values e.g. turbidity or changes in discharge are transgressed. During one event, at least 2 to 3 samples of each spring and of the treated drinking water should be taken. After filling the sample bottles, the local authorities should automatically be informed so that they collect the bottles from the sampling device and take them to the laboratory for analysis. It is only with this kind of automated sampling that the function of water treatment during high contamination phases can be verified.

Acknowledgements

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Summary

To optimize sampling strategy in a small water supply in Northwestern Switzerland, event-specific sampling of turbidity and microorganisms was conducted. These data were compared with previously performed tracer tests and water quality data from routine drinking water sampling 1 to 4 times a year. Whereas the data from routine sampling only give information on the general behaviour of karst springs, event-specific sampling gives specific information of the karst system and residence times of microorganisms. In addition, previously conducted tracer test gave partly wrong evidence on the input locations of microorganisms. Furthermore, the present sampling strategy can not account for microbial risk. Therefore, karst systems with short response times on precipitation in the order of hours should be equipped for automatic sampling. After the transgression of defined tolerance values of e.g. turbidity, a sample device should be activated to take several samples and send a signal to the local authorities who should collect the bottles from the sampling device and take them to the laboratory for analysis.

Zusammenfassung

In einer kleinen Wasserversorgung in der Nordwestschweiz wurden zu Verbesserung der Probenahmestrategie die Trübung und die Mikroorganismen bei Niederschlagsereignissen untersucht. Ein Verglich dieser Daten mit früher durchgeführten Tracertests, sowie den routinemässig ein- bis viermal jährlich erhobenen Trinkwasseranalysen zeigt, dass Routineuntersuchungen lediglich eine allgemeine Beschreibung des Verhaltens von Karstquellen geben können, aus den ereignisbezogenen Probennahmen jedoch spezifische Information zum Karstsystem und der Aufenthaltszeit von Mikroorganismen gewonnen werden. Frühere Tracertests führten zudem teilweise zu falschen Schlüssen zum Eintrag von Mikroorganismen ins Quellwasser. Die heutige Untersuchungsstrategie wird deshalb der Erfassung der mikrobiologischen Risiken nicht gerecht. Als Alternative ist zu empfehlen, Karstsysteme mit kurzen Ansprechzeiten auf Niederschläge automatisiert zu beproben. Nach der Überschreitung von definierten Grenzwerten beispielsweise der Trübung, sollte ein Probensampler aktiviert werden, der in definierten Zeitabständen mehrere Proben des Roh- und Trinkwassers zieht. Ein Vertreter der lokalen Wasserversorgung würde daraufhin informiert, um die Proben zu sammeln und zur Analyse ins Labor zu bringen.

Résumé

Dans le but d'améliorer les procédures de prélèvement d'échantillons par les distributeurs d'eau de petits captages de le Nord-Ouest de la Suisse, des mesures de turbidité ainsi que la teneur en microorganismes lors des périodes de précipitations sont effectuées. Une comparaison de ces données avec les résultats d'essais de traçage réalisés antérieurement permet d'obtenir des informations spécifiques sur les systèmes karstiques et sur le temps de résidence des microorganismes dans ces aquifères. Ces observations confirment que les contrôles de routine effectués sur ce type de système aquifère, réalisés entre une et quatre fois par an, ne donnent que des indications générales sur leur fonctionnement. Les essais de traçage effectués dans le passé ont partiellement conduit à de fausses estimations du taux de microorganismes des eaux de sources. Ainsi, la stratégie de contrôle actuelle qui en résulte ne permet pas d'évaluer correctement le risque microbiologique. Il est par conséquent recommandé d'automatiser la prise d'échantillons au niveau des captages d'eau potable pour des systèmes karstiques très sensibles aux précipitations. Si les valeurs limites, notamment fixées pour la turbidité, sont dépassées, il serait alors nécessaire d'installer des préleveurs automatiques asservis à la turbidité et capables de prélever plusieurs échantillons d'eau brute et d'eau traitée. Le responsable locale de la distribution d'eau serait en charge de collecter les échantillons et de les transmettre à un laboratoire d'analyses.

Key words

karst, drinking water, microorganisms, sampling strategy, tracer

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