8. GENERAL CONCLUSIONS

8.1. METHODOLOGICAL ASPECTS OF WATER-TRACING EXPERIMENTS (H. BEHRENS, R. BENISCHKE, W. KÄSS)

Water tracing methodology consists of different components of which the most important are the availability of suited tracer materials and efficient methods for the tracer detection at observation/sampling points. Besides them, modes of tracer injection, sampling or measurement in-situ, display of data, and interpretation of results are essential features. It is revealing to follow the development of these aspects in the course of the past ATH-events (Graz 1966, Freiburg 1970, Ljubljana/Bled 1976, Bern 1981, Athens 1986, and Karlsruhe 1992).

Among the tracer materials from begin until now fluorescent dyes have played the major role because of their detectability with high sensitivity. Uranine (disodium-fluoresceine) was all time the most efficient candidate. Already 1966 direct measurement in the field with a TURNER filter fluorometer was performed. Laboratory detection at that time was performed on a ZEISS spectrophotometer with fluorescence assessory attachment making it a mixed spectro/filter fluorometer (KÄSS). A breakthrough was achieved in the experiments in Slovenia 1972-1975 with the use of real spectro fluorometers (PERKIN ELMER 203) and application of the new synchronous scanning method which offered higher detection sensitivity by background reduction and more selectivity by optimal spectral resolution. Later also in-situ fluorometers (VARIOSENS, by C. LEIBUNDGUT) were applied particularly in lake-circulation studies. The more recently developed optical-fiber fluorometers (e.g. R. BENISCHKE) which allow in-situ measurements in boreholes and in fissures, however, have not been used in the ATH-experiments until now. Also more advanced analytical techniques using HPLC separation of tracers were not yet applied.

The scale of fluorescent water tracers (eosin, pyranin, sulphorhodamines G and B, rhodamines B and WT besides uranine) was extended to the blue fluorescent region by use of optical brighteners and especially by naphthionate (WERNLI 1986).

Already in Graz 1966 with iodine-131 a radioactive tracer was applied (BEHRENS). In later experiments chromium-51, indium-114, and also stable indium as an activable tracer were used with good success.

Bacteria as tracers were also already applied in 1966 (*Serratia marcescens*, by DOMBROWSKI). Later the scale of microbial tracer methods was extended by use of phages (e.g. BRICELJ, Athens 1987).

Lycopodium spores played an important role since the begin of karst tracing experiments. The method was made more versatile by the introduction of discernible spores which were labelled by colouring with different dyes (DECHANT 1967). More recently fluorescent microspheres have become available for water tracing purposes (e.g. KÄSS 1992).

Collection of water samples for tracer identification has mainly been improved by the introduction of automatic sampling equipment, as well as self-constructed (LEIBUNDGUT) and also commercial (e.g. by BÜHLER, ISCO).

The display of data made profit of the arising availability of efficient personal computers. Comparison of the behaviour and yield of simultaneously injected different tracers was improved by introduction of normalising tracer concentrations to the injected amounts of individual tracers. Mathematical modelling which was not in discussion in the first ATH-events, made the interpretation more and more sound in the following (e.g. MALOSZEWSKI).

Altogether the water tracing methodology has been developed to a high standard. Therefore in the here submitted description of the recent joint experiments in Slovenia a concern on further developments appeared not to be in urgent need. However, the gained successes should not be a reason to rest and efforts should be made to find even more effective techniques (e.g. other types of tracers or advanced analytical procedures). A special demand is the concern on tracer transport properties which until now are not always satisfying with the materials on disposal. Sorption behaviour and stability of tracers are important items, because interfering retardation or full loss of water tracers have been observed in numerous cases where the losses in some events may be attributed to microbial action. From the actual experiments in Slovenia, an example of influence of bottle type for collecting and storing water sample on the results of a fluorescent dye is given.

8.1.1. Degradation of Uranine during tracer tests

On April 16, 1994 7 kg Uranine were injected into the Lokva near Predjama castle (6.3.1). The investigations on Uranine from the Vipava spring 4/3 were carried out in Graz. The samples filled in plastic bottles partly showed conspicuous values. The content of Uranine was too low measured against the other samples.

In Umkirch 2 samples were subjected to store tests:
1. sample from April 20,1994, 7.00 a.m.
2. sample from April 20,1994, 5.00 p.m.

Both samples were again tested on Uranine on October 30, 1994. Conspicuously low values were measured then (Tab. 8.1). The samples were endowed with Uranine on the same day and investigated on Uranine in more or less regular intervals in the following time up to November 13, 1995. On April 15, 1995, approximately in the middle of the observation period about half the content from the plastic bottles was filled into brown-glass-bottles. It appeared that the content of Uranine in the plastic bottles had permanently decreased since the endowment, while the content of Uranine in the glass bottles remained constant (Fig. 8.1 and Table 8.1).

The Uranine test on the Nanos plateau near “Slapenski Ledenik” was carried out with 5 kg Uranine on October 26, 1995. The spectrafluorimetric investigations were done by HMZ in Ljubljana. Here the Uranine concentration values of 33 samples from Vipava spring 4/2 between Nov. 13, 1995, 10.00 a.m. and Nov. 21, 1995, 7.00 a.m. are considered. The samples were alternately

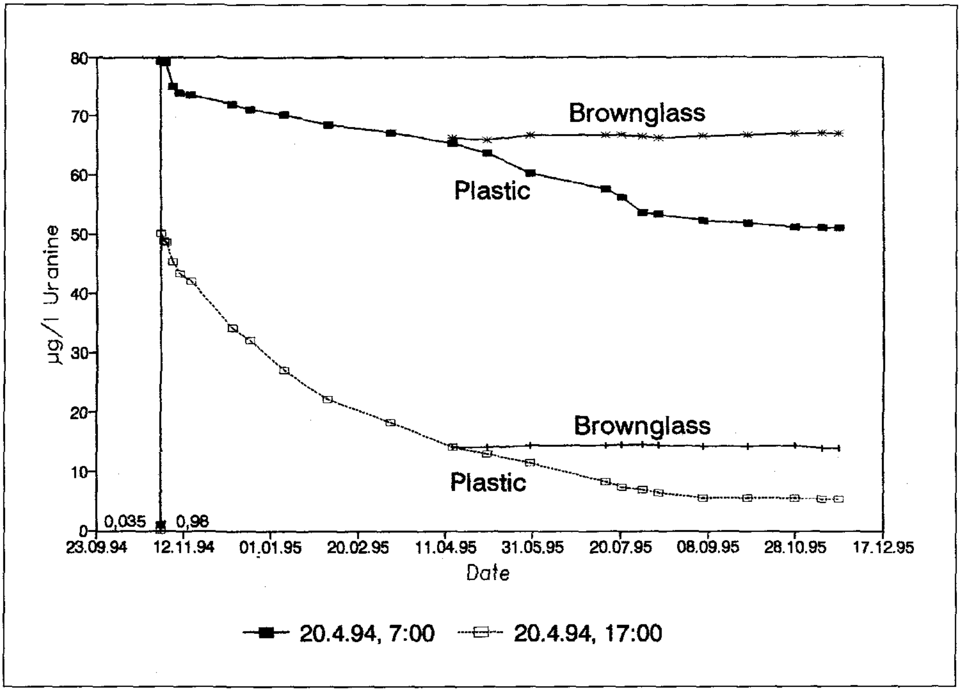

Fig. 8.1: Uranine degradation during a store test in plastic and glass bottles from Vipava spring 4/3.

filled into bottles out of glass (17 samples) and out of plastic (16 samples). The samples in the glass bottles were for the first time tested between Nov. 20 and 22 for the second time on April 18, 1996, at which no noticeable difference of concentration was to be seen. In the diagram of Fig. 8.2 the Uranine values from the glass bottles were interpolated for the between-samples (for the plastic bottles) The concentrations in the plastic bottles were also measured twice: on Jan. 25, 1996, and April 18, 1996.

The decrease of Uranine contents between the sampling and the time of determination can be well recognised in those samples filled in plastic bottles. The diminution lies between 34 and 100 %.

Result: In both described cases there probably exists an adsorption at the sides of the bottles. A microbiological degradation of Uranine would have caused an essentially faster decrease of Uranine (KÄSS 1992).

Recommendation: Uranine investigations from plastic bottles must be finished within a few hours after the sampling.

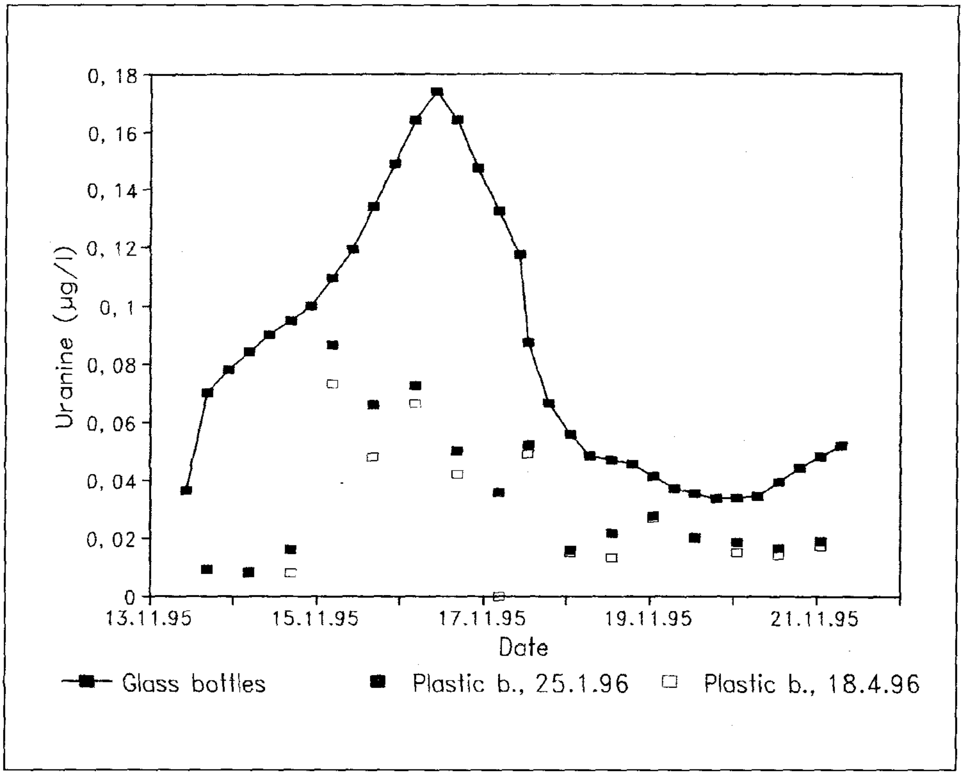

Fig. 8.2: Uranine concentrations in glass and plastic bottles during the tracer test on the Nanos plateau in October 1995.

Table 8.1: Uranine concentrations in the stire test with water samples of Vipava spring 4/3 from April 20, 1994, 7.00 and 17.00. values in µg/l.

Date	30.10.94		15.4.95	13.11.95	15.4.95	13.11.95
Sampling	Uranine endowment		Plastic bottles		Glass bottles	
20.4.94	before	after				
7.00	0.98	79.3	65.3	45.6	65.4	65.6
17.00	0.0035	44.7	13.7	4.4	13.7	12.7

8.2. METHODOLOGICAL ASPECTS OF INVESTIGATIONS OF SINGLE EVENTS - THE USE OF THE NATURAL TRACER SILICA (V. ARMBRUSTER)

With the natural tracer silica it was possible to detect and characterise the arrival of an allogenic flysch component from sinking streams in a karst spring during a heavy precipitation event. Before the arrival of the concentrated flysch water, the level of silica in the karst spring was already higher than in a neighbouring comparable karst spring without such a flysch component. After the precipitation event the arrival of concentrated flysch water in the karst spring was detectable by a strong increase in silica. The travel time of the flysch water could be determined and its dispersion qualitatively described. The travel time corresponds well with results from an artificial tracer experiment. A hydrograph separation of the spring water into flysch recharge water and karst recharge water showed, that it might be promising to determine long term silica contents of spring water, flysch water and mere karst water. With these contents it would be possible to estimate the part of the catchment area of the spring, that is made up by flysch areas.

8.3. FUTURE ASPECTS (P. HABIČ)

After the 6th International Symposium in Karlsruhe in 1992 the Association for Tracing Hydrology (ATH) decided to adopt as an experimental polygon *within the preparations for the* 7th SWT the area of the High Karst in western Slovenia covering about 700 km^2 of surface that belongs to common background of four big karst springs.

An extensive research programme is being designed which was later adapted to available material, temporal and financial means of the participating institutions from Slovenia, Austria and Germany. As it was impossible to