7

Monitoring Wells for Level-determined Sampling in a Shallow Phreatic Aquifer

Panagiotis D. Anastasiadis
Technological Education Institute of Serres
Terma Magnisias, 62124 Serres, Greece

Recenzent: Janusz Pempkowiak
Instytut Oceanologii PAN

1. Introduction

Level-determined groundwater samples are important for all the scientists involved with monitoring (LeBlane et al., 1991, Kelly et al., 1991). Level-determined samples are collected from a known, usually small depth interval in an aquifer. Most of the successful examples of level-determined sampling have been in shallow unconsolidated deposits where simple, cheep sampling devices have been used. Specially constructed, small diameter boreholes are dedicated these devices. All the procedures of level-determined sampling involve the drilling and construction of a dedicated borehole which is costly, time consuming and represents a permanent installation. On the other hand, existing boreholes offer a convenient and cost-effective option for obtaining groundwater samples, with the advantage that the borehole can be used for pumping, trace and other tests. However, it is difficult to obtain level-determined samples from existing open boreholes, owing to problems of induced flow in and around the borehole which causes mixing of groundwater from different levels in the aquifer (Segar 1993, Lerner and Teutsch 1995).

Many previous reviews of sampling techniques (Pohlmann and Hess, 1988, Nilsson et al., 1995, Jones and Lerner, 1995, Anastasiadis and Xefteris, 2000) have concentrated on the technology for retrieving water. A careful recovered sample will be worthless if it has been obtained without understanding the local hydrogeological environment. The local hydrogeological environments play an important role for the choosing sample methods. For example, a rapid observation of a high porosity system with vertical hydraulic gradients would be ill-advised if low pumping rate methods were used because of their poor flushing. Other reviews (Lerner and Teutsch 1995) have discussed the hydrogeological issues surrounding level-determined sampling in an existing deeper wells.

Must be noted that there is not a perfect method for all occasions and the final choice will depend on combination of a) the location, size and purpose of the sample required, b) the hydrogeological environment to be sampled, and c) the choice of the available equipment and the performance of the sampling methods.

Categorized the groundwater samples can be noted as the flux samples and volume samples (Maloszewski and Zuber 1982). A volume sample could be obtained by coring and would capture the water within an aquifer volume independent of its mobility. A flux sample is captured by pumping. Concentrations in flux and volume samples will differ if there are permeability and concentration variation in the aquifer. In homogeneous aquifer, solutes may be located in low permeability zones, where movement is mainly controlled by diffusion. Volume samples, which give the total mass are often useful when investigating a polluted site for possible remediation or for scientific investigations. On the other hand, flux samples are important when assessing a polluted water supply well. The difference between flux and volume samples is smaller for low pumping rates.

This paper describes a study case in Northern Greece, where a well proven level determined sampling system was installed and operated to observe the pollution caused to the agricultural activities. The location of the samplers have been organized after a detailed reconnaissance of the hydrogeological environment.

2. Sampling techniques

Groundwater sampling is conducted to provide accurate information of subsurface water resources. The reliable detection and assessment of groundwater contamination require minimal or no disturbance of geochemical and hydrogeological conditions during sampling. The subsurface environment is not as readily accessible as surface water systems so a minimal disturbance is inevitable. Therefore "representative" or error free or artifact sampling is really a function of the degree of detail needed to characterize groundwater hydrologic and geochemical conditions and the care taken to eliminate disturbance of these conditions in the process.

The groundwater environment is dynamic over extended time frames and the processes of recharge and groundwater flow are very important to a thorough understanding of the system. Short term investigation may only provide a snapshot of contaminant levels or distributions. It is very important to use a reliable collection methods for high data quality over the course of the investigation with the assumption that the water quality monitoring data are collected normally on discrete dates. The reliable of the sampling methods should be intensively investigated during the preliminary phase of monitoring network implementation.

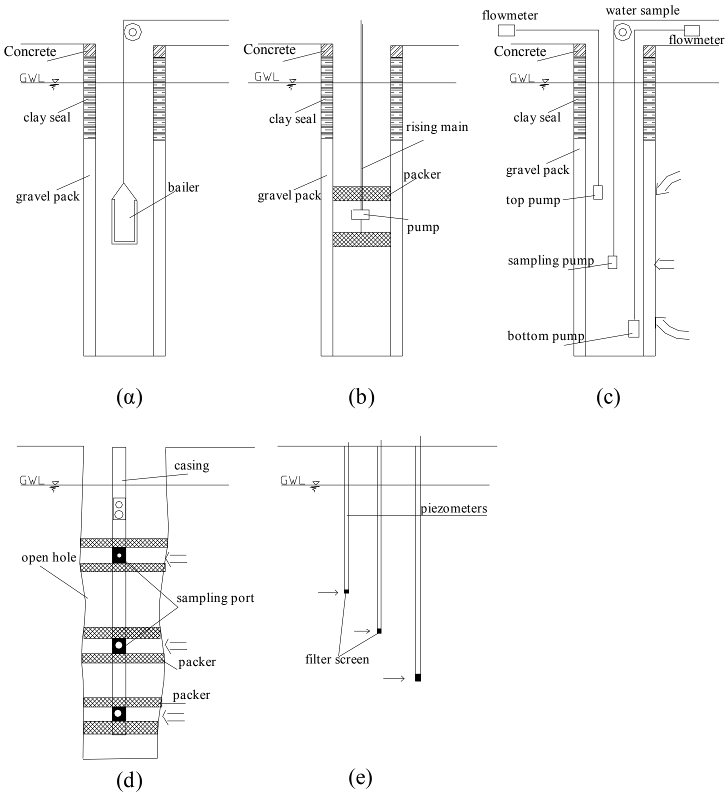

Fig. 1 Level-determined sampling methods: a) depth samplers, b) pucker system, c) separation pumping, d) dedicated multi level system, e) individual piezometers

Rys. 1. Metody poboru prób z ustalonym poziomem: a) próbnik głębokościowy, b) system z uszczelniaczami, c) oddzielne pompowanie, d) specjalistyczny system wielopoziomowy, e) oddzielne piezometry

The sampling devices may be categorized as a) grab or bailer samplers (Fig. 1a), b) positive displacement mechanism (Fig. 1b,1c,1d), and c) in situ devices (Fig. 1e). Bailer or grab samplers are consisted by a bailer which lowered to the desired sampling depth in a well. The sample is mix water in well and is not level accurate (not representative) (Pohlmann and Hess, 1988). Positive displacement mechanism such as: a) packer systems (Price and Williams, 1993), b) multi port sock samplers (Nilsson et al., 1995a), c) baffle systems

(Nilsson et al., 1995b), and d) separation pumping (Nilsson et al., 1995b), used for level determined sampling and the samples are level accurate. In situ devices such as: a) dedicated multi level system (Bishop et al., 1992), and b) individual wells and nests (Andersen, 1990) are also level determined sampling methods and the samples are level accurate (representative).

3. Operation a commercial multi-level sampling system

A representative commercial available system for level-determined sampling is the BAT system (Best Available Technology - Fig. 2). Individual boreholes are installed at different depths and used independently for sampling. The designs have been used in practice, the classic where drilling a few small diameter boreholes and the second where drilling one large diameter borehole and install the piezometric nest, separating each level by bentonite layers. The BAT monitoring system is an integrated system for: a) sampling groundwater, b) measurement of groundwater pressure, c) in situ permeability testing, and d) tracer tests (Blegen et al., 1988). The BAT system contains three basic components: 1) a permanently installed, sealed filter tip attached to an extension pipe, 2) an evacuated and sterilized sample container of glass, and 3) a disposable double-ended hypodermic needle. Groundwater samples are collected in sealed, pressurized glass vials which may be sent directly to the laboratory. The system makes it possible to collect pressurized water and gas samples without the necessity of purging large amounts of well water. The primary feature of the system is the filter tip the standard configuration of which consists of a thermoplastic body and a filter of high density polyethylene. The filter tip is reinforced with a core of Teflon coated stainless steel and sealed with a flexible disc of resilient material. The filter tip is threaded onto the bottom of an extension pipe and additional lengths of pipe are added as needed. The major advantage of the system is that only a small amount contained within the filter tip itself must be purged from the system prior to sampling. Ground water samples are obtained by inserting a pre-sterilized, pre-evacuated sample vial into a sample container which is then lowered down the extension pipe. At the lower and of the housing is a spring loaded guide sleeve and the filter tip cap causes the needle to puncture the septa in both the cap and the sample vial. The guide sleeve mechanism causes the needle to withdraw from the sample vial first, thus preventing a loss of sample fluid or gas. Filter samples are obtained through the use of an in-line filter adapter.

Site description

The study area lies in the south-western region in Greece and the structure and hydrogeology of the system are typical of coastal multiaquifer system in Greece (Xefteris, 2000, Latinopoulos et al., 1993) The aquifer under study is part of a large watershed. The area is used mostly as agricultural land and the intensive use of nitrogen fertilizers caused for the nitrate contamination (Anastasiadis, 1995, Xefteris, 2000, Anastasiadis and Xefteris, 2000). The water table has an average gradient value of 0.006. Pumping tests performed in the aquifer showed a variation of the hydraulic conductivity in the permeable strata of about 4 m/d to 45 m/d. The main criterion to selection the install location of the sample boreholes was the nitrate recharge. The intensive nitrate pollution area was determined from the sampling of an existing irrigate boreholes which are spread at the coastal agriculture area.

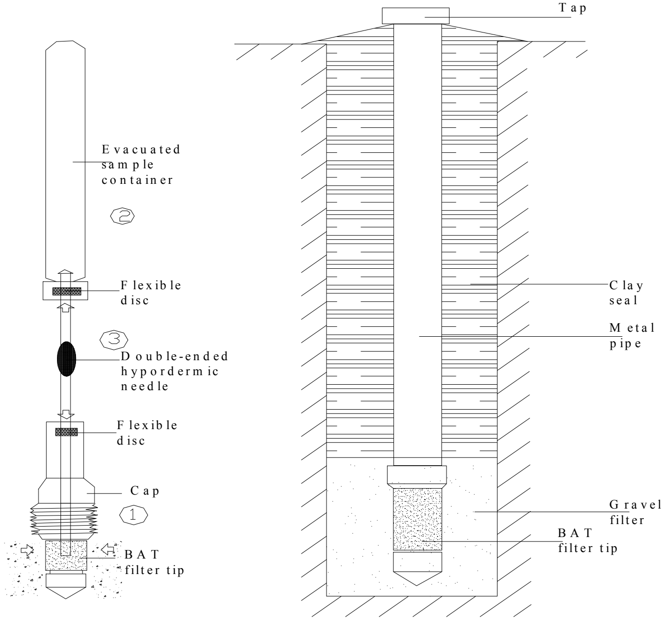

Fig. 2. BAT system equipment and borehole installation
Rys. 2. Wyposażenie systemu NDT i instalacja odwiertu

Drilling of individual piezometers relies upon standard drilling technology. To install the BAT system drilling seven individuals piezometers at three different location across to the principal direction of groundwater flow. Any piezometer nest in a signal borehole had required careful placing to avoid leakage. Figure 3 represents the geological sections at the location where the BAT system installed and the Table 1 represents the depths where the filter tip of the system was installed.

Table 1. Technical elements of BAT system installation
Tabela 1. Elementy techniczne instalacji systemu NDT

a/a	Number of individual boreholes	Depth of filter installation	Thickness of aquifer layer
1	3 (A1, A2, A3)	2.0 11.5 8.2	3.6 0.5 3.0
2	2 (B1, B2)	9.5 12.5	4.0
3	2 (C1, C2)	20.0 5.4	1.0 2.2

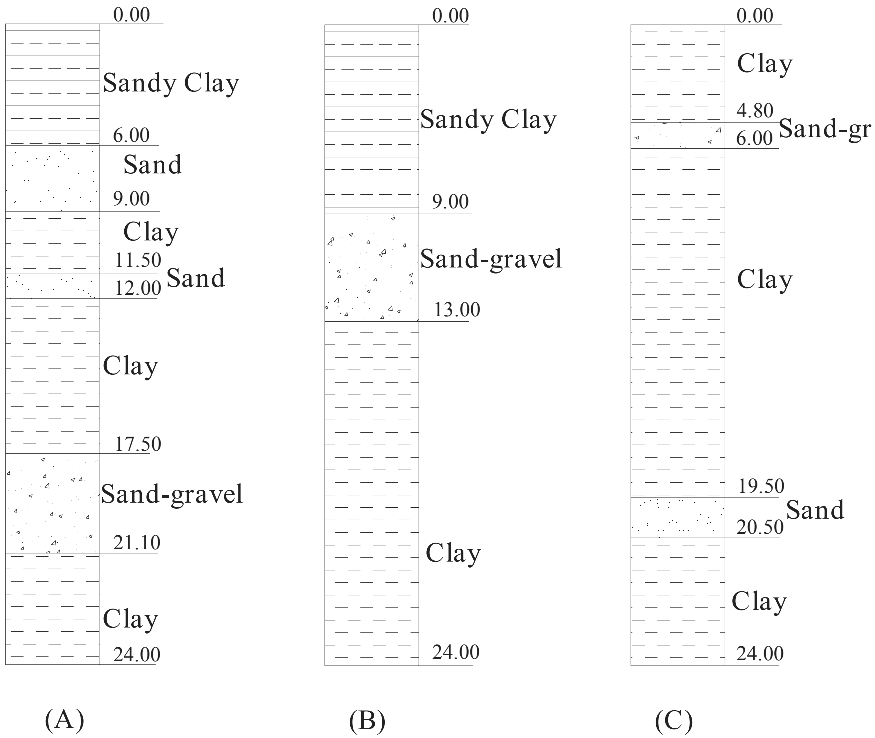

Fig. 3. Geological sections for BAT system installation
Rys. 3. Przekroje geologiczne instalacji systemu NDT

4. Results and discussion

Plots of concentration versus time (almost for two sampling years) for the nitrate illustrate the correlation between the nitrate and the depth of the aquifer. Figure 4 represents the results of the analyzing samples for nitrate concentration collected from the seven individual piezometers at different locations versus time. The gaps for selection data are caused to innate problems during the application of the sampling system at the field. The lack of correlation in nitrate concentration versus depth for the samples of the piezometers of group (B) believed to cause water mixing, the small thickness of the stratum and the long time period between two sequentially sampling. The results of this study confirm some of the conclusion reached by previous studies (Bjerg and Chistensen, 1992, Frind et al., 1990, Pedersen et al., 1991). These results are from a field-orientated study, a true assessment of accuracy and therefore are acceptable as “representative samples” or level-determined samples. The large variance of nitrate concentration during the sampling period is the result of the intensive irrigation from boreholes which are spread at the coastal agriculture area, the intensive use of fertilizer all over the year and from the small thickness of the phreatic aquifer. Finally, according to the chemical analysis of the samples plotted the piper diagram presents the quality characteristics of the groundwater (Fig. 5). Temperature, pH and electrical conductivity were measured in the field while all common ions were analyzed in the laboratory using standard methods (Hem, 1985). The nitrate was measured with a portable equipment of type Eijkelkamp (Marckoquant 10020) and sporadically verified using analytical methods in the laboratory.

The results from the field study confirm the ability of a commercially available in situ groundwater sampling device to collect accurate and representative data without the necessity of a pre-sampling purge of large quantities of stagnant well water. The in situ devices allow samples to be collected quickly and with a minimal amount of exposure to sampling personnel. The applicability of such devices to a variety of monitoring situations can be proved from the usefulness to form and use a detailed mathematical model for prediction the nitrate concentration or to develop remediation techniques.

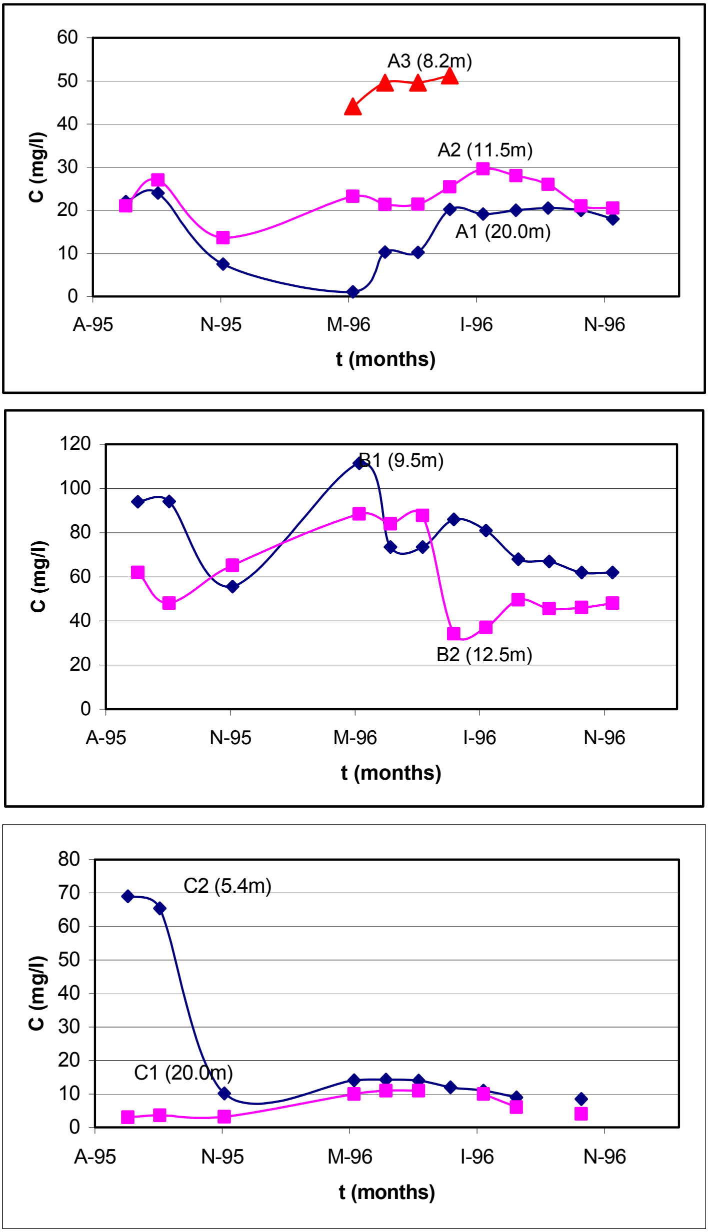

Fig. 4. Nitrate concentration versus time for three different locations and different depths at each location

Rys. 4. Zależność stężenia azotanów od czasu dla trzech różnych lokacji i różnych głębokości w każdej lokacji

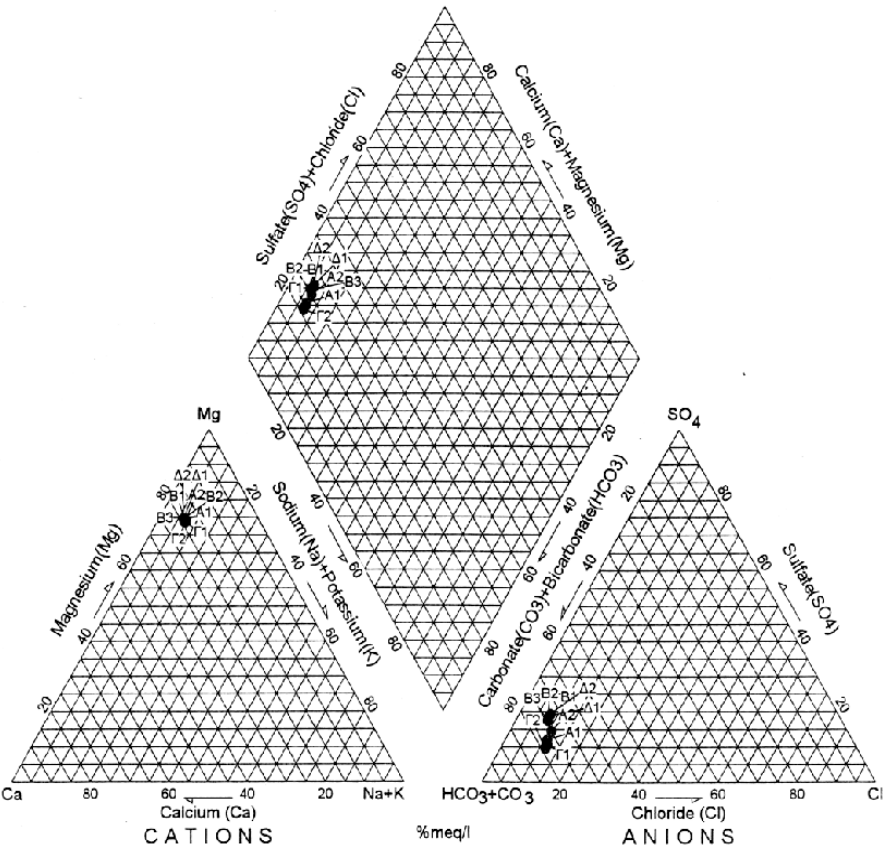

Fig. 5. Piper diagram of groundwater sampling
Rys. 5. Diagram pobierania próbek wody gruntowej Piper'a

5. Acknowledgements

This work has been partially completed by the financial support of a research program from Prefecture of Chalkidiki, Greece. Support for Dr. Xefteris A. and Prof. Latinopoulos P., from the Aristotle University of Thessaloniki, Greece, is gratefully acknowledged.

References

1. **Anastasiadis P.:** *Investigation of nitrate pollution of groundwater with application to a phreatic aquifer in Chalkidiki Peninsula*, Ph.D. Thesis, Dep. Civil Engn. A.U.TH, 1994
2. **Anastasiadis P., and A. Xefteris:** *Control of nitrogen fertilizer pollution in groundwater, Journal* "Fresenius Environmental Bulletin" Vol. 10 (5) pp. 501-505, 2001
3. **Andersen L. J.:** *BOTESAM, separation pumping and capillary barrier: a remedial-action concept applicable to point pollution*, Proc. 1st USA-USSR joint confer. on Environmental Hydrology and Hydrogeology, Lenigrad, 18-21 June, American Inst. Of Hydrol., 1990
4. **Bishop P.K., Gosk E., Burston M.W., and Lerner D.N.:** *Level determined groundwater sampling from open boreholes*, Q.J. Eng. Geol., 25, pp. 145-157, 1992
5. **Bjerg P., and Christensen T.:** *Spatial and temporal small scale variation in groundwater quality of a shallow sandy aquifer.* J. of Hydrology 131, pp. 133-149, 1992
6. **Blegen R., Hess J., and Denne J.:** *Field comparison of groundwater sampling devices*, presented at NWWA second Annual Outdoor AQ\ction, Confer. Las Vegas, CA, 1988
7. **Jones I., and Lerner D.N.:** *Level-determined sampling in an uncased borehole*, Journal of Hydrology, vol. 171, pp. 291-317, 1995
8. **Frind, O.E., Duynisveld W., Strebel O., and Boettcher J.:** *Modeling of multicomponent transport with microbial transformation in groundwater*: The Furhberg case., *Water Resour. Res.* vol. 26(8) pp. 1707-1719, 1990
9. **Hem, J. D.:** *Study and interpretation of the chemical characteristics of Natural Water*, U.S. Geol., Survey Water Supply paper 2254, 1985
10. **Kelly, W.E., Curtis, B. and Adelman, D.:** *Nitrate ground-water modeling for agricultural and other nonpoint sources*, In "Nitrate Contamination", NATO ASI Series, Vol. G 30, I. Bogardi and R.D. Kuzelka, Springer-Verlag, 97-113, 1991
11. **Latinopoulos P., Anastasiadis P., and Xefteris A.:** *Nitrate pollution from agricultural activities of a shallow aquifer in Chalkidiki peninsula*, Greece, Proc. Second International Conference on Water Pollution, Milan, 631-638, 1993
12. **Leblanc D.R., Garabedian S.P., Hess K.M., Gelhar L.W., Quardi R.D., Stollenwerk K.D. and Wood W.W.:** *Large scale natural gradient tracer test in sand and gravel, Water*, Resource Research, 27, pp. 895-910, 1991
13. **Lerner, D.N., Teutsch G.:** *Recommendation for level-determined sampling in wells*, Journal of Hydrology, Vol. 171, 355-377, 1995a
14. **Maloszewski P., and Zuber A.:** *Determining the turnover time of groundwater systems with the aid of environmental tracers*. Models and their applicability, J. of Hydrology, 57, pp. 207-231, 1982
15. **Nilsson B., Luckner L., and Schirmer M.:** *Field trials of active and multi-port socks samplers in gravel-packed wells*, J. of Hydrology, 171, pp. 259-289, 1995a
16. **Nilsson B., Jakobsen R., and Andersen L.J.:** *Development and testing of active groundwater samplers*, J. of Hydrology, 171 pp. 223-238, 1995b

17. **Pedersen, K.J., Bjerg P.L., and Christensen T.H.:** *Correlation of nitrate profiles with groundwater and sediment characteristics in a shallow sandy aquifer*, J. of Hydrology, vol. 124, 263-277, 1991
18. **Pohlmann K.F., and Hess J.W.:** *Generalized groundwater sampling matrix*, Ground Water Monitor. Rev. 8(4) pp. 82-84, 1988
19. **Price, M., and Williams A.:** *A pumped double-packer system for use in aquifer evaluation and groundwater sampling*, Proc. Inst. Civil Eng. Water Marit. Energ., 101, pp.85-92, 1993
20. **Segar D.A.:** *The effect of open boreholes on groundwater flows and chemistry*, Ph D. Thesis, School of Earth Science, University of Birmingham, 1993
21. **Xefteris A.:** *Investigation of groundwater quality degradation in Kalamaria plain with emphasis to nitrate contamination*, Ph.D. Thesis, Dep. Civil Engn. A.U.TH Greece, 2000

Monitorowanie studni przez próbkowanie na określonym poziomie w płytkich nasyconych formacjach wodonośnych

Streszczenie

Próbki wody gruntowej z określonych poziomów są ważne dla szczegółowych badań dotyczących hydrologii wód gruntowych. Zastosowanie ich wzrasta w ostatnich latach gdy badania hydrologiczne skupiły się na szczegółowych procesach projektowania i rozwoju technik remediacyjnych. Używanie urządzeń pozwalających badać wodę gruntową in situ pozwoliłoby na poradzenie sobie z tym problemem. W tym referacie przedstawiono zastosowanie sprawdzonego, dostępnego w sprzedaży systemu do pobierania próbek na określonych poziomach, zwanego systemem NDT. Przedstawiono również wyniki instalacji i używania tego systemu. Był on używany do pobierania próbek z przybrzeżnych, płytkich i nasyconych formacji wodonośnych, znajdujących się w północnej Grecji, gdzie prowadzone jest intensywne nawożenie azotem.

Wyniki prób terenowych potwierdzają zdolność dostępnego w handlu urządzenia do pobierania próbek wód gruntowych in situ, do zbierania dokładnych i reprezentatywnych danych bez konieczności wstępnego opróbowywania ogromnych ilości stojącej wody studziennej. Urządzenia pracujące in situ pozwalają na szybki pobór próbek przy minimalnej ilości personelu pobierającego. Możliwość zastosowania takich urządzeń w różnorodnych przypadkach monitorowania potwierdza przydatność do tworzenia i stosowania szczegółowych modeli matematycznych do przewidywania stężenia azotanów lub do rozwoju technik remediacyjnych.