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A SIMPLE BUT EFFECTIVE METHOD TO DETERMINE GROUND-WATER FLOW VELOCITIES NEAR PUMPING WELLS

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INTRODUCTION

The quality of ground-water in pumping wells can only be guaranteed if flow conditions near the pumping station are well known. Both the direction and velocity of ground-water flow are best investigated by tracer experiments. For good results, repetetive tracing (using the same tracer material) or the combined tracer method (using more than one tracer) have to be used, followed by fully quantified sample analyses.

These procedures as employed up to now, are both time consuming and expensive and thus have not been used systematically in everyday routine.

The method presented in this paper has the considerable advantage of being effective and economical both on time and labour as well as on the quantity of tracers used: there is only one application of tracing material (combined tracing, with comparatively small quantities).

METHOD

Two boreholes projected for the input of tracer material should be located on one and the same supposed line of ground-water flow but in different distances to the pumping well aimed at. At a given time, a different fluorescent tracer in watery solution is washed into each of these borings.

The tracers used should be such that they do not interfere with one another during quantitative analysis.

The quantity of tracing material should be so small as not to produce a visible effect on the pumpage, since e.g. with waterworks sampling will as a rule take place during normal pumping hours. On the other hand, the amount of tracers used should allow for safe quantitative sample analysis. Both factors should be evaluated on practical experience in handling fluorescent tracers. In most cases, the amount applied per input hole will not exceed some 100 g. However, the methods mentioned in literature

on how to compute the exact quantity of tracer material needed will rarely give satisfactory results.

With fluorescent tracers, there is no health risk involved. In angiography, for instance, intravenous injections of 10 ml fluoresceine solution (10%) are used - i.e. 1 g pure fluoresceine per patient. The tracers in the water main, however, will be diluted by at least some million liters of water.

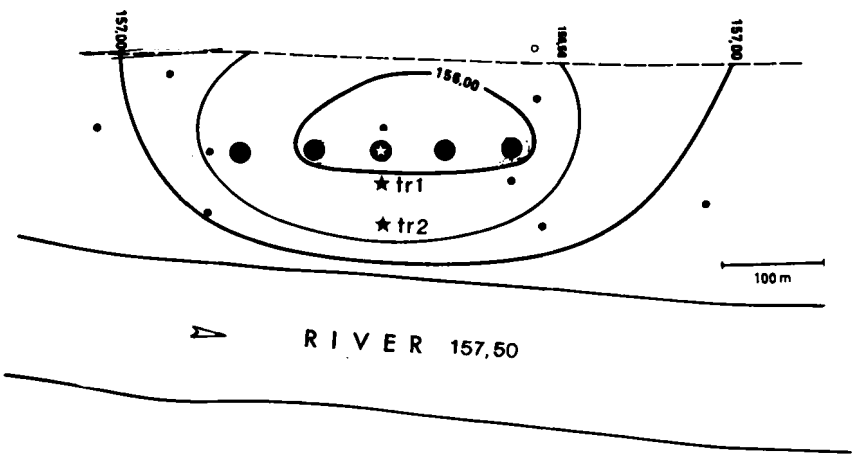

Fig. 1. Application of the method presented to a pumping well gallery. Ground-water contour lines in meters above average sea level. Bold point = pumping well; small point = standpipe; black star = tracer input pipe; white star = tracer influenced well.

Both tracer clouds will now be extended by hydraulic dispersion and flow towards the pumping well. Here samples would be taken at regular intervals in order to determine the exact velocity of ground-water. However, practical experiments have shown that it is as effective to use the much more convenient and economical method of sampling directly off the waterwork tap (e.g. by the waterwork personnel). With this method the same results will be obtained as with the conventional way of well sampling since (a) the time differences between the various stages in tracer concentration are preserved; (b) compared over against ground-water velocity the flow time in the pipes system between pumping well(s) and waterwork is very short and thus can often be neglected; (c) if necessary, the flow time of this water may easily be calculated from the pumping rate and the diameter and length of piping.

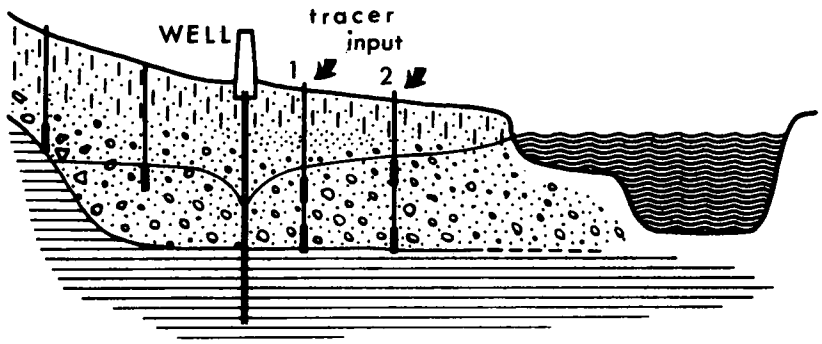

Fig. 2. Cross section (heights not in scale) of fig. 1. The impermeable base of the valley fill rises to the left, walling off the aquifer.

Fig. 1 and 2 show the use of this method at a well gallery. Here, if possible, the 2 input boreholes should be located on a straight, radial flowline. Normally, only one or two of the wells will be influenced by the tracing. In spite of this, pumping routine may go on as usual, and the samples may be taken at the waterwork as described - under the condition that the ratios of the pumpages of the different wells be not changed during the tracing experiment.

It is important that blind samples be taken before starting the experiment. In cases where river infiltration is envolved, sampling at set intervals should begin already some weeks before the tracing because background fluorescence in rivers may vary considerably.

The types of bottles to be used for sampling should be settled with the analysing laboratory (fluorescent tracers are sensitive to light).

The samples are analysed by means of a fluorescence spectrometer as available at most water research institutes.

INTERPRETATION

Time concentration diagrams of tracer analyses will in most cases be of the type shown in fig. 2. The peaks serve as temporal points of reference to the interpretation which is based on the average linear ground-water velocity, i.e. on the velocity of ground-water flow as carried by the greatest number of tracer particles.

In some countries, a 50-days-line (flow time from boundary to well) serves to establish the protection area around pumping wells used for the gaining of drinking water. A graphical means to define this area is shown in fig. 3 (based on the data of the tracing experiment):

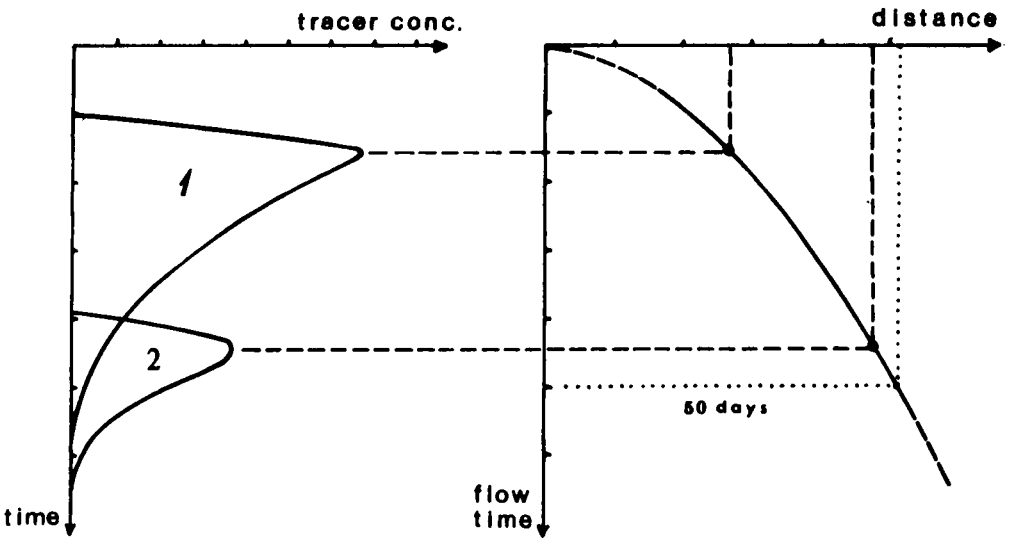

Fig. 3. Graphical construction of flow-time - distance diagram and 50-days-line.

distance interpolated relative to flow time.

For some problems like that of hazardous pollutants, not the average but the maximum linear ground-water velocity (i.e. flow time till first appearance of tracer particles) should be considered.

SUMMARY

The paper presents a method to determine flow velocities at different points along one ground-water flow line by means of tracing with different fluorescent materials.

So far, some investigations of ground-water problems would only have been handled by approximative methods since more exact analyses were too expensive and time consuming. - Some of the problems which can now be handled quite simply and effectively are: maximum and average flow time of seepage water, evidence of ground-water contamination from diffuse and local polluting sources, definition of ground-water protection areas, and investigation of ground-water conditions for geological engineering purposes (e.g. dewatering).

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