REAL TIME MONITORING AND CONTROL OF CARSTIC DRINKING WATER SOURCES

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ABSTRACT

At a carstic spring in Austria several microbiological, chemical-physical and meteorological data have been measured over a 10 month period. The intention was to find easy to measure parameters to describe the microbiological quality of the spring. The strongest relation of the coliforms and E.coli counts was found with the product of SAC(254nm) and air temperature. From the additional information gathered from particle counting compared to turbidity measurement it was not possible to deduce advantages for the practical management of the examined spring. The SAC(254nm) and turbidity data determined with a novel submersible UV-VIS-spectrometer were of the same quality like the conventional measured data with a prior membrane filtration.

BACKGROUND AND OBJECTIVES

Springs in geological regions with karstic rock formations are the source for public drinking water supply for about 60% of the Austrian population. Unfortunately the water quality from these springs shows temporary instabilities for some parameters. High turbidity fluctuations, elevated DOC and increased bacteria counts typically occur in an almost unpredictable way during storm weather. For the water suppliers the bacteria counts are the most important parameters, since these parameters determine, whether disinfection is necessary.

The aim of the study was to find out, whether chemical-physical water quality parameters and meteorological data, which can be easily measured online, can be used to predict the number of faecal indicator bacteria at a typical karstic spring in Austria. Further objectives have been to judge, whether particle counting gives additional information compared to turbidity measurement, and if conventional turbidity and SAC(254nm) measurement can be replaced by the use of a novel submersable UV-VIS spectrometer.

MATERIALS AND METHODS

From the already existing monitoring system measuring the spectral absorption coefficient at 254nm (SAC(254nm)), turbidity, electrical conductivity, pH, and O_2-concentration hourly averages have been provided by the water supply company over the project period of March to December 2001.

Additionally a novel submersible UV-VIS-spectrometer and two particle counters have been installed at the spring and compared. For all three units a measurement interval of 15 min has been fixed.

The UV-VIS-spectrometer (spectro::lyser from s::can Messtechnik GesmbH. Vienna) measures the light absorption in the spectral range of 200 nm to 750 nm. While in the existing monitoring system a membrane filtration is installed prior to SAC(254 nm)–measurement, the spectro::lyser-unit is able to calculate the SAC (254 nm) and the turbidity from the UV-VIS-spectra of the unfiltered sample. Also calibrations to other parameters like organic carbons (e.g. TOC) or Nitrate can be calculated from the spectral information.

Particle counter 1 (Abakus mobil fluid from Klotz Analytische Messtechnik, Germany) covers a particle size range of 1 µm to 120 µm with 32 selectable size channels. An implemented sampling pump guarantees that the number of particles is always related to the same volume of water.

This is different with particle counter 2 (WPC 2000 from ART Instruments, Inc.), where an optional drain extension installation should take over this function. The unit 2 covers a particle size range of 1 µm to 100 µm with 8 selectable size channels.

Over the project period the E.coli and coliforms numbers in the spring water have been determined almost daily using the Colilert test from IDEXX laboratories, Inc., the meteorological data air temperature, precipitation and snow height have been recorded.

The relation between the collected data have been determined by calculating the correlation coefficient $\rho_{X,Y}$.

RESULTS AND CONCLUSIONS

While the already existing monitoring system worked well, several problems occurred with the additionally installed instruments causing gaps in the time series. High particle loads after heavy rainfalls are probably the reason why both particle counters failed several times. Problems with the drain extension installation of particle counter 2 caused changes in the sample flow; the numbers of particles counted with this instrument were not related to a constant water volume.

With the UV-VIS-spectrometer wrong references have been used at the beginning of the measurement campaign. A too small sample flow through the additional ByPass-System caused problems.

Correlation of microbiological water quality parameters with chemical-physical and meteorological data

High numbers of coliforms and E.coli in the spring water have been found

during the warm season from June till October. After heavy or long lasting rainfall the numbers are increasing dramatically. The same is true for the SAC(254nm) with the difference, that this parameter increases after rainfall over the whole year and not during the warm season only (comp. Figure 1).
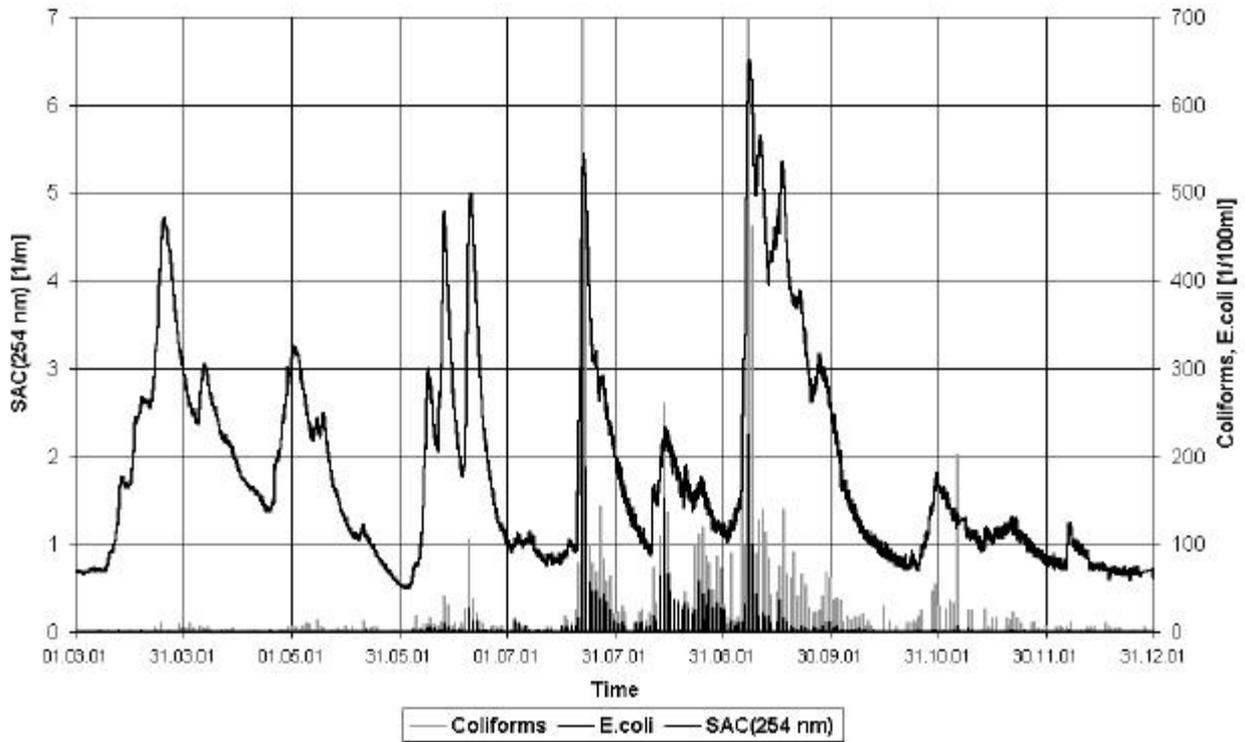

Figure 1.   Time series of coliforms, E.coli and SAC(254nm)

This observation was confirmed, when calculating the correlation coefficients between the microbiological parameters and the other data series. With SAC(254 nm) the highest value was found followed by the particle counts for small particle size classes (comp. Table 1). Even higher is the relation between the bacteria numbers and the product of (SAC 254nm) and the air temperature. This is one simple way to bring the seasonal variation of the bacteria counts into the relation. Plotting this product versus coliforms and E.coli counts (comp. Figure 2) shows, that the correlation is too weak for exact quantitative statements but can be used as an water quality information in order to produce an early warning parameter.

Table 1. Correlation coefficients $\rho_{X,Y}$ of coliforms and E-coli. counts with chemical-physical water quality parameters and meteorological data

|		electrical conductivity	SAC (254 nm)	pH	O2-concentration	turbidity	air temperature	precipitation	snow height	SAC (254 nm) * air temperature	Particle counts (Abakus mobil fluid)							
											2-5µm	5-8µm	8-10µm	10-15µm	15-25µm	25-50µm	50-100µm	>100µm
Coliforms																		
all data	n	235	235	190	233	235	247	247	247	235								
	ρ_{XY}	0,08	**0,48**	-0,22	-0,01	0,22	0,21	0,04	-0,10	**0,59**								
only these data considered, where simultaneous particle counts available	n	86	86	72	86	86	88	88	88		85	85	85	85	85	85	85	85
	ρ_{XY}	0,31	**0,60**	-0,41	0,09	0,14	0,13	0,17	-		**0,29**	0,25	0,24	0,27	0,28	0,12	-0,12	-0,16
E.coli																		
all data	n	235	235	190	233	235	247	247	247	235								
	ρ_{XY}	0,05	**0,37**	-0,15	-0,06	0,20	0,23	-0,01	-0,08	**0,53**								
only these data considered, where simultaneous particle counts available	n	86	86	72	86	86	88	88	88		85	85	85	85	85	85	85	85
	ρ_{XY}	0,28	**0,50**	-0,49	-0,03	0,15	0,28	0,13	-		**0,30**	0,26	0,25	0,28	0,29	0,14	-0,11	-0,14
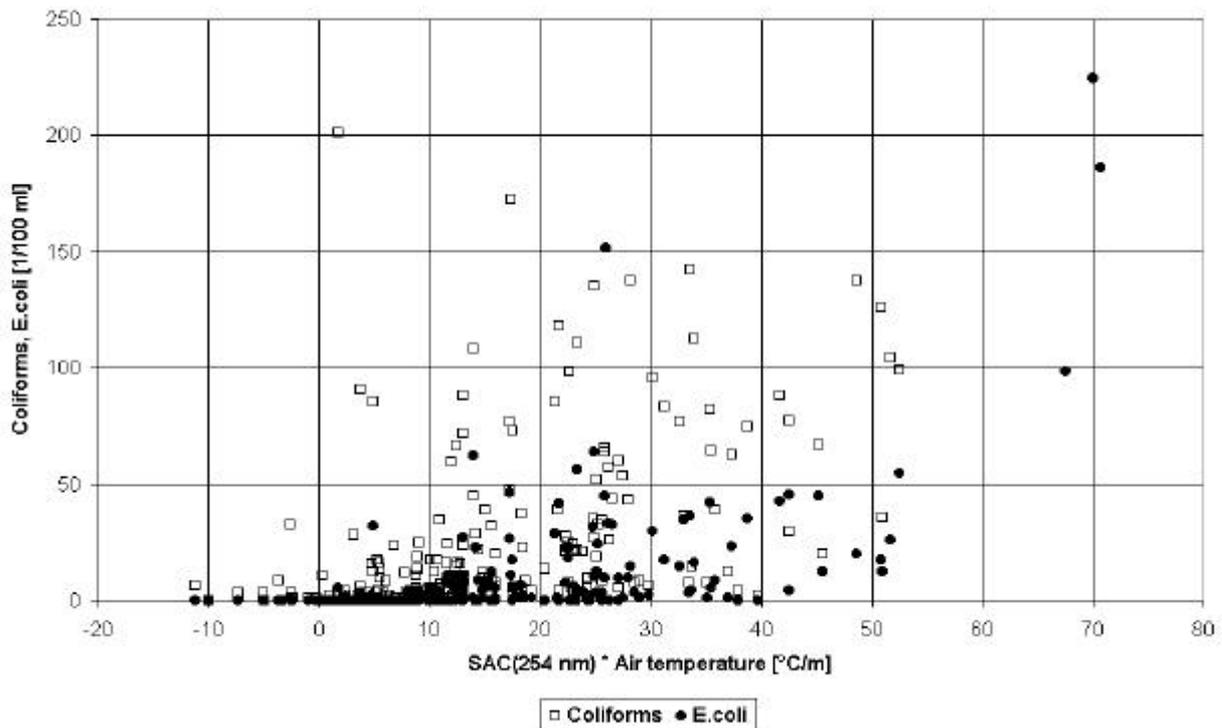
Figure 2. SAC(254nm) times air temperature vs. coliforms and E.coli counts

Particle counting

The particle counts follow well the turbidity data having a $\rho_{X,Y}$ value of 0.98 for the smallest particle size class (2-5 µm) (comp. Figure 3). The distribution of particle sizes varied over the examination period, but a relation between the particle size distribution and the occurrence of high numbers of bacteria in the

spring water was not found. From the additional information gathered from particle counting compared to turbidity measurement, which are the particle size distribution and the higher resolution at low turbidity values, it was not possible to deduce advantages for the practical management of the examined spring.
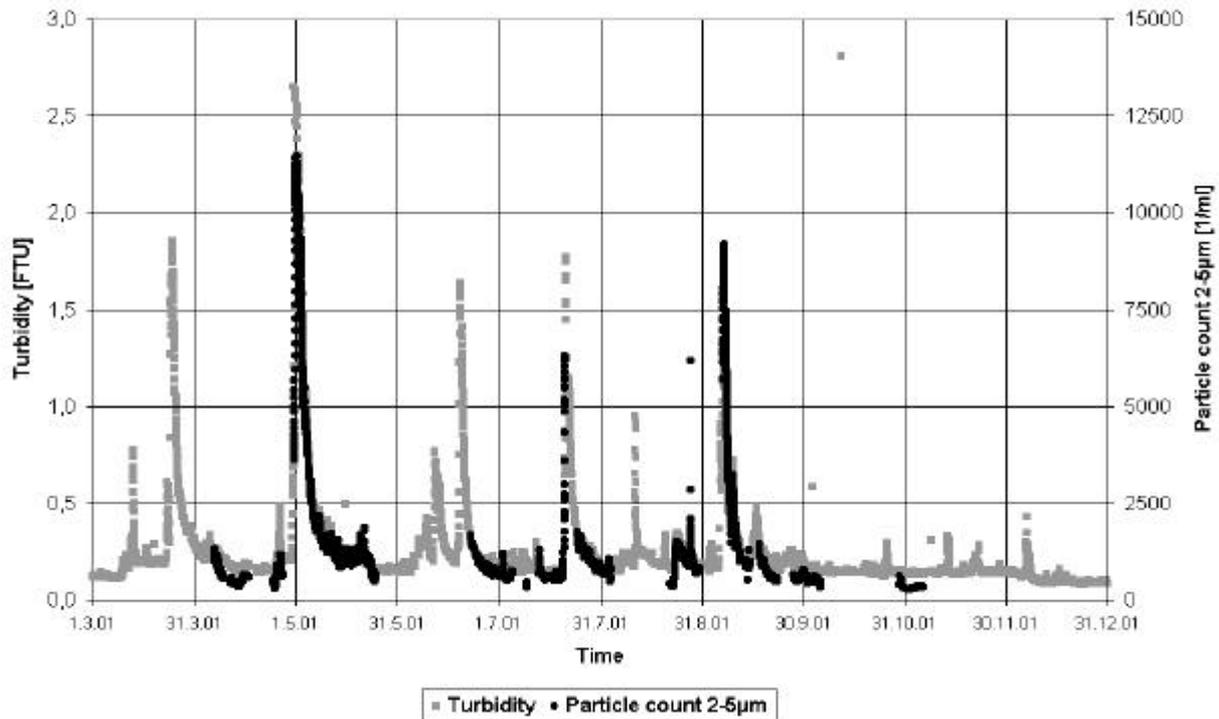

Figure 3.   Time series of turbidity and particle counts (2-5 µm)

UV-VIS-spectrometer

The SAC(254nm) values determined with the spectro::lyser-instrument are of the same quality like the conventional measured data with membrane filtration (comp. Figure 4). After improving the conditions concerning the whole measuring system (probe and ByPass-system) it was also possible to verify the equivalence of spectral and conventional measurements of the turbidity (comp. Figure 5).

The correlation coefficients (comp. Figure 4) are calculated from measuring data obtained over long time periods of various months and show the equivalence of both SAC(254nm) measurement methods. There are three different graphs as two times not distilled water has been used as the correct reference media. The time series of the turbidities (comp. Figure 5) show the influence of an rainfall to the turbidity of the spring water. As the turbidity increases sharply with the beginning of the rainfall the importance of on-line measurements becomes evident. Although the probe has been mounted in a ByPass-system the spectro::lyser is primarily designed for making InSitu measurements in order to offer OnLine data from the original water quality.
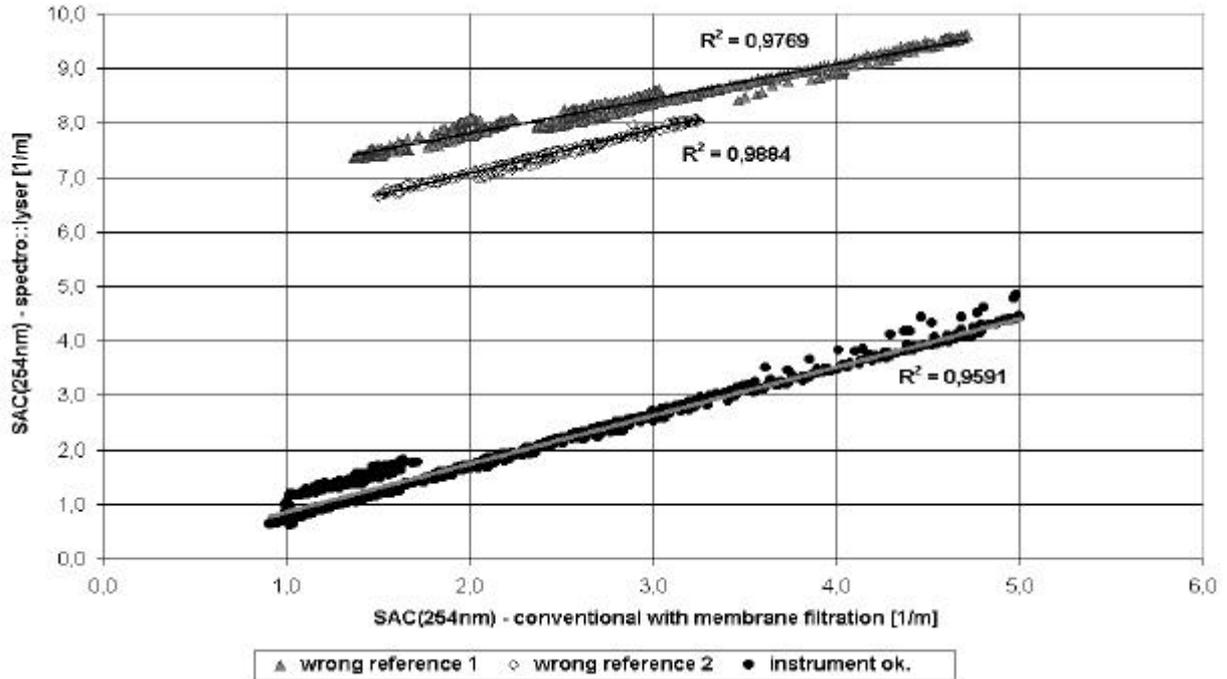
Figure 4.   SAC(254 nm) from a conventional measurement instrument after membrane filtration vs. SAC(254nm) data measured with spectro::lyser without filtration
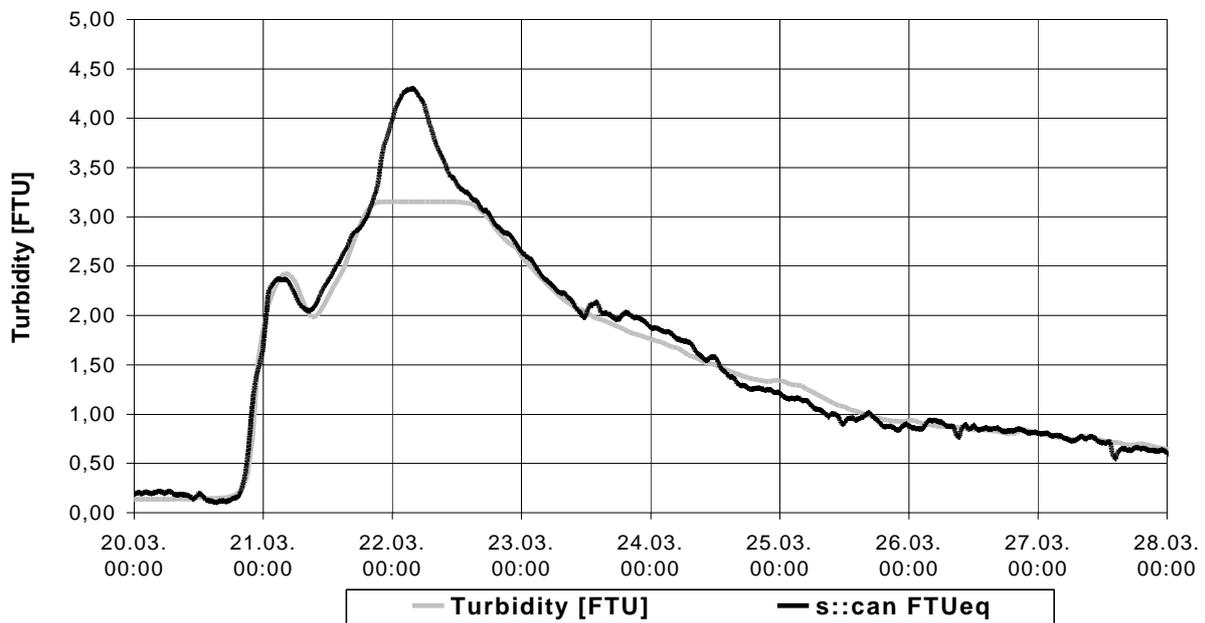

Figure 5.   Time series of turbidities from a conventional measurement instrument and turbidity data determined with spectro::lyser