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MULTI-STAGE SAMPLING AND TESTING OF GROUNDWATER - A PRE-REQUISITE FOR MAXIMUM UTILIZATION OF AQUIFER SYSTEMS

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ABSTRACT

Since 1964 the writer has developed a series of new devices, instruments, techniques and methods especially for multilayered aquifers. (These have since been adapted for use in general groundwater investigations).

A multistage sampler capable of pumping water from any required depth in a small diameter bore produces samples unaffected by contact with air, metals, or by change in temperature and pressure. A bank of iron-selective electrodes linked in series with the sampler enables continuous reading of pH, eH and other physical, chemical and biochemical parameters. The equipment demonstrated the existence of compositional stratification within typical common aquifers.

The discharge-recharge principle which utilizes natural head differences between the different layers of an aquifer as an energy source, and controlled flow through specially designed orifices, enables aquifer parameters to be determined in both discharging and recharging layers at minimal cost. The addition of a gravity spray aerator to the construction permits subterranean groundwater treatment to remove iron, manganese and even organic pollutants.

The subterranean groundwater treatment techniques and the in situ groundwater sampling and quality testing were acknowledged as the most appropriate health related invention of 1979 and 1980 by the World Health Organization (Geneva, 1980).

INTRODUCTION

Multilayered aquifer systems are much more common in nature than isotropic, homogeneous aquifers. Even relatively thin layers containing higher proportions of fines, within a thicker, coarser grained aquifer, can have a substantial effect on the flow pattern, chemistry and biochemistry of the aquifer. A major emphasis should therefore be placed on determining the precise nature of the system using specialized bore construction and other field techniques to ensure that the best possible primary data are obtained. These can then be used to achieve the most efficient means of exploitation of an aquifer.

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INVESTIGATION METHODS

Several new pieces of equipment and techniques developed and patented by the writer have enabled improved methods of groundwater investigation and treatment to be adopted. These new methods include:

1 Multi-stage Groundwater Sampling.
2 Continuous Groundwater Quality Testing in situ.
3 Removable Porous Bore Insert Colourimetry.
4 Interaquifer Flow Testing.
5 Subterranean Groundwater Treatment.

1 Multi-stage Groundwater Sampling

A multi-stage groundwater sampler was developed and a prototype built in 1976; it was later patented (Riha, 1980). The device is operated by compressed air which actuates a flexible membrane which in turn squeezes the water sample out of the bore. There is no physical contact between the compressed air and the water sample. The intake pipe is equipped with rubber packers at top and bottom, ensuring the inflow of water from a particular producing zone of the aquifer. The sampler is simple in design and versatile in use. The outer casing may be rigid for vertical bores or flexible for twisted or deviated bores.

It can be made in tube form for telescopic bores. Where it is being used to sample the upper layers, cased with a larger diameter casing (for example 100 mm OD) and the hole within the tube sampler of about 50 mm OD the central hole can then be used to insert another narrower sampler to sample the lower layers, cased with smaller diameter casing. In such cases different water samples may be taken from different aquifers simultaneously. The pressure head capacity of one of the samplers tested is 60 m and may be increased to 80 m. If two or more samplers are positioned in series in one bore and pump from one to another, the total water lift can be proportionately increased. The depth below the water table from which samples may be taken is practically unlimited.

The standard unit is constructed entirely of thermoplastic and the sampled water does not come into contact with any metals, which is important when sampling for trace heavy metals. The pumping rate is adjustable and pumping is very gentle so as to avoid turbulent flow at the inlet or disturbance of the natural hydrology, chemistry and biochemistry of the aquifer.

The multi-stage water sampler may also be used for mineral prospecting by monitoring trace elements at different water levels in bores throughout an area of interest, for sampling surface waters and pipelines, dewatering low yielding soils and for other applications.

2 Continuous Groundwater Quality Testing in Situ

Apparatus for continuous analysis of liquids was developed and patented in 1979. It contains a series of cells each capable of housing specific ion-selective electrodes required to determine the various cations, anions and other parameters. The apparatus is especially designed for use in series with the multi-stage water sampler enabling water quality testing "in situ". Contact with the air and changes of temperature and pressure are avoided thus preventing chemical, physical and biochemical alteration of the water being sampled. This contrasts with normal sampling procedures in which samples bailed or pumped from a bore are poured into a sample bottle, transported to laboratory and analysed often days or weeks later. Such samples do not give a true indication of the chemical, physical and biochemical character of the water in the aquifer.

The apparatus is equipped with jets which direct the water towards the active membrane of the electrodes thus avoiding accumulation of suspended solids, common in groundwater, which can impair the accuracy of measurements. Some of the electrodes require relatively high flow rates to give reliable results and this is achieved by recycling the water with a secondary pump located in the unit. Inlet ports to each of the cells permit periodical calibration.

The water quality data tested in situ may be simultaneously recorded and translated into computer-compatible form for computer processing and analysis.

3 Removable Porous Bore Insert Colourimetry

A special bore joint positioned within a small diameter telescopic bore allows a porous bore insert to be removed after having served temporarily as part of the bore construction. This porous bore insert when removed provides colourimetric evidence (staining) of layering phenomena resulting from absorption or precipitation of some of the chemicals and over a period enables monitoring of changes in the layering (Riha 1976, 1979).

Another advantage of this technology is that if the bore insert is exactly oriented before it is lifted from the aquifer, it enables the identification of the local direction of the groundwater flow (Riha & Kenley, 1978).

4 Interaquifer Flow Testing

A method of aquifer testing based on controlled interaquifer flow in unconsolidated sediments was devised by the writer in 1964 and subsequently modified in 1970 for consolidated rocks (Riha, 1979). This method uses differences in the fluid potential of the aquifer layers as the principal energy source driving the test. Considering the areal complexity of multilayered aquifers the interaquifer flow testing method produces a large amount of aquifer data cheaply thus enabling construction of contours of transmissivity values for each of the aquifers and aquitards as well as simulation of the areal flow conditions.

5 Subterranean Groundwater Treatment

The method of interaquifer water mixing (Riha, 1964) was used firstly in Czechoslovakia for the Čataj and Partyzánské town water supplies and then further developed as a surface treatment plant alternative. Since 1973 this patented technique has been used for subterranean groundwater treatment by aeration of groundwater with a naturally high content of iron or manganese or containing organic pollutants. Multilayered aquifers generally have complex recharge and discharge systems and sometimes exhibit substantial internal differences in potential water head pressures. If these are sufficient they can be used as the sole energy source to operate the system. If the water pressure head differences are inadequate to drive the system the head pressure required can be created artificially, by means of compressed air. The technique has now been employed in Australia for a number of years. To date it has been used at Footscray, Victoria for removing an immiscible organic oil layer which was 1.52 m thick in 1971. The downgradient movement of this oil was hydraulically arrested in 1973 by interaquifer flow and the subsequent cone of depression, which is a part of the treatment system. The oil thickness decreased in two years to 0.24 m (Riha, 1977) and in another two years to zero. This method was also used experimentally at the same locality for reduction of high phenol concentrations (Riha & Kenley, 1978).

Subterranean groundwater treatment has also been utilized at Mocamboro, Victoria, where a small groundwater basin provides a water supply for the township of Merino. Two discharge-recharge bores treat groundwater containing upto 96 mg/L of iron and some organic substances with air. This precipitates part of the iron and initiates rapid growth of iron-oxidizing bacteria (Riha, 1980). The method has proved to be highly efficient, with low maintenance and zero operational costs, because the technology of the system is based on and incorporates the natural local conditions and employs natural head differences as the sole energy for the operation. The basic philosophy is to build a treatment plant (subterranean) which has negligible environmental impact, low maintenance and zero energy costs.

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REFERENCES

1 M.D. Campbell and J.H. Lehr, in J.H. Campbell (Ed.), McGraw-Hill Book Company, 1973.
2 International (9th) Exhibition of Inventions and New Technology, Geneva, 1980.
3 M. Riha, Improvement proposals (patents) for 1964, Bratislava.
4 M. Riha, Contribution to aquifer testing. Minerals and Energy Dept., Victoria. Geol. Surv. Rept. 1971/72, pp.2-3.
5 M. Riha, Hydrochemical effects of waste percolation on groundwater in basalt near Footscray, Victoria. Proc. 8th Intern. Conf., Sydney, October 17-22, 1976, Pergamon Press, Great Britain, 1977, pp.251-255.
6 M. Riha, A method of aquifer testing and its application to an anisotropic inhomogeneous multiple aquifer system. Ground Water, 17(1979) pp.423-427.
7 M. Riha, Groundwater sampling and testing. National Water Well Association of Australia, Conf. Cowes, 1980.
8 M. Riha, Subterranean groundwater treatment. Hydrol. and Water Res. Symp. Adelaide, 1980, pp.49-53.
9 M. Riha and P.R. Kenley, Investigation in the hydrogeology and groundwater pollution in the basalt aquifer system, west of Melbourne. Dept. Minerals and Energy. Unpubl. Rep. Geol. Surv. Vic., 1980/20, pp.1-19.
10 K.D. Schmidt, Water quality variations for pumping wells. Ground Water, 15(1977), pp.130-137.
11 F. Schwille, Anthropogenically reduced groundwaters. IAGC-IAHS Intern. Symp. Burlington, Canada, 1975.